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WHOLE BODY VIBRATION IN KITESURFING

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ABSTRACT

The effects of vibrations on the human body have been the focal point of several literature studies. Aim of this thesis is the investigation of the whole-body vibration exposure during kitesurfing and the dependence of the vibration characteristics on a set of possibly influencing parameters. A purposely designed measurement system was used to monitor the board vibration (translations and rotations), the wave magnitude, the wind strength, the kiter position and his velocity. The board vibration was measured with a triaxial and a single axis accelerometer placed with a computer inside a sealed box rigidly fixed on the board. Waves magnitude was measured with a purposely designed buoy, while the wind was measured with a cup anemometer placed over a 3 m tall mast. The kiter position and speed were measured with a GPS sensor.

ISO 2631 was used to quantify the kiter exposure to vibration; results showed that the dominant vibration axis is usually the Z one (average value a_{wz} 5,51 m/s^2) while the exposures on the other axes were respectively 2,19 m/s^2 and 2,35 m/s^2 for X and Y axes. With these values the European Directive 2002/44/EC thresholds are reached only after 3 (EAV) and 15 minutes (ELV). The averaged 8-hours based exposures along X, Y and Z axes were 0,61, 0,64 and 1,56 m/s^2. The crest factor pointed out the necessity of using the additional (running RMS) evaluation method.

Correlation analysis showed that the vibration depends on the riding speed, while the effect of wave magnitude and wind seems more limited. The board motion during kitesurfing is a combination of translation and rotation; the exposure is usually more severe on the tip of the bow foot. The damping effect of the foot pads was identified through the frequency response function between the actual tests measurement position and the kiter heel with different boards, postures and kiters. Results showed that the difference between the vibration measured on the board and the one at the heel-pad interface is trivial.

Although EU limits were meant for workers, it is clear how the kitesurfing may lead to degenerative back pathologies in case of long exposures or for people already exposed to WBV during their working activities.

SOMMARIO

Il presente lavoro di tesi, è stato svolto con l'obiettivo di misurare le vibrazioni a cui è sottoposto un soggetto durante la pratica sportiva del kitesurfing e la sua dipendenza da possibili variabili. Dopo una attenta valutazione, si è deciso di misurare: le vibrazioni della tavola (sia di traslazione che rotazione), il moto ondoso, l'intensità del vento, la velocità e la direzione di navigazione. Per la misura delle vibrazioni della tavola è stata adoperata una scatola in alluminio con all'interno una coppia di accelerometri, uno triassiale e uno monoassiale. A turno la scatola è stata montata sia sulla tavola che all'interno della boa, per la misura delle onde. Inoltre un anemometro posto a 3 metri da terra e un GPS indossato al polso sono stati utilizzati per misurate le ultime variabili.

Per valutare le vibrazioni è stata presa come riferimento la norma ISO 2631; i risultati hanno evidenziato che l'asse dominate è quello Z (a_{wz} 5,51 m/s^2) mentre 2,19 m/s^2 and 2,35 m/s^2 rispettivamente sull'asse X e Y. Con questi valori i limiti imposti dalla Direttiva Europea 2002/44/EC vengono superati dopo 3 (valore limite di esposizione giornaliero) e 15 minuti (per quanto riguarda il valore d'azione giornaliero). Il valore normalizzato a un periodo di riferimento di 8 ore lungo X, Y e Z è stato di 0,61, 0,64 and 1,56 m/s^2. Il fattore di cresta ha evidenziato la necessità di usare oltre al metodo base anche il metodo alternativo (metodo dei valori rms costanti).

L'analisi di correlazione ha evidenziato che la vibrazione dipende dalla velocità di conduzione mentre la dipendenza dal moto ondoso o dall'intensità del vento non ha dato risultati evidenti. Il movimento della tavola è una combinazione di una traslazione e una rotazione. La vibrazione è risultata più severa sulla punta del piede della gamba di prua. Il comportamento dei pad è stato caratterizzato in laboratorio tramite l'utilizzo di uno shaker elettrodinamico. La funzione di trasferimento tra il punto di misura e il tallone è stata misurata più volte con posture, tavole e soggetti diversi. Risultati hanno mostrato che la differenza fra la vibrazione misurata sulla tavola che sul tallone è trascurabile.

I limiti della direttiva UE 2002/44/EC sono validi per i lavoratori, è chiaro come il kitesurfing possa portare a patologie in caso di lunga esposizione o a persone già esposte a vibrazione di corpo intero durante le attività lavorative.

CHAPTER 1 - INTRODUCTION TO WHOLE BODY VIBRATION

The effects of vibrations on the human body have been studied and documented for several years [1].

Briefly, the vibration is the oscillatory motion of various bodies. All bodies with mass elements and elasticity are capable of vibration; hence, most machines and structures, including the human body, experience vibration to some extent. Two different categories of vibration are distinguished in literature. Free vibration takes place when the system oscillates due to the action of internal forces only. Forced vibration is caused by the action of external forces. If the frequency of excitation coincides with the natural frequency of the system, resonance occurs. The result is large oscillations within the structure of creating potentially harmful stress.

Vibration influences the human body in many different ways. The response to a vibration exposure is primarily dependent on the frequency, amplitude, and duration of exposure. Other factors may include the direction of vibration input, location and mass of different body segments, level of fatigue and the presence of external support. The human response to vibration can be both mechanical and psychological. Mechanical damage to human tissue can occur, which are caused by resonance within various organ systems.

Psychological stress reactions also occur from vibrations; however, they are not necessarily frequently related.

From an exposure point of view, the low frequency range of vibration is the most interesting. Exposure to vertical vibrations in the 5-10 Hz range generally causes resonance in the thoracic-abdominal system, at 20-30 Hz in the head-neck-shoulder system, and at 60-90 Hz in the eyeball. When vibrations are attenuated in the body, its energy is absorbed by the tissue and organs. The muscles are important in this respect. Vibration leads to both voluntary and involuntary contractions of muscles, and can cause local muscle fatigue, particularly when the vibration is at the resonant-frequency level. Furthermore, it may cause reflex contractions, which will reduce motor performance capabilities.

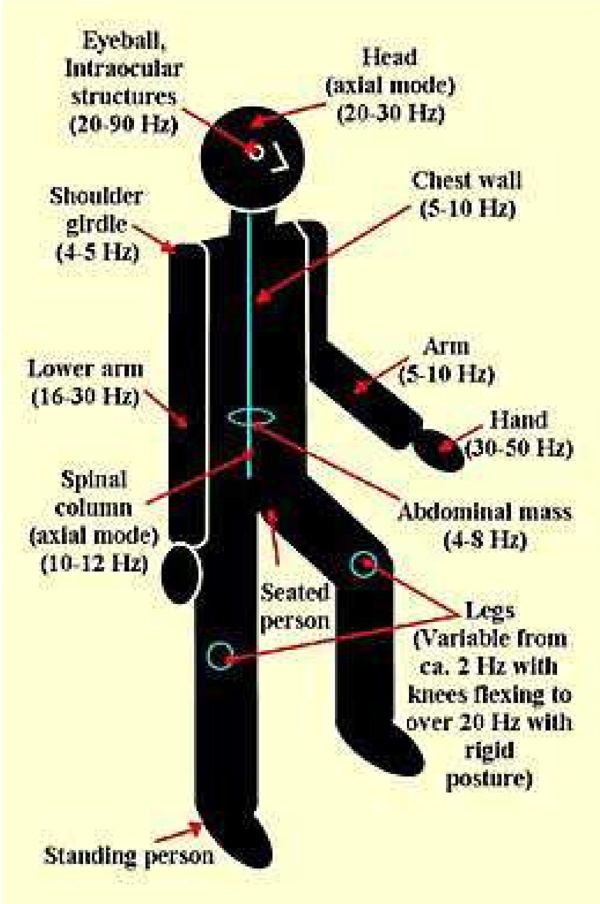


Figure 1.1 Frequency of resonance in the human body.

The amount of mechanical energy transmission due to vibrations is dependent on the body position and muscle contractions. In standing subject, the first resonance occurs at the hip, shoulder, and head at about 5 Hz. With sitting subjects, resonance occurs at the shoulders and to some degree at the head at 5 Hz. Furthermore, a significant resonance from shoulder to head occurs at about 30 Hz.

Based on psychological studies, observations indicated that the general state of consciousness is influenced by vibrations. Low frequency vibrations (1-2 Hz) with moderate intensities induce sleep. Unspecific psychological stress reactions have also been noted, as well as degraded visual and motor effects on functional performance.

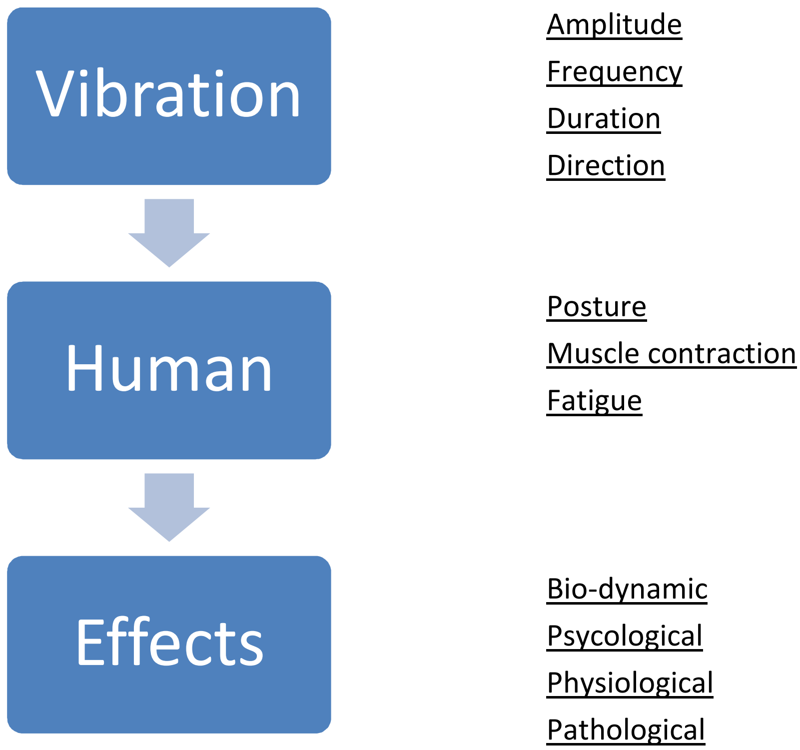


Figure 1.2 Vibration - Human - Effects.

In contrast with what mentioned in the previous page, positive vibrations effects on the human body were reported in specific fields (mainly in the physiotherapeutic and clinical settings in which vibrations have been used for pain management). Recently, research was focused on the examination of the whole-body-vibration use in the treatment and prevention of osteoporosis [2]. Nowadays, human vibration research is mainly carried out on the working environments and the results have been used to establish International Standards for the evaluation of human exposure to vibration.

There are two main types of human vibration: whole-body vibration and hand-arm vibration. Whole-body vibration is transmitted to the body as a whole, generally through the supporting surface. For example, a person driving a vehicle is subjected exposed to whole-body vibration through the buttocks, and if there is back support, through the back as well. Hand-arm vibration is transmitted to the hands and arms. It is mainly experienced by operators of hand-held power tools. The whole-body system and the hand-arm system are "mechanically different" and they are therefore studied separately.

1.1 Standard ISO 2631

1.1.1 Presentation

The ISO 2631 standard [3] defines the methods for quantifying whole-body vibration in relation to:

- human health and comfort;
- the probability of vibration perception;
- the incidence of motion sickness.

This standard contains evaluation methods for the measurement of periodic, random, and transient vibration which can interfere with comfort activities and health. Furthermore it also describes the principal factors that determine the acceptability of an exposure and suggests the possible effects, recognizing the large variations in responses between individuals.

The considered frequency ranges are;

- from 0,5 Hz to 80 Hz for health, comfort and perception, and
- from 0,1 Hz to 0,5 Hz for motion sickness.

The reason why there is this distinction is because vibrations are often complex, containing many frequencies, occuring in several directions and changing over the time. The effects of vibration may be manifold. Exposure to whole-body vibration causes a complex distribution of oscillatory motions and forces within the body.

There can be large variations between subjects with respect to biological effects. Whole-body vibration may cause sensations (e.g. discomfort or annoyance), influence human performance capability or present a health and safety risk (e.g. pathological damage or physiological change). The presence of oscillatory force with little motion may cause similar effects.

1.1.2 Vibration axes

The exposure of the human body to vibrations is assessed by measuring vibrations entering the body. The ISO 2631 defines an orthogonal coordinate system for the expression of magnitudes of vibration entering the body from the different directions.

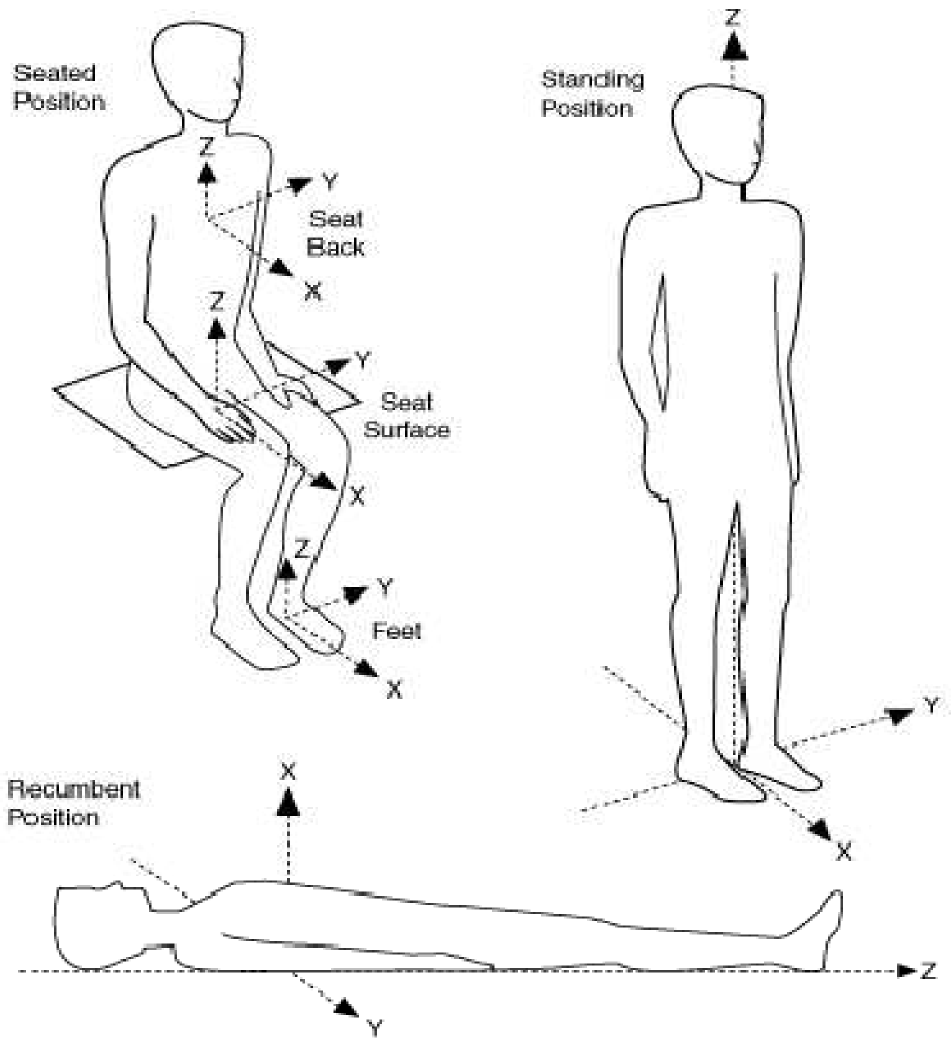


Figure 1.3 Coordinate system for the measurement of whole-body vibration (ISO 2631-1:1997).

The main directions are:

X-axis	back to front;
Y-axis	right to left;
Z-axis	foot to head.

The standard states that if it is not feasible to obtain precise alignment of the vibration transducer with these axes, the sensitive axes of the transducers may deviate from the preferred axis by 15° where necessary. Moreover in case there is more than one point at which vibration enters the body, there will be more than one coordinate system for obtaining the correct measurements. The standard also imposes the transducer has to be located at the interface between the human body and the source of vibration. In case it is not possible to measure between the surface and the body the measure has been done closely adjacent to the area of contact between the body and that surface and then corrected for the transmissivity of the pad material.

1.1.3 Frequency-weighting curves

The way in which the WBV influences the health, the comfort, the perception and motion sickness is dependent on the vibration frequency content. Different frequency weightings are required for the different axes of vibration.

The main frequency weighting are:

- *Wk* for the *Z* direction;
- *Wd* for the *X* and *Y* directions.

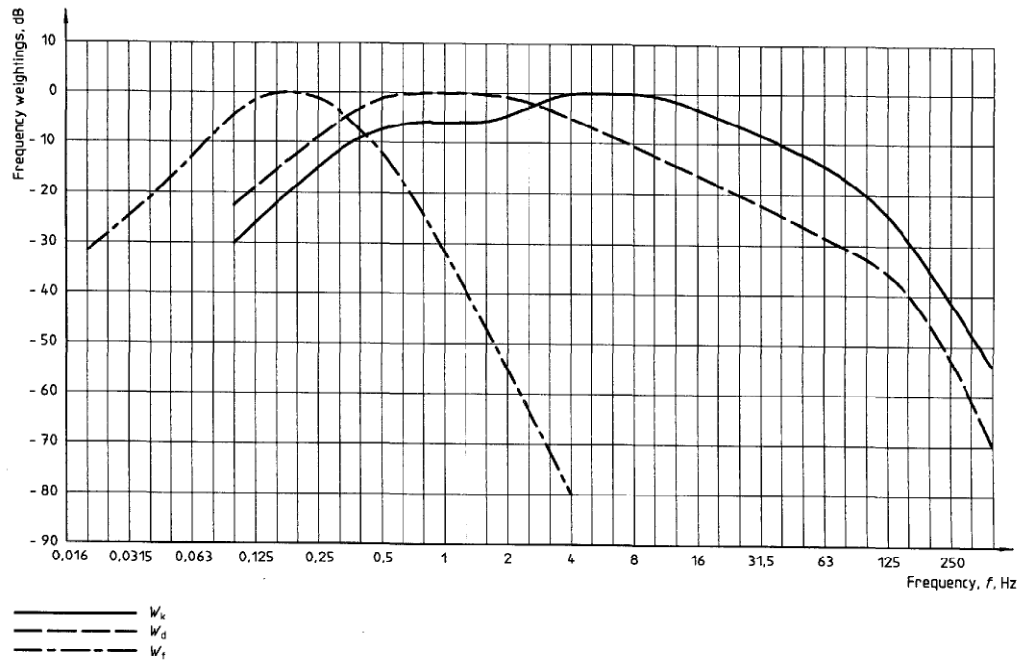


Figure 1.4 Frequency-weighting curves for the assessment of whole-body vibration.

Additional frequency weighting, not used during the tests, are given in the standard:

- *Wc* for the seat-back measurement;
- *We* for the measurement of rotational vibration;
- *Wj* for the measurement of vibration under the head of a recumbent person;
- *Wf* related to motion sickness.

1.1.4 Basic evaluation method

The basic evaluation method is based on the calculation of the frequency weighted root-mean-square (r.m.s.) acceleration, defined in the following equation 1.1:

$$a_w = \left\{\frac{1}{T}\int_0^T a_w^2(t)dt\right\}^{1/2} \qquad \textbf{(1.1)}$$

Where;

$a_w(t)$ is the weighted acceleration as a function of time, in meters per second squared (m/s^2);

T is the duration of the measurement, in seconds.

Frequency-weighting curves reduce the modulus where the human body is less sensitive to the vibration.

1.1.5 Crest factor

The standard suggests the use of the crest factor (CF) for the evaluation of the vibration stationarity. The CF is defined as the modulus of the ratio of the maximum instantaneous peak value of the frequency-weighted acceleration signal to its r.m.s. value.

$$Crest\ Factor\ = \frac{Max\ peak\ value}{r.m.s.} \qquad \textbf{(1.2)}$$

The crest factor has to be used to investigate if the basic evaluation method is suitable for describing the severity of the vibration in relation to its effects on human beings. For vibration with crest factors below or equal to nine, the basic evaluation method is normally sufficient, but in case the crest factor exceeds nine then the vibration effects are underestimated and one of the alternative measures described hereinafter should also be determined; the running r.m.s. or the fourth power vibration dose value.

In some situation, like in case of discomfort, even when the crest factor is not greater than nine is recommended to use and report the additional evaluations.

1.1.6 The running r.m.s. method

The running r.m.s. evaluation method takes into account occasional shocks and transient vibration by use of a short integration time constant. The vibration magnitude is defined as a maximum transient vibration value (MTVV), given as the maximum in time of $a_w(t_0)$ defined by:

$$a_w(t_0) = \left\{\frac{1}{\tau}\int_{t_0-\tau}^{t_0}[a_w(t)]^2 dt\right\}^{1/2} \quad \textbf{(1.3)}$$

where;

$a_w(t)$ is the instantaneous frequency-weighted acceleration;
τ is the integration time for running averaging;
t is the time (integration variable);
t_0 is the time of observation (instantaneous time).

The maximum transient vibration value, MTVV, is defined as;

$$\mathrm{MTVV} = \max[a_w(t_0)] \quad \textbf{(1.4)}$$

1.1.7 The fourth power vibration dose method

The fourth power vibration dose method is more sensitive to peaks than the basic evaluation method by using the fourth power instead of the second power of the acceleration time history as the basis for averaging. The fourth power vibration dose value (VDV) in meters per second to the power 1,75 ($m/s^{1,75}$) is defined as:

$$\mathrm{VDV} = \left\{\int_0^{\mathrm{T}}[\mathrm{a_w(t)}]^4 \mathrm{dt}\right\}^{\frac{1}{4}} \quad \textbf{(1.5)}$$

where;

$a_w(t)$ is the instantaneous frequency-weighted acceleration;
T is the duration of the measurement

1.1.8 Ratio among basic and additional methods

Experience suggests that the use of the additional evaluation methods will be important for the judgement of the effects of vibration on human beings when the following ratios are exceeded for evaluating health or comfort:

$$\frac{\mathrm{MTVV}}{a_w} = 1{,}5 \qquad \textbf{(1.6)}$$

$$\frac{VDV}{a_w T^{1/4}} = 1{,}75 \qquad \textbf{(1.7)}$$

The basic evaluation method shall be used for the evaluation of the vibration. In cases where one of the additional methods is also use, both the basic evaluation value and the traditional evaluation value shall be reported.

1.1.9 Vibration in more than one direction

The vibration total value of weighted r.m.s. acceleration, detemined from vibration in othogonal coordinatesi is calculated as follow:

$$a_v = \left(k_x^2 a_{wx}^2 + k_y^2 a_{wy}^2 + k_z^2 a_{wz}^2\right)^{1/2} \qquad \textbf{(1.8)}$$

Where:

a_{wx} ; a_{wy} ; a_{wz} are the weighted r.m.s. accelerations with respect to the orthogonal X, Y and Z, eq.1.1 at page 10.
k_x; k_y; k_z are multiplying factors.

The use of the vibration total value a_v, is mainly recommended for comfort. Nevertheless it has also been proposed for the evaluation with respect to health and safety if no dominant axis of vibration exists.

1.1.10 Health consideration

Research has given evidence for an elevated risk of health impairment due to long-term exposure with high-intensity whole-body vibration. Increased duration and increased vibration intensity mean increased vibration dose and are assumed to increase the risk, while periods of rest can reduce the risk.

The health-related vibration assessment assumes that two daily vibration exposures are equivalent when;

$$a_{w1} \cdot T_1^{1/2} = a_{w2} \cdot T_2^{1/2} \quad \textbf{(1.9)}$$

Where;

a_{w1} and a_{w2} are the weighted r.m.s. accelerations values for the first and second exposure, respectively;

T_1 and T_2 are the corresponding durations for the first and second exposure.

For low exposures, (values below 0,5 m/s^2) health effects have not been clearly documented and/or objectively observed; if the vibration is between 0,5 and 1,15 m/s^2 health risks are possible, while above 1,15 m/s^2 health risks are likely. This recommendation is mainly based on exposures in the range of 4 h to 8 h as indicated by the shading in figure 1.5. Shorter durations should be treated with extreme caution. Other studies indicate a time dependence according to the following relationship:

$$a_{w1} \cdot T_1^{1/4} = a_{w2} \cdot T_2^{1/4} \quad \textbf{(1.10)}$$

This health guidance caution zone is indicated by dotted lines in figure 1.5, (The health guidance caution zones for equations 1.9 and 1.10 are the same for durations from 4 h to 8 h for which most occupational observations exist).

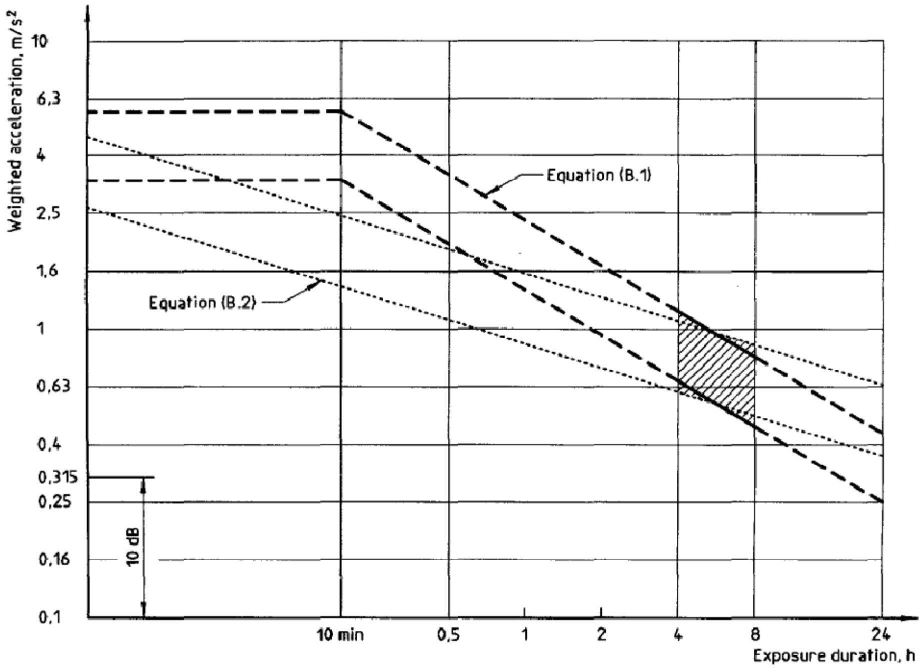


Figure 1.5 Health guidance caution zone.

The assessment of the vibration health effect shall be made independently along each axis with respect to the highest frequency-weighted acceleration determined in any axis. Only when vibration in two or more axes is comparable, the vector sum is sometimes used to estimate health risk. It generally takes several years for health changes caused by whole-body vibration to occur. It is therefore important that exposure measurements are representative of the whole exposure period. If the total daily exposure is composed of several exposures for times T_i to different frequency-weighted component accelerations a_{wi} then the equivalent acceleration magnitude corresponding to the total time of exposure $a_{w,e}$ may be constructed using;

$$a_{w,e} = \left[\frac{\sum a_{wi}^2 T_i}{\sum T_i}\right]^{\frac{1}{2}} \qquad \textbf{(1.11)}$$

Most of the guidance in this standard is based upon data available from research on human response to Z-axis vibration of seated persons. There is only limited experience in applying this part of ISO 2631 for X, Y-axes seating and for all axes of standing, reclining and recumbent positions.

1.1.11 Comfort consideration

Given the complexity of the phenomenon, there are no satisfactory threshold exposure values. An evaluation of exposure of individuals to whole-body vibration is given in the International Standard ISO 2631. The following values give approximate indications of likely reactions to various magnitudes for overall vibration total values.

Table 1.1 Relationship between various levels of discomfort and equivalent acceleration (ISO 2631).

Less than 0,315 m/s^2	Not uncomfortable
0,315 m/s^2 to 0,63 m/s^2	A little uncomfortable
0,5 m/s^2 to 1 m/s^2	Fairly uncomfortable
0,8 m/s^2 to 1,6 m/s^2	Uncomfortable
1,25 m/s^2 to 2,5 m/s^2	Very uncomfortable
Greater than 2 m/s^2	Extremely uncomfortable

1.1.12 European Directive 2002/44/EC

The European Union adopted a Directive in 2002 [4] concerning the workers exposure to vibration. This introduced all over Europe a minimum protection requirement for workers exposed to vibrations at the workplace. Referring to the article 3 section 1 of the European Directive concerning only the WBV, the exposure limit values and action values are given:

(a) the daily exposure limit value standardised to an eight hours reference period shall be **1,15 m/s^2** or, at the choice of the Member State concerned, a vibration dose value of **21 $m/s^{1,75}$**; above which it is considered that regular exposure to vibration presents such a risk to health that vibration levels should immediately be reduced.

(b) the daily exposure action value standardised to an eight hours reference period shall be **0,5 m/s^2** or, at the choice of the Member State concerned, a vibration dose value of **9,1 $m/s^{1,75}$**. If this value is exceeded, employers are asked to assess and monitor the risks, to reduce vibration levels, to inform and train workers and to arrange health surveillance.

However, although there are exposure standards limits to vibrations in the workplace, in the athletic field, sports such skiing, sailing, skating, kitesurfing etc. where it is well known that the athletes are under significant vibration load, no relevant study or standard exists. For this reason, hereinafter has been investigated the vibration dose exposure practicing kitesurfing comparing it with the limits for workers’ exposure.

1.2 Kitesurf

The kitesurfing is considered an extreme watersport that combines the traits of windsurfing and wakeboarding. Despite its short history, nowadays kitesurfing is one of the fastest growing sports. In 2009, the number of kitesurfers has been estimated around 200.000 to 300.000 worldwide, with more than 100.000 new kites sold per year. Nowadays there are more than thirty companies manufacturing kites.

Kitesurfing became more popular than windsurfing as a watersport because it is easier to learn the basics and because it is much easier to transport the necessary equipment; the main reason, though, is because even in light wind conditions it is possible to jump, accelerate and enjoy. Furthermore, this sport is becoming safer due to innovations in kite design, safety release systems, and instructions. Riding styles have evolved as well to suit riders and conditions, such as freestyle (most common and utilises standard kite and board) or wake-style (flatter water using board with bindings) and wave-riding which is focused on big waves using a board designed for wave riding.

The ideal condition to kitesurf for a beginner is between 12 to 25 knots (6 to 13 m/s) instead for an expert kiter the wind condition can be from 10 up to 35/40 knots (5 to 20 m/s). Today kitesurfing is an official sport and there are dedicated organizations, competitions, videos and magazines worldwide.

1.2.1 History

The use of kites is traced back to China, where materials ideal for kite were readily available: silk fabric for sail material, high-tensile-strength silk for flying line and resilient bamboo for a strong, lightweight framework. The birth of the kitesurfing was written by the Legaignoux brothers that during the development of sails and boats got inspired in kites.

After a research, in 1984, Dominique and Bruno Legaignoux understood that no water relaunchable kites existed, so it became obvious that they had to create one. They started to sketch and experiment with kite theory and the plausibility of using a kite for realistic use, such as going upwind. Early stage prototypes involved 2 line kites with battens and a bar with reels on either end. The first experiments were with stacking kites, but they later realized that a single kite would be more efficient and that an inflatable frame would be better than rigid battens. The first inflatable kite was manufactured in Oct 1984. The first patent on an inflatable kite was Nov 16, 1984 [5].

At first they tried to use windsurf boards, because that was familiar and they built several boards for that purpose. Kites were unstable at the time, so they also used water-skis because the waterstart was easier. After a year of development in 1985 the Legaignoux brothers show their kite at the Brest International Speed.

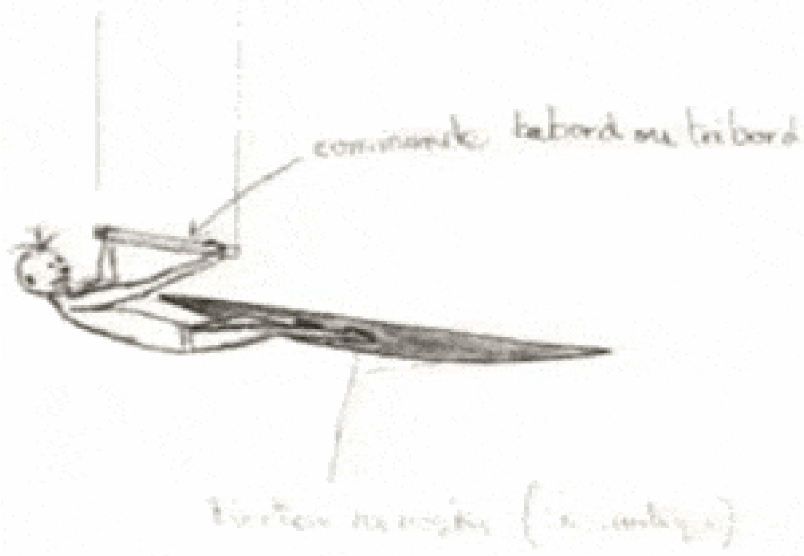


Figure 1.6 Dominique's sketch - 1984

Unfortunately no windsurfing companies were interested in the idea. Nevertheless the Legaignoux brothers never lost hope, believing that their concept was going to create a new sport. In 1993 after 10 years they finally started a company in France. Other revolutionaries like Cory Roeseler were coming up with similar ideas like his Kiteski and Andreas Kuhn with a paraglider and a kind of wakeboard helped in popularizing the sport. Between 1995 and 1998 a company called Wipika emerged and started selling kites. Not long after, Naish windsurfing got involved in kiteboarding after purchasing a licence from Legainoux. Immediatelly in the years after all the other companies purchased the license and the kitesurfing has spread worldwide.

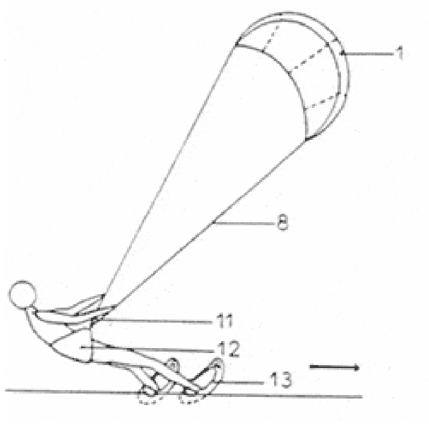


Figure 1.7 Official drawing of the patent.

Right after the invention, the Legaignoux brothers made other brilliant ideas.

- A patent relates to a 4 line control system [6] which allows better control of the angle of incidence and steering of the wing. The patent had been kept secret as long as possible and applied for just before the sales start of the Wipika wings in 1997.
- Another one concerns a bridle system [7] which allows easier backwards flying for re-launch purposes of big wingspan 4 line kite / wings. The same system also facilitates easier and less physical handling of the kite in medium and strong winds. It was marketed on the Wipika Airblast in 2001 and 2002 under the name of "Reactive Bridle".
- Two less known patents were applied for on April 16, 2003, one on a "leash free" [8] control bar device for 4-line kite (the kite leash is integrated into the system) and the other on the span line [9] intended to eliminate the jellyfishing from the high aspect ratio curved wings.
- Their new highly successful patent relates to the Bow concept [10] which consists in living some sweep to a wing to flatten its trailing edge then flattening the leading edge in a mechanical way to match the shape of the trailing edge and thus obtaining a flatter wing with large depower. It was applied the 1st of March, 2004 under the title: "Wing having a negative dihedron for towing a load".
- The BOW concept was the subject of two other patents: one on the pulley bar [11], the other one on a particular bridle [12].

- This was applied in April 2007 to protect the arch bridle which connects the two front lines.
- The last one was to protect the sliding bridle which connects a front line to a back line.

The Legaignoux brothers have never patented any safety devices to favour to their diffusion.

1.2.2 Equipment

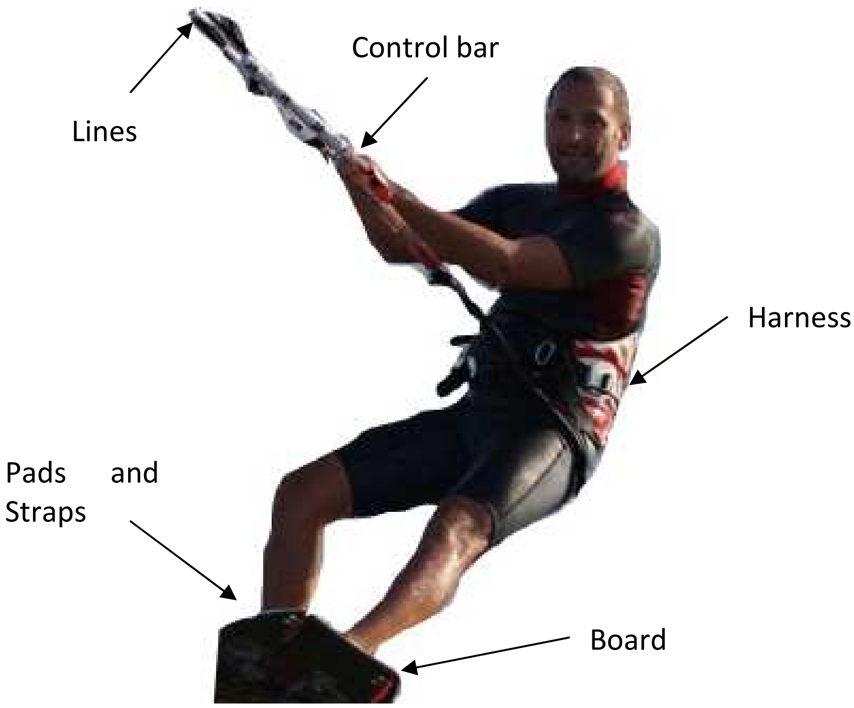


Figure 1.8 Kitesurfing equipment.

The choice of the right equipment to be used while kitesurfing depends on mainly by two factors;

- the weight of the kiter;
- the wind condition.

Basically the stronger is the wind, the larger is the power that can be generated by the kite; hence, to enjoy in a safe way, the kite must be smaller. The same applies (with minor importance) to the board. Furthermore, being a newbie sport, the research and development is moving very fast dropping out in the market continuos different solutions concerning the desing and the materials.

KITE

Figure 1.9 kite ROYAL SOLO 2010.

The kite is the key of this sport; nowadays various types of kites are commercially available, ranging from 5 to over 20 square meters. Kites come in a variety of designs, in the last years even kite dedicated to new discipline, such as wave riding, race etc. were coming out. Some kites are more rectangular in shape; others have more tapered ends; each design determines the kites flying characteristics. The “Aspect Ratio”, ratio of span to length, is the most rappresentative parameter. Wider and shorter kites have less drag because the wing-tip vortices are smaller. High aspect ratio develops more power in lower wind speeds.

The sport of kitesurfing has evolved in many different ways and so did the equipment. The first kites were mostly Ram-Air kites, which were then followed by the traditional C-kite. The next kites to come out were Bow kites which have a greater range of uses because of its enormous de-powering capabilities and light wind applications. Available today are also Hybrid kites that are neither Bow nor C-kite but a mix of what is thought to be the best points of both styles of kite.

C-Kites also known as LEI kites, are typically made from ripstop nylon with a main inflatable plastic bladder that spans across the front edge of the kite with separate smaller bladders that are perpendicular to the main bladder to form the chord or foil of the kite. The inflated bladders give the kite its shape and also keep it floating once dropped in the water.

Bow kites, also known as flat LEI kites were developed with features including a concave trailing edge, a shallower arc in planform, and frequently a bridle along the leading edge. These features allow the kite angle of attack to be altered more and thus adjust the amount and range of power being generated to a much greater degree than previous LEIs. These kites can be fully depowered, which is a significant safety feature. They can also cover a wider wind range than a comparable C-shaped kite. The ability to adjust the angle of attack also makes them easier to relaunch when lying front first on the water. Bow kites are popular with riders from beginner to advanced levels.

In 2006 second generation flat LEI kites were developed which combine near total depower and easy, safe relaunch with higher performance, no performance penalties and reduced bar pressure, called **Hybrid or SLE kites** (Supported Leading Edge).

For 2009 the performance revolution shows no sign of slowing. Bridled designs feel more like C-kites, and five-line hybrids have better depower capability than ever before.

The **deltakites** are growing in popularity since 2008 with around 12 companies offering delta-kites since 2008/2009.

Foil kites are made of fabric with air pockets, cells, and a fixed bridle to maintain the kite shape, similar to a paraglider. Foil kites are designed with either an open or closed cell configuration; open cell foils rely on a constant airflow against the inlet valves to stay inflated, but are generally impossible to relaunch if they hit the water, since they have no means of avoiding deflation, and quickly become soaked. Closed cell foils are almost identical to open cell foils except they are equipped with inlet valves to hold air in the chambers, thus keeping the kite inflated or, at least, making the deflation extremely slow even once in the water. Foil kites are more popular for land or snow, where getting the kite wet is not a factor and they have the advantage of not needing to have bladders manually inflated, which can take up to ten minutes. Seasoned kitesurfers will likely have three or more kite sizes which are needed to accommodate various wind levels.

CONTROL BAR

The control bar, normally made in aluminium and carbon fiber cladded with rubber, is used to control the kite. The kiter holds on to this bar and steers the kite by pulling at its ends, causing the kite to rotate clockwise or counter-clockwise, like a bicycle. Typically a chicken loop from the control bar is attached to a hook on a spreader bar of the harness. Most bars also provide a quick release safety-system and a control strap to adjust the kite's angle of attack.

While kite control bars are made intentionally light, they must be very strong, thus they are usually heavier than the water; "bar floats" made of foam are generally fixed at the beginning of the lines in order to avoid the sinking if lost in the water. Nowadays control bars are usually specific to a particular kite type and size and are not usually suitable for use with different kite types.

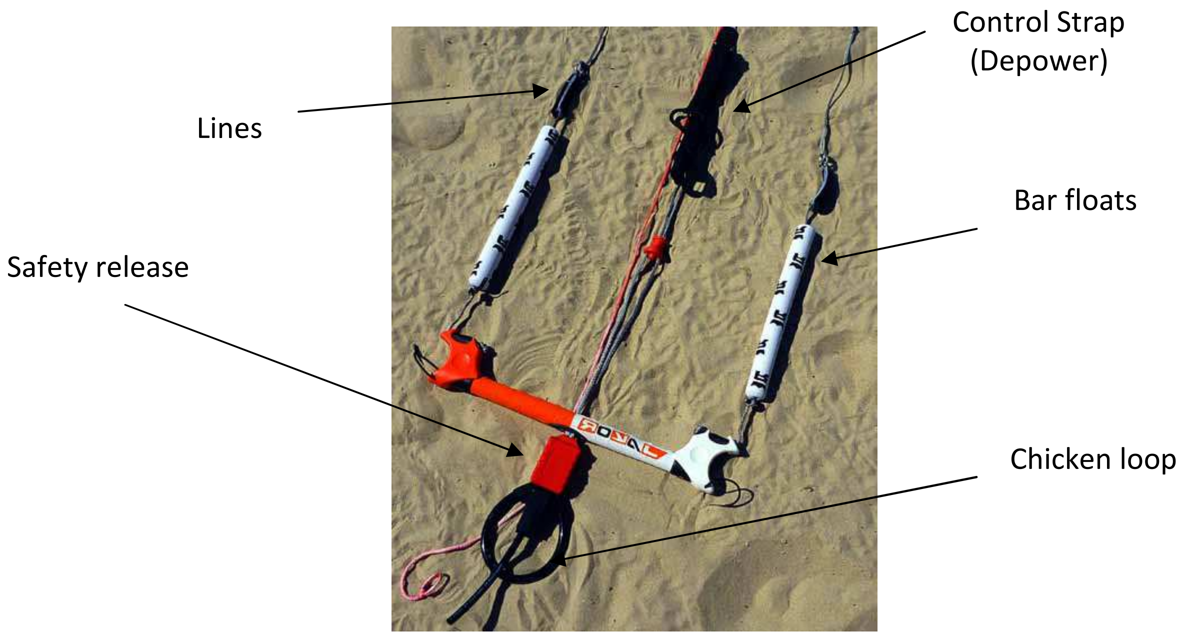


Figure 1.10 Control bar.

All the control bars have different colours to distinguish the left from the right side. It has to be very intuitive in order to let the kiter understand without thinking during the performance of tricks. In the previous figure 1.10 the orange colour means left.

Most kites are supplied with one set of lines of usually about 25 meters. Additional lines sets are also available; 17 m, 20 m, 22 m, 25 m, 27 m and 30 m. Using shorter lines in strong wind it helps to reduce the kite power and it can give a bigger wind range with one kite size. On the other hand, longer lines give to the kite more potential power because the wind window becomes bigger.

BOARD

Nowadays there are four main different models: directional surf-style, race, twin-tip, and mutant.

Figure 1.11 Picture of a Twin-tip board.

The board is the interface between the kiter and the water therefore all the main characteristic of the board can influence in some way the assessment of the vibrations. A twin-tip is identical to use a wake board or snowboard, and it can cover all types of conditions, that is why it is the most common. The length is probably the most important aspect. It depends on weight, style of riding, and wind and water conditions. Twin tip average size is between 120 cm and 150 cm long. The longer boards are for the heavier rider, beginners, and light winds because it requires less speed to plane on the water. The width of boards normally increases as the length, by the way newer designs get shorter and shorter, therefore the width increases to make up for the loss of surface area and allows the rider to plane easier.

The board edges are known as rails. The sharper the rail, the more aggresively the board will bite into the water. While sharper rails tend bite harder and be less forgiving, the twin-tip and wake-style boards actually rely more on them than the fins to hold an edge and keep from drifting downwind.

If one wants to jump more, squared tails are required. This gives the more pop off of the surf. Rounded tails will provide more of a "surfboard" feel, and grooved tails will sink the rails deeper into the water for increased grip, but sacrifice the lift out of the water for jumps and tricks.

The "rocker" refers to the curve (or banana shape) of the board from end to end. A high rocker means a steeper curve, and ultimately has a "loose" feel. A board with a lower rocker will be straighter from end to end, and tends to be more stable with quicker acceleration.

Most of your common twin-tip boards will come with 4 fins (2 at each end), while some will allow for additional fins to be placed on the heel edge side for added tracking.

Kitesurfing pad and strap are a critical transfer between the body and the board. The proper pad and strap can make a huge difference in your ability to ride. You can choose from foot straps, plates, and boots. Plates are foot straps and pads that are integrated onto a metal plate. Changes to the foot position can be made quickly just by moving the entire plate. Boots provide maximum board control and are preferred by wake style riders, but they are more difficult to get on and off.

HARNESS

A harness is worn to attach the chiken loop of the control bar to a spreader bar by a hook, this allows the kiter to jump and perform tricks while remaining attached to the kite via the control bar. While waist harnesses are the most popular among advanced kiters, seat and vest harnesses give beginner kiters more protection from impacts and can serve as flotation device. In addition, the harness helps to spread out some of the pressure coming from the kite force to the rest of your body.

CHAPTER 2 – KITESURFING and WBV

2.1 Physics of the kitesurfing

The kitesurfing, as all the sailboats, use the wind for propulsion. Kitesurfing greatly differs from all the other sail sports because the force that is generated by the kite and that drives the board goes through the kiter, besides, the weight of all the equipment is far less than the weight of the kiter who controls it. The main forces can be grouped roughly into five categories;

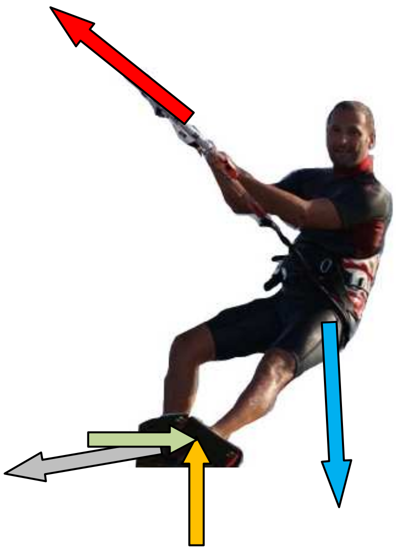


Figure 2.1 Forces.

- gravitational weight acting downward through the center-of-gravity.
- hydrodynamic force acting on the board and on the fins in reaction to sideways components of the kite and the point of sail.
- hydrodynamic lift acting upward on the bottom of the board. This depends on the speed and board dimension.
- Hydrodynamic drag on the board that balances the forward component of the wind on the kite.

- aerodynamic wind force acting on the kite at its center-of-pressure and connected to the harness through the control bar. This force can be divided in vertical and horizontal component and it depends on the apparent wind.

The apparent wind is the combination of the true wind, measured by anemometer, and the wind caused by the forwarding motion of the kiter.

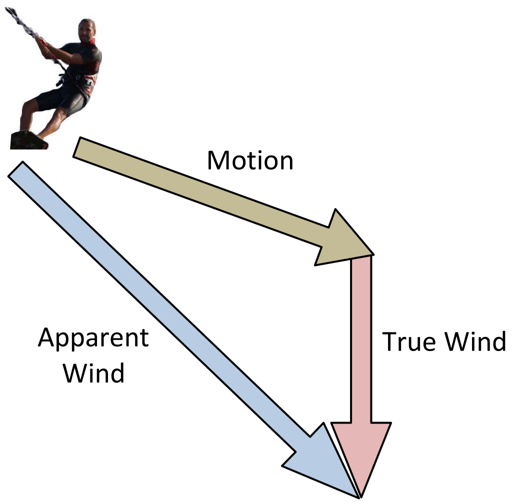


Figure 2.2 Apparent wind.

Therefore the travel speed can be faster than the true wind.

2.1.1 Physics of the kite

Kite performances can be understood knowing a few concepts of how it works and some basic aerodynamics principles. The lift was originally explained by Daniel Bernoulli. He discovered that air pressure becomes lower if the air is moving, and the faster the air moves the lower the pressure becomes. As air passes below and above the kite, the air on top has to cover a longer distance over the curved surface of the kite and therefore it moves at a faster speed. This reduces the pressure above the kite. The air below the kite moves slower than the air above, this causes the air pressure to be increased. The air pressure below the kite then tries to move upwards, pushing the kite up, in order to try and to equalize the high and low pressures. Lift becomes greater when the difference between the high and low pressures increases.

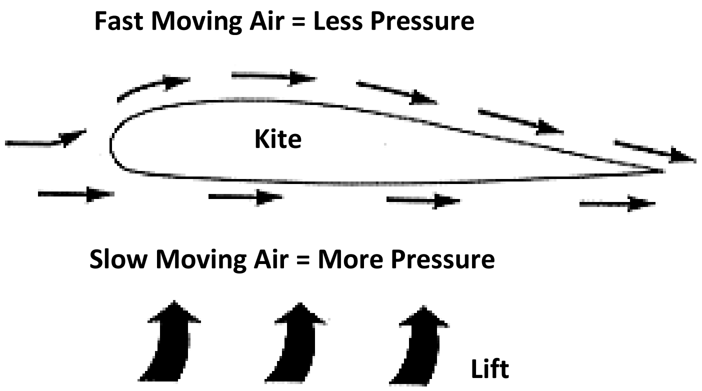


Figure 2.3 Working principle of a kite.

The lift force, by definition, is the force perpendicular to the direction of motion. This is very important in relation to the shape of a kite. The lift is not the only force that allows making jump but it is the one that is needed to navigate and make all the tricks. The second force is the drag that for definition is the one parallel and against to the direction of motion.

It is common to see kites with same area but with totally different performances; this because they have different profile and are designed to fly with different angles of attack.

Figure 2.4 LIFT and DRAG.

The last force is the gravity which is the force acting upon the kite to pull it down to ground level. The heavier is the kite the harder will be to fly. For this reason most modern kites are made of very lightweight materials reducing the effect that gravity has on the kite.

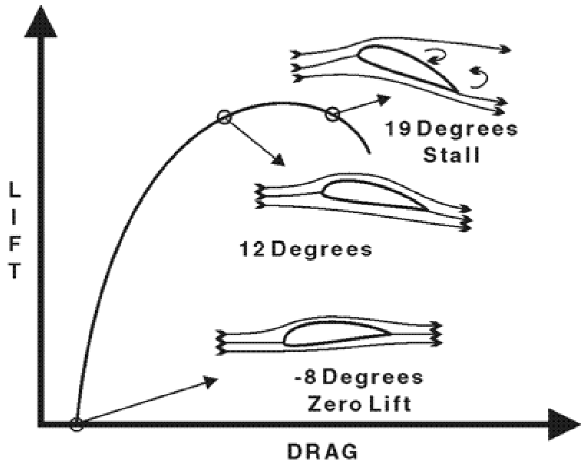


Figure 2.5 LIFT and DRAG according to the attack angle.

The angle at which the kite flies can also cause the wind to speed up over the top of the kite and change the generated power.

2.1.2 Wind window

The wind window is where the kite can fly, and has approximately the shape of a quarter of a sphere. Along the edge of the wind window the kite will have the minimal power.

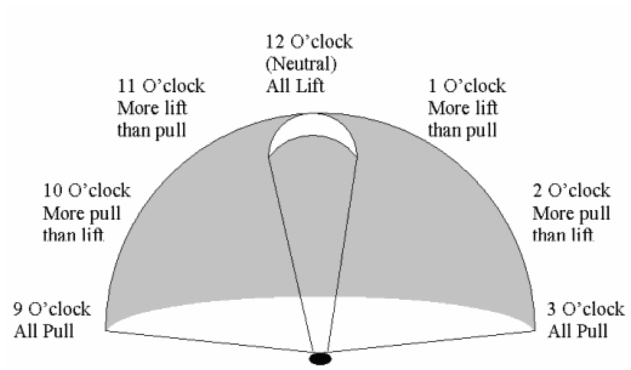


Figure 2.6 Wind window.

As you fly the kite inner into the wind window, the kite is exposed to more wind and can generate more power. This area is called power zone. The launching and landing manoeuvres are done at the window edge, 3 or 9 o'clock in figure 2.6, where there is the minimal power so it will be easier to control the kite. When you are kitesurfing to the left, riding across the wind to your left, you will keep the kite on the left side of the wind window and it will pull you to the left. When you are kitesurfing to the right, riding across the wind to your right, you will keep the kite on the right side of the wind window and it will pull you to the right.

2.1.3 Kite management

The movement of the kite varies according to the intensity of the wind. In case of light wind to generate power with your kite it is important to move it up and down trying to follow a sinusoidal pattern. In case of strong wind the kite is fully powered then it can simply parked on one side of the wind window.

2.2 Body posture

During the navigation the posture of the body is essencial for an optimal conduction;

- arms outstretched on the control bar;
- back and shoulders backward to the water, more the kite pulls more it has to be balanced,the body works as a counterweight;
- both legs must be bent but the one forward should be bent less respect to the one backward;
- the weight should be moved to stern;
- to look toward the direction, trying to do not watch the kite;
- the board has to work on the edge and not flat;
- control the pulling of the kite, moving the control bar, in order to absorb the gusts and avoid spurts.

2.3 Points of sail

Like all the other sail sports it is possible to go in all the directions while kitesurfing. In the kitesurfing there are three main directions, upwind, beam and downwind. To distinguish them it is important to refer to the direction where the wind is blowing and where you want to go.

When the kiter wants to go toward the direction of the wind is called upwind. The closest you can get is more or less 45°, although this value strongly depends on the equipment and on the feeling that the kiter has to keep a certain speed avoiding breaking with the edge of the board. Furthermore, in case the kiter tries to reach extreme angles, the kite flies too much on the window edge so less power is generated and the speed reduces till to stop; this condition is called no-sail zone. When the kiter goes at favour of the wind is called downwind. The most common direction is the beam, which consists in keeping the same position without losing water, going downwind.

The points of sail are controlled by the trade-off between the pull of the kite and the inclination of the board. Moreover a different point of sail changes the approach angle of the kiter against the waves, thus achieving different theoretical maximum speed.

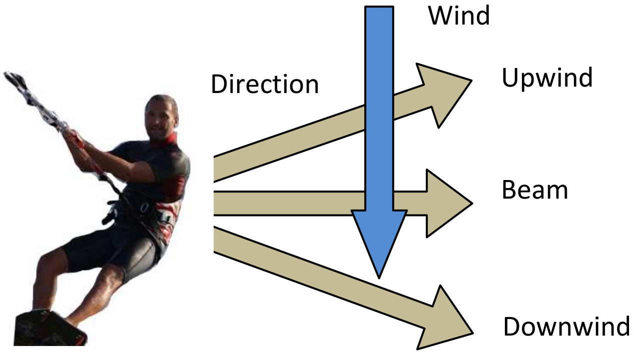


Figure 2.7 Points of sail.

2.4 Speed

A good speed can be reached following several rules;

- faster is the kite faster can be the kiter.
- going faster the more apparent wind is generated by the speed,
- More fins has the board more drag is generated, thus for a twin-tip better to do not use more than four fins.
- The board has to be kept flatter in order to opposite less resistance.
- It is very important to keep a smooth sailing, avoiding impacts and trying to move the legs up and down following the waves.

2.5 Board movements

There are three axes on the board, called vertical (Z), transverse (Y) and longitudinal (X). The movements around them are known as yaw, pitch and roll.

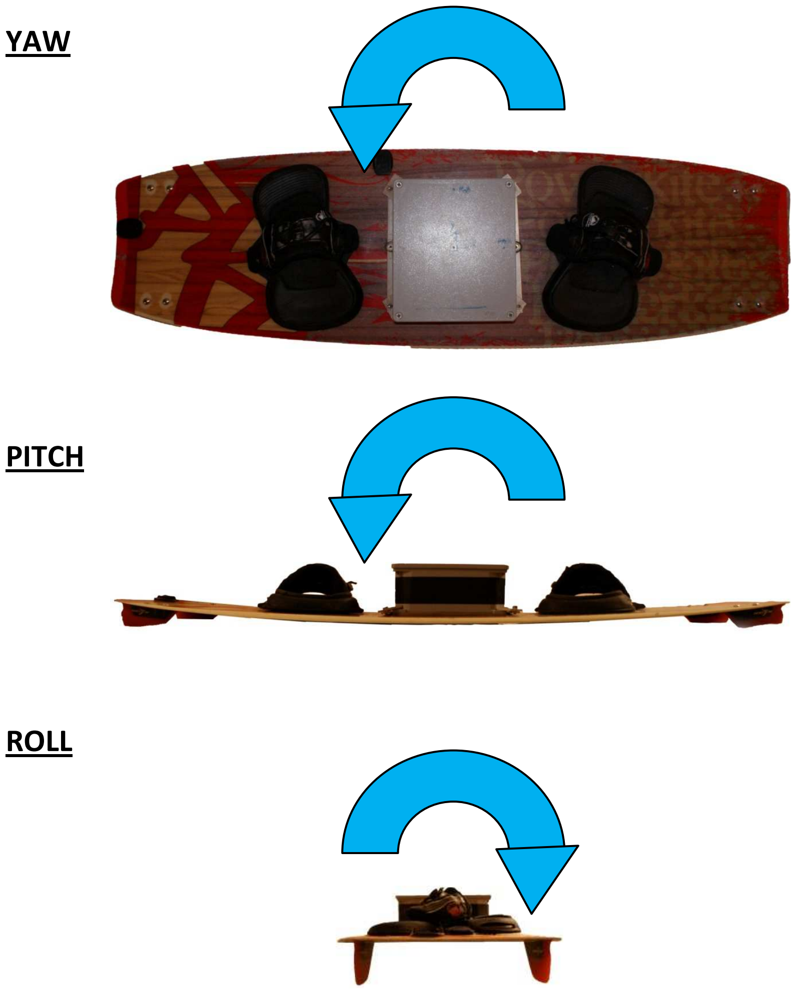
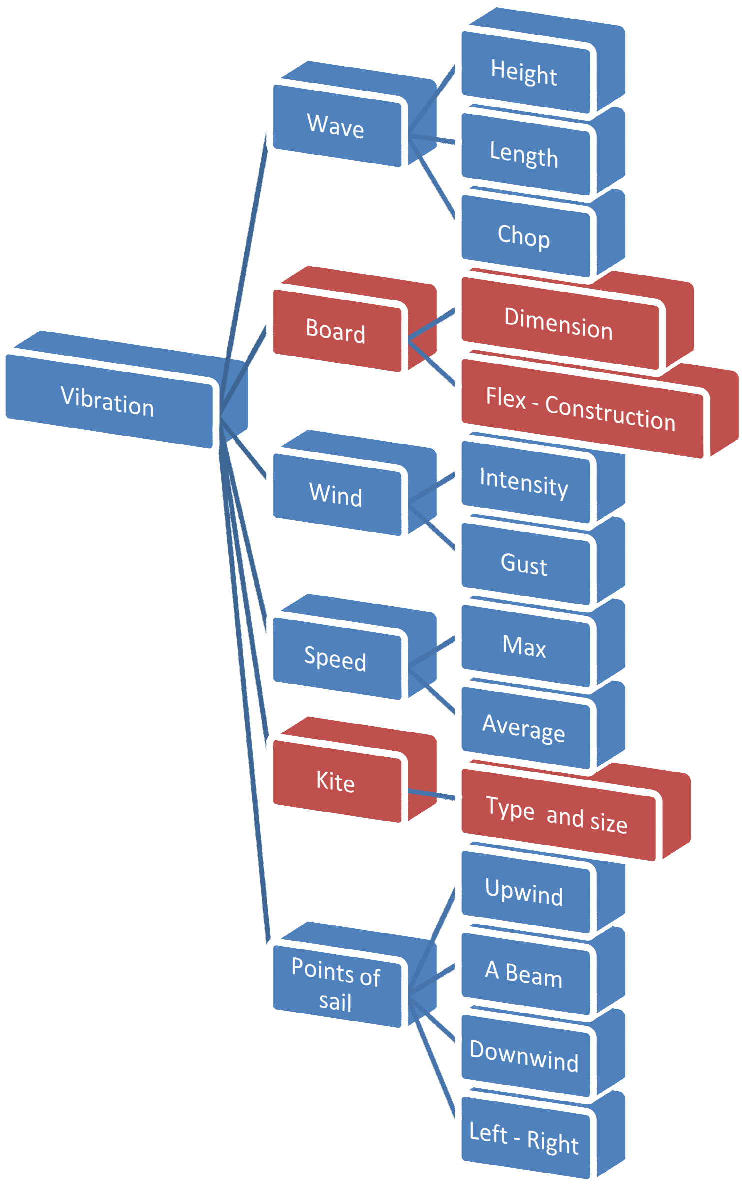


Figure 2.8 Board movements, yaw, pitch and roll.

The roll is when the board rotates around the transverse, right to left, axis. The pitch is when the board rotates around the longitudinal, back to front, axis. The yaw is when the board rotates around the vertical, foot to head, axis.

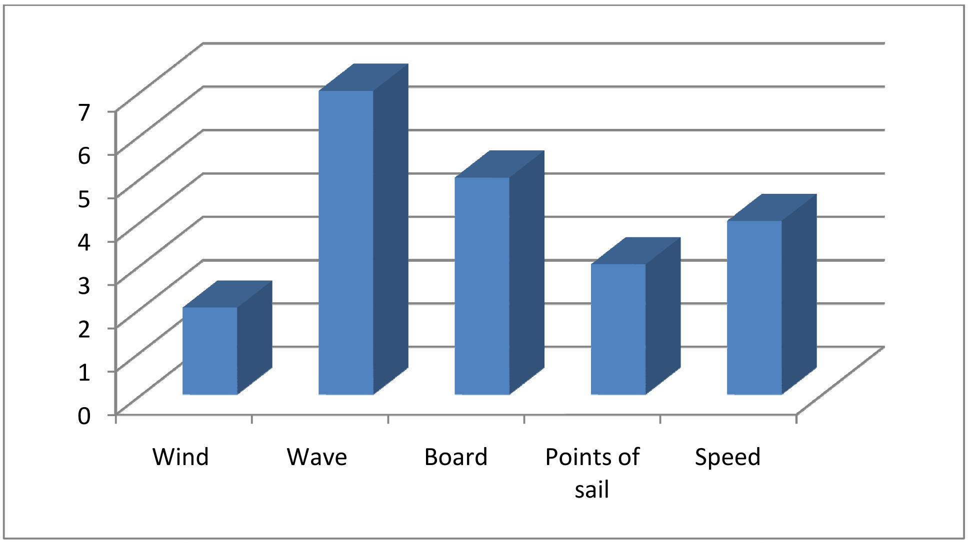
2.6 Variables

Upon my personal experience I have created a list of variables that may affect the board vibration (Graph 2.1).



Graph 2.1 Variables tree, in red the frozen ones.

The variables tree is divided in macro and micro variables. After freezing some variables, highlighted in red, a shorter list was created. A survey, as second step, was conducted among different subjets with different skill levels in order to understand from the riding feeling what was thought by the different subjets concerning the source of vibration. Subjects were asked to choose the five parameters that, upon their opinion, affect the board vibration and the riding. More than twenty subjects answered the questionnaire; results are shown in the next plot. It is worth noting that the most influencing factors are the wave and the board type, followed by the speed, the points of sail and as last the wind.



Graph 2.2 Survey results.

CHAPTER 3 – EXPERIMENTAL SET-UP and MEASUREMENT CHAIN

The purpose of this chapter is the definition of measurement methods for the vibrations according to the ISO 2631 standard. The proposed system is set-up with two accelerometers, one triaxial and one monaxial, interfaced to an ultra-mobile PC equipped with a data acquisition board.

Thanks to his compactness, the measurement system could be assembled inside an aluminium box and directly installed on the board or inside a bouy for the waves characterization.

3.1 Measure of the board vibration

Before arriving to the final decision to install the aluminium box on the board, different solutions have been evaluated. ISO 2631 states that the trasducers shall be located at the interface between the human body and the source of vibration. In our case this was clearly impossible, owing to the difficulty of placing transducers between the feet and the board. Consequently vibration was measured at the midpoint between the two feet.

The first attempt was to carry all the instrumentation in water-resistance backpack, but the main drawbacks were:

- the need of water-proof cables connectors, to connect the accelerometers to the acquisition board;
- problems arising if the kiter looses the board, since the connectors should disconnect immediately to avoid cables ruptures or problems for the kiter.

A second solution was adopted, and all the measurement instrumentation was fitted inside a sealed box placed midway between the feet. The first problem was to find a box with the right dimensions, shocks and water resistant, rigid etc.. Commercially available boxes were evaluated: in particular, different options were:

- PVC; more flexible but less resistance;
- Aluminium, less flexible but more resistance;

- Ad hoc made in Fiber glass; the best compromise between the above, the only problem was the construction.

At the end the second solution, the aluminium box, was chosen.

Figure 3.1 ILME aluminium box, IP66.

The choice of the aluminium was justified by the DIN 40050 standard. Where; the first digit indicates the level of protection that the enclosure provides against access to hazardous parts and the ingress of solid foreign objects. The second digit indicates the level of protection that the enclosure provides against harmful ingress of water.

In case of our box the internal protection was IP66.

Table 3.1 Table for the first digit of the IP code.

Level	**Object size protected against**	**Effective against**
6	Dust tight	No ingress of dust; complete protection against contact

Table 3.2 Table for the second digit of the IP code.

Level	**Protected against**	**Details**
6	Powerful water jets	Water projected in powerful jets against the enclosure from any direction shall have no harmful effects.

Tests were performed to evaluate the board flexion during the sailing, in order to see if a rigid mounting could alter the board behaviour. Results showed the low displacement (less than 1 mm) between the mounting positions and, consequently, a rigid system was adopted.

A further step was the fixation of the aluminium box. The box was fixed rigidly on the board, as shown in the next figure. The vibration transmission between the board and the measurement accelerometer will be evaluated in a dedicated section of the next chapter.

Figure 3.2 Aluminium box on the board.

The box sealing was checked with preliminary water tests, which showed the good box sealing and that the box volume did not hamper the navigation.

Figure 3.3 First test in the water with the aluminium box.

The next step was to assemble the instruments inside and carry out other secondary tests;

- **Working temperature**, by measuring the temperature of the external box with a portable infrared termometer. While navigating the cold water cool down the aluminium box. Wisely the aluminium box was never left under the sun for long time.
- **Battery life**, to understand the correct timing for all the measurement.

3.1.2 Positioning of the accelerometers

Figure 3.4 View of the final assembling.

As previously mentioned, measurements were performed with two accelerometers; one triaxial and one monoaxial. The triaxial acceleromter, at the center of the box cover, was used to measure the vibration of the board between the legs in all the three directions. The manoaxial accelerometer was used to monitor the rotation of the board along the three main axes; pitch, roll and yaw.

It was not possible to measure all the three rotations on the same time during the test due to the unavailability of an acquisition board with al least 6 channels. Therefore tests with different position of the monoaxial accelerometer have been conducted, focusing mainly on the roll.

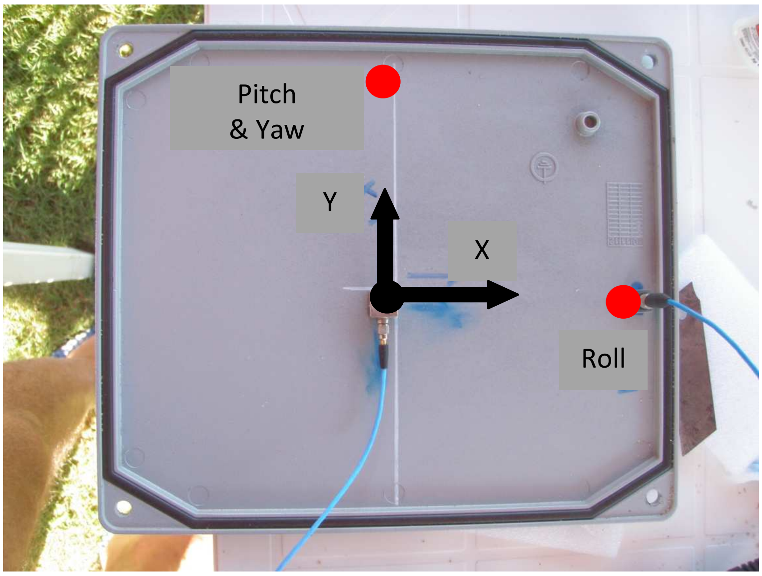


Figure 3.5 *Positioning of the triaxial (black) and monaxial (red) accelometers.*

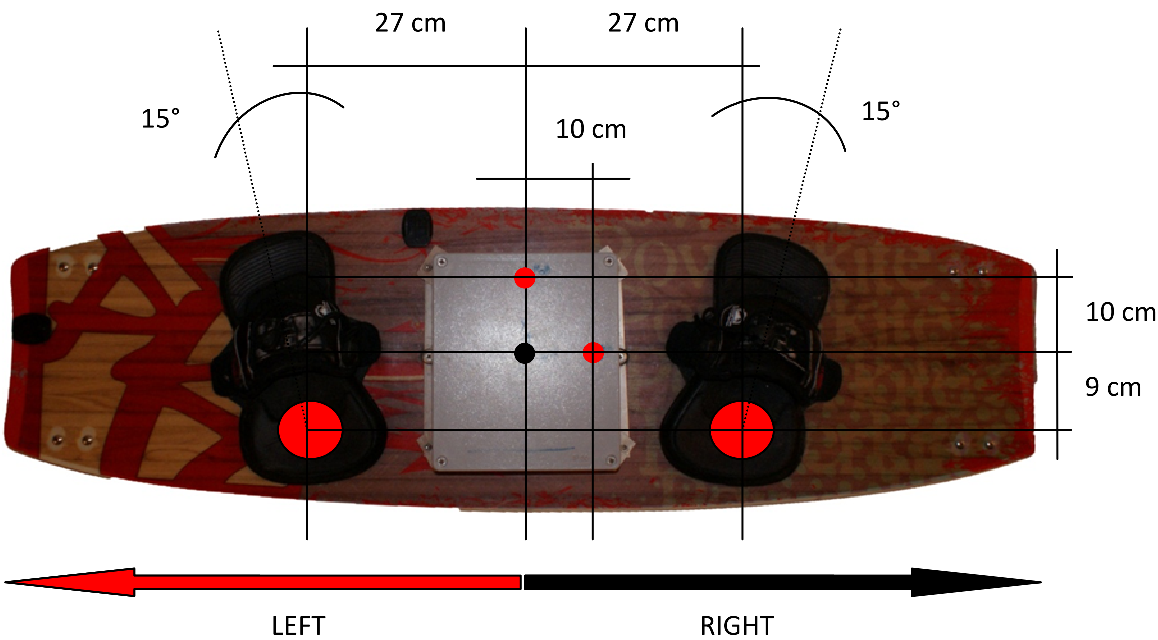


Figure 3.6 *Positioning of the triaxial and monaxial accelometers on the board respect to the feet position.*

Thanks to the fact of using a twin-tip, "symmetric" board, there was no need to jibe for changing the direction. Going to the left the monoaxial accelerometer was always beyond the triaxial accelerometer, going to the right the monoaxial accelerometer was always ahead the triaxial accelerometer.

Measuring in this way it was possible to understand the center of rotation of the board on the three planes.

3.1.3 Weight and dimension

The total dimension is defined by the dimension of the aluminium box while the total weight is the sum of all the items, listed in the below table 3.3.

Table 3.3 Table showing the weight and dimension of all the items composing the box.

Item	Model	Dimension (LxWxH)	Weight (kg)
Mobile PC	SAMSUNG Q1	100x210x20	1,0
Board – 4 channels	NI USB-9233	141x86x20	0,25
Triaxial accelerometer with cable	pcb356 a 21	7x7x7	0,005
Monoaxial accelerometer with cable	Bk4508	7x7x7	0,005
Aluminium Box	ILME IP66	217x253x93	1,50
Stuff for fixing the instruments inside the box	NONE	NONE	0,10
Stirrup to fix the aluminium box on the board	NONE	20x270x3x	0,16
		Total Weight	**3,02**

The total weight of the box and his volume has been needed to understand the buoyancy of the aluminium box, resulting in no need of any addittional safety device in case of losing the box while navigating.

In addition, the total weight of board increase up to 6,22 kg. Surely it has influence on the navigability, but doing the test without any special path the only influence was in the mass increasing of the system only.

3.2 Measure of the wind - WMO guide N.8

The wind is an almost horizontal motion that the air does respect to the earth surface. It is generated by the difference in pressure among the different parts of the earth, moving from high pressure to low pressure. Among the methereologic parameters it is the one most important in the maritime navigation. Until today, the wind direction is meant as the direction of origin of the air flux and it is can shown using the rose wind.

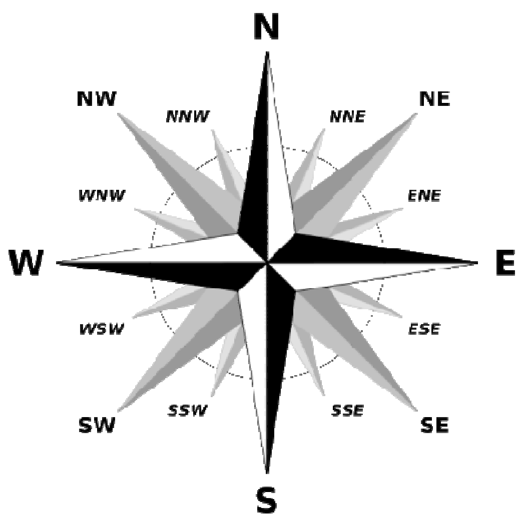


Figure 3.7 Wind rose.

One of the first ways to measure the speed of the wind was by looking at its effects on the local environment. In 1805, Admiral Francis Beaufort invented a scale of this type for measuring winds at sea by describing their effect on ships and waves. His scale was later adapted for use on land, and the same system is still used by many weather stations today. Errors in observations made in this way may be large, but used with caution the method may be justified as providing data that would otherwise not be available in anyway.

Table 3.4 The Beaufort Scale.

Force and Description	Wind Speed (kn)	Specifications for estimating speed over land
0 – Calm	< 1	Calm, smoke rises vertically.
1 – Light Air	1 -3	Smoke drift indicates wind direction; vanes do not move.
2 – Light breeze	4 – 6	Wind felt on face; leave rustle; wind vanes begin to move.
3 – Gentle breeze	7 – 10	Leaves & small twigs in constant motion; light flags extended.
4 – moderate breeze	11 – 16	Raises dust and loose paper, small braches are moved.
5 – Fresh breeze	17 – 21	Small trees begin to sway; flags flap & ripple.
6 – Strong breeze	22 – 27	Large braches in motion; whistling heard in wires.
7 – Near gale	28 – 33	Whole trees in motion, resistance felt in walking again the wind.
8 – Gale	34 – 40	whole trees in motion, resistance felt in walking again the wind.
9 – Strong gale	41 – 47	Slight structural damage occurs, shingles blow from roof.
10 – Violent strorm	48 – 55	Trees broken or uprooted, considerable structural damage accurs.
11 – Violent storm	56 – 63	Widespread damage to trees & building.
12 - Hurricane	64 and over	Severe & extensive damage.

The wind strength or rather the wind speed is measured in meter per second (m/s). However, in metereology, for reason linked to the navigation it is used the knots (kn), corresponding at a nautic mile/hour.

The anemometer is the device for measuring the wind, this term is derived from the Greek word “anemos”, meaning wind. Nowadays there are many ways for measuring the wind and anemometers can be divided into two main classes: those that measure the velocity of the wind, and those that measure the pressure of the wind.

- Cup anemometers

The simplest type of anemometer is the cup anemometer, this instrument consists of a three or four cup centrally connected to a vertical shaft for rotation. At least one cup always faces the oncoming wind. The aerodynamic shape of the cups converts the pressure to rotational torque. The cup rotation is nearly linearly proportional to the wind speed over a specified range. A transducer in the anemometer converts this rotational movement into an electrical signal, which is sent through a wire to a data logger.

- Propeller anemometers

This instrument consists of a propeller mounted on a horizontal shaft that is oriented into the wind through the use of a tail vane. The propeller anemometer also generates an electrical signal proportional to wind speed.

- Hot-wire anemometers

Hot wire anemometers use a very fine wire (on the order of several micrometers) heated up to some temperature above the ambient. Air flowing past the wire has a cooling effect on the wire. As the electrical resistance of most metals is dependent upon the temperature of the metal (tungsten is a popular choice for hotwires), a relationship can be obtained between the resistance of the wire and the flow velocity.

Hot-wire anemometers are extremely delicate, have extremely high frequency-response and fine spatial resolution compared to other measurement methods, and as such are almost universally employed for the detailed study of turbulent flows, or any flow in which rapid velocity fluctuations are of interest.

Other systems are available:

- Pitot tube anemometers.
- Laser Doppler anemometers.
- Sonic anemometers.
- Plate anemometers.
- Tube anemometers.
- Sphere anemometers.

For nearly all applications, it is necessary to measure the averages of the wind speed and direction, even if more and more applications also require information on the variability or gustiness of the wind.

Averaged quantities are quantities that are averaged over a time period, for forecasting purpose the average quantities are over 10-minute intervals climatological statistics usually need averages over each entire hour, day and night, aeronautical applications often use shorter averaging intervals.

The most difficult aspect of wind measurement is the exposure of the anemometer. WMO [13] states that standard exposure of wind instruments in open terrain should be at least 10 m above the ground. Open terrain is defined as an area where the distance between the anemometer and any obstruction is at least 10 times the height of the obstruction.

Wind measurements that are made in the direct wake of trees, buildings or any other obstacles contain little information about the unperturbed wind. Since wakes can easily extend downwind to 12 or 15 times the obstacle height, the requirement of 10 obstruction heights is an absolute minimum. In practice, it is often difficult to find a good location or even an acceptable location for a wind station.

When wind measurements are made on the side of masts or towers rather than at their top, the instruments should be placed on boom with a length of at least three mast or tower widths.

Surface wind measurements without exposure problems hardly exist. The requirement of flat terrain is difficult to meet and most wind stations over land are perturbed by topographic effects. Furthermore if the terrain varies little with azimuth, this may affect the measure even placing the anemometer at a height exceeding 10 m.

Nowadays simple calculation procedures exist to determine the effect of local topography to determine exposure corrections in inhomogeneous surroundings. Since it is nearly impossible to find a location where the wind speed is representative of a large area, it is recommended to make and estimation of the exposure errors.

3.4.1 Wind Measurement

In our case a cup anemometer (BROOKES & GATEHOUSE LTD. Model 152 00 005) was used for the measurements. The anemometer was placed at the top of a 3 m mast; although the transducer height is definitely different from the ones suggested by the WMO guide, the measured wind speed provided a term of comparison between the different sailing conditions. Wind speed was measured during all the duration of the tests. Once connected all the instruments a final check of the verticalness of the anemometer was done using a bubble level in order to avoid further mismeasuring of the actual wind [14].

Figure 3.8 Measurement chain for the wind measurement.

In order to keep certain repeatability in each location of the measurement position of the anemometer was always the same.

3.3 Measure of the waves - WMO guide N.720

The measure of the wave [15] is rather complex; five factors influence the formation of waves:

- wind speed;
- distance of open water that the wind has blown over (called the fetch);
- width of area affected by fetch;
- time duration the wind has blown over a given area;
- water depth;

All of these factors work together to determine the wave's size. The greater each of the variables, the larger are the waves. The evolution of waves in deep water is dominated by wind and the propagation comes along straight lines or great circles. When waves approach the coast, when the depth is about half of the wavelength, the waves are affected by the bottom, currents and, also by obstacles. These effects, which dominate the effect of the local wind, result in modification of the wave propagation.

The first effect is that the forwarding speed of the waves is reduced. This generally leads to a slight turning of the wave direction (refraction) and to a shortening of the wavelength (shoaling) which in turn may lead to a slight increase or decrease in wave height.

Normally the wave height tends to decrease but propagation effects may focus energy in certain regions, resulting in higher rather than lower waves. However, the same propagation effects may also defocus wave energy, resulting in lower waves. In short, the waves may vary considerably as they approach the coast.

Very often near the coast the currents become appreciable. These currents may be generated by tides or by the discharge from rivers. In these cases the currents may affect waves in roughly the same sense as the bottom.

The optimal duration of wave records is determined by several factors. First of all, for a correct description of the state, conditions should be statistically stationary during the sampling period. In fact, this will never be achieved completely as wave fields are usually evolving (i.e. growing or decaying). The optimal time over which waves are usually measured is 15–35 minutes, as this reasonably accommodates both conditions.

Waves are characterized by:

- wave height, from trough to crest;
- wavelength, from crest to crest;
- period, time interval between arrival of consecutive crests at a stationary point;
- wave propagation direction.

Normally the wave behaviour is descripted statistical by:

$\bar{H}_{1/3}$ significant wave height of the 1/3 highest waves,

$\bar{T}_{H1/3}$ significant wave period of the 1/3 highest waves.

Many different techniques are used for the measurement of sea waves; at the state of the art, there are no standard instruments for the different kinds of measurements. Wave measurement techniques can be grouped into three categories:

- Measurements from below the water surface;

Systems to measure waves from below the surface have an advantage in that they are not as vulnerable to damage as systems on the surface. However, there are problems in bringing the data ashore as cable is expensive and can be damaged. An alternative technique is to transmit the information by radio from a buoy moored nearby.

- Measurements at the water surface;

In shallow water, where a platform or structure is available, it is possible to obtain wave measurements at the sea surface by using resistance or capacitance wave staffs. The wave elevation is then directly related to the change in resistance or capacity of the wave staff. Wave staffs can however be easily damaged by floating objects and are subject to fouling by marine growth.

- Measurements from above the water surface.

Waves can be measured from above the surface by downward-pointing laser, infra-red, radar or acoustic instruments. Advantages with this type of instrument are that they are non-intrusive (that is, they do not disturb the flow), and can be easily mounted and maintained.

3.2.1 Wave measurement

Figure 3.9 Bouy, wood plate.

The decision fell on the second category; using a buoy following all the movement of the water surface. The buoy was set-up with two plastic vases. The vase diameter was identified starting from the dimensions of the aluminium box. A vase with 38 cm diameter was suitable for the construction.

The positioning of the box required a friendly use and fast interchangeability. The operation of changing from board to bouy or buoy to board is not made in a nice enviroment, under the sun, with strong wind and a lot of sand around, therefore this operation has to be easy and on the same time fast in order to do not waste battery.

A plane for the box fixation was created using a wooden plate. The aluminium box was rigidly fixed to the buoy using an elastic rope. The final sealing of the vases were done with four screws at 90°, with the interposition of a rubber layer that prevented water entering the bouy and changing the weight and the way of floating.

Figure 3.10 Bouy assembling.

The flat wooden plate inside to buoy was levelled (with the tool of Figure 3.11) in order to limit the alignment errors between the box and the calm water.

Figure 3.11 Bubble level.

After the final assembling, a first test was performed to see the instrumentation buoyancy, and no problems were reported.

3.4 GPS

Speed is one of the most influencing factors according to the preliminary survey and consequently it has been chosen to monitor it using a GPS receiver. The data given by the GPS provides information not only concerning the instantaneous speed but even on the actual path allowing a comparison among the different RMS index acquired during the various sides.

Figure 3.12 GARMIN 305

Tests were performed with a **Garmin 305** wore on the wrist. The reason why this model was selected is because it was not possible to use a GPS inside the aluminium box together with the other instruments (GPS signal was absent). Resuming the use of the GPS, it has the function of:

- to show the path and the type of points of sail;
- to understand the dependance of the RMS index on the path and on the speed.

On the same time the GPS recorded and saved on a file the following data;

- latitude and longitude;
- altitude;
- speed;
- distance.

Moreover together with the above data it was recorded the information concerning the date and the acquisition time. The freeware software GPSvisualizer was used to analyse the followed paths, and to visualize them with Google Earth.

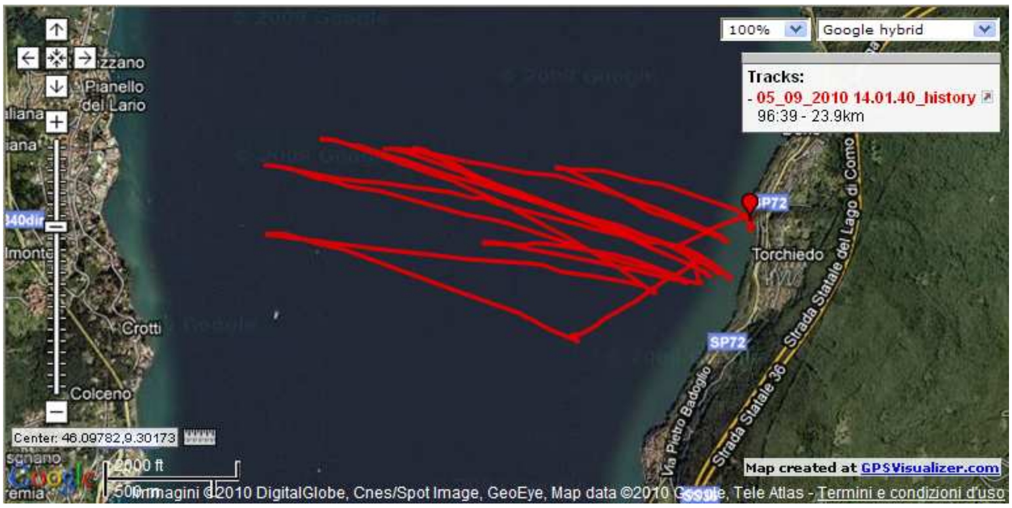


Figure 3.13 Test 5th September 2010.

3.5 Kite and board

As a rule of thumb, the larger is the kite surface, the more is the kite power. The tests were performed using only one kite model, the size was chosen depending on the wind strength.

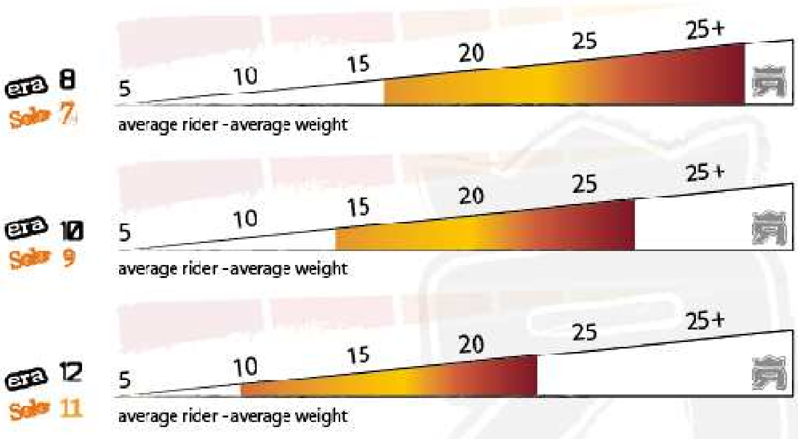


Figure 3.14 Wind range of the kite.

During all the tests it was used a board twin-tip style with the charateristics listed in the below table.

Table 3.5 Characteristic of the twin-tip board.

Length	133	m
Width	39,5	m
Weight	3,2	kg
Construction	Wood	

3.6 Test procedure

The purpose of the tests was to measure the variables defined before; vibration of the board, wind, wave and speed.

Since the beginning it was recognised that the bottleneck in the measurement was due to the lasting of the battery of the notebooks used inside the aluminum box or for the recording the wind. For this reason a set of batteries and one inverter were used in order to recharge them.

In order to do not waste time in thinking what to do a small method and procedure was thought in advance. Possible delay or bad organization could lead first to an earlier discharge of the batteries secondly to the change of the enviroment condition, for instance the wind could stop to blow.

Procedure;

1) Assembling the box and the mast of the anemometer.
2) Start of the acquisition of the boxed-computer and of the GPS.
3) Complete the buoy assembling and place the buoy into water and start the waves measurement.
4) Start the measure of the wind condition, which lasted the entire duration of the trial.
5) Preparation of the kite equipment; pump the kite, unwind the lines etc.
6) After 15 minutes disassembling of the buoy and installation of the aluminium box on the board;
7) Start of the measurement session.

During the test, in order to reduce the influence of the kite on the vibration the kite has been kept steady using the control bar at the minimum, only adjusting the pull and in case of underpower.

During the test between one side to another a couple of second was used in order to have a better distinction of the start and the end of a side. The duration of the measurement was determined by the place morphology and by the respect of the sailing rules.

CHAPTER 4 – CHARACTERIZATION OF THE BOARD

As introduced in the paragraph 1.2.2 the board is the interface between the kiter and the water. Aim of this chapter is to observe and analyse the dynamic response of the board between the point of measurement and the foot pads, where the kiter fixes his feet, and the board movement during the navigation.

The test was divided in three parts for different purposes;

- **Part 1**

Analysis of the frequency response function between board and the heel with and without the aluminium box, in order to understand its influence on the measurement.

- **Part 2**

This test was performed to understand the difference in the dynamic response comparing different boards with different testers and different postures.

- **Part 3**

As previously mentioned, paragraph 2.2, the posture of the kiter is not exaclty centered on the feet; hence the vibration is distributed in different doses between the left and right leg, mainly related to the direction, left or right. This difference can be seen in the studying of the pich, yaw and roll.

4.1 Experimental set-up

Measurements were performed on an electromagnetic shaker. The board was placed on the shaker without any costrain, only a thin film of rubber in order to avoid the board to slide, more for safety reason than for other purposes.

Figure 4.1 Position of the accelerometers during the test with the aluminium box.

Three single-axis accelerometers were used to characterize the response of the board-kiter system. The first accelerometer was used to measure the vibration of the shaker along the Z axis. A second accelerometer was sticked on the cover of the box or placed at the centre of the board. A third accelerometer was sticked on a small rounded plate placed in between the heel and the left foot pad, in order to identify the vibration actually reaching the kiter. The accelerometers were always oriented vertically during the measurement. The total mass of the plate and accelerometer was negligible and accomplishing the ISO 8041 requests.

Figure 4.2 Position of the second accelerometer during the test without the aluminium box.

Figure 4.3 Position of the third accelerometer to measure the vibration on the heel, vibration entering the body.

Once assembled all the instruments and made a proper set-up the tests started.

Table 4.1 Shaker sep-up.

Stimulus	**White Noise**	
Min. frequency	4	Hz
Max. Frequency	20	Hz
RMS Level	2	m/s^2

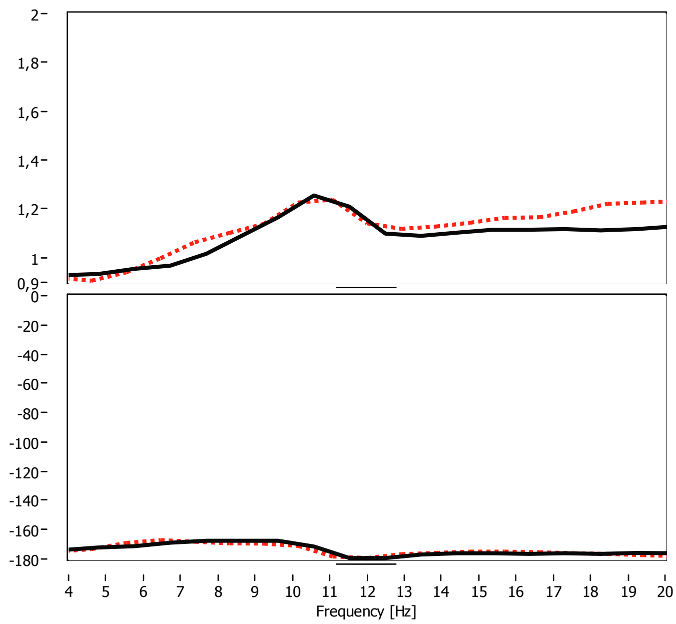
Before the data acquisition the tester has been exposed to vibration for a short period of time to familiarize with the vibration stimulus. The FRF between the shaker and the board was reasonably unitary (+/- 5%) within the whole frequency range, pointing out that the effect of the thin rubber film is negligible.

4.2 Data Analysis – Part 1

These tests were performed to identify the influence of the aluminium box on the dynamic response of the board. For this reason a test with and without the box was carried out to see the difference of the FRF between the shaker and the board and to identify the FRF between the aluminium box, where all the measurement has been taken, and the heel, where the vibration is supposed to enter into the body.

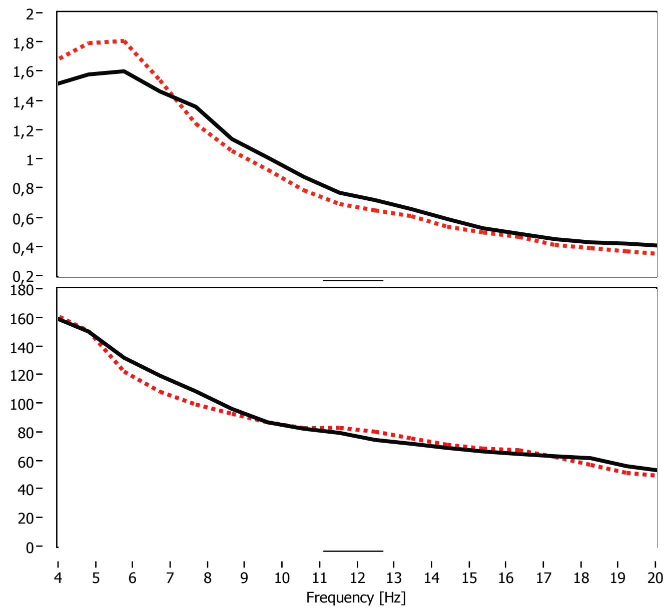
The board n.1 has been the one used in all the tests, for this reason the part 1 of this test was carried out in order to study its dynamic behaviour.

4.2.1 Board n.1 without and with the aluminium box



Graph 4.1 FRF between the shaker and the board without (black) and with (red) the aluminium box.

The graph shows that the FRF differences between the two cases are lower than 5 % in the whole frequency range.

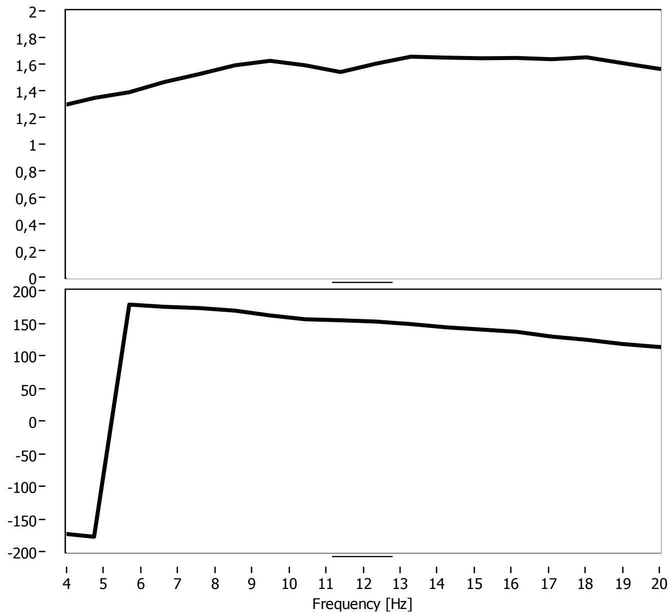


Graph 4.2 FRF between the board and the heel with (black) and without (red) the aluminium box.

The plot shows that the difference between the vibration transmissibility with and without the box is limited and comparable with the test repeatability. The damped resonance at 5 Hz is the one of the standing man on a relaxed position.

4.2.2 Board n.1 loading the stern leg.

Figure 4.4 Test loading more weight on the stern leg.



Graph 4.3 FRF between the board and the heel with the aluminium box and the weight on the stern.

The comparison between the previous graphs 4.2 and 4.3 shows that the amplification at 5 Hz disappeared.

Table 4.2 FRF summary table between the board and the heel with the aluminium box and the weight on the stern.

FRF Board - Heel			
Frequency (Hz)	**FRF Mag.**	**FRF Phase (°)**	**Coherence**
4	1,168544	-173,308303	0,961347
5	1,290084	-173,988052	0,983252
6	1,355979	-178,818221	0,991269
7	1,407645	177,701998	0,990871
8	1,485462	174,310740	0,988955
9	1,56638	171,624006	0,980698
10	1,631126	165,373039	0,979767
11	1,612141	158,228397	0,983815
12	1,556598	154,347606	0,986925
13	1,548995	153,442427	0,984236
14	1,632693	150,730349	0,981019
15	1,639936	144,584485	0,985680
16	1,636849	140,721951	0,987356
17	1,655112	136,895807	0,984688
18	1,663341	129,867874	0,981404
19	1,649892	124,203700	0,982003
20	1,601249	117,611675	0,981664

4.3 Data Analysis – Part 2

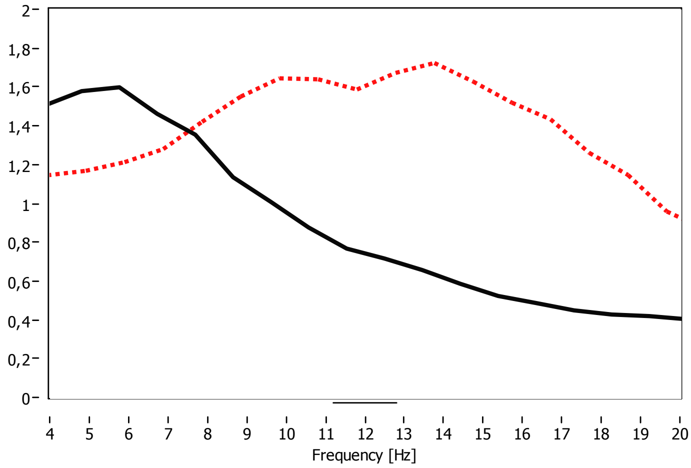
Tests were performed to identify the different vibration transmission with different boards, postures and kiters. In this case two testers were used;

Tester n.1	80 kg	1,78 m
Tester n.2	64 kg	1,72 m

Results are shown in the next plots. The first couple of graphs compare the response of the board n.1 between both testers moving the weight from a central to heel position. The second couple of graphs show the same but using the board n.2.

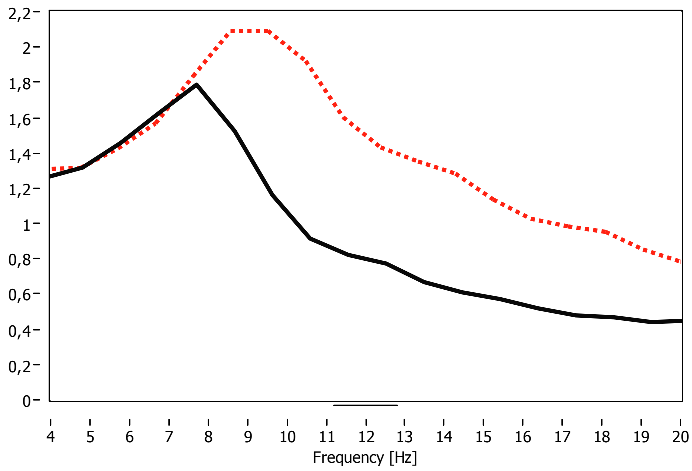
4.3.1 FRF of Board n.1 without the aluminium box with tester n.1 and tester n.2 with different weight positions.

BOARD to HEEL – Central weight/heel weight, board n.1 with tester n.1



Graph 4.4 BOARD n.1 - FRF between the board and the heel without box with tester n.1 and different weight positions; central weight (black), heel weight (red).

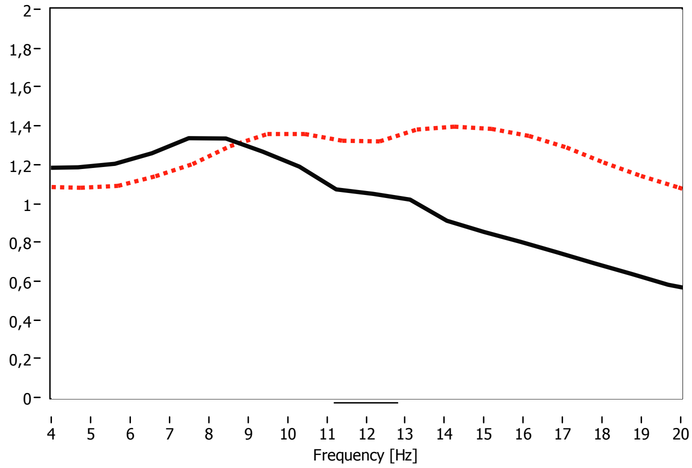
BOARD to HEEL – Central weight/heel weight, board n.1 with tester n.2



Graph 4.5 BOARD n.1 - FRF between the board and the heel without box with tester n.2 and different weight positions; central weight (black), heel weight (red).

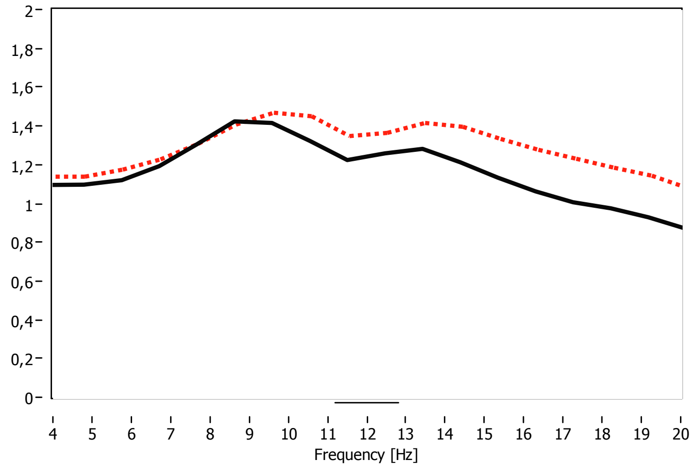
4.3.2 FRF of Board n.2 without the aluminium box with tester n.1 and tester n.2 with different weight positions.

BOARD to HEEL – Central weight/heel weight, board n.2 with tester n.1



Graph 4.6 BOARD n.2 - FRF between the board and the heel without box with tester n.1 and different weight positions; central weight (black), heel weight (red).

BOARD to HEEL – Central weight/heel weight, board n.2 with tester n.2



Graph 4.7 BOARD n.2 - FRF between the board and the heel without box with tester n.2 and different weight positions; central weight (black), heel weight (red).

In both tests the results have similarities, as can be seen increasing the weight on the heel the FRF moves to the right, this can be easy understandable by the increasing of the stiffness of the entire system.

However the graphs show a difference between the two boards. Board n.1 keeps the shape of the curve like a bell, in both weight positions and testers, decreasing sharply after 10/14 Hz. Instead for board n.2 the response changes becoming almost constant at the increasing of the frequency.

This same behaviour was recognised in the previous test, paragraph 4.2.2, where it was measured the FRF loading the weight on the stern leg of board n.1.

4.4 Data Analysis – Part 3

All the measures have been taken between the legs, on the rigid part of the board. The analysis of the data, exposed in the next chapter, are carried out referring to the point of measurement, therefore there are still two aspects to be considered;

- the first concerns the FRF between the point of measurement and the heel, where it is supposed the vibration enters the body;
- the second concerns the board movements since the motion of the board is not a pure translation, thus the vibration is different on the different board positions.

Therefore, first, it is important to define the accelerations of the board and then calculating backward adding the effects of the foot pad and the board motion.

4.5 Discussion

The constraints used to test the board was something not reported in any lecture, and very difficult to defined due to the fact that the board slides on the water which is deformable but uncompressible.

PART 1

After this test, the first conclusion was that the FRF differences between the two cases are lower than 5 % in the whole frequency range.

Moreover taking the vibration along the Z and multiplying it with the FRF the vibration increase of 29%.

PART 2

A difference was seen in the analysis of different boards with different foot pads and different weight positions. The weight difference between the two testers was 15 kg; such a weight difference influences the FRF between the board and the heel due to more compression of the foot pad. In fact in all the curves at the increasing of the weight on the heel the system got stiffer increasing its natural frequency.

One thing must notice that in the physics of the kitesurfing the pulling force coming from the kite can be divided in vertical and horizontal. The vertical force influences the weight of the kiter on the foot pad increasing/reducing the trasmission of vibration along the Z axis.

PART 3

The results of this part will be explained in the next chapter, paragraph 5.7.

CHAPTER 5 – DATA ANALYSIS & RESULTS

5.1 Test Summary

The test summary is shown in the next table. Six hours and half of measurements were performed in twelve experimental sessions in the months of August, September and October, 2010 with a total distance of over 200 km.

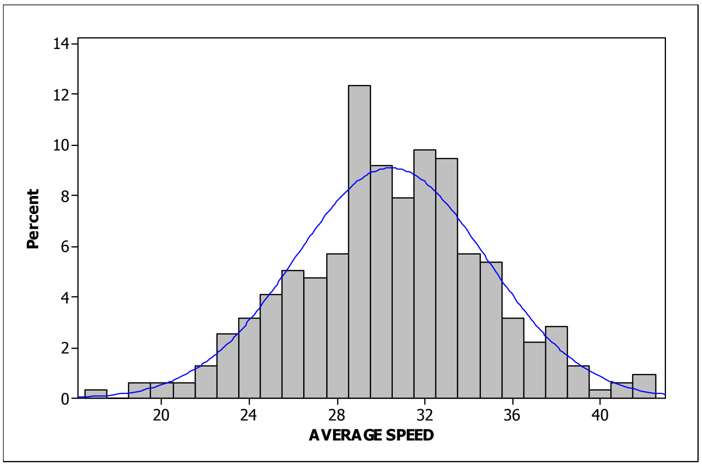
Table 5.1 Summary test table.

Location	Date	Start	End	Duration (h)	Sides	Distance (m)
PORTO BOTTE	**25_08_2010**	13.07.54	13.21.32	0.12.44	22	7.207
PORTO BOTTE	**26_08_2010**	12.12.33	12.24.23	0.10.48	10	6.106
PORTO BOTTE	**28_08_2010**	11.42.06	11.58.25	0.13.50	26	8.413
DORIO	**04_09_2010**	15.23.47	15.41.57	0.17.44	10	8.606
DORIO	**05_09_2010**	14.45.51	15.33.12	0.45.34	19	23.307
DORIO	**05_09_2010**	16.30.50	17.02.47	0.26.44	16	14.395
VALMADRERA	**11_09_2010**	7.04.16	7.39.14	0.32.27	22	16.128
DORIO	**11_09_2010**	14.56.54	16.01.11	0.57.34	38	28.975
DORIO	**11_09_2010**	17.30.21	18.20.58	0.45.44	32	23.505
DORIO	**12_09_2010**	14.19.54	15.48.38	1.13.08	60	36.292
HYERES	**02_10_2010**	13.48.53	14.14.26	0.21.36	26	10.620
HYERES	**03_10_2010**	12.46.37	13.40.28	0.34.04	35	17.353

	Total
Duration (h)	6.31.57
Sides	316
Distance (m)	200.906

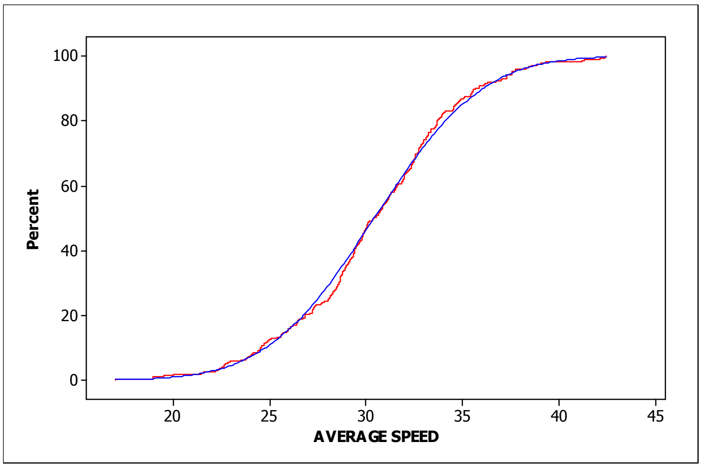
5.1.1 Probability density function of the average speed

Preliminary analyses were performed to identify the descriptive statistics of all the data. As an example, the speed histogram is shown in the next figure.



Graph 5.1 Probability density function of the average speed.

The istogram shows the distribuition of the average speed during all the tests. During the 316 sides the grand speed average was 30,44 m/s, with an average standard deviation of 4,384 m/s^2.



Graph 5.2 Cumulative distribution function of the average speed.

Another way to present the same information is to use a cumulative distribution curve. This distribution curve plots the percentage, of the total measurement for which the average speed level is less than one read directly from the graph.

The minimum speed is related to hydrodynamic force acting on the board and the vertical pull of the kite in order to don't sink, instead the max speed is more connected to the wind speed and the ability to go fast.

5.1.2 Probability density function of the weighted accelerations

During all the tests the following data was recorded from the triaxial accelerometer located midway between the legs;

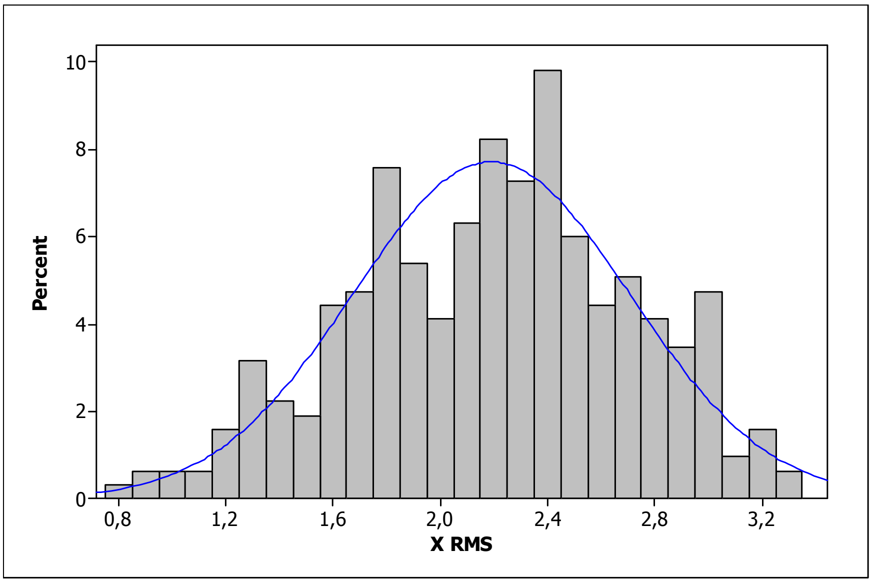
Table 5.2 Vibration along X, Y, Z listed for each test.

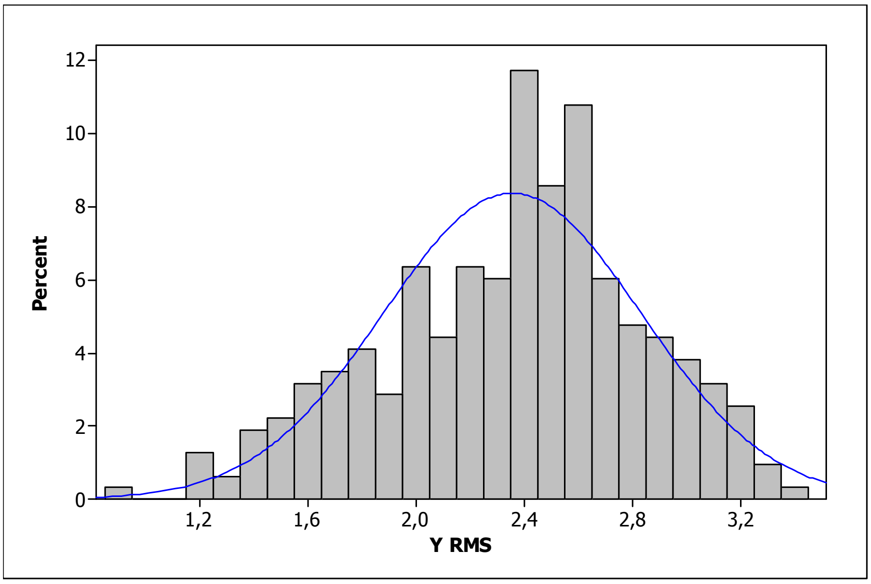
Location	Date	Average Speed (km/h)	a_{wx} (m/s^2)	a_{wy} (m/s^2)	a_{wz} (m/s^2)
PORTO BOTTE	**25_08_2010**	32,13	1,96	1,80	5,73
PORTO BOTTE	**26_08_2010**	32,50	2,06	1,99	5,62
PORTO BOTTE	**28_08_2010**	33,60	2,40	2,02	6,20
DORIO	**04_09_2010**	27,90	2,57	2,34	6,02
DORIO	**05_09_2010**	30,01	2,77	2,42	6,02
DORIO	**05_09_2010**	32,38	2,61	2,51	6,66
VALMADRERA	**11_09_2010**	29,88	2,34	2,75	5,94
DORIO	**11_09_2010**	28,81	2,35	2,54	5,80
DORIO	**11_09_2010**	30,70	2,36	2,65	5,75
DORIO	**12_09_2010**	29,43	2,11	2,52	5,15
HYERES	**02_10_2010**	29,15	2,34	2,64	6,17
HYERES	**03_10_2010**	31,07	1,85	2,21	6,32

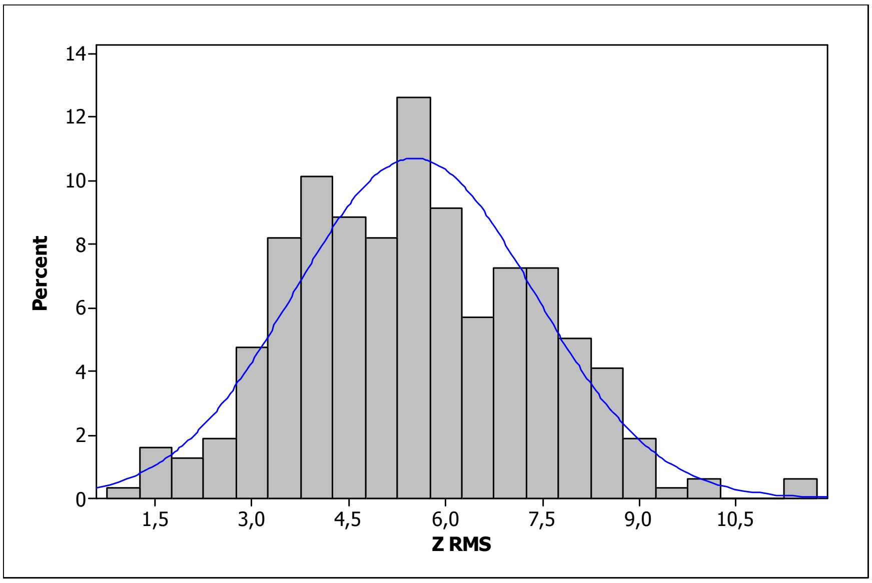
As can be seen from the below table 5.3 the vibration along the Z axis, the vertical one, is more than the double compared to the vibration along X and Y. The histograms, in the next pages show the probability distribution of the vibration along X, Y and Z.

Table 5.3 R.M.S and Standard Dev. of the vibration along X, Y, Z for all the 316 sides.

Vibration (m/s^2)	RMS	St. Deviation
a_{wx}	2,190	0,5157
a_{wy}	2,356	0,4771
a_{wz}	5,518	1,8730







Graph 5.3 Probability Density Function of $a_{wx} - a_{wy} - a_{wz}$.

Even if there is a different exposure between the left and right leg, as later explained, the total vibration entering into the human body is the sum of both; consequently, the one measured by the triaxial accelerometer placed between the legs summarizes the actual exposure.

The EU directive limits for workers exposure to vibration are 0,5 m/s^2 (EAV) and 1,15 m/s^2 (ELV) for the worst axis. The following table shows, in red, the values exceeding the action values instead in red background the ones exceeding the exposure limit values.

Table 5.4 Vibration along the X, Y, Z based on 8 hours.

			Vibration (m/s^2)			Vector sum (m/s^2)
Location	**Date**	**Duration (min)**	$a_{wx}(8)$	$a_{wy}(8)$	$a_{wz}(8)$	$a_v(8)$
PORTO BOTTE	**25_08_2010**	0.12.44	0,32	0,29	0,93	1,03
PORTO BOTTE	**26_08_2010**	0.10.48	0,31	0,30	0,84	0,95
PORTO BOTTE	**28_08_2010**	0.13.50	0,41	0,34	1,05	1,18
DORIO	**04_09_2010**	0.17.44	0,49	0,45	1,16	1,34
DORIO	**05_09_2010**	0.45.34	0,85	0,75	1,86	2,17
DORIO	**05_09_2010**	0.26.44	0,62	0,59	1,57	1,79
VALMADRERA	**11_09_2010**	0.32.27	0,61	0,72	1,54	1,81
DORIO	**11_09_2010**	0.57.34	0,81	0,88	2,01	2,34
DORIO	**11_09_2010**	0.45.44	0,73	0,82	1,77	2,09
DORIO	**12_09_2010**	1.13.08	0,82	0,99	2,01	2,38
HYERES	**02_10_2010**	0.21.36	0,50	0,56	1,31	1,51
HYERES	**03_10_2010**	0.34.04	0,49	0,59	1,68	1,85

In the chapter 4, part 1, with the use of a shaker the vibration recorded during the tests was simulated in order to calculate the transfer function between the board and the heel.

Furthermore at the next paragraph 5.9.5, the study of the roll gave the percentage of which the measured vibration along Z has to be reduced because the heel is not along the same axis of the accelerometer.

Combining these two considerations the next table estimates the vibration magnitude at the heel, the one entering the body.

Table 5.5 Vibration along the X, Y, Z based on 8 hours with foot pad and considering the vibration on the heels.

			Vibration (m/s²)			Vector Sum (m/s²)
Location	**Date**	**Duration (min)**	$a_{wx}(8)$	$a_{wy}(8)$	$a_{wz}(8)$	$a_v(8)$
PORTO BOTTE	**25_08_2010**	0.12.44	0,32	0,29	0,95	1,05
PORTO BOTTE	**26_08_2010**	0.10.48	0,31	0,30	0,86	0,96
PORTO BOTTE	**28_08_2010**	0.13.50	0,41	0,34	1,07	1,20
DORIO	**04_09_2010**	0.17.44	0,49	0,45	1,18	1,36
DORIO	**05_09_2010**	0.45.34	0,85	0,75	1,89	2,21
DORIO	**05_09_2010**	0.26.44	0,62	0,59	1,60	1,82
VALMADRERA	**11_09_2010**	0.32.27	0,61	0,72	1,58	1,83
DORIO	**11_09_2010**	0.57.34	0,81	0,88	2,05	2,37
DORIO	**11_09_2010**	0.45.44	0,73	0,82	1,81	2,12
DORIO	**12_09_2010**	1.13.08	0,82	0,99	2,05	2,42
HYERES	**02_10_2010**	0.21.36	0,50	0,56	1,34	1,53
HYERES	**03_10_2010**	0.34.04	0,49	0,59	1,72	1,88

Despite the small changes of the exposure numerical values, the situation is still critical since even very short exposures (15 minutes) leads to daily exposures larger than the ELV. The time at which the ELV is reached is shown in the next table.

Table 5.6 Time and Distance for each test in order to stay under the thresholds.

Location	Date	Exceeding the action values 0,50 m/s² Time	Distance	Exceeding the exposure limit values 1,15 m/s² Time	Distance
PORTO BOTTE	**25_08_2010**	0.04.38	2.607	NONE	NONE
PORTO BOTTE	**26_08_2010**	0.04.34	2.551	NONE	NONE
PORTO BOTTE	**28_08_2010**	0.02.43	1.688	NONE	NONE
DORIO	**04_09_2010**	0.03.25	1.701	0.15.33	7.488
DORIO	**05_09_2010**	0.01.36	912	0.12.54	6.994
DORIO	**05_09_2010**	0.02.31	1.455	0.13.26	7.197
VALMADRERA	**11_09_2010**	0.03.08	1.740	0.16.11	8.054
DORIO	**11_09_2010**	0.03.33	2.042	0.12.53	7.122
DORIO	**11_09_2010**	0.02.45	1.458	0.13.58	7.197
DORIO	**12_09_2010**	0.04.04	2.088	0.19.09	9.922
HYERES	**02_10_2010**	0.03.16	1.622	0.14.32	7.283
HYERES	**03_10_2010**	0.02.05	1.054	0.15.05	7.268

Table 5.7 Average Time and Distance in order to stay under the thresholds.

	Exceeding the action values of 0,5 m/s²		Exceeding the exposure limit values of 1,15 m/s²	
	Time (h)	Distance (m)	Time (h)	Distance (m)
Average	0.03.12	1.743	0.14.51	7.614

5.2 Data analysis

In order to compare the different variable each test was divided in sides before the analysis.

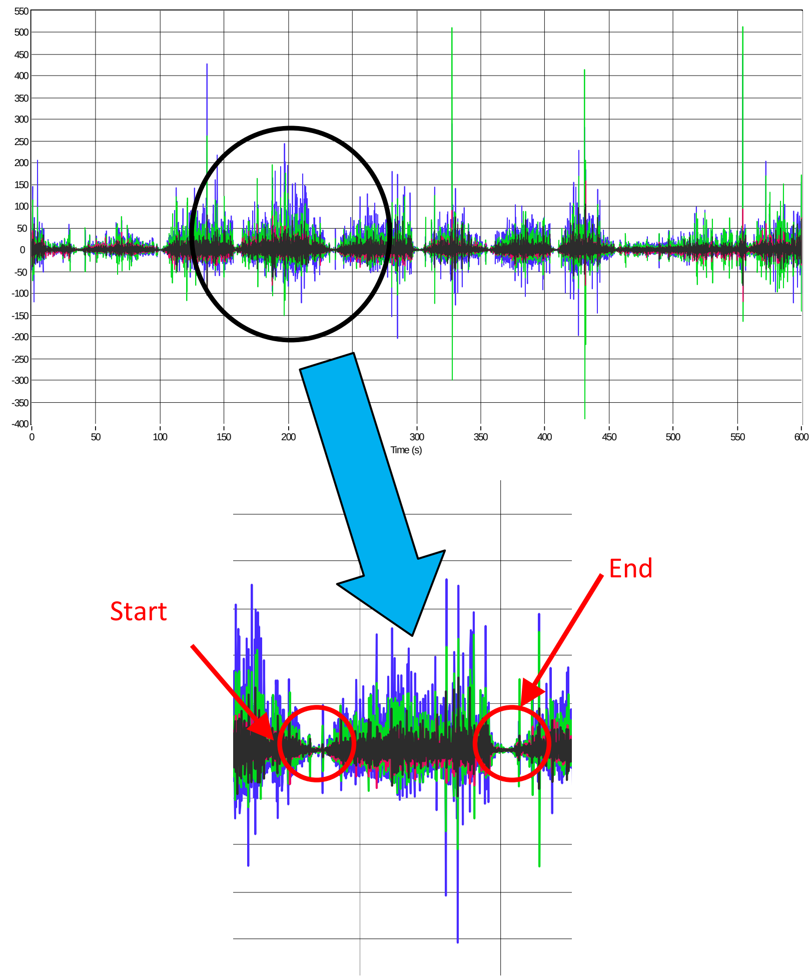


Figure 5.1 Side n.3 of the Test dated on 12th September 2010.

In order to divide the sides correctly the timing was cross-checked with the data coming from the GPS. As can be seen from the figure 5.1 the start and the end of the side can be easily recognised by the stop and the start of the vibration.

At the end of each test a calculation sheet saved with the name of the date and the hour of the test was prepared in order to analyse all the data together. First of all it was exported a file .tcx from the GPS and using a program made in Excel with a macro automatically a summary table of the test was done, a sample of the table is here below.

Table 5.8 Summary test table of 25th September 2010 - Porto Botte.

								Speed (km/h)		
File Name	Side N.	Start	End	sec	Main Direction	Side	Total Distance	Min	Max	Ave.
0825_01	1	13.07.54	13.08.15	21	-0,001559	RIGHT	213,11	17,31	37,31	31,55
0825_02	2	13.08.21	13.08.45	24	0,001567	LEFT	202,37	17,96	30,87	27,25
0825_03	3	13.08.49	13.09.15	26	-0,002463	RIGHT	291,33	23,27	45,73	38,89
0825_04	4	13.09.17	13.09.56	39	0,002405	LEFT	299,45	10,61	36,19	26,54
0825_05	5	13.09.59	13.10.24	25	-0,001827	RIGHT	257,37	21,76	38,60	33,35
0825_06	6	13.10.27	13.11.02	35	0,002201	LEFT	302,64	10,25	35,31	28,89
0825_07	7	13.11.03	13.11.34	31	-0,002628	RIGHT	331,11	26,58	40,57	36,99
0825_08	8	13.11.40	13.12.25	45	0,002612	LEFT	351,92	12,51	34,64	27,67
0825_09	9	13.12.27	13.12.59	32	-0,002784	RIGHT	357,85	27,07	43,31	37,56
0825_10	10	13.13.02	13.13.45	43	0,002954	LEFT	377,69	10,29	37,65	30,71
0825_11	11	13.13.47	13.14.30	43	-0,003404	RIGHT	443,54	16,46	41,58	35,51
0825_12	12	13.14.32	13.15.19	47	0,003124	LEFT	396,99	9,73	34,73	28,33
0825_13	13	13.15.20	13.15.56	36	-0,002761	RIGHT	360,83	23,18	39,48	35,43
0825_14	14	13.15.59	13.16.46	47	0,003329	LEFT	426,97	11,21	37,55	31,64
0825_15	15	13.16.47	13.17.30	43	-0,003023	RIGHT	399,13	9,93	39,31	31,61
0825_16	16	13.17.32	13.18.11	39	0,002849	LEFT	379,68	18,76	39,13	32,44
0825_17	17	13.18.14	13.18.41	27	-0,001820	RIGHT	267,24	13,13	37,93	30,73
0825_18	18	13.18.43	13.19.13	30	0,002071	LEFT	273,06	9,31	36,32	29,62
0825_19	19	13.19.15	13.19.35	20	-0,001508	RIGHT	204,67	15,36	42,27	33,66
0825_20	20	13.19.37	13.20.05	28	0,001781	LEFT	242,04	10,63	37,99	29,09
0825_21	21	13.20.07	13.20.45	38	-0,003088	RIGHT	417,20	22,62	41,30	37,30
0825_22	22	13.20.47	13.21.32	45	0,003325	LEFT	410,61	14,03	39,36	32,00

Time histories were frequency weighted according to the ISO 2631 standard; data were eventually analysed with Minitab software.

5.2 Uncertainty

Being the choice of the beginning and the end of each side arbitrary, it was chosen to investigate the repeatability of the measurements in these conditions. The relative uncertainty is shown in the next tables.

Table 5.9 Uncertainty estimate of side n.3 of the test dated 2nd October 2010.

	Vibration (m/s^2)		
n.	a_{wx}	a_{wy}	a_{wz}
1	2,737	2,989	8,151
2	2,861	3,105	8,540
3	2,833	3,075	8,456
4	2,716	2,968	8,080
5	2,912	3,161	8,716
6	2,806	3,046	8,375
7	2,833	3,075	8,456
RMS	2,81	3,06	8,40
St.Dev	0,06	0,06	0,20
Uncertainty	2,26%	2,01%	2,43%

Table 5.10 Uncertainty estimate of side n.5 of the test dated 12th September 2010.

	Vibration (m/s^2)		
n.	a_{wx}	a_{wy}	a_{wz}
1	1,404	2,120	2,974
2	1,352	2,033	2,853
3	1,394	2,125	3,009
4	1,365	2,057	2,881
5	1,362	2,048	2,875
6	1,365	2,057	2,881
7	1,383	2,101	2,963
RMS	1,37	2,08	2,92
St.Dev	0,02	0,03	0,06
Uncertainty	1,28%	1,67%	1,93%

Table 5.11 Uncertainty estimate of side n.9 of the test dated 12th September 2010.

	Vibration (m/s^2)		
n.	a_{wx}	a_{wy}	a_{wz}
1	1,629	2,548	3,988
2	1,611	2,507	3,912
3	1,608	2,492	3,856
4	1,609	2,508	3,891
5	1,699	2,659	4,203
6	1,607	2,498	3,895
7	1,603	2,486	3,859
RMS	1,62	2,53	3,95
St.Dev	0,03	0,06	0,11
Uncertainty	1,95%	2,24%	2,88%

Table 5.12 Summary table concerning the uncertainty estimate.

Side	a_{wx}	a_{wy}	a_{wz}
n.3 of the test dated 2nd October 2010	2,26%	2,01%	2,43%
n.5 of the test dated 12th September 2010	1,28%	1,67%	1,93%
n.9 of the test dated 12th September 2010.	1,95%	2,24%	2,88%
Mean	1,83%	1,97%	2,41%

A similar evaluation was performed on GPS data; in this case, the average variability was 3,17 %, as shown in the next table.

Table 5.13 Uncertainty estimate of average speed changing the start/end of the side considering the first n.22 sides of the test dated 12th September 2010.

n.	Wide	Narrow	Mean	De ST	
1	30,46	30,83	30,65	0,19	0,60%
2	22,88	24,07	23,47	0,59	2,52%
3	32,11	32,89	32,50	0,39	1,19%
4	26,38	27,39	26,88	0,50	1,87%
5	30,04	31,16	30,60	0,56	1,82%
6	28,82	29,40	29,11	0,29	1,00%
7	33,27	37,50	35,39	2,12	5,98%
8	30,16	32,12	31,14	0,98	3,14%
9	31,78	34,56	33,17	1,39	4,19%
10	29,24	31,86	30,55	1,31	4,28%
11	35,05	39,05	37,05	2,00	5,40%
12	27,98	31,55	29,76	1,78	5,99%
13	30,18	33,68	31,93	1,75	5,48%
14	33,79	36,15	34,97	1,18	3,36%
15	30,04	31,29	30,66	0,62	2,02%
16	32,45	34,52	33,48	1,04	3,09%
17	27,21	31,56	29,39	2,17	7,40%
18	26,90	29,38	28,14	1,24	4,41%
19	27,75	29,91	28,83	1,08	3,75%
20	33,28	34,14	33,71	0,43	1,27%
21	39,27	39,31	39,29	0,02	0,04%
22	25,65	26,09	25,87	0,22	0,85%
				Mean	**3,17%**

5.3 Analysis of influencing parameters on the vibration

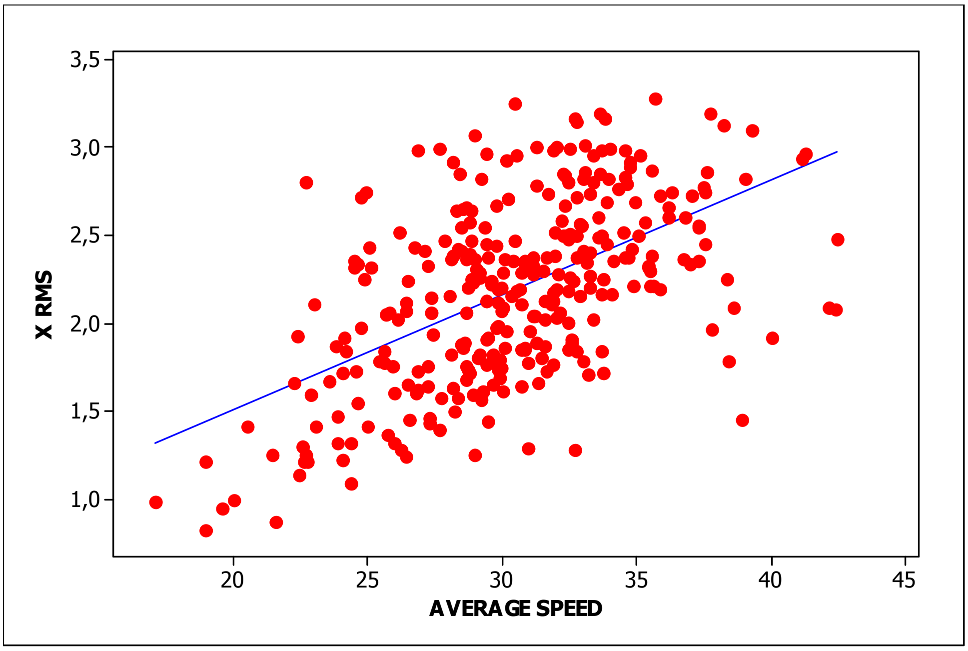
Aim of this paragraph is to find if there is any relationship between the variables previously listed in chapter 3. A further step is the correlation analysis for the possibility of foreseeing the exposure given the different environmental variables.

Table 5.14 Summary table.

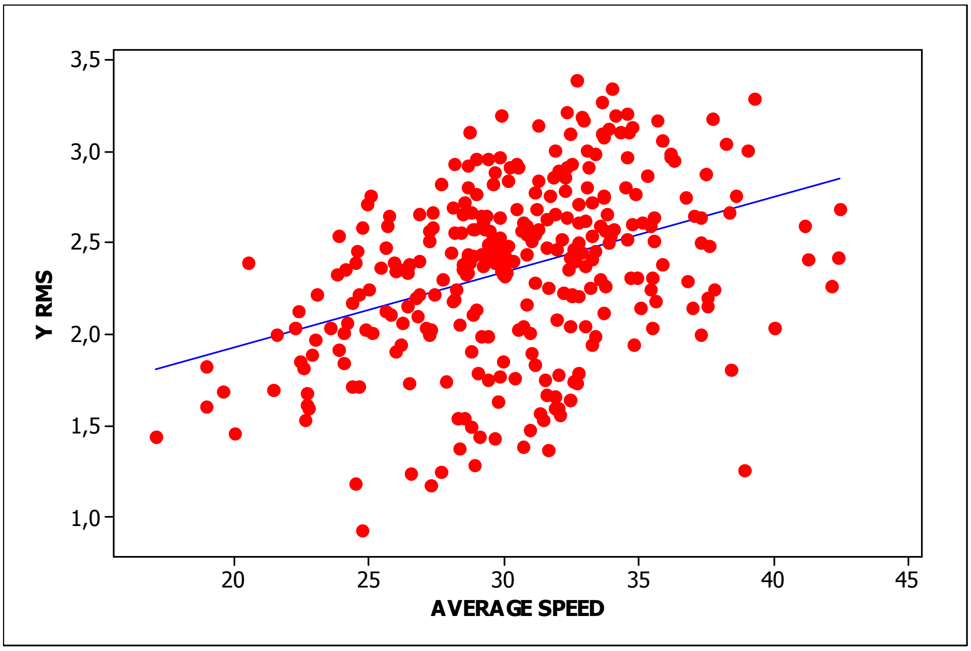
Max Speed (km/h)	Average Speed (km/h)	a_{wx} (m/s^2)	a_{wy} (m/s^2)	a_{wz} (m/s^2)	WAVE (m/s^2)	WIND (kn)
45,73	32,13	1,96	1,80	5,73	1,92	**18,6**
37,97	32,50	2,06	1,99	5,62	2,12	**18,9**
47,25	33,60	2,40	2,02	6,20	2,34	**18,8**
40,17	27,90	2,57	2,34	6,02	1,98	**14,3**
41,73	30,01	2,77	2,42	6,02	2,51	**14,8**
47,87	32,38	2,61	2,51	6,66	2,30	**10,2**
50,15	29,88	2,34	2,75	5,94	2,02	**14,7**
52,41	28,81	2,35	2,54	5,80	2,30	**10,0**
59,05	30,70	2,36	2,65	5,75	2,46	**7,9**
51,92	29,43	2,11	2,52	5,15	2,10	**9,5**
48,42	29,15	2,34	2,64	6,17	2,46	**12,3**
54,60	31,07	1,85	2,21	6,32	1,40	**19,1**

5.3.1 Vibration Vs Average Speed

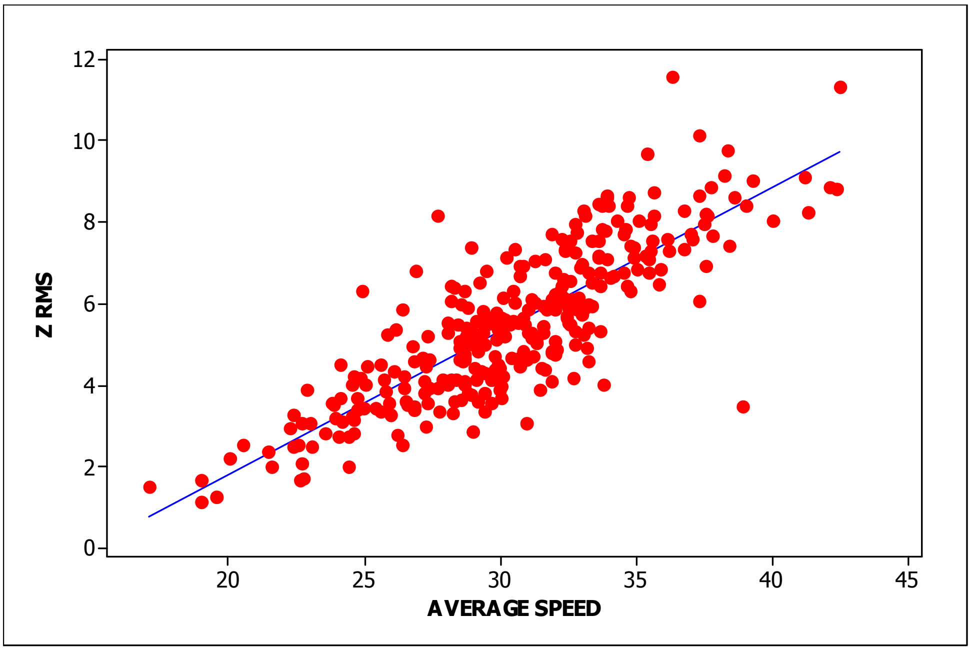
The below scatterplots show in the abscissa the independent variable, average speed calculate for each side, instead in the ordinate the dependent variable, vibration along the X, Y and Z axis.



Graph 5.4 Scatterplot between a_{wx} Vs Average Speed.



Graph 5.5 Scatterplot between a_{wy} Vs Average Speed.



Graph 5.6 Scatterplot between a_{wz} Vs Average Speed.

All the three scatterplots show a visible correlation among the variables; in all these cases, a speed increasing generally implies larger vibration values along the three axes.

Table 5.15 Correlation (R^2) and regression equation between a_{wx}, a_{wy} and a_{wz} Vs Average speed.

Vibration (m/s^2)	Regression equation	R-Sq(adj)	Remark
a_{wx}	0,202 + 0,0653 AVERAGE SPEED	**30,5 %**	LOW Correlation
a_{wy}	1,11 + 0,0410 AVERAGE SPEED	**13,9 %**	LOW Correlation
a_{wz}	- 5,22 + 0,352 AVERAGE SPEED	**69,0 %**	HIGH Correlation

5.3.2 Vibration Vs Wave

Table 5.16 Correlation (R^2) and regression equation between a_{wx}, a_{wy} and a_{wz} Vs Wave.

Vibration (m/s^2)	Regression equation	R-Sq(adj)	Remark
a_{wx}	1,08 + 0,520 TOT WAVE	**10,3 %**	LOW Correlation
a_{wy}	1,71 + 0,300 TOT WAVE	**3,8 %**	LOW Correlation
a_{wz}	5,71 – 0,096 TOT WAVE	**0,0 %**	LOW Correlation

5.3.3 Vibration Vs Wind

Table 5.17 Correlation (R^2) and regression equation between a_{wx}, a_{wy} and a_{wz} Vs Wind.

Vibration (m/s^2)	Regression equation	R-Sq(adj)	Remark
a_{wx}	3,25 – 0,0104 Mean Wind	**9,0 %**	LOW Correlation
a_{wy}	3,05 – 0,00681 Mean Wind	**4,4 %**	LOW Correlation
a_{wz}	6,52 – 0,00986 Mean Wind	**0,3 %**	LOW Correlation

The above tables show that the vibration is mainly affected by the kiter speed, while other factors have negligible effects.

It is worth noting that the wave strength was the most influencing parameter according to the preliminary survey conducted in paragraph 2.6. This because the majority of tests were performed in similar wave conditions and other confounding factors had an effect on the measured vibration.

In the following paragraph a deeper analysis was performed dividing the tests by location.

5.4 Correlation and regression by location

Tests were carried out in four locations. This paragraph wants to analyse each location, one by one, in order to understand if there is any correlation that cannot be clearly seen considering all the data together.

Table 5.18 Summary table, tests in different location.

Location	Date	Distance (m)	Duration (h)
PORTO BOTTE	**25_08_2010**	7.207	0.12.44
PORTO BOTTE	**26_08_2010**	6.106	0.10.48
PORTO BOTTE	**28_08_2010**	8.413	0.13.50
DORIO	**04_09_2010**	8.606	0.17.44
DORIO	**05_09_2010**	23.307	0.45.34
DORIO	**05_09_2010**	14.395	0.26.44
VALMADRERA	**11_09_2010**	16.128	0.32.27
DORIO	**11_09_2010**	28.975	0.57.34
DORIO	**11_09_2010**	23.505	0.45.44
DORIO	**12_09_2010**	36.292	1.13.08
HYERES	**02_10_2010**	10.620	0.21.36
HYERES	**03_10_2010**	17.353	0.34.04

	Total Distance (m)	Total Duration (h)
PORTO BOTTE	21.726	0.37.22
DORIO	135.079	4.26.28
VALMADRERA	16.128	0.32.27
HYERES	27.973	0.55.40

The location where most of the tests were carried out is Dorio, second Hyères, Porto Botte and Valmadrera. Considering a location at a time a further analysis could be conducted, infact in this case has been possible to analyse even the influence of the direction, points of sail, dividing the side in left and right.

5.4.1 Porto Botte

Table 5.19 Correlation (R^2) and regression equation between a_{wx}, a_{wy} and a_{wz} Vs Average speed - Porto Botte.

Vibration (m/s^2)	Regression equation	R-Sq(adj)	Remark
a_{wx}	- 0,524 + 0,0816 AVERAGE SPEED	**49,2 %**	FAIR Correlation
a_{wy}	- 0,836 + 0,0833 AVERAGE SPEED	**45,4 %**	FAIR Correlation
a_{wz}	- 5,91 + 0,356 AVERAGE SPEED	**57,5 %**	FAIR Correlation

Table 5.20 Correlation (R^2) and regression equation between a_{wx}, a_{wy} and a_{wz} Vs Wave - Porto Botte.

Vibration (m/s^2)	Regression equation	R-Sq(adj)	Remark
a_{wx}	- 0,202 + 1,10 TOT WAVE	**27,2 %**	LOW Correlation
a_{wy}	0,575 + 0,620 TOT WAVE	**6,4 %**	LOW Correlation
a_{wz}	2,57 + 1,50 TOT WAVE	**1,5 %**	LOW Correlation

Table 5.21 Correlation (R^2) and regression equation between a_{wx}, a_{wy} and a_{wz} Vs Wind - Porto Botte.

Vibration (m/s^2)	Regression equation	R-Sq(adj)	Remark
a_{wx}	- 0,14 + 0,0204 MEAN WIND	**2,3 %**	LOW Correlation
a_{wy}	0,66 + 0,0110 MEAN WIND	**0,0 %**	LOW Correlation
a_{wz}	7,70 – 0,0170 MEAN WIND	**0,0 %**	LOW Correlation

Porto Botte LEFT

Table 5.22 Correlation (R^2) and regression equation between a_{wx}, a_{wy} and a_{wz} Vs Average speed - Porto Botte left.

Vibration (m/s^2)	Regression equation	R-Sq(adj)	Remark
a_{wx}	- 1,50 + 0,112 AVERAGE SPEED	**41,0 %**	FAIR Correlation
a_{wy}	- 1,27 + 0,0938 AVERAGE SPEED	**40,1 %**	FAIR Correlation
a_{wz}	- 5,43 + 0,330 AVERAGE SPEED	**54,1 %**	FAIR Correlation

Table 5.23 Correlation (R^2) and regression equation between a_{wx}, a_{wy} and a_{wz} Vs Wave - Porto Botte left.

Vibration (m/s^2)	Regression equation	R-Sq(adj)	Remark
a_{wx}	- 0,439 + 1,11 TOT WAVE	**44,8 %**	FAIR Correlation
a_{wy}	- 0,091 + 0,789 TOT WAVE	**30,9 %**	LOW Correlation
a_{wz}	2,39 + 1,05 TOT WAVE	**2,9 %**	LOW Correlation

Table 5.24 Correlation (R^2) and regression equation between a_{wx}, a_{wy} and a_{wz} Vs Wind - Porto Botte left.

Vibration (m/s^2)	Regression equation	R-Sq(adj)	Remark
a_{wx}	- 0,76 + 0,0238 MEAN WIND	**6,6 %**	LOW Correlation
a_{wy}	- 0,29 + 0,0167 MEAN WIND	**3,4 %**	LOW Correlation
a_{wz}	3,87 + 0,0069 MEAN WIND	**0,0 %**	LOW Correlation

Table 5.25 Correlation (R^2) and regression equation between a_{wx}, a_{wy} and a_{wz} Vs Direction - Porto Botte left.

Vibration (m/s^2)	Regression equation	R-Sq(adj)	Remark
a_{wx}	1,82 + 35,6 DIRECTION	**0,0 %**	LOW Correlation
a_{wy}	1,31 + 97,8 DIRECTION	**12,8 %**	LOW Correlation
a_{wz}	3,39 + 422 DIRECTION	**29,1 %**	LOW Correlation

Porto Botte RIGHT

Table 5.26 Correlation (R^2) and regression equation between a_{wx}, a_{wy} and a_{wz} Vs Average speed - Porto Botte right.

Vibration (m/s^2)	Regression equation	R-Sq(adj)	Remark
a_{wx}	0,551 + 0,0520 AVERAGE SPEED	**19,3 %**	LOW Correlation
a_{wy}	1,39 + 0,0231 AVERAGE SPEED	**1,6 %**	LOW Correlation
a_{wz}	- 0,19 + 0,202 AVERAGE SPEED	**17,9 %**	LOW Correlation

Table 5.27 Correlation (R^2) and regression equation between a_{wx}, a_{wy} and a_{wz} Vs Wave - Porto Botte right.

Vibration (m/s^2)	Regression equation	R-Sq(adj)	Remark
a_{wx}	0,035 + 1,10 TOT WAVE	**36,9 %**	FAIR Correlation
a_{wy}	1,24 + 0,451 TOT WAVE	**4,3 %**	LOW Correlation
a_{wz}	2,75 + 1,95 TOT WAVE	**4,3 %**	LOW Correlation

Table 5.28 Correlation (R^2) and regression equation between a_{wx}, a_{wy} and a_{wz} Vs Wind - Porto Botte right.

Vibration (m/s^2)	Regression equation	R-Sq(adj)	Remark
a_{wx}	- 0,12 + 0,0223 MEAN WIND	**2,3 %**	LOW Correlation
a_{wy}	0,84 + 0,0121 MEAN WIND	**0,0 %**	LOW Correlation
a_{wz}	8,76 – 0,0162 MEAN WIND	**0,0 %**	LOW Correlation

Table 5.29 Correlation (R^2) and regression equation between a_{wx}, a_{wy} and a_{wz} Vs Direction - Porto Botte right.

Vibration (m/s^2)	Regression equation	R-Sq(adj)	Remark
a_{wx}	2,39 + 2,3 DIRECTION	**0,0 %**	LOW Correlation
a_{wy}	2,12 – 29,8 DIRECTION	**0,0 %**	LOW Correlation
a_{wz}	7,47 + 190 DIRECTION	**0,0 %**	LOW Correlation

5.4.2 Dorio

Table 5.30 Correlation (R^2) and regression equation between a_{wx}, a_{wy} and a_{wz} Vs Average speed – Dorio.

Vibration (m/s²)	Regression equation	R-Sq(adj)	Remark
a_{wx}	- 0,401 + 0,0888 AVERAGE SPEED	**39,5 %**	FAIR Correlation
a_{wy}	0,384 + 0,0700 AVERAGE SPEED	**41,1 %**	FAIR Correlation
a_{wz}	- 6,28 + 0,387 AVERAGE SPEED	**74,0 %**	HIGH Correlation

Table 5.31 Correlation (R^2) and regression equation between a_{wx}, a_{wy} and a_{wz} Vs Wave – Dorio.

Vibration (m/s²)	Regression equation	R-Sq(adj)	Remark
a_{wx}	0,975 + 0,563 TOT WAVE	**3,2 %**	LOW Correlation
a_{wy}	2,08 + 0,172 TOT WAVE	**0,0 %**	LOW Correlation
a_{wz}	2,41 + 1,26 TOT WAVE	**1,3 %**	LOW Correlation

Table 5.32 Correlation (R^2) and regression equation between a_{wx}, a_{wy} and a_{wz} Vs Wind - Dorio.

Vibration (m/s²)	Regression equation	R-Sq(adj)	Remark
a_{wx}	3,75 – 0,0148 MEAN WIND	**10,0 %**	LOW Correlation
a_{wy}	1,84 + 0,00613 MEAN WIND	**2,5 %**	LOW Correlation
a_{wz}	8,33 – 0,0303 MEAN WIND	**3,8 %**	LOW Correlation

Dorio LEFT

Table 5.33 Correlation (R^2) and regression equation between a_{wx}, a_{wy} and a_{wz} Vs Average speed – Dorio left.

Vibration (m/s^2)	Regression equation	R-Sq(adj)	Remark
a_{wx}	0,176 + 0,0773 AVERAGE SPEED	**47,1 %**	FAIR Correlation
a_{wy}	0,916 + 0,0570 AVERAGE SPEED	**46,4 %**	FAIR Correlation
a_{wz}	- 5,63 + 0,378 AVERAGE SPEED	**79,0 %**	HIGH Correlation

Table 5.34 Correlation (R^2) and regression equation between a_{wx}, a_{wy} and a_{wz} Vs Wave – Dorio left.

Vibration (m/s^2)	Regression equation	R-Sq(adj)	Remark
a_{wx}	0,639 + 0,850 TOT WAVE	**10,1 %**	LOW Correlation
a_{wy}	2,03 + 0,282 TOT WAVE	**1,1 %**	LOW Correlation
a_{wz}	2,27 + 1,66 TOT WAVE	**1,8 %**	LOW Correlation

Table 5.35 Correlation (R^2) and regression equation between a_{wx}, a_{wy} and a_{wz} Vs Wind – Dorio left.

Vibration (m/s^2)	Regression equation	R-Sq(adj)	Remark
a_{wx}	4,28 – 0,0169 MEAN WIND	**17,3 %**	LOW Correlation
a_{wy}	2,97 – 0,00291 MEAN WIND	**0,0 %**	LOW Correlation
a_{wz}	10,8 – 0,0466 MEAN WIND	**8,6 %**	LOW Correlation

Table 5.36 Correlation (R^2) and regression equation between a_{wx}, a_{wy} and a_{wz} Vs Direction – Dorio left.

Vibration (m/s^2)	Regression equation	R-Sq(adj)	Remark
a_{wx}	2,44 + 73,1 DIRECTION	**4,4 %**	LOW Correlation
a_{wy}	2,61 + 39,6 DIRECTION	**1,8 %**	LOW Correlation
a_{wz}	5,43 + 384 DIRECTION	**9,6 %**	LOW Correlation

Dorio RIGHT

Table 5.37 Correlation (R^2) and regression equation between a_{wx}, a_{wy} and a_{wz} Vs Average speed – Dorio right.

Vibration (m/s^2)	Regression equation	R-Sq(adj)	Remark
a_{wx}	- 0,072 + 0,0700 AVERAGE SPEED	**26,5 %**	LOW Correlation
a_{wy}	0,307 + 0,0682 AVERAGE SPEED	**31,6 %**	LOW Correlation
a_{wz}	- 5,23 + 0,338 AVERAGE SPEED	**66,9 %**	HIGH Correlation

Table 5.38 Correlation (R^2) and regression equation between a_{wx}, a_{wy} and a_{wz} Vs Wave – Dorio right.

Vibration (m/s^2)	Regression equation	R-Sq(adj)	Remark
a_{wx}	1,10 + 0,376 TOT WAVE	**1,6 %**	LOW Correlation
a_{wy}	2,01 + 0,118 TOT WAVE	**0,0 %**	LOW Correlation
a_{wz}	2,11 + 1,06 TOT WAVE	**1,1 %**	LOW Correlation

Table 5.39 Correlation (R^2) and regression equation between a_{wx}, a_{wy} and a_{wz} Vs Wind – Dorio right.

Vibration (m/s^2)	Regression equation	R-Sq(adj)	Remark
a_{wx}	3,36 – 0,0139 MEAN WIND	**13,4 %**	LOW Correlation
a_{wy}	0,868 + 0,0138 MEAN WIND	**16,8 %**	LOW Correlation
a_{wz}	6,31 – 0,0177 MEAN WIND	**1,3 %**	LOW Correlation

Table 5.40 Correlation (R^2) and regression equation between a_{wx}, a_{wy} and a_{wz} Vs Direction – Dorio right.

Vibration (m/s^2)	Regression equation	R-Sq(adj)	Remark
a_{wx}	1,74 – 129 DIRECTION	**23,2 %**	LOW Correlation
a_{wy}	2,23 – 25,5 DIRECTION	**0,0 %**	LOW Correlation
a_{wz}	3,95 – 355 DIRECTION	**18,4 %**	LOW Correlation

5.4.3 Valmadrera

Table 5.41 Correlation (R^2) and regression equation between a_{wx}, a_{wy} and a_{wz} Vs Average speed – Valmadrera.

Vibration (m/s^2)	Regression equation	R-Sq(adj)	Remark
a_{wx}	0,274 + 0,0687 AVERAGE SPEED	**28,5 %**	LOW Correlation
a_{wy}	1,09 + 0,0539 AVERAGE SPEED	**27,3 %**	LOW Correlation
a_{wz}	- 4,52 + 0,345 AVERAGE SPEED	**66,5 %**	HIGH Correlation

Table 5.42 Correlation (R^2) and regression equation between a_{wx}, a_{wy} and a_{wz} Vs Wave – Valmadrera.

Vibration (m/s^2)	Regression equation	R-Sq(adj)	Remark
a_{wx}	NONE	**NONE**	
a_{wy}	NONE	**NONE**	
a_{wz}	NNOE	**NONE**	

Having carried out only one test in Valmadrera there was no possibility to calculate the correlation with the wave measured once during the test period.

Table 5.43 Correlation (R^2) and regression equation between a_{wx}, a_{wy} and a_{wz} Vs Wind – Valmadrera.

Vibration (m/s^2)	Regression equation	R-Sq(adj)	Remark
a_{wx}	0,96 + 0,0154 MEAN WIND	**0,0 %**	LOW Correlation
a_{wy}	4,06 – 0,0154 MEAN WIND	**0,0 %**	LOW Correlation
a_{wz}	1,2 + 0,052 MEAN WIND	**0,0 %**	LOW Correlation

Valmadrera LEFT

Table 5.44 Correlation (R^2) and regression equation between a_{wx}, a_{wy} and a_{wz} Vs Average speed – Valmadrera left.

Vibration (m/s^2)	Regression equation	R-Sq(adj)	Remark
a_{wx}	0,939 + 0,0418 AVERAGE SPEED	**33,6 %**	FAIR Correlation
a_{wy}	0,079 + 0,0803 AVERAGE SPEED	**50,3 %**	FAIR Correlation
a_{wz}	- 4,11 + 0,313 AVERAGE SPEED	**81,8 %**	HIGH Correlation

Table 5.45 Correlation (R^2) and regression equation between a_{wx}, a_{wy} and a_{wz} Vs Wave – Valmadrera left.

Vibration (m/s^2)	Regression equation	R-Sq(adj)	Remark
a_{wx}	NONE	**NONE**	
a_{wy}	NONE	**NONE**	
a_{wz}	NNOE	**NONE**	

Table 5.46 Correlation (R^2) and regression equation between a_{wx}, a_{wy} and a_{wz} Vs Wind – Valmadrera left.

Vibration (m/s^2)	Regression equation	R-Sq(adj)	Remark
a_{wx}	3,71 – 0,0168 MEAN WIND	**0,0 %**	LOW Correlation
a_{wy}	3,02 – 0,0055 MEAN WIND	**0,0 %**	LOW Correlation
a_{wz}	14,2 – 0,098 MEAN WIND	**0,0 %**	LOW Correlation

Table 5.47 Correlation (R^2) and regression equation between a_{wx}, a_{wy} and a_{wz} Vs Direction – Valmadrera left.

Vibration (m/s^2)	Regression equation	R-Sq(adj)	Remark
a_{wx}	2,11 + 81,2 DIRECTION	**0,0 %**	LOW Correlation
a_{wy}	2,65 – 99 DIRECTION	**0,0 %**	LOW Correlation
a_{wz}	5,40 + 45 DIRECTION	**0,0 %**	LOW Correlation

Valmadrera RIGHT

Table 5.48 Correlation (R^2) and regression equation between a_{wx}, a_{wy} and a_{wz} Vs Average speed – Valmadrera right.

Vibration (m/s^2)	Regression equation	R-Sq(adj)	Remark
a_{wx}	- 0,94 + 0,116 AVERAGE SPEED	**46,3 %**	FAIR Correlation
a_{wy}	1,60 + 0,0431 AVERAGE SPEED	**52,1 %**	FAIR Correlation
a_{wz}	- 6,58 + 0,433 AVERAGE SPEED	**77,0 %**	HIGH Correlation

Table 5.49 Correlation (R^2) and regression equation between a_{wx}, a_{wy} and a_{wz} Vs Wave – Valmadrera right.

Vibration (m/s^2)	Regression equation	R-Sq(adj)	Remark
a_{wx}	NONE	**NONE**	
a_{wy}	NONE	**NONE**	
a_{wz}	NNOE	**NONE**	

Table 5.50 Correlation (R^2) and regression equation between a_{wx}, a_{wy} and a_{wz} Vs Wind – Valmadrera right.

Vibration (m/s^2)	Regression equation	R-Sq(adj)	Remark
a_{wx}	- 0,98 + 0,0389 MEAN WIND	**0,0 %**	LOW Correlation
a_{wy}	3,29 – 0,0048 MEAN WIND	**0,0 %**	LOW Correlation
a_{wz}	- 6,2 + 0,140 MEAN WIND	**0,0 %**	LOW Correlation

Table 5.51 Correlation (R^2) and regression equation between a_{wx}, a_{wy} and a_{wz} Vs Direction – Valmadrera right.

Vibration (m/s^2)	Regression equation	R-Sq(adj)	Remark
a_{wx}	2,72 + 234 DIRECTION	**48,0 %**	FAIR Correlation
a_{wy}	2,92 + 45,6 DIRECTION	**6,7 %**	LOW Correlation
a_{wz}	6,72 + 537 DIRECTION	**23,1 %**	LOW Correlation

5.4.4 Hyères

Table 5.52 Correlation (R^2) and regression equation between a_{wx}, a_{wy} and a_{wz} Vs Average speed – Hyères.

Vibration (m/s^2)	Regression equation	R-Sq(adj)	Remark
a_{wx}	0,600 + 0,0468 AVERAGE SPEED	**28,1 %**	FAIR Correlation
a_{wy}	1,28 + 0,0351 AVERAGE SPEED	**22,0%**	FAIR Correlation
a_{wz}	- 4,69 + 0,350 AVERAGE SPEED	**74,9 %**	HIGH Correlation

Table 5.53 Correlation (R^2) and regression equation between a_{wx}, a_{wy} and a_{wz} Vs Wave – Hyères.

Vibration (m/s^2)	Regression equation	R-Sq(adj)	Remark
a_{wx}	1,19 + 0,448 TOT WAVE	**21,3 %**	LOW Correlation
a_{wy}	1,68 + 0,358 TOT WAVE	**19,1 %**	LOW Correlation
a_{wz}	6,04 – 0,072 TOT WAVE	**0,0 %**	LOW Correlation

Table 5.54 Correlation (R^2) and regression equation between a_{wx}, a_{wy} and a_{wz} Vs Wind – Hyères.

Vibration (m/s^2)	Regression equation	R-Sq(adj)	Remark
a_{wx}	3,01 – 0,00993 MEAN WIND	**22,6 %**	LOW Correlation
a_{wy}	3,12 – 0,00772 MEAN WIND	**19,0 %**	LOW Correlation
a_{wz}	5,92 – 0,0002 MEAN WIND	**0,0 %**	LOW Correlation

Hyères LEFT

Table 5.55 Correlation (R^2) and regression equation between a_{wx}, a_{wy} and a_{wz} Vs Average speed – Hyères left.

Vibration (m/s^2)	Regression equation	R-Sq(adj)	Remark
a_{wx}	1,10 + 0,0317 AVERAGE SPEED	**13,3 %**	LOW Correlation
a_{wy}	1,67 + 0,0234 AVERAGE SPEED	**10,2 %**	LOW Correlation
a_{wz}	- 4,63 + 0,344 AVERAGE SPEED	**71,9 %**	HIGH Correlation

Table 5.56 Correlation (R^2) and regression equation between a_{wx}, a_{wy} and a_{wz} Vs Wave – Hyères left.

Vibration (m/s^2)	Regression equation	R-Sq(adj)	Remark
a_{wx}	1,31 + 0,429 TOT WAVE	**23,3 %**	LOW Correlation
a_{wy}	1,94 + 0,261 TOT WAVE	**11,3 %**	LOW Correlation
a_{wz}	6,86 – 0,285 TOT WAVE	**0,0 %**	LOW Correlation

Table 5.57 Correlation (R^2) and regression equation between a_{wx}, a_{wy} and a_{wz} Vs Wind – Hyères left.

Vibration (m/s^2)	Regression equation	R-Sq(adj)	Remark
a_{wx}	3,03 – 0,00918 MEAN WIND	**24,0 %**	LOW Correlation
a_{wy}	2,97 – 0,00544 MEAN WIND	**10,9 %**	LOW Correlation
a_{wz}	5,93 + 0,0040 MEAN WIND	**0,0 %**	LOW Correlation

Table 5.58 Correlation (R^2) and regression equation between a_{wx}, a_{wy} and a_{wz} Vs Direction – Hyères left.

Vibration (m/s^2)	Regression equation	R-Sq(adj)	Remark
a_{wx}	2,03 – 18,5 DIRECTION	**0,0 %**	LOW Correlation
a_{wy}	2,10 – 80,3 DIRECTION	**8,5 %**	LOW Correlation
a_{wz}	4,36 – 485 DIRECTION	**7,6 %**	LOW Correlation

Hyères RIGHT

Table 5.59 Correlation (R^2) and regression equation between a_{wx}, a_{wy} and a_{wz} Vs Average speed – Hyères right.

Vibration (m/s^2)	Regression equation	R-Sq(adj)	Remark
a_{wx}	0,165 + 0,0615 AVERAGE SPEED	**36,9 %**	FAIR Correlation
a_{wy}	0,970 + 0,0451 AVERAGE SPEED	**26,3 %**	LOW Correlation
a_{wz}	- 5,23 + 0,374 AVERAGE SPEED	**76,4 %**	HIGH Correlation

Table 5.60 Correlation (R^2) and regression equation between a_{wx}, a_{wy} and a_{wz} Vs Wave – Hyères right.

Vibration (m/s^2)	Regression equation	R-Sq(adj)	Remark
a_{wx}	1,08 + 0,462 TOT WAVE	**18,6 %**	LOW Correlation
a_{wy}	1,44 + 0,449 TOT WAVE	**25,0 %**	LOW Correlation
a_{wz}	5,28 + 0,112 TOT WAVE	**0,0 %**	LOW Correlation

Table 5.61 Correlation (R^2) and regression equation between a_{wx}, a_{wy} and a_{wz} Vs Wind – Hyères right.

Vibration (m/s^2)	Regression equation	R-Sq(adj)	Remark
a_{wx}	3,00 – 0,0107 MEAN WIND	**20,8 %**	LOW Correlation
a_{wy}	3,28 – 0,0101 MEAN WIND	**26,2 %**	LOW Correlation
a_{wz}	5,93 – 0,0044 MEAN WIND	**0,0 %**	LOW Correlation

Table 5.62 Correlation (R^2) and regression equation between a_{wx}, a_{wy} and a_{wz} Vs Direction – Hyères right.

Vibration (m/s^2)	Regression equation	R-Sq(adj)	Remark
a_{wx}	1,49 + 109 DIRECTION	**4,8 %**	LOW Correlation
a_{wy}	1,82 + 110 DIRECTION	**8,1 %**	LOW Correlation
a_{wz}	2,68 + 701 DIRECTION	**14,9 %**	LOW Correlation

Table 5.63 Summary correlation (R^2) table by location.

		Average Speed			TOT Wave			Wind			Direction	
Location		TOT	LEFT	RIGHT	TOT	LEFT	RIGHT	TOT	LEFT	RIGHT	LEFT	RIGHT
PORTO BOTTE	a_{wx}	49,20%	41,00%	19,30%	27,20%	44,80%	36,90%	2,30%	6,60%	2,30%	0,00%	0,00%
	a_{wy}	45,40%	40,10%	1,60%	6,40%	30,90%	4,30%	0,00%	3,40%	0,00%	12,80%	0,00%
	a_{wz}	57,50%	54,10%	17,90%	1,50%	2,90%	4,30%	0,00%	0,00%	0,00%	29,10%	0,00%
DORIO	a_{wx}	39,50%	47,10%	26,50%	3,20%	10,10%	1,60%	10,00%	17,30%	13,40%	4,40%	23,20%
	a_{wy}	41,10%	46,40%	31,60%	0,00%	1,10%	0,00%	2,50%	0,00%	16,80%	1,80%	0,00%
	a_{wz}	74,00%	79,00%	66,90%	1,30%	1,80%	1,10%	3,80%	8,60%	1,30%	9,60%	18,40%
VALMADRERA	a_{wx}	28,50%	33,60%	46,30%	NONE	NONE	NONE	0,00%	0,00%	0,00%	0,00%	48,00%
	a_{wy}	27,30%	50,30%	52,10%	NONE	NONE	NONE	0,00%	0,00%	0,00%	0,00%	6,70%
	a_{wz}	66,50%	81,80%	77,00%	NONE	NONE	NONE	0,00%	0,00%	0,00%	0,00%	23,10%
HYERES	a_{wx}	28,10%	13,30%	36,90%	21,30%	23,30%	18,60%	22,60%	24,00%	20,80%	0,00%	4,80%
	a_{wy}	22,00%	10,20%	26,30%	19,10%	11,30%	25,00%	19,00%	10,90%	26,20%	8,50%	8,10%
	a_{wz}	74,90%	71,90%	76,40%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	7,60%	14,90%

The analysis by location confirmed that the kiter speed is still the variable which has the most influence on the vibration.

Concerning the waves, there is not so much evidence of their influence on the vibration, although from this analysis emerged that the waves have some influence on the vibration along the X axis. Conclusions here are that tests were performed far from the buoy and, especially on the lake, local phenomena (boats, ferries, wind gradients) may have a confounding effect. In addition, vibration is strongly affected by the combination between the wave direction and the riding direction.

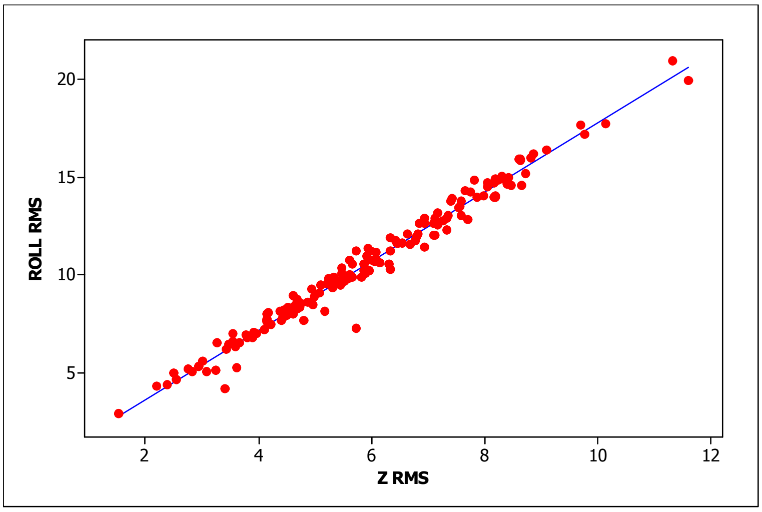
The wind was not judged an important parameter in the questionnaire survey; data analysis confirms this hypothesis showing a negligible correlation.

5.5 Roll – Pitch – Yaw

ROLL

Table 5.64 Correlation (R^2) and regression equation between the Roll and a_{wz} Vs Average speed.

Vibration (m/s^2)	Regression equation	R-Sq(adj)	Remark
a_{wz}	- 4,14 + 0,322 AVERAGE SPEED	**61,1 %**	FAIR Correlation
Roll	- 7,60 + 0,582 AVERAGE SPEED	**62,2 %**	FAIR Correlation



Graph 5.7 Scatterplot between the Roll Vs a_{wz}.

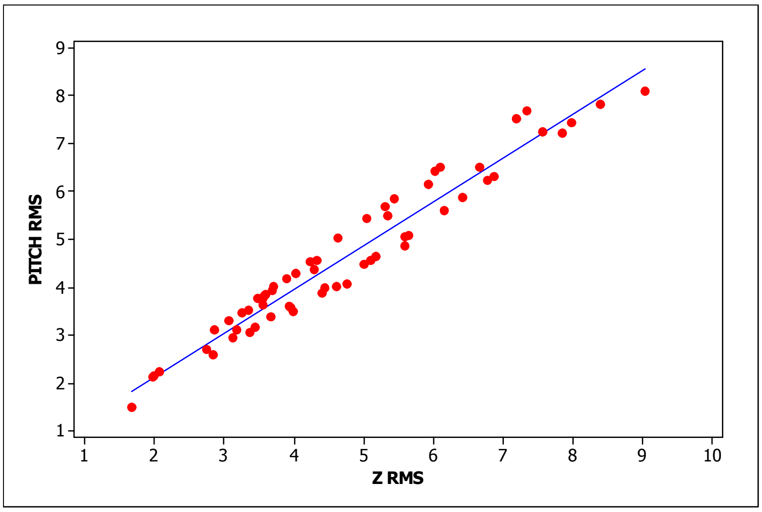
Table 5.65 Correlation (R^2) and regression equation between the Roll Vs a_{wz}.

Regression equation	R-Sq(adj)	Remark
0,085 + 1,77 a_{wz}	**97,8 %**	HIGH Correlation

PITCH

Table 5.66 Correlation (R^2) and regression equation between the Pitch and a_{wz} Vs Average speed.

Vibration (m/s^2)	Regression equation	R-Sq(adj)	Remark
a_{wz}	- 5,81 + 0,358 AVERAGE SPEED	**81,3 %**	HIGH Correlation
Pitch	- 5,23 + 0,334 AVERAGE SPEED	**80,5 %**	HIGH Correlation



Graph 5.8 Scatterplot between the Pitch Vs a_{wz}.

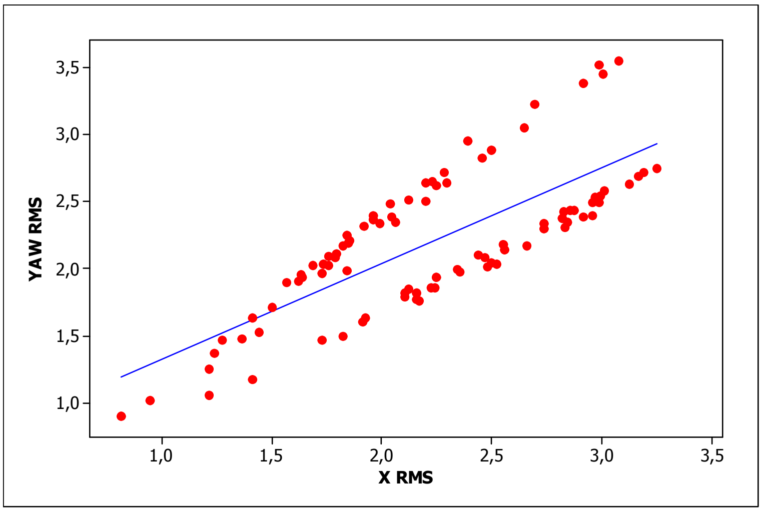
Table 5.67 Correlation (R^2) and regression equation between the Pitch Vs a_{wz}.

Regression equation	R-Sq(adj)	Remark
0,291 + 0,915 a_{wz}	**94,8 %**	HIGH Correlation

YAW

Table 5.68 Correlation (R^2) and regression equation between the Yaw and a_{wx} Vs Average speed.

Vibration (m/s²)	Regression equation	R-Sq(adj)	Remark
a_{wx}	- 0,734 + 0,0992 AVERAGE SPEED	**45,0 %**	FAIR Correlation
Yaw	- 0,189 + 0,0801 AVERAGE SPEED	**33,3 %**	FAIR Correlation



Graph 5.9 Scatterplot between the Yaw Vs a_{wx}.

Table 5.69 Correlation (R^2) and regression equation between the Yaw Vs a_{wx}.

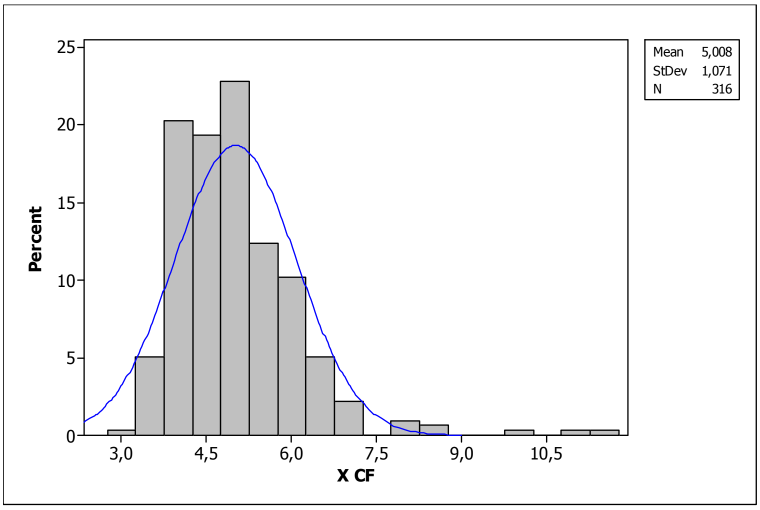
Regression equation	R-Sq(adj)	Remark
0,608 + 0,714 a_{wx}	**58,0 %**	FAIR Correlation

All the above tables confirmed a good correlation of the three rotations versus the average speed and the reference axes.

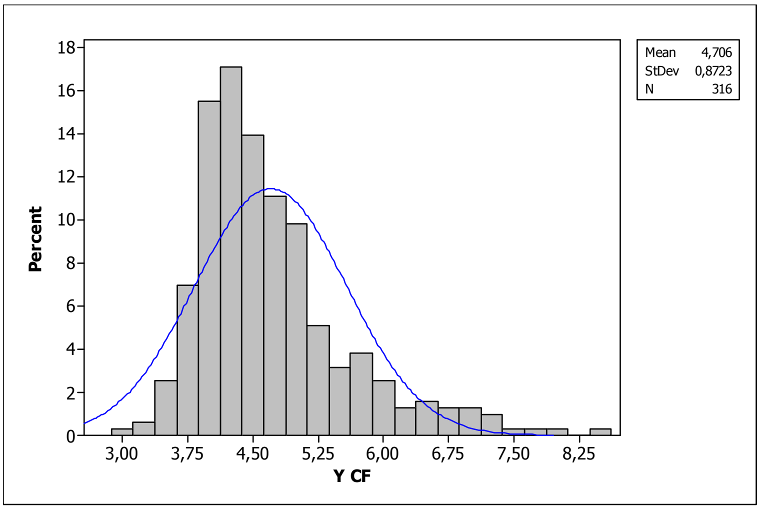
Moreover, the scatterplots of the pitch and the yaw show the distribution of the data on two lines, symmetric to regression line. As explained in the paragraph 3.1.2, the monoaxial accelerometer is positioned at the right of the triaxial accelerometer therefore; going to the right the measure will be higher than the triaxial accelerometer instead going to the left it will be lower.

5.6 X,Y, Z CREST FACTOR

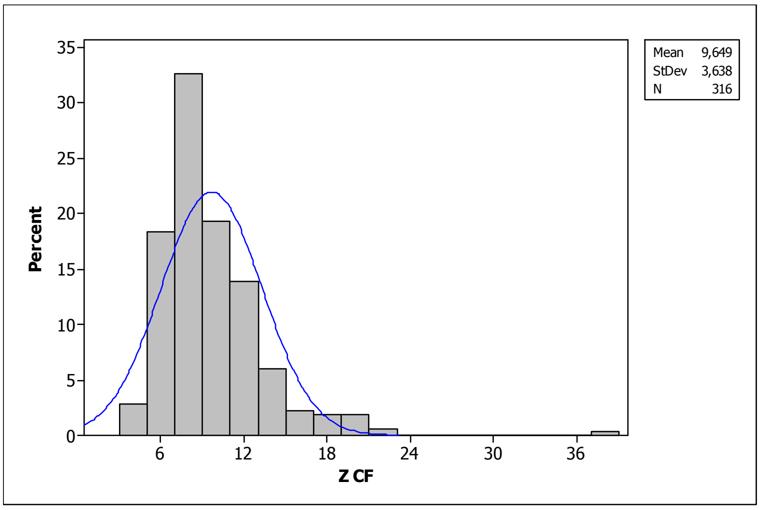
The Crest Factor can be used to identify whether the basic criterion of the ISO 2631 is suitable or not for the exposure assessment. The limit of 9 is not exceeded along X and Y axes (except in a few cases); the situation along the Z axis is more critical (as shown in the next figures).



Graph 5.10 Probability Density Function of X Crest Factor.



Graph 5.11 Probability Density Function of Y Crest Factor



Graph 5.12 Probability Density Function of Z Crest Factor

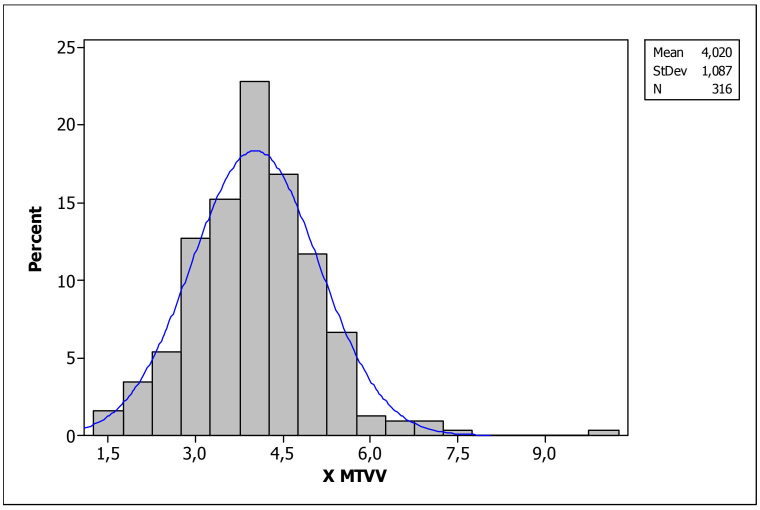
5.7 X,Y, Z MTVV

When the equation (1.6), ratio between the maximum transient vibration value (MTVV) and the $a_w(t)$ exceeds 1,5 the standard suggests the use of the additional evaluation methods. The table below shows the acceptable max value of MTVV and the actual.

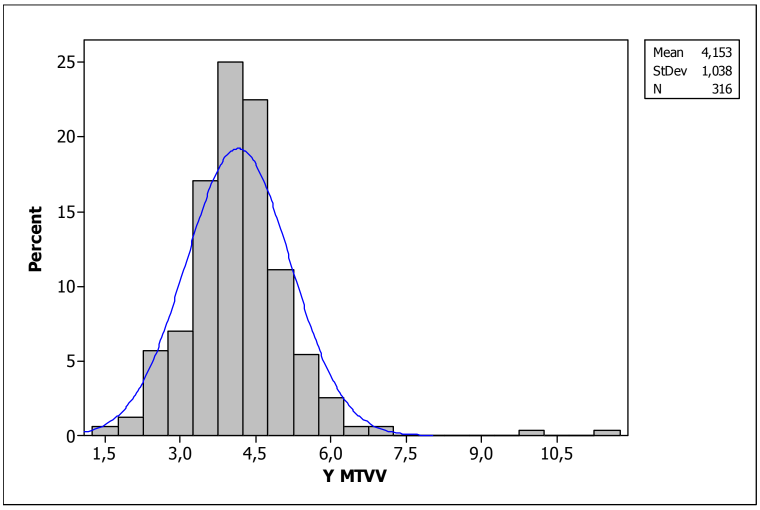
Table 5.70 MTVV limit.

		MTVV		
Vibration (m/s^2)	**RMS**	**MAX**	**ACTUAL**	**Diff.**
a_{wx}	2,19	3,285	4,020	18,28%
a_{wy}	2,356	3,534	4,153	14,90%
a_{wz}	5,518	8,277	11,280	26,62%

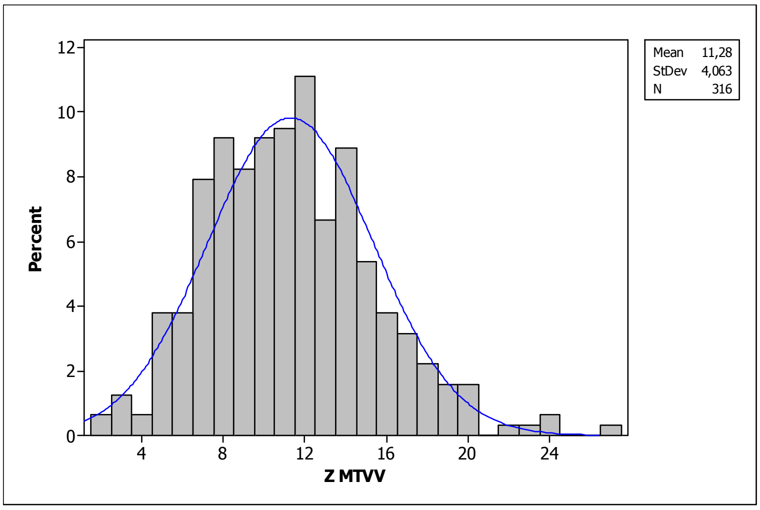
In all the three axes the limit value is overtook; therefore in this case the use of the additional methods can be considered uselfull for the assessment of the exposition.



Graph 5.13 Probability Density Function of X MTVV.



Graph 5.14 Probability Density Function of Y MTVV.



Graph 5.15 Probability Density Function of Z MTVV.

5.7 Board Rigid Motion

As emplaned in the body posture 2.2 the weight of the kiter is not in the central position but during the navigation it stays on the stern (i.e the largest part of the weight is on the backward leg). The board motion, as a consequence of the non-symmetrical constraints and excitations, is not a pure translation. Roll Pitch and Yaw motions were characterized using an auxiliary accelerometer placed in different box positions.

Table 5.71 Summary table remarking the purpose of the test about; Roll, Pitch and Yaw.

Location	Date	Average Speed	Distance (m)	Duration (h)	Remark
PORTO BOTTE	**25_08_2010**	29,90	7.207	0.12.44	Roll
PORTO BOTTE	**26_08_2010**	30,31	6.106	0.10.48	Roll
PORTO BOTTE	**28_08_2010**	31,25	8.413	0.13.50	Roll
DORIO	**04_09_2010**	30,33	8.606	0.17.44	Roll
DORIO	**05_09_2010**	28,63	23.307	0.45.34	Roll
DORIO	**05_09_2010**	28,26	14.395	0.26.44	Roll
VALMADRERA	**11_09_2010**	31,41	16.128	0.32.27	Yaw
DORIO	**11_09_2010**	30,69	28.975	0.57.34	Yaw
DORIO	**11_09_2010**	30,82	23.505	0.45.44	Yaw
DORIO	**12_09_2010**	30,87	36.292	1.13.08	Pitch
HYERES	**02_10_2010**	30,80	10.620	0.21.36	Roll
HYERES	**03_10_2010**	30,67	17.353	0.34.04	Roll

Table 5.72 Summary table showing the covered distance and time for the test about; Roll, Pitch and Yaw.

	Distance (m)	Duration (h)
Roll	96.007	3.03.04
Pitch	36.292	1.13.08
Yaw	68.607	2.15.45

5.1.3 Pitch

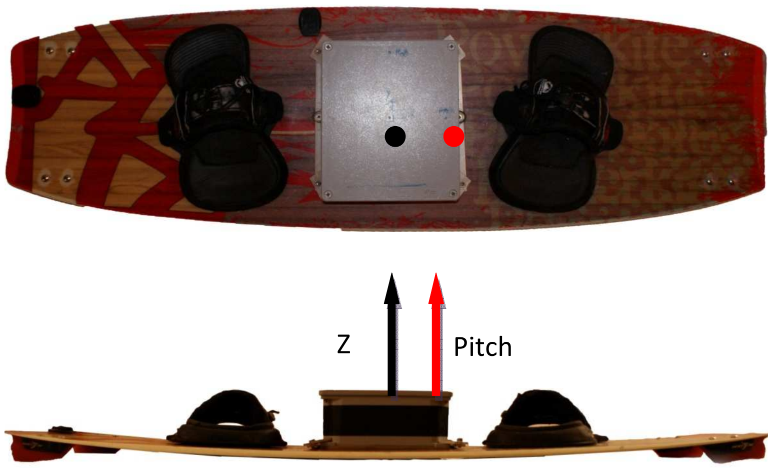
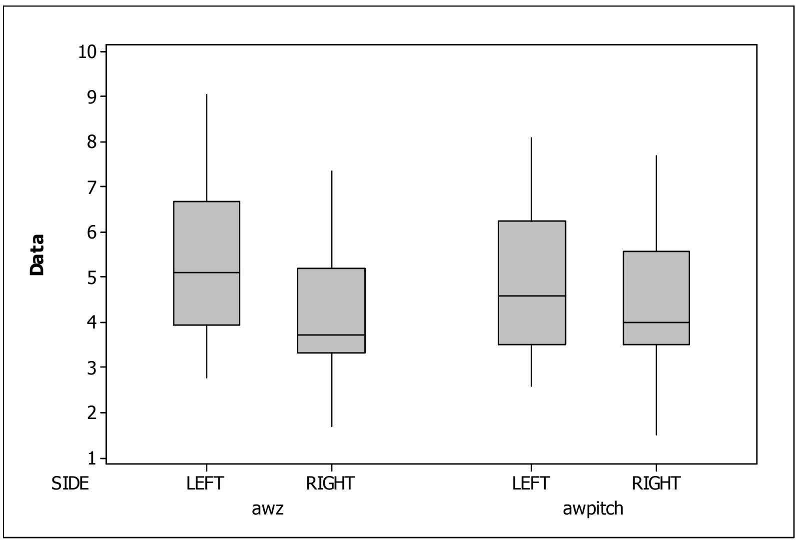


Figure 5.2 Position of the triaxial and monoaxial accelerometers for the measure of the pitch, triaxial (black) monaxial (red).

As shown in the paragraph 3.1.2 the position of the monoaxial accelerometer inside the aluminum box is closer to the right leg, therefore going to left the vibration measured on the Z axis is always higher, instead going to right always lower.



Graph 5.16 Vibration along Z and Pitch axis going to left and to right.

The difference (in percentage) between weighted accelerations measured from the two accelerometers can be used to point out the presence of pitch motion. We report here a summary of experimental data.

Table 5.73 Modulus vibration difference between the triaxial and monoaxial accelerometers according to the different directions.

DIRECTION	MIN	MAX	AVERAGE	TOTAL MODULUS AVERAGE
LEFT	1,8%	14,5%	8,8%	7,6%
RIGHT	1,3%	8,3%	6,2%	

Table shows that the vibration difference between the two accelerometers is from 1,3 to 14,5 % with modulus grand average of 7,6%.

Knowing the distance of the accelerometers respect to the foot position it is possible to recalculate the vibration affecting the feet along the same axis, in its central position.

Table 5.74 Summary vibration difference between the measurement of the triaxial accelerometer and the bow and stern foot.

DIRECTION	MIN	MAX	AVERAGE	TOTAL MODULUS AVERAGE
LEFT	4,7 %	39,0 %	23,7	20,4 %
RIGHT	3,5 %	22,5 %	16,9	

In this case the dow leg, (the forward one with less weight), will vibrate between 3,5 to 39,0 % more than the vibration measured by the triaxial accelerometer; the stern leg, conversely, is exposed to a lower vibration level.

The grand average showed that the stern leg vibrates 33,9 % less than the bow leg. This implies that if, for instance, the vibration measured by the triaxial accelerometer along the Z axis is 5,0 m/s^2 and the kiter moves to the right, the bow leg will be exposed to a vibration of 6,02 m/s^2 and the stern leg 3,98 m/s^2.

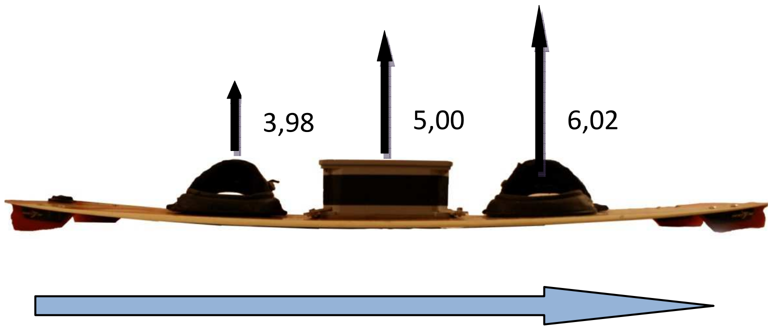


Figure 5.3 Example of vibration between the legs.

The FRF between the two accelerometers oriented in the same direction was used to point out the presence of non-rigid rotation, that would result in FRF modulus amplifications and non constant phase. Results showed that the FRF modulus was constant (within the accelerometer tolerance) and that the phase was null.

Furthermore the squared multiple correlation coefficient (R^2) between the ratio of the a_{wpitch} with the a_{wz} and all the other variables;

Wave		**NONE**	
Direction	**Left**	**8,6**	**%**
	Right	**5,0**	**%**
Average speed		**0,0**	**%**
Wind		**0,0**	**%**

5.1.4 Yaw

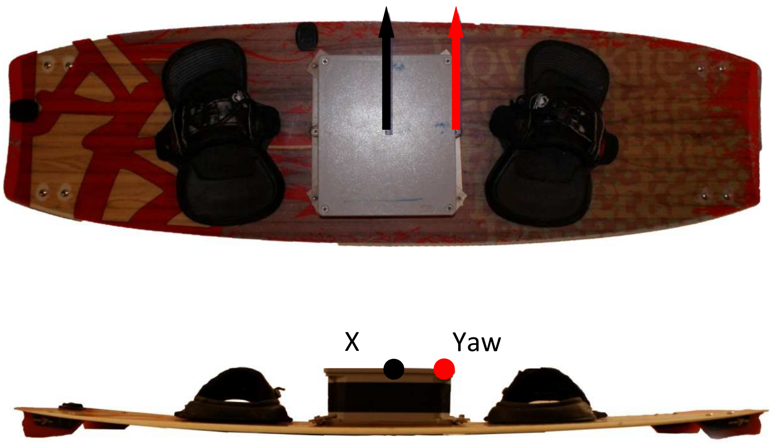
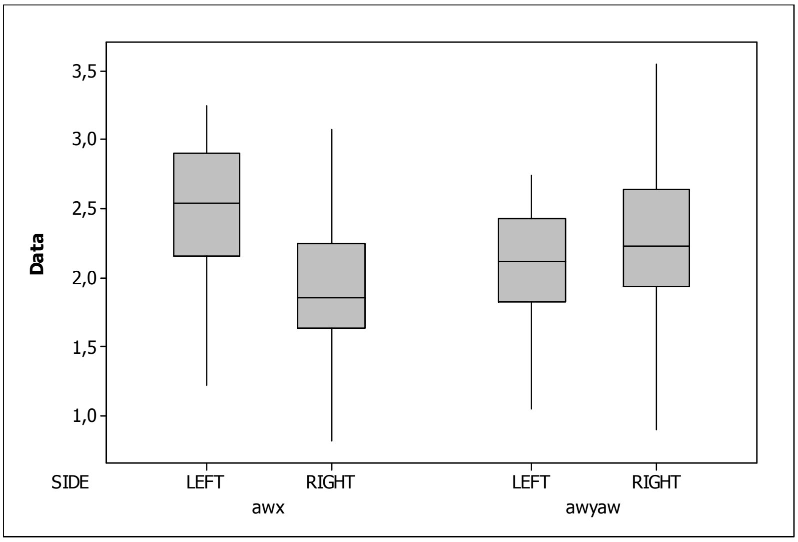


Figure 5.4 Position of the triaxial and monoaxial accelerometers for the measure of the yaw, triaxial (black) monaxial (red).

As shown in the paragraph 3.1.2 the position of the monoaxial accelerometer inside the aluminum box is closer to the right leg, therefore going to left the vibration measured on the X axis is always higher, instead going to right always lower.



Graph 5.17 Vibration along X and Yaw axis going to left and to right.

The difference (in percentage) between weighted accelerations measured from the two accelerometers can be used to point out the presence of yaw motion. We report here a summary of experimental data.

Table 5.75 Modulus vibration difference between the triaxial and monoaxial accelerometers according to the different directions.

DIRECTION	MIN	MAX	AVERAGE	TOTAL MODULUS AVERAGE
LEFT	12,8 %	19,3 %	16,1 %	16,4 %
RIGHT	7,3 %	23,6 %	16,6 %	

Table shows that the vibration difference between the two accelerometers is from 7,3 to 23,6 % with modulus grand average of 16,4 %.

Knowing the distance of the accelerometers respect to the foot position it is possible to recalculate the vibration affecting the feet along the same axis, in its central position.

Table 5.76 Summary vibration difference between the measurement of the triaxial accelerometer and the bow and stern foot.

DIRECTION	MIN	MAX	AVERAGE	TOTAL MODULUS AVERAGE
LEFT	34,7 %	52,1 %	43,4 %	44,2 %
RIGHT	19,8 %	63,6 %	45,0 %	

In this case the dow leg, (the forward one with less weight), will vibrate between 19,8 to 63,6 % more than the vibration measured by the triaxial accelerometer; the stern leg, conversely, is exposed to a lower vibration level.

The grand average showed that the stern leg vibrates 61,3 % less than the bow leg. This implies that if, for instance, the vibration measured by the triaxial accelerometer along the Z axis is 5,0 m/s^2 and the kiter moves to the right, the bow leg will be exposed to a vibration of 7,21 m/s^2 and the stern leg 2,79 m/s^2.

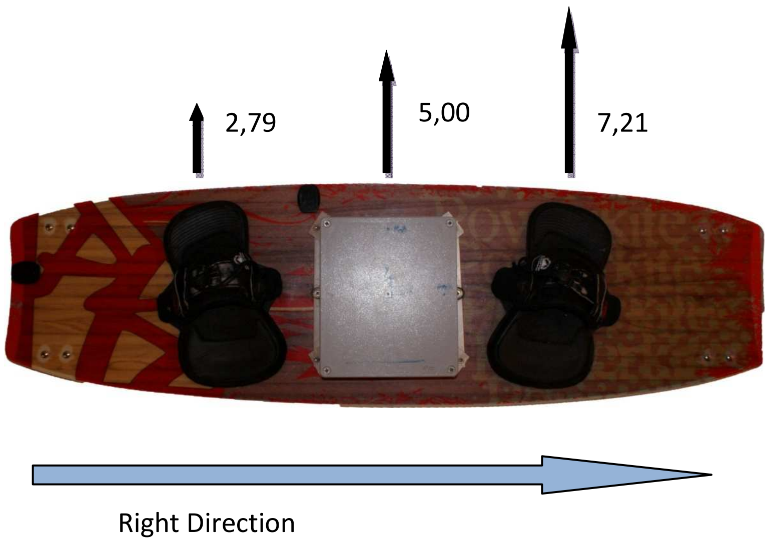


Figure 5.5 Example of vibration between the legs.

The FRF between the two accelerometers oriented in the same direction was used to point out the presence of non-rigid rotation, that would result in FRF modulus amplifications and non constant phase. Results showed that the FRF modulus was constant (within the accelerometer tolerance) and that the phase was null.

Furthermore the squared multiple correlation coefficient (R^2) between the ratio of the a_{wyaw} with the a_{wx} and all the other variables;

Wave		**0,0**	**%**
Direction	**Left**	**18,9**	**%**
	Right	**4,5**	**%**
Average speed		**1,6**	**%**
Wind		**0,0**	**%**

5.1.5 Roll

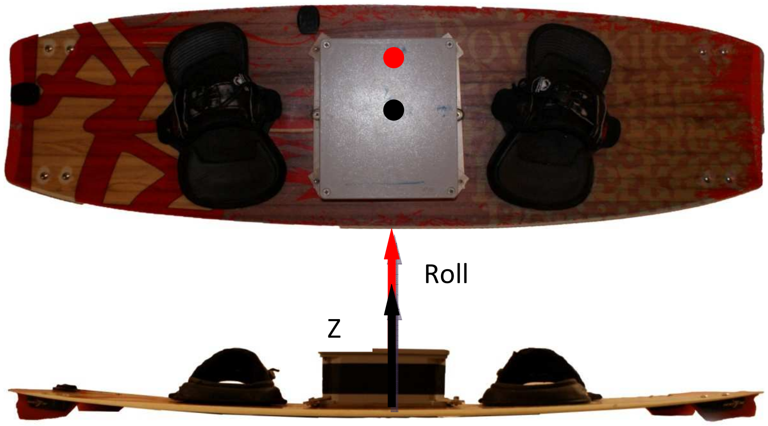
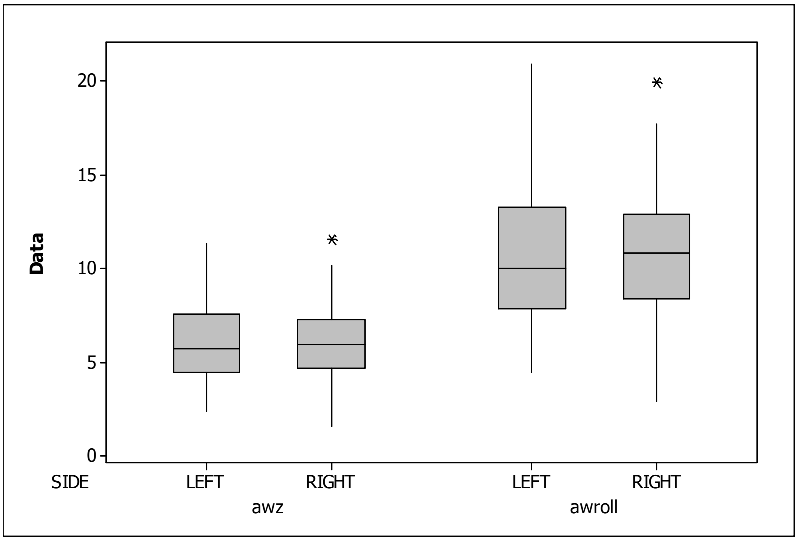


Figure 5.6 Position of the triaxial and monoaxial accelerometers for the measure of the roll, triaxial (black) monaxial (red).

As shown in the paragraph 3.1.2 the position of the monoaxial accelerometer inside the aluminum box is placed between the legs and slightly external to the triaxial accelerometer, therefore it can be used to point out rotations in the horizontal plane.



Graph 5.18 Vibration along Z and Roll axis going to left and to right.

The difference (in percentage) between weighted accelerations measured from the two accelerometers can be used to point out the presence of roll motion. We report here a summary of experimental data.

Table 5.77 Modulus vibration difference between the triaxial and monoaxial accelerometers according to the different directions.

DIRECTION	MIN	MAX	AVERAGE	TOTAL MODULUS AVERAGE
LEFT	26,8 %	96,1 %	78,0 %	78,7 %
RIGHT	22,9 %	101,0 %	79,4 %	

Table shows that the vibration difference between the two accelerometers is from 22,9 to 101,0 % with modulus grand average of 78,7 %.

Knowing the distance of the accelerometers respect to the foot position it is possible to recalculate the vibration affecting the feet.

Table 5.78 Summary vibration difference between the measurement of the triaxial accelerometer and the heel.

DIRECTION	MIN	MAX	AVERAGE	TOTAL AVERAGE
LEFT	-24,1 %	-86,4 %	-70,2 %	-70,9 %
RIGHT	-20,6 %	-90,9 %	-71,5 %	

In this case both legs are affected by the same vibration; the difference is between the toe and the heel. The heel receives a vibration between 20,6 to 90,9 % less than the one measured by the triaxial accelerometer.

The grand average showed that the heels vibrate 70,9 % less than the triaxial accelerometer.

This implies that if, for instance, the vibration measured by the triaxial accelerometer along the Z axis is 5,0 m/s^2 and going to the heel, where is supposed the vibration enters into the body, the vibration becomes 1,46 m/s^2.

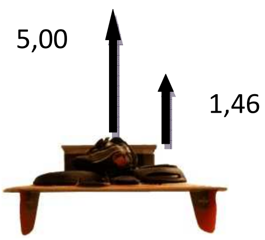


Figure 5.7 Example of vibration between the triaxial accelerometer and the heel.

The FRF between the two accelerometers oriented in the same direction was used to point out the presence of non-rigid rotation, that would result in FRF modulus amplifications and non constant phase. Results showed that the FRF modulus was constant (within the accelerometer tolerance) and that the phase was null.

Furthermore the squared multiple correlation coefficient (R^2) between the ratio of the a_{wroll} with the a_{wz} and all the other variables;

Wave		**5,0**	**%**
Direction	**Left**	**3,0**	**%**
	Right	**1,5**	**%**
Average speed		**0,0**	**%**
Wind		**3,2**	**%**

Summing up; studying the roll, pich and roll it was possible to define the different vibration dose between the bow and stern leg or the heel and the toe referring to the value measured by the triaxial accelerometer.

PITCH	Stern	-20,4 %	Bow	+20,4 %
YAW	Stern	-44,2 %	Bow	+44,2 %
ROLL	Heel	-70,9 %	Toe	78,7 %

The stern leg is where most of the weight of the kiter is loaded in order to give a direction to the board then the leg is bent. On this leg the vibration are decreased and the transmission to the body is reduced by the bending of the leg.

The bow leg is the one that vibrates more but not so much weight is loaded on it. Furthermore having an almost straight posture the vibration is trasfered totally to the body.

Summing up all the results coming from the different tests; board characterization, roll, pitch, yaw and correlation of vibration Vs average speed, a program with Excel was developed in order to simulate the vibration of the board according to the average speed and the direction.

a_{wx}	2,49	m/s^2
a_{wy}	2,55	m/s^2
a_{wz}	7,10	m/s^2
Average Speed	35,0	km/h
Direction	right	

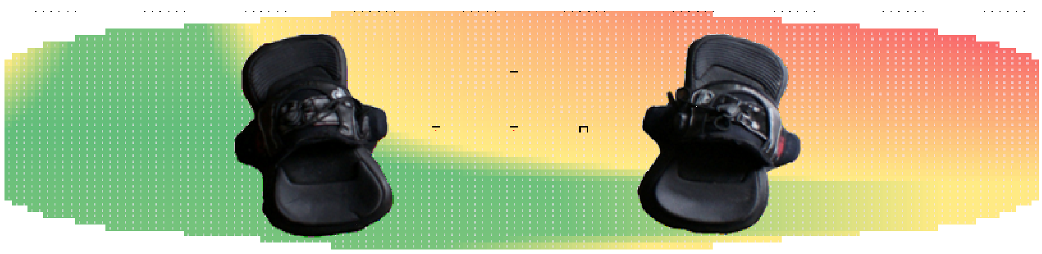


Figure 5.8 Example of vibration at 35 km/h – right.

a_{wx}	2,49	m/s^2
a_{wy}	2,55	m/s^2
a_{wz}	7,10	m/s^2
Average Speed	35,0	km/h
Direction	left	

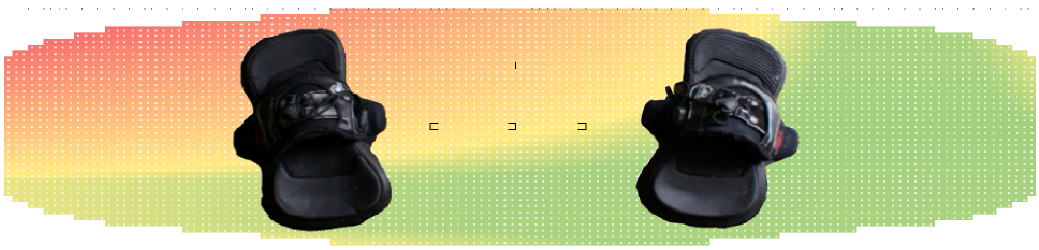


Figure 5.9 Example of vibration at 35 km/h – left.

a_{wx}	1,64	m/s^2
a_{wy}	2,01	m/s^2
a_{wz}	2,52	m/s^2
Average Speed	22,0	km/h
Direction	left	

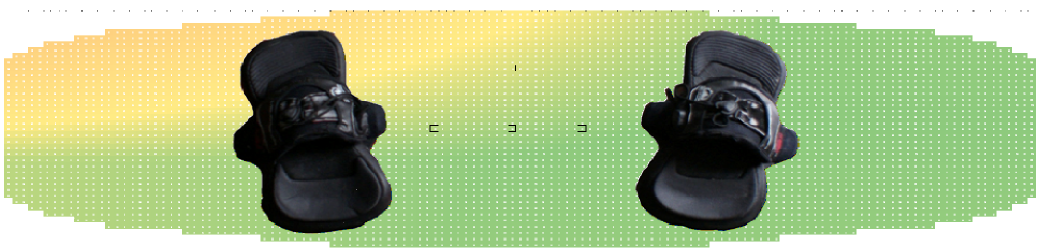


Figure 5.10 Example of vibration at 22 km/h – left.

The colors of the vibration vary from green, low vibration, to red, high vibration.

CHAPTER 6 – CONCLUSION and FURTHER DEVELOPMENT

This work described an experimental campaign performed to identify the vibration exposure during the practice of the kitesurfing and the dependence of the vibration characteristics on a set of possibly influencing parameters.

A purposely designed measurement system was used to monitor the board vibration (translations and rotations), the wave magnitude, the wind strength, the kiter position and his velocity. The board vibration was measured with a triaxial and a single axis accelerometer placed with a computer inside a sealed box rigidly fixed on the board. Waves magnitude was measured with a purposely designed buoy, while the wind was measured with a cup anemometer placed over a 3 m tall mast. The kiter position and speed were measured with a GPS sensor.

Preliminary tests performed in laboratory with an electrodynamic shaker showed the negligible effect of the box on the board dynamic characteristics. The damping effect of the foot pads was identified through the frequency response function between the actual tests measurement position and the kiter heel with different boards, postures and kiters. Results showed that the difference between the vibration measured on the board and the one at the heel-pad interface is trivial.

More than 200 km of tests were performed with a single kiter and board. The kite was changed depending on the wind conditions. ISO 2631 was used to quantify the kiter exposure to vibration; results showed that the dominant vibration axis is usually the Z one (average value a_{wz} 5.51 m/s^2) while the exposures on the other axes were respectively 2.19 m/s^2 and 2.35 m/s^2 for X and Y axes. With these values the European Directive 2002/44/EC thresholds are reached after only 3 (EAV) and 15 minutes (ELV). The averaged 8-hours based exposures along X, Y and Z axes were 0,61, 0,64 and 1,56 m/s^2. The crest factor pointed out the necessity of using the additional (running RMS) evaluation method.

Correlation analysis showed that the vibration depends on the riding speed, while the effect of wave magnitude and wind seems more limited.

The board motion during kitesurfing is not a pure translation but it is combination of translation and rotation; data collected with the auxiliary accelerometer allowed pointing out that the exposure is usually more severe on the tip of the bow foot.

Although EU limits were meant for workers, it is clear how the kitesurfing may lead to degenerative back pathologies in case of long exposures or for people already exposed to WBV during their working activities.

The next step, as a further development, will deal with the measurement of the force transmitted by the kite using purposely designed load cells.

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[7] PATENT-WO 02/38440 A1 – Bridle for power kite launching.

[8] PATENT-0304781 – Dispositif de commande d'une aile propulsive.

[9] PATENT-0304782 – Aile propulsive a diedre negatif.

[10] PATENT-11/067,842 – Wing having a negative dihedron for towing a load.

[11] PATENT-0407790 – Dispositif de controle pour ailes de traction.

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ANNEX A

Test n.1 - 25th August 2010 – PORTO BOTTE

						Speed (km/h)			a_{wx} (m/s^2)				a_{wy} (m/s^2)				a_{wz} (m/s^2)				a_{wroll} (m/s^2)			
File Name	#	sec	Main Direction	Side	Total Distance	Min	Max	Ave.	RMS	RMS Peak	Crest Factor	MTVV	RMS	RMS Peak	Crest Factor	MTVV	RMS	RMS Peak	Crest Factor	MTVV	RMS	RMS Peak	Crest Factor	MTVV
0825_01	1	21	- 0,0016	RIGHT	213	17,31	37,31	31,55	1,87	10,24	5,48	3,70	1,67	8,62	5,16	3,49	5,44	35,75	6,58	10,35	9,44	70,51	7,47	17,80
0825_02	2	24	0,0016	LEFT	202	17,96	30,87	27,25	1,43	6,12	4,28	2,45	1,17	4,11	3,51	1,71	3,00	14,62	4,87	4,89	5,57	27,51	4,94	9,08
0825_03	3	26	- 0,0025	RIGHT	291	23,27	45,73	38,89	1,45	6,39	4,39	2,35	1,26	5,39	4,28	2,05	3,48	22,43	6,45	6,24	6,46	43,58	6,74	12,30
0825_04	4	39	0,0024	LEFT	299	10,61	36,19	26,54	1,46	6,39	4,39	2,34	1,24	5,39	4,36	1,84	3,54	22,43	6,34	6,26	6,59	43,58	6,62	12,22
0825_05	5	25	- 0,0018	RIGHT	257	21,76	38,60	33,35	2,03	8,93	4,41	3,65	1,99	7,88	3,96	3,48	5,95	41,69	7,01	12,04	10,21	93,30	9,14	19,61
0825_06	6	35	0,0022	LEFT	303	10,25	35,31	28,89	1,60	6,05	3,79	2,20	1,28	5,01	3,90	2,54	3,77	17,72	4,70	5,74	6,94	37,81	5,45	11,05
0825_07	7	31	- 0,0026	RIGHT	331	26,58	40,57	36,99	2,34	13,62	5,82	4,73	2,14	11,98	5,59	4,10	7,71	45,36	5,89	14,66	12,86	76,48	5,95	23,94
0825_08	8	45	0,0026	LEFT	352	12,51	34,64	27,67	1,40	5,80	4,15	2,50	1,25	7,41	5,94	2,83	3,95	26,95	6,82	8,92	6,99	52,04	7,44	15,46
0825_09	9	32	- 0,0028	RIGHT	358	27,07	43,31	37,56	2,45	9,93	4,05	3,81	2,20	9,91	4,51	3,63	8,19	54,90	6,70	14,00	13,95	102,24	7,33	23,84
0825_10	10	43	0,0030	LEFT	378	10,29	37,65	30,71	1,64	6,28	3,82	2,70	1,38	5,01	3,63	2,17	4,68	31,00	6,63	9,03	8,61	58,84	6,84	16,88
0825_11	11	43	- 0,0034	RIGHT	444	16,46	41,58	35,51	2,22	11,09	5,00	3,69	2,31	10,59	4,58	4,22	7,32	57,18	7,81	13,55	12,31	104,81	8,51	23,45
0825_12	12	47	0,0031	LEFT	397	9,73	34,73	28,33	1,58	7,66	4,85	2,71	1,38	6,83	4,95	2,85	4,13	25,83	6,25	8,49	7,58	45,58	6,01	14,73
0825_13	13	36	- 0,0028	RIGHT	361	23,18	39,48	35,43	2,32	11,22	4,85	4,62	2,25	9,32	4,14	4,03	7,09	52,35	7,39	12,55	12,05	101,22	8,40	20,72
0825_14	14	47	0,0033	LEFT	427	11,21	37,55	31,64	1,73	7,33	4,25	3,08	1,37	5,87	4,29	2,31	4,37	21,40	4,89	6,94	8,15	42,58	5,22	12,51
0825_15	15	43	- 0,0030	RIGHT	399	9,93	39,31	31,61	2,38	15,74	6,62	4,57	2,26	12,95	5,73	4,18	7,11	48,04	6,76	11,90	12,02	95,37	7,94	20,34
0825_16	16	39	0,0028	LEFT	380	18,76	39,13	32,44	2,01	10,15	5,06	3,23	1,65	7,59	4,61	3,16	5,66	69,73	12,32	15,11	10,51	139,11	13,23	27,24
0825_17	17	27	- 0,0018	RIGHT	267	13,13	37,93	30,73	2,29	11,85	5,17	3,86	2,62	11,53	4,40	4,92	6,92	57,81	8,35	11,56	11,45	120,26	10,50	20,68
0825_18	18	30	0,0021	LEFT	273	9,31	36,32	29,62	1,83	7,12	3,90	2,91	1,43	7,70	5,37	2,39	4,15	25,90	6,25	7,16	7,75	53,14	6,86	14,45
0825_19	19	20	- 0,0015	RIGHT	205	15,36	42,27	33,66	2,17	9,28	4,28	3,63	2,12	9,51	4,48	4,29	6,76	77,66	11,48	15,33	11,79	150,59	12,78	28,39
0825_20	20	28	0,0018	LEFT	242	10,63	37,99	29,09	1,81	7,13	3,95	2,81	1,44	5,74	3,99	2,41	4,15	21,30	5,14	7,06	7,67	38,32	5,00	12,73
0825_21	21	38	- 0,0031	RIGHT	417	22,62	41,30	37,30	2,55	13,35	5,22	4,09	2,51	16,48	6,57	4,77	8,65	55,34	6,40	16,13	14,55	103,13	7,09	25,82
0825_22	22	45	0,0033	LEFT	411	14,03	39,36	32,00	2,03	9,89	4,87	3,60	1,59	7,76	4,87	2,39	5,09	25,07	4,92	9,15	9,45	46,01	4,87	16,58

Test n.2 - 26th August 2010 – PORTO BOTTE

						Speed (km/h)			a_{wx} (m/s^2)				a_{wy} (m/s^2)				a_{wz} (m/s^2)				a_{wroll} (m/s^2)			
File Name	#	sec	Main Direction	Side	Total Distance	Min	Max	Ave.	RMS	RMS Peak	Crest Factor	MTVV	RMS	RMS Peak	Crest Factor	MTVV	RMS	RMS Peak	Crest Factor	MTVV	RMS	RMS Peak	Crest Factor	MTVV
0826_01	1	67	- 0,00518	RIGHT	624	19,26	37,34	32,47	2,18	10,38	4,75	4,08	2,05	11,48	5,61	3,58	5,53	45,31	8,04	11,27	9,85	89,61	9,10	19,60
0826_02	2	71	0,00515	LEFT	640	23,67	33,55	31,32	1,66	6,06	3,65	2,71	1,57	6,20	3,95	2,85	5,18	32,46	7,25	7,57	8,10	68,94	8,51	14,54
0826_03	3	66	- 0,00494	RIGHT	636	14,59	36,86	32,50	2,26	10,40	4,60	3,91	2,22	9,47	4,27	3,86	5,93	41,28	6,04	10,53	11,34	73,47	6,48	17,74
0826_04	4	70	0,00507	LEFT	651	15,32	37,10	32,47	1,85	8,80	4,76	2,88	1,65	6,54	3,97	2,71	5,90	32,59	5,62	10,63	10,30	66,90	6,49	18,87
0826_05	5	74	- 0,00525	RIGHT	714	27,83	35,31	33,23	2,21	10,03	4,54	3,68	2,41	10,96	4,54	4,14	5,99	48,65	7,17	11,77	11,20	96,01	8,57	20,11
0826_06	6	71	0,00538	LEFT	696	17,40	36,68	32,57	1,91	8,02	4,20	3,22	1,74	7,41	4,26	2,91	5,51	46,11	8,40	11,85	9,69	85,78	8,85	21,15
0826_07	7	59	- 0,00452	RIGHT	592	22,27	37,97	34,67	2,38	9,04	3,80	3,97	2,32	12,27	5,30	3,65	6,45	72,80	10,47	13,10	11,62	101,69	8,75	19,82
0826_08	8	67	0,00501	LEFT	617	19,12	36,54	32,99	2,41	9,04	3,75	3,95	2,38	7,98	3,36	3,59	5,73	72,80	10,82	11,43	11,23	101,69	9,05	18,47
0826_09	9	50	- 0,00342	RIGHT	458	18,03	37,51	31,90	1,76	8,87	5,03	3,14	1,66	7,00	4,21	3,33	4,80	26,48	6,16	8,43	7,69	43,11	5,60	13,70
0826_10	10	53	0,00371	LEFT	479	14,88	36,87	30,93	1,77	7,12	4,02	2,56	1,48	6,40	4,34	2,39	4,62	30,40	6,88	8,22	8,09	57,64	7,13	15,16

Test n.3 - 28th August 2010 – PORTO BOTTE

						Speed (km/h)			a_{wx} (m/s²)				a_{wy} (m/s²)				a_{wz} (m/s²)				a_{wroll} (m/s²)			
File Name	#	sec	Main Direction	Side	Total Distance	Min	Max	Ave.	RMS	RMS Peak	Crest Factor	MTVV	RMS	RMS Peak	Crest Factor	MTVV	RMS	RMS Peak	Crest Factor	MTVV	RMS	RMS Peak	Crest Factor	MTVV
0828_01	1	23	- 0,0015	RIGHT	235	11,37	38,73	28,32	2,43	10,00	4,12	4,02	2,06	11,19	5,44	3,97	6,41	56,98	8,88	12,26	11,78	95,45	8,10	23,00
0828_02	2	27	0,0020	LEFT	267	21,54	35,11	32,04	2,28	10,53	4,61	3,93	1,56	8,36	5,36	2,97	4,87	38,08	7,82	10,19	8,58	62,75	7,31	17,00
0828_03	3	27	- 0,0022	RIGHT	285	17,62	40,09	37,07	2,73	11,34	4,15	4,04	2,65	11,17	4,22	4,38	7,58	73,97	9,76	12,25	13,77	117,83	8,56	22,99
0828_04	4	31	0,0024	LEFT	303	13,26	36,92	30,53	2,19	8,97	4,10	3,90	2,02	8,72	4,31	3,43	6,04	29,83	4,94	9,79	10,65	58,44	5,49	17,22
0828_05	5	23	- 0,0020	RIGHT	298	21,38	44,69	37,31	2,55	9,91	3,89	3,55	2,64	12,76	4,83	4,41	10,14	51,43	5,07	16,24	17,71	112,79	6,37	26,42
0828_06	6	32	0,0022	LEFT	300	18,76	38,44	30,98	2,33	8,74	3,74	3,30	1,90	9,06	4,78	3,27	5,87	37,00	6,30	9,64	10,52	69,30	6,58	17,08
0828_07	7	23	- 0,0023	RIGHT	285	27,45	44,57	41,18	2,94	12,87	4,38	4,62	2,59	13,74	5,29	4,74	9,10	105,22	11,57	14,54	16,37	159,24	9,73	26,06
0828_08	8	33	0,0024	LEFT	316	10,46	36,62	29,78	1,98	7,89	3,99	3,05	1,63	6,47	3,96	2,71	4,73	23,66	5,01	7,94	8,34	46,50	5,57	14,40
0828_09	9	29	- 0,0026	RIGHT	380	20,01	47,25	36,77	2,60	9,25	3,55	3,83	2,29	11,96	5,22	3,62	8,30	65,21	7,86	12,99	14,94	85,11	5,70	23,80
0828_10	10	41	0,0030	LEFT	384	12,67	38,21	31,15	2,37	9,69	4,08	4,00	1,83	7,08	3,86	2,86	5,31	29,30	5,52	8,49	9,56	56,75	5,94	15,94
0828_11	11	21	- 0,0018	RIGHT	217	25,04	40,68	34,79	2,43	9,97	4,11	4,08	1,95	9,35	4,80	4,00	6,32	75,37	11,93	13,49	11,19	114,15	10,20	21,68
0828_12	12	24	0,0018	LEFT	234	22,53	34,46	31,46	1,80	6,76	3,75	2,83	1,53	8,15	5,33	2,68	3,91	25,72	6,57	7,22	7,06	55,97	7,93	12,60
0828_13	13	26	- 0,0021	RIGHT	266	11,35	40,41	32,74	2,38	8,42	3,54	3,38	2,22	11,08	5,00	4,42	7,25	73,90	10,19	18,68	12,74	136,98	10,75	30,81
0828_14	14	31	0,0021	LEFT	274	20,99	33,82	28,51	1,86	7,28	3,90	2,84	1,54	6,12	3,98	2,32	3,66	18,54	5,06	9,85	6,53	31,64	4,85	11,50
0828_15	15	39	- 0,0037	RIGHT	470	29,65	43,39	41,28	2,97	14,14	4,76	5,19	2,41	17,55	7,28	5,50	8,24	64,99	7,88	16,61	14,84	119,50	8,05	25,10
0828_16	16	57	0,0042	LEFT	509	11,33	34,51	32,00	2,20	8,52	3,88	3,76	1,78	9,57	5,37	2,92	4,76	29,70	6,24	8,08	8,57	62,93	7,35	14,25
0828_17	17	39	- 0,0034	RIGHT	424	22,17	43,59	37,55	2,75	10,51	3,82	4,58	2,16	10,49	4,86	3,52	6,93	58,25	8,41	11,95	12,89	111,08	8,62	20,72
0828_18	18	43	0,0034	LEFT	421	19,28	36,57	33,24	2,40	9,54	3,97	3,73	1,94	9,16	4,71	3,31	5,41	53,93	9,97	12,39	9,70	121,56	12,53	24,09
0828_19	19	27	- 0,0022	RIGHT	289	19,44	41,86	35,04	2,50	10,15	4,07	4,03	2,14	10,96	5,11	3,82	6,84	77,88	11,39	14,97	12,61	153,66	12,19	28,05
0828_20	20	30	0,0022	LEFT	278	21,81	36,14	31,51	2,30	8,77	3,81	3,49	1,75	5,95	3,40	2,59	4,44	23,63	5,32	6,76	7,91	43,68	5,52	11,86
0828_21	21	28	- 0,0025	RIGHT	310	22,34	41,39	37,29	2,36	8,46	3,58	3,35	2,00	8,85	4,43	3,42	6,06	65,12	10,74	11,47	11,14	96,42	8,66	19,92
0828_22	22	38	0,0026	LEFT	318	19,79	31,79	28,79	1,72	6,11	3,55	2,35	1,49	6,00	4,02	2,29	3,81	18,49	4,85	6,21	6,81	36,20	5,31	10,98
0828_23	23	36	- 0,0031	RIGHT	390	22,59	44,09	37,59	2,86	11,70	4,09	4,81	2,48	12,13	4,89	4,79	8,16	73,48	9,00	16,66	14,71	149,26	10,15	29,49
0828_24	24	39	0,0028	LEFT	359	19,69	33,63	31,89	2,12	11,28	5,31	3,65	1,60	7,41	4,63	2,39	4,09	24,10	5,89	6,47	7,20	49,76	6,91	10,85
0828_25	25	27	- 0,0022	RIGHT	292	24,17	38,10	35,85	2,73	11,50	4,22	4,39	2,38	11,24	4,72	4,37	6,47	47,73	7,37	13,83	11,65	86,32	7,41	24,73
0828_26	26	36	0,0025	LEFT	309	21,46	34,19	29,03	2,31	9,03	3,91	3,89	1,79	6,76	3,77	3,30	4,42	50,24	11,36	8,06	7,80	75,12	9,63	14,23

Test n.4 - 4th September 2010 – DORIO

						Speed (km/h)			a_{wx} (m/s²)				a_{wy} (m/s²)				a_{wz} (m/s²)				a_{wroll} (m/s²)			
File Name	#	sec	Main Direction	Side	Total Distance	Min	Max	Ave.	RMS	RMS Peak	Crest Factor	MTVV	RMS	RMS Peak	Crest Factor	MTVV	RMS	RMS Peak	Crest Factor	MTVV	RMS	RMS Peak	Crest Factor	MTVV
904_01	1	205	0,0071	LEFT	1.701	7,31	39,04	27,66	3,00	15,62	5,21	4,99	2,83	21,36	7,56	6,25	8,16	85,66	10,50	17,72	13,99	171,27	12,24	31,02
904_02	2	67	- 0,0018	RIGHT	513	11,73	29,12	26,13	2,52	10,58	4,19	4,02	1,94	7,96	4,10	3,31	5,36	40,07	7,48	9,22	9,73	79,22	8,14	16,22
904_03	3	37	0,0005	LEFT	286	10,80	30,25	24,89	2,75	10,75	3,91	4,15	2,72	16,37	6,03	6,07	6,33	46,28	7,31	11,76	10,29	88,44	8,60	17,18
904_04	4	106	- 0,0037	RIGHT	816	17,17	30,19	26,74	2,43	11,57	4,76	4,09	2,21	10,07	4,56	4,13	4,95	57,02	11,51	9,87	8,48	97,27	11,47	16,99
904_05	5	91	0,0023	LEFT	845	13,12	35,88	32,27	2,85	11,98	4,20	4,48	2,87	12,52	4,37	5,42	7,58	58,80	7,76	13,97	13,02	125,62	9,65	25,34
904_06	6	101	- 0,0033	RIGHT	720	11,09	28,38	25,10	2,32	11,18	4,81	3,94	2,01	12,56	6,25	3,78	4,49	36,37	8,11	7,21	7,90	77,88	9,86	13,15
904_07	7	69	0,0021	LEFT	597	17,07	34,79	30,07	2,37	9,95	4,19	3,60	2,40	12,24	5,10	3,86	6,15	37,97	6,18	12,85	10,63	91,45	8,60	21,01
904_08	8	155	- 0,0047	RIGHT	1.163	10,86	30,27	26,46	2,24	9,47	4,22	3,79	1,73	7,72	4,46	3,40	4,21	31,01	7,36	7,47	7,49	58,19	7,77	13,22
904_09	9	102	0,0027	LEFT	847	10,09	37,00	29,33	2,55	10,82	4,24	4,08	2,65	15,09	5,69	4,76	5,82	39,16	6,72	11,75	9,89	75,82	7,67	20,24
904_10	10	131	- 0,0015	RIGHT	1.119	11,74	40,17	30,38	2,36	11,36	4,82	5,01	1,76	11,23	6,38	3,89	4,68	45,89	9,81	12,11	8,29	119,69	14,44	20,20

Test n.5 - 5th September 2010 – DORIO

						Speed (km/h)			a_{wx} (m/s²)				a_{wy} (m/s²)				a_{wz} (m/s²)				a_{wroll} (m/s²)			
File Name	#	sec	Main Direction	Side	Total Distance	Min	Max	Ave.	RMS	RMS Peak	Crest Factor	MTVV	RMS	RMS Peak	Crest Factor	MTVV	RMS	RMS Peak	Crest Factor	MTVV	RMS	RMS Peak	Crest Factor	MTVV
905_01	1	96	0,0019	LEFT	912	19,16	40,13	33,61	3,19	18,14	5,68	5,72	3,27	22,42	6,85	7,00	8,47	74,99	8,85	16,90	14,57	156,54	10,75	29,22
905_02	2	96	- 0,0032	RIGHT	868	18,82	38,39	32,36	2,50	11,82	4,73	3,72	2,36	12,58	5,33	4,09	7,33	48,61	6,63	15,05	12,89	95,81	7,43	26,97
905_03	3	165	0,0038	LEFT	1.654	19,50	41,20	35,66	3,28	15,75	4,80	5,43	3,17	22,62	7,13	5,82	8,72	72,95	8,36	19,19	15,21	162,95	10,71	32,17
905_04	4	210	- 0,0054	RIGHT	1.631	15,67	32,14	27,85	2,48	14,99	6,05	5,36	1,74	11,45	6,57	3,52	4,15	62,10	14,98	11,00	8,02	135,99	16,97	22,09
905_05	5	207	0,0056	LEFT	1.929	20,64	36,59	32,77	3,15	15,44	4,90	5,47	2,50	14,18	5,66	4,08	5,86	88,15	15,04	10,74	10,24	149,68	14,62	19,95
905_06	6	225	- 0,0065	RIGHT	1.711	16,33	30,32	27,22	2,33	11,55	4,96	3,99	2,00	8,20	4,09	3,42	4,46	54,11	12,14	8,69	8,18	114,41	13,99	17,22
905_07	7	209	0,0024	LEFT	1.830	20,50	35,12	31,24	2,79	12,87	4,61	4,45	2,84	17,54	6,17	5,29	6,01	75,53	12,57	11,59	10,77	142,64	13,25	19,80
905_08	8	184	- 0,0045	RIGHT	1.535	10,87	35,58	28,81	2,64	11,22	4,25	4,25	2,11	14,18	6,73	4,39	5,90	57,19	9,69	10,89	10,95	132,73	12,12	19,42
905_09	9	123	0,0024	RIGHT	862	14,92	33,97	24,71	2,72	14,27	5,24	5,30	0,93	5,51	5,93	1,70	3,40	58,23	17,11	9,82	4,18	66,77	15,96	10,73
905_10	10	52	0,0016	LEFT	443	10,58	38,18	28,67	2,66	13,60	5,11	5,60	2,81	16,28	5,80	5,79	6,31	59,00	9,35	17,71	10,58	125,06	11,82	30,00
905_11	11	41	- 0,0017	RIGHT	424	18,49	41,73	35,48	2,30	12,32	5,36	3,95	2,03	12,19	5,99	3,79	6,76	34,60	5,12	11,40	11,74	62,24	5,30	19,37
905_12	12	172	0,0052	LEFT	1.587	15,19	41,51	33,09	3,01	12,03	3,99	5,27	3,01	16,48	5,48	5,46	8,18	85,40	10,44	18,65	14,03	171,29	12,21	32,18
905_13	13	179	- 0,0044	RIGHT	1.359	12,40	33,29	27,11	2,41	12,40	5,14	4,63	2,04	13,55	6,64	4,21	4,67	66,26	14,20	10,02	8,71	132,46	15,22	20,53
905_14	14	232	0,0035	LEFT	1.983	19,78	35,52	30,12	2,93	12,79	4,37	4,87	2,84	16,22	5,71	5,12	5,60	70,73	12,62	12,03	10,01	148,91	14,88	21,94
905_15	15	248	- 0,0049	RIGHT	2.025	17,77	37,50	28,75	2,58	12,10	4,69	4,09	1,91	13,46	7,06	3,96	5,20	47,09	9,05	12,97	9,53	108,99	11,44	22,12
905_16	16	106	0,0016	LEFT	971	19,04	36,03	32,71	3,17	12,20	3,85	5,08	3,39	23,51	6,93	7,12	7,98	55,85	7,00	15,83	14,02	136,74	9,75	27,25
905_17	17	109	- 0,0018	RIGHT	1.028	15,84	38,35	32,76	2,72	14,31	5,26	5,33	1,79	10,48	5,87	3,26	5,32	68,58	12,89	11,13	9,90	110,88	11,20	18,87
905_18	18	33	0,0015	LEFT	216	17,19	26,47	22,68	2,81	13,38	4,77	5,66	1,68	9,50	5,66	3,55	3,08	41,69	13,54	7,18	5,03	102,91	20,45	13,96
905_19	19	47	0,0012	RIGHT	340	15,86	32,31	24,51	2,32	12,27	5,28	4,24	1,19	5,93	4,99	2,17	3,25	72,99	22,48	8,74	5,13	89,85	17,51	14,65

Test n.6 - 5th September 2010 – DORIO

						Speed (km/h)			a_{wx} (m/s²)				a_{wy} (m/s²)				a_{wz} (m/s²)				a_{wroll} (m/s²)			
File Name	#	sec	Main Direction	Side	Total Distance	Min	Max	Ave.	RMS	RMS Peak	Crest Factor	MTVV	RMS	RMS Peak	Crest Factor	MTVV	RMS	RMS Peak	Crest Factor	MTVV	RMS	RMS Peak	Crest Factor	MTVV
905_20	1	151	0,0031	LEFT	1.455	20,17	46,56	34,63	2,80	13,67	4,89	4,56	3,11	22,93	7,37	6,25	8,39	75,79	8,92	19,63	14,61	160,61	10,99	30,97
905_21	2	182	- 0,0035	RIGHT	1.489	14,58	40,68	29,40	2,13	10,51	4,94	3,84	1,75	12,33	7,04	3,69	4,99	53,77	10,97	10,44	8,90	97,66	10,97	19,14
905_22	3	122	0,0022	LEFT	1.132	16,09	38,05	33,35	2,81	11,66	4,15	4,42	2,99	16,25	5,43	5,16	7,53	61,43	8,05	14,04	13,42	138,22	10,30	25,50
905_23	4	80	- 0,0023	RIGHT	651	17,53	33,59	29,12	2,26	11,55	5,11	3,75	1,99	9,26	4,64	3,28	5,58	43,27	7,76	10,84	9,80	75,40	7,70	19,13
905_24	5	81	0,0013	LEFT	767	19,38	37,50	33,98	3,00	10,74	3,58	4,59	3,35	18,87	5,64	5,68	8,41	120,99	13,42	22,83	14,99	158,62	10,59	29,71
905_25	6	93	- 0,0022	RIGHT	775	17,08	38,69	29,93	2,20	10,09	4,58	4,03	1,85	8,79	4,76	4,05	5,31	48,70	9,17	10,16	9,56	103,14	10,79	18,76
905_26	7	97	0,0010	LEFT	927	17,06	39,94	34,29	2,77	9,93	3,58	3,91	3,11	17,38	5,59	6,14	8,05	68,70	8,22	17,75	14,50	135,88	9,37	29,47
905_27	8	88	- 0,0018	RIGHT	788	17,54	41,91	32,18	2,59	10,23	3,96	4,15	2,23	10,56	4,73	4,19	6,32	47,41	7,38	13,06	11,86	108,34	9,14	25,04
905_28	9	85	0,0006	LEFT	800	20,20	47,87	33,62	2,85	11,28	3,95	4,49	3,10	18,91	6,09	5,32	7,56	60,36	7,78	12,99	13,50	137,97	10,22	25,19
905_29	10	102	- 0,0021	RIGHT	923	16,99	43,62	32,54	2,51	10,23	4,08	3,96	2,21	15,54	7,04	4,62	6,54	47,50	7,26	13,88	11,64	100,37	8,62	22,89
905_30	11	73	0,0004	LEFT	665	21,64	38,06	32,43	2,80	13,15	4,69	4,21	3,10	14,69	4,73	5,58	5,72	28,46	4,98	9,41	7,25	41,72	5,75	11,81
905_31	12	93	- 0,0020	RIGHT	830	22,03	37,20	31,97	2,39	11,10	4,65	4,55	2,08	13,30	6,39	5,07	5,87	50,06	8,52	15,16	10,57	101,80	9,63	26,51
905_32	13	120	0,0026	LEFT	1.131	15,35	39,95	33,93	2,82	10,76	3,81	4,48	2,54	15,25	6,00	4,59	7,09	77,60	10,79	14,97	12,64	172,81	13,67	30,11
905_33	14	96	- 0,0021	RIGHT	899	21,98	43,39	33,58	2,61	14,53	5,57	5,03	2,30	13,16	5,71	4,35	7,17	61,76	8,62	14,81	12,56	117,81	9,38	24,99
905_34	15	22	0,0006	LEFT	219	13,67	41,50	34,91	2,69	11,94	4,44	4,27	2,31	10,74	4,64	3,59	7,12	41,24	5,79	12,23	12,78	92,55	7,24	22,03
905_35	16	119	0,0023	RIGHT	943	20,01	33,68	28,29	2,65	10,92	4,13	4,35	1,55	8,05	5,21	3,08	3,61	66,91	18,55	8,40	5,24	90,83	17,35	12,33

Test n.7 - 11th September 2010 – VALMADRERA

						Speed (km/h)			a_{wx} (m/s^2)				a_{wy} (m/s^2)				a_{wz} (m/s^2)				a_{wyaw} (m/s^2)			
File Name	#	sec	Main Direction	Side	Total Distance	Min	Max	Ave.	RMS	RMS Peak	Crest Factor	MTVV	RMS	RMS Peak	Crest Factor	MTVV	RMS	RMS Peak	Crest Factor	MTVV	RMS	RMS Peak	Crest Factor	MTVV
911_01	1	88	0,0015	LEFT	798	13,08	39,50	32,61	2,24	13,06	5,83	4,27	2,40	12,90	5,38	4,53	6,12	89,21	14,57	14,02	1,85	10,61	5,73	3,76
911_02	2	100	-0,0003	RIGHT	942	13,94	39,29	33,70	2,99	15,98	5,34	5,44	2,75	11,89	4,33	4,67	8,43	69,48	8,24	17,18	3,52	18,16	5,16	6,14
911_03	3	109	0,0017	LEFT	1.098	20,31	43,73	36,19	2,66	13,85	5,21	4,75	2,97	12,80	4,31	4,68	7,32	63,50	8,67	14,52	2,17	10,97	5,05	4,06
911_04	4	127	-0,0017	RIGHT	1.141	16,06	37,62	32,33	2,50	15,26	6,11	5,16	2,92	14,77	5,06	4,66	6,14	68,65	11,19	11,79	2,88	16,11	5,59	5,49
911_05	5	126	0,0018	LEFT	1.154	17,10	40,48	32,94	2,56	16,13	6,31	4,47	3,17	12,67	4,00	5,20	6,88	85,65	12,45	13,97	2,13	14,29	6,69	3,90
911_06	6	163	-0,0017	RIGHT	934	12,71	28,77	20,51	1,41	10,15	7,18	2,79	2,40	10,40	4,34	3,89	2,53	48,93	19,33	6,76	1,63	10,64	6,54	3,02
911_07	7	105	0,0021	LEFT	653	7,98	31,04	22,36	1,92	9,09	4,72	3,55	2,13	12,09	5,68	3,95	3,26	41,30	12,67	6,46	1,63	8,07	4,94	3,10
911_08	8	77	-0,0009	RIGHT	616	16,37	32,35	28,67	2,06	11,57	5,61	3,88	2,92	14,49	4,96	5,00	4,66	54,89	11,78	8,91	2,34	14,06	6,00	4,33
911_09	9	76	0,0008	LEFT	717	13,78	50,15	34,03	2,17	9,55	4,40	3,46	2,58	9,74	3,77	4,15	6,66	65,14	9,78	11,40	1,76	7,17	4,08	2,92
911_10	10	50	-0,0006	RIGHT	417	14,94	35,70	29,84	2,20	10,16	4,62	3,91	2,97	10,96	3,69	4,63	5,79	48,48	8,37	10,26	2,50	12,23	4,89	4,42
911_11	11	36	0,0009	LEFT	251	14,97	28,16	24,84	2,25	8,35	3,71	3,83	2,02	7,49	3,70	3,08	4,17	28,71	6,89	8,46	1,93	6,50	3,37	3,16
911_12	12	62	-0,0003	RIGHT	586	19,14	38,20	33,89	2,69	12,49	4,63	5,54	3,13	13,32	4,25	5,09	8,67	60,33	6,96	15,66	3,23	13,69	4,24	6,09
911_13	13	107	0,0022	LEFT	958	14,25	38,89	32,23	2,50	12,73	5,09	4,86	2,79	11,22	4,02	4,39	6,45	46,97	7,28	13,95	2,04	9,98	4,89	4,05
911_14	14	89	-0,0006	RIGHT	772	14,79	36,34	31,24	3,00	13,42	4,47	5,19	3,15	12,33	3,92	4,54	7,06	54,59	7,73	12,44	3,45	14,56	4,22	5,63
911_15	15	80	0,0019	LEFT	677	15,76	35,53	30,33	2,16	10,04	4,65	4,47	2,40	10,64	4,43	4,04	5,48	36,90	6,74	9,83	1,77	8,46	4,78	3,81
911_16	16	60	-0,0001	RIGHT	484	14,04	34,73	28,93	3,08	16,91	5,49	5,54	2,96	11,48	3,87	4,42	7,37	71,43	9,70	15,40	3,55	17,79	5,02	6,12
911_17	17	60	0,0017	LEFT	494	14,74	34,03	29,38	1,91	7,88	4,12	3,26	1,99	8,20	4,12	2,87	3,81	27,70	7,27	6,58	1,60	6,55	4,10	2,85
911_18	18	81	-0,0002	RIGHT	635	11,61	33,23	28,15	2,92	13,62	4,67	5,35	2,93	17,85	6,09	5,36	6,45	73,51	11,40	16,12	3,39	16,93	5,00	6,30
911_19	19	26	0,0002	LEFT	204	10,72	31,96	28,06	1,82	9,87	5,41	3,19	2,19	10,95	5,01	3,85	4,00	34,12	8,54	6,90	1,49	8,25	5,53	2,56
911_20	20	62	0,0002	RIGHT	493	16,32	34,50	28,53	2,65	13,37	5,05	4,91	2,73	13,27	4,87	5,43	5,98	59,97	10,03	11,63	3,05	15,73	5,15	5,09
911_21	21	110	-0,0011	LEFT	1.004	15,07	47,26	32,87	2,16	13,63	6,32	3,58	3,19	14,05	4,40	5,08	5,90	102,19	17,32	12,50	1,81	12,49	6,89	3,21
911_22	22	153	-0,0067	RIGHT	1.097	16,69	31,48	25,74	1,36	7,42	5,44	2,79	2,66	12,14	4,57	4,46	3,87	70,01	18,09	8,60	1,47	7,52	5,10	3,02

Test n.8 - 11th September 2010 – DORIO

						Speed (km/h)			a_{wx} (m/s^2)				a_{wy} (m/s^2)				a_{wz} (m/s^2)				a_{wyaw} (m/s^2)			
File Name	#	sec	Main Direction	Side	Total Distance	Min	Max	Ave.	RMS	RMS Peak	Crest Factor	MTVV	RMS	RMS Peak	Crest Factor	MTVV	RMS	RMS Peak	Crest Factor	MTVV	RMS	RMS Peak	Crest Factor	MTVV
911_23	1	213	0,0059	LEFT	2.042	14,22	52,41	34,55	2,83	14,94	5,28	4,97	2,53	10,51	4,16	4,50	7,73	61,64	7,97	16,68	2,31	11,90	5,16	4,12
911_24	2	162	- 0,0037	RIGHT	1.344	13,23	35,04	29,80	1,99	12,25	6,16	5,88	2,64	10,59	4,01	4,77	5,50	72,60	13,19	14,22	2,34	12,17	5,20	5,98
911_25	3	157	0,0029	LEFT	1.532	18,88	40,48	35,09	2,96	14,78	5,00	6,17	2,61	10,54	4,03	4,32	8,05	72,48	9,01	18,32	2,39	11,63	4,87	4,76
911_26	4	145	- 0,0035	RIGHT	1.256	16,77	37,75	31,11	2,29	9,36	4,10	4,34	2,78	11,30	4,07	4,53	6,11	54,43	8,90	12,26	2,72	11,20	4,12	4,93
911_27	5	96	0,0020	LEFT	947	14,67	42,22	35,53	2,87	17,17	5,98	6,29	2,51	11,03	4,40	4,53	7,97	83,43	10,47	19,54	2,43	15,45	6,34	5,62
911_28	6	133	- 0,0028	RIGHT	1.090	15,22	36,74	29,45	1,92	8,68	4,52	3,43	2,43	10,17	4,19	3,97	5,48	53,93	9,83	11,05	2,31	9,98	4,32	3,91
911_29	7	117	0,0016	LEFT	1.130	17,26	39,38	34,75	2,92	12,14	4,16	5,13	2,60	9,75	3,75	4,10	7,43	56,54	7,61	13,91	2,38	12,34	5,19	4,51
911_30	8	134	- 0,0025	RIGHT	1.113	15,62	41,58	29,87	1,79	9,04	5,04	4,14	2,35	10,27	4,37	3,76	4,51	37,73	8,36	8,58	2,11	9,67	4,58	4,44
911_31	9	100	0,0012	LEFT	941	16,11	43,46	33,84	3,17	25,71	8,12	7,23	2,66	10,78	4,05	4,51	7,80	66,81	8,56	17,16	2,69	23,74	8,84	6,60
911_32	10	70	- 0,0014	RIGHT	570	13,24	35,02	29,17	1,82	7,77	4,26	3,18	2,65	11,73	4,43	4,75	4,85	36,01	7,43	9,61	2,17	9,55	4,40	3,68
911_33	11	78	0,0016	LEFT	721	15,50	48,95	33,22	2,74	14,38	5,25	5,05	2,54	9,83	3,88	4,02	6,75	62,40	9,24	17,08	2,29	12,07	5,26	4,77
911_34	12	90	0,0000	RIGHT	721	11,11	37,74	28,70	1,73	10,81	6,23	3,91	3,11	13,21	4,25	5,44	5,40	68,58	12,70	13,86	2,03	10,11	4,98	4,14
911_35	13	77	- 0,0013	RIGHT	613	14,43	34,61	28,63	1,76	8,21	4,68	3,15	2,43	11,06	4,55	3,83	4,02	26,58	6,62	7,04	2,09	9,72	4,65	3,65
911_36	14	193	0,0005	LEFT	1.570	18,54	39,35	29,21	2,83	16,15	5,71	5,66	2,61	11,25	4,31	4,66	6,51	78,87	12,12	17,95	2,42	15,07	6,21	4,63
911_37	15	201	- 0,0028	RIGHT	1.522	18,60	32,35	27,20	1,64	9,97	6,08	3,27	2,57	10,68	4,16	4,46	4,08	43,72	10,71	7,98	1,93	11,96	6,19	3,88

911_38	16	52	0,0021	LEFT	336	15,26	26,73	23,04	1,41	7,12	5,04	2,70	2,22	11,94	5,37	4,21	2,50	22,67	9,05	4,63	1,18	6,03	5,12	2,21
911_39	17	64	0,0000	LEFT	595	17,56	36,46	33,37	2,96	13,29	4,49	5,02	2,46	9,72	3,95	4,10	6,53	56,46	8,64	12,13	2,49	13,41	5,38	4,88
911_40	18	131	- 0,0027	RIGHT	1.094	10,04	35,06	30,13	1,96	11,47	5,85	3,84	2,48	11,30	4,56	4,97	5,22	66,07	12,66	11,22	2,36	13,00	5,50	4,69
911_41	19	118	0,0005	LEFT	963	12,55	35,26	29,40	2,97	14,58	4,91	5,17	2,44	14,36	5,89	5,40	5,70	48,60	8,52	12,92	2,53	13,34	5,27	4,96
911_42	20	85	- 0,0018	RIGHT	733	15,14	45,77	31,03	1,96	8,61	4,39	3,45	2,52	10,88	4,32	4,39	5,28	35,09	6,65	10,28	2,39	10,10	4,22	4,09
911_43	21	31	0,0006	RIGHT	165	10,78	23,51	18,96	0,82	3,13	3,83	1,45	1,60	8,06	5,02	3,08	1,13	9,94	8,80	1,91	0,90	3,51	3,90	1,61
911_44	22	38	0,0012	LEFT	202	6,39	23,11	18,96	1,22	5,88	4,83	2,16	1,83	7,52	4,12	3,05	1,66	26,20	15,79	3,64	1,05	5,42	5,15	1,81
911_45	23	36	0,0002	RIGHT	198	8,02	25,95	19,54	0,95	3,47	3,65	1,50	1,69	6,85	4,05	2,85	1,27	11,75	9,28	2,40	1,02	4,23	4,16	1,66
911_46	24	56	- 0,0001	RIGHT	408	12,64	34,61	26,20	1,28	6,16	4,82	2,08	2,06	10,67	5,17	3,75	2,79	24,77	8,87	5,64	1,46	7,92	5,41	2,53
911_47	25	24	0,0003	LEFT	182	14,34	31,99	26,41	2,12	9,74	4,59	3,27	2,34	11,59	4,96	4,04	3,94	39,09	9,93	7,14	1,85	8,15	4,41	2,84
911_48	26	17	- 0,0001	RIGHT	111	10,93	28,10	22,73	1,21	4,01	3,30	1,90	1,60	4,76	2,98	2,41	1,72	10,53	6,11	3,09	1,25	4,24	3,39	2,01
911_49	27	30	0,0003	LEFT	195	16,24	28,48	22,96	2,11	8,43	4,00	3,67	1,97	8,63	4,37	3,73	3,08	26,37	8,57	5,79	1,82	7,37	4,06	3,27
911_50	28	119	0,0012	LEFT	816	2,40	34,26	24,59	2,34	11,71	5,00	4,72	2,22	10,08	4,55	4,30	4,24	44,42	10,47	8,68	1,99	10,31	5,18	4,09
911_51	29	15	- 0,0001	RIGHT	114	13,84	32,71	27,20	1,76	8,26	4,70	4,08	2,52	8,90	3,53	5,28	3,81	32,39	8,51	9,06	2,02	9,32	4,62	4,63
911_52	30	41	- 0,0008	RIGHT	323	16,07	33,18	28,16	1,64	6,43	3,93	2,93	2,20	8,93	4,07	3,29	4,15	38,69	9,32	7,58	1,95	8,45	4,33	3,60
911_53	31	73	0,0006	LEFT	645	9,46	45,03	31,99	3,01	13,57	4,51	4,98	2,90	12,40	4,28	5,01	6,77	100,14	14,79	14,04	2,58	12,44	4,82	4,48
911_54	32	79	- 0,0014	RIGHT	677	15,65	34,40	30,82	1,85	9,71	5,25	3,09	2,60	11,70	4,51	4,79	4,84	44,95	9,29	9,95	2,21	9,32	4,22	3,60
911_55	33	79	0,0000	LEFT	669	16,40	35,88	30,45	3,25	16,49	5,07	6,08	2,94	11,50	3,91	4,93	6,31	51,46	8,16	11,92	2,74	14,74	5,38	5,49
911_56	34	88	- 0,0007	RIGHT	719	16,46	34,50	29,28	1,62	10,97	6,78	3,76	2,57	12,16	4,73	4,03	4,35	52,45	12,05	8,99	1,91	11,26	5,91	4,07
911_57	35	31	0,0003	LEFT	220	12,47	31,07	25,01	2,44	11,74	4,82	3,72	2,76	13,99	5,07	5,48	4,01	49,23	12,28	9,23	2,10	10,93	5,21	3,18
911_58	36	57	- 0,0006	RIGHT	463	15,53	34,21	29,18	1,57	7,17	4,57	2,69	2,37	8,51	3,59	3,79	3,60	30,48	8,46	7,10	1,89	8,01	4,24	3,26
911_59	37	93	0,0017	LEFT	842	14,80	43,95	32,52	2,99	17,92	5,99	5,10	2,93	14,34	4,89	5,01	7,56	65,29	8,63	14,04	2,54	15,72	6,19	4,65
911_60	38	131	- 0,0006	RIGHT	1.193	15,60	39,67	32,74	1,84	10,77	5,84	3,38	2,61	12,34	4,73	4,47	4,99	56,20	11,25	9,80	2,25	13,07	5,81	4,07

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						Speed (km/h)			a_{wx} (m/s^2)				a_{wy} (m/s^2)				a_{wz} (m/s^2)				a_{wyaw} (m/s^2)			
File Name	#	sec	Main Direction	Side	Total Distance	Min	Max	Ave.	RMS	RMS Peak	Crest Factor	MTVV	RMS	RMS Peak	Crest Factor	MTVV	RMS	RMS Peak	Crest Factor	MTVV	RMS	RMS Peak	Crest Factor	MTVV
0911_61	1	165	0,0040	LEFT	1.458	10,25	43,36	31,85	2,98	17,80	5,96	6,30	3,01	13,94	4,64	5,11	7,70	90,89	11,81	18,73	2,50	14,27	5,72	5,60
0911_62	2	72	- 0,0023	RIGHT	580	17,10	33,14	28,89	2,23	9,85	4,41	4,01	2,57	9,54	3,71	4,15	5,37	40,73	7,59	10,43	2,64	10,46	3,96	4,42
0911_63	3	129	0,0036	LEFT	1.159	13,57	40,70	32,34	2,85	14,40	5,06	5,80	2,64	12,78	4,85	4,79	7,31	61,58	8,42	15,46	2,34	12,27	5,24	5,07
0911_64	4	159	- 0,0052	RIGHT	1.275	10,77	37,98	28,82	2,25	13,44	5,98	4,94	2,58	12,73	4,93	4,88	5,26	45,64	8,67	13,11	2,62	14,14	5,39	5,52
0911_65	5	97	0,0022	LEFT	886	10,10	43,61	33,01	2,82	12,90	4,57	5,10	2,62	11,03	4,21	4,04	6,98	61,19	8,77	13,34	2,37	12,07	5,09	4,61
0911_66	6	110	- 0,0041	RIGHT	898	13,36	34,32	29,37	2,45	12,80	5,22	4,48	2,50	10,82	4,33	4,29	5,29	50,41	9,53	11,48	2,82	14,38	5,10	5,13
0911_67	7	106	0,0020	LEFT	941	11,52	41,12	31,96	2,52	14,28	5,66	5,19	2,47	11,83	4,80	4,39	6,23	48,19	7,74	11,59	2,04	12,47	6,13	4,38
0911_68	8	94	- 0,0030	RIGHT	800	10,33	40,12	30,66	2,20	9,33	4,24	3,74	2,57	10,75	4,18	3,90	5,53	34,00	6,15	10,18	2,64	11,14	4,22	4,73
0911_69	9	99	0,0023	LEFT	890	9,93	40,99	32,47	2,48	14,64	5,90	4,88	2,42	11,30	4,66	4,47	6,05	53,33	8,81	12,66	2,02	12,62	6,26	4,08
0911_70	10	91	- 0,0014	RIGHT	749	10,83	39,69	29,67	1,79	10,62	5,93	3,34	2,89	11,10	3,84	4,65	4,15	55,28	13,31	8,15	2,08	11,37	5,47	3,79
0911_71	11	96	0,0032	LEFT	847	7,54	41,41	31,84	2,11	13,27	6,30	4,21	2,86	11,21	3,92	4,99	4,83	65,34	13,53	9,49	1,79	11,51	6,43	3,64
0911_72	12	157	- 0,0032	RIGHT	1.359	12,05	40,64	31,19	2,05	10,44	5,10	3,85	2,69	12,91	4,80	4,88	4,71	87,84	18,64	10,04	2,39	11,89	4,98	4,48
0911_73	13	61	0,0013	LEFT	562	18,20	38,71	33,12	2,35	9,47	4,02	4,09	2,91	10,93	3,75	4,51	5,92	76,81	12,98	11,28	1,98	9,21	4,66	3,60
0911_74	14	68	- 0,0016	RIGHT	509	17,02	33,45	26,84	1,73	7,16	4,15	3,23	2,22	9,31	4,19	3,89	3,42	22,21	6,50	6,29	1,97	8,19	4,16	3,62
0911_75	15	69	0,0004	LEFT	553	13,39	37,76	28,86	2,47	15,16	6,13	5,24	2,43	13,14	5,41	4,24	5,29	96,22	18,20	12,74	2,08	14,14	6,79	4,82
0911_76	16	79	- 0,0015	RIGHT	653	11,23	37,95	29,82	2,12	9,83	4,63	3,56	2,53	12,34	4,88	4,50	5,13	45,28	8,82	10,53	2,51	11,58	4,61	4,25
0911_77	17	67	0,0017	LEFT	706	18,15	45,95	37,75	3,19	16,37	5,13	5,37	3,18	13,17	4,14	4,95	8,86	58,14	6,57	15,77	2,72	12,73	4,68	5,11
0911_78	18	59	- 0,0011	RIGHT	585	16,40	44,96	35,58	2,39	9,63	4,03	3,74	2,65	9,13	3,45	3,83	7,53	59,56	7,91	14,90	2,95	11,47	3,89	4,66
0911_79	19	58	0,0013	LEFT	619	18,76	59,05	38,23	3,13	14,87	4,75	5,22	3,05	12,54	4,11	4,56	9,16	63,43	6,93	17,70	2,62	13,65	5,20	4,94
0911_80	20	40	0,0010	RIGHT	375	18,06	42,38	33,68	1,84	9,11	4,95	3,59	3,08	12,16	3,95	5,97	5,34	76,38	14,32	11,07	1,98	10,57	5,34	3,98

0911_81	21	111	0,0030	LEFT	914	1,45	39,58	29,56	2,22	10,91	4,90	4,14	2,82	13,58	4,81	5,55	5,52	112,64	20,40	12,88	1,86	9,89	5,32	3,56
0911_82	22	115	- 0,0037	RIGHT	936	17,77	35,23	29,16	2,29	14,21	6,20	4,44	2,44	12,44	5,11	3,92	5,26	46,26	8,80	11,38	2,64	15,27	5,79	5,03
0911_83	23	64	- 0,0011	RIGHT	503	13,87	31,93	28,20	1,50	6,80	4,53	2,60	2,25	10,25	4,56	3,90	3,34	28,92	8,67	6,47	1,71	8,64	5,06	3,04
0911_84	24	86	0,0006	LEFT	758	16,38	36,95	31,68	2,74	21,58	7,88	5,73	2,76	13,69	4,96	4,60	5,88	69,33	11,79	12,21	2,34	20,12	8,61	5,30
0911_85	25	60	- 0,0010	RIGHT	479	14,95	33,70	28,67	1,68	7,46	4,43	3,05	2,44	9,41	3,85	3,80	4,11	31,91	7,76	8,39	2,02	9,06	4,49	3,67
0911_86	26	64	- 0,0004	LEFT	509	19,21	31,60	28,40	2,86	19,00	6,65	5,35	2,56	13,34	5,22	4,46	5,49	53,96	9,82	10,34	2,43	17,12	7,03	4,85
0911_87	27	68	- 0,0013	RIGHT	582	13,87	34,45	30,72	1,85	8,01	4,34	3,12	2,62	12,22	4,67	4,37	4,47	39,52	8,85	7,91	2,19	9,32	4,25	3,69
0911_88	28	33	0,0009	RIGHT	242	12,99	31,54	26,39	1,24	6,56	5,29	2,34	2,16	8,82	4,09	3,53	2,52	51,88	20,61	7,33	1,36	5,89	4,32	2,74
0911_89	29	91	0,0012	LEFT	721	16,33	38,12	28,46	2,55	15,04	5,90	4,38	2,66	10,29	3,86	4,49	4,92	55,52	11,29	9,85	2,18	13,40	6,15	3,76
0911_90	30	86	- 0,0020	RIGHT	746	18,29	43,33	31,14	2,04	7,40	3,63	3,44	2,55	9,49	3,72	3,93	5,22	43,30	8,30	10,52	2,48	9,39	3,78	4,22
0911_91	31	23	0,0009	LEFT	161	17,28	27,20	24,57	1,73	11,99	6,94	3,73	2,46	9,70	3,94	3,68	3,17	42,70	13,48	7,69	1,46	11,82	8,07	3,42
0911_92	32	67	0,0011	RIGHT	550	16,90	35,37	29,43	1,44	11,99	8,30	3,73	2,44	10,97	4,49	4,13	3,37	64,59	19,18	7,63	1,53	11,82	7,74	3,40

Test n.10 - 12th September 2010 – DORIO

						Speed (km/h)			a_{wx} (m/s^2)				a_{wy} (m/s^2)				a_{wz} (m/s^2)				a_{wpitch} (m/s^2)			
File Name	#	sec	Main Direction	Side	Total Distance	Min	Max	Ave.	RMS	RMS Peak	Crest Factor	MTVV	RMS	RMS Peak	Crest Factor	MTVV	RMS	RMS Peak	Crest Factor	MTVV	RMS	RMS Peak	Crest Factor	MTVV
912_01	1	244	0,0054	LEFT	2.088	8,31	39,11	30,83	2,36	15,08	6,40	5,74	2,55	11,63	4,56	4,74	5,66	62,86	11,11	12,54	5,08	68,03	13,40	11,81
912_02	2	96	- 0,0019	RIGHT	648	17,82	29,11	24,07	1,72	7,88	4,59	3,36	2,01	8,68	4,33	3,64	3,69	30,50	8,26	7,21	3,94	35,60	9,03	7,62
912_03	3	100	0,0016	LEFT	913	9,85	40,09	32,89	2,57	13,08	5,09	4,39	2,45	10,37	4,23	4,04	6,16	61,06	9,91	13,23	5,60	66,67	11,91	12,99
912_04	4	104	- 0,0024	RIGHT	796	18,97	32,08	27,39	1,94	8,67	4,47	3,61	2,22	8,94	4,02	3,62	4,64	36,71	7,91	8,43	5,02	35,61	7,09	9,19
912_05	5	115	0,0006	LEFT	1.000	22,37	42,20	31,16	2,33	11,30	4,84	4,21	2,29	12,38	5,41	4,05	5,18	34,07	6,57	9,59	4,65	30,03	6,46	8,73
912_06	6	172	- 0,0036	RIGHT	1.413	22,32	37,92	29,40	2,13	12,34	5,80	3,99	2,47	10,56	4,28	4,53	5,45	72,59	13,31	12,05	5,84	85,45	14,62	12,43
912_07	7	80	0,0009	LEFT	842	26,66	48,62	37,50	2,78	14,90	5,36	5,14	2,88	11,66	4,05	4,43	7,98	51,34	6,43	14,10	7,44	48,77	6,56	13,02
912_08	8	117	- 0,0021	RIGHT	1.051	23,70	41,04	32,12	2,06	9,98	4,84	4,38	2,52	12,85	5,09	4,38	6,03	72,12	11,96	11,74	6,43	72,86	11,34	12,16
912_09	9	121	- 0,0000	LEFT	1.171	23,23	39,63	34,56	2,98	20,58	6,90	6,44	2,97	14,63	4,92	4,55	7,85	85,90	10,95	20,48	7,23	86,74	12,01	18,93
912_10	10	60	- 0,0010	RIGHT	538	24,99	40,32	31,86	2,17	12,55	5,78	4,01	2,66	13,11	4,92	4,97	6,10	57,59	9,44	10,74	6,52	76,42	11,72	12,27
912_11	11	53	0,0005	LEFT	582	21,87	51,92	39,05	2,82	11,50	4,07	4,65	3,00	11,70	3,90	4,68	8,40	62,30	7,41	13,88	7,83	69,03	8,81	13,24
912_12	12	155	- 0,0019	RIGHT	1.365	22,32	44,88	31,55	2,02	10,36	5,12	3,78	2,63	12,15	4,62	4,59	5,31	73,64	13,87	10,40	5,69	68,64	12,07	12,29
912_13	13	51	0,0005	LEFT	485	18,62	41,91	33,68	2,50	14,08	5,64	4,99	2,76	11,48	4,16	4,64	6,43	63,50	9,88	12,67	5,89	70,41	11,95	12,45
912_14	14	82	0,0015	LEFT	827	23,84	42,62	36,15	2,60	15,62	6,00	4,90	2,99	13,85	4,63	5,11	7,58	72,20	9,53	22,07	7,25	84,17	11,60	26,64
912_15	15	134	- 0,0014	RIGHT	1.168	18,66	40,46	31,29	1,89	9,59	5,08	3,65	2,58	11,39	4,41	4,39	5,05	46,65	9,23	9,88	5,45	53,03	9,73	10,98
912_16	16	96	0,0004	LEFT	925	25,26	42,59	34,52	2,52	11,67	4,64	4,59	2,80	11,04	3,94	4,23	6,78	70,40	10,38	14,36	6,24	69,16	11,09	13,30
912_17	17	62	- 0,0009	RIGHT	547	20,43	35,71	31,56	2,13	14,98	7,03	4,15	2,48	10,06	4,06	4,06	5,93	83,02	14,00	13,93	6,16	98,40	15,98	15,51
912_18	18	58	0,0014	RIGHT	478	20,04	32,74	29,38	1,77	8,07	4,56	3,10	2,97	11,53	3,89	4,52	4,29	53,44	12,45	7,68	4,37	64,49	14,76	7,87
912_19	19	47	0,0018	LEFT	395	18,44	41,68	29,91	1,69	8,21	4,85	3,14	3,20	14,86	4,64	5,70	5,36	101,79	19,00	11,36	5,50	92,06	16,75	12,05
912_20	20	24	0,0006	LEFT	231	18,67	42,48	34,14	2,35	13,17	5,59	4,63	3,20	14,86	4,64	5,71	6,67	41,59	6,23	12,41	6,50	43,36	6,67	11,45
912_20b	21	40	0,0005	LEFT	440	19,22	44,21	39,31	3,10	14,90	4,81	7,28	3,29	16,30	4,95	6,09	9,04	69,75	7,71	16,86	8,10	73,42	9,07	15,44
912_21	22	201	- 0,0033	RIGHT	1.460	18,27	39,03	26,09	2,03	12,08	5,97	4,43	2,36	10,83	4,58	4,89	4,34	56,31	12,98	12,26	4,55	57,27	12,58	13,02
912_22	23	207	0,0032	LEFT	1.380	17,48	29,25	23,88	1,47	9,13	6,21	3,18	2,54	14,36	5,66	5,82	3,19	52,35	16,40	7,78	3,11	50,50	16,22	7,86
912_23	24	133	- 0,0024	RIGHT	883	13,95	34,21	23,77	1,87	10,70	5,70	4,15	2,33	10,71	4,60	4,00	3,58	45,38	12,69	8,08	3,82	41,24	10,81	7,94
912_24	25	98	- 0,0000	LEFT	679	15,88	31,01	24,70	1,97	11,95	6,05	4,08	2,58	13,15	5,09	5,06	3,68	74,15	20,17	8,39	3,38	57,59	17,04	8,24
912_25	26	94	- 0,0018	RIGHT	681	20,31	32,54	25,88	1,76	6,80	3,87	2,88	2,40	8,58	3,58	3,93	3,57	30,37	8,52	7,19	3,76	33,22	8,83	7,49
912_26	27	98	- 0,0006	LEFT	789	23,68	33,62	28,77	2,40	13,13	5,48	4,58	2,67	11,66	4,37	4,53	5,10	44,55	8,74	8,89	4,57	46,91	10,27	9,93
912_27	28	40	- 0,0007	RIGHT	398	27,06	39,50	35,33	2,58	12,46	4,83	4,63	2,87	13,06	4,54	4,68	7,19	79,70	11,08	15,21	7,52	76,42	10,16	15,31
912_28	29	31	0,0006	LEFT	317	26,64	43,42	35,87	2,20	10,87	4,95	4,32	3,06	12,91	4,21	5,00	6,87	45,58	6,64	12,11	6,33	41,91	6,62	10,85
912_29	30	105	- 0,0007	RIGHT	1.077	23,88	40,73	36,74	2,37	11,21	4,73	4,28	2,75	10,07	3,66	4,44	7,35	52,15	7,10	14,22	7,68	52,18	6,80	15,14
912_30	31	73	0,0004	LEFT	626	18,86	44,32	30,45	2,47	11,93	4,82	4,52	2,68	12,41	4,62	4,55	5,60	50,36	9,00	11,54	5,06	51,90	10,25	11,37
912_31	32	74	- 0,0009	RIGHT	539	18,53	30,99	25,95	1,61	6,58	4,09	3,28	2,35	9,55	4,06	3,87	3,26	44,19	13,56	7,29	3,47	55,81	16,08	7,89
912_32	33	39	- 0,0001	LEFT	283	15,57	27,78	25,59	1,78	10,01	5,63	3,48	2,13	10,70	5,03	4,00	3,38	41,50	12,29	8,38	3,05	46,70	15,32	9,66
912_33	34	44	- 0,0008	RIGHT	332	20,63	30,71	26,84	1,63	7,71	4,74	2,92	2,40	10,88	4,53	3,99	3,50	32,83	9,39	6,38	3,78	37,96	10,04	7,21
912_34	35	71	0,0007	LEFT	595	20,59	36,14	29,97	2,07	9,60	4,63	3,86	2,48	11,09	4,48	4,10	4,44	63,17	14,23	10,24	3,97	53,19	13,39	9,22

912_35	36	50	- 0,0004	RIGHT	422	19,53	34,31	30,09	1,87	10,85	5,82	4,80	2,34	11,21	4,80	4,24	4,24	29,62	6,98	10,81	4,54	33,09	7,28	11,74
912_36	37	40	0,0002	RIGHT	242	10,71	27,01	21,56	0,87	4,17	4,77	1,48	2,00	8,20	4,11	3,48	2,00	23,84	11,92	4,77	2,14	32,03	14,97	4,90
912_37	38	31	0,0013	LEFT	214	18,87	28,46	24,38	1,32	6,69	5,06	2,30	2,18	10,90	5,01	3,73	2,75	62,49	22,71	8,94	2,70	57,17	21,15	9,20
912_38	39	54	- 0,0004	RIGHT	454	15,19	36,16	30,00	1,62	8,87	5,49	3,10	2,43	10,62	4,37	4,18	3,70	35,61	9,61	7,53	4,00	38,90	9,72	8,68
912_39	40	50	0,0003	LEFT	396	14,10	32,41	28,46	2,42	11,61	4,81	4,65	2,38	10,72	4,50	3,83	4,62	34,71	7,51	9,30	4,01	31,93	7,96	8,28
912_40	41	38	- 0,0005	RIGHT	320	17,16	42,62	29,94	1,75	7,40	4,23	3,03	2,33	8,53	3,67	3,68	3,90	27,35	7,01	7,14	4,19	29,72	7,10	7,69
912_41	42	38	0,0000	LEFT	321	12,80	42,65	29,78	2,67	11,96	4,48	4,30	2,50	10,89	4,35	3,84	5,59	37,36	6,68	8,90	4,86	35,69	7,35	7,75
912_42	43	78	- 0,0006	RIGHT	632	21,97	38,04	28,97	1,26	5,33	4,24	2,04	2,13	9,55	4,47	3,40	2,87	33,65	11,72	5,08	3,10	42,58	13,73	5,50
912_43	44	47	0,0007	LEFT	399	25,62	33,57	30,03	2,09	13,75	6,57	4,17	2,32	9,04	3,89	3,65	3,96	61,12	15,42	8,51	3,58	46,73	13,07	7,99
912_44	45	12	0,0001	LEFT	83	7,97	29,84	24,17	1,84	12,02	6,53	4,73	2,07	9,50	4,60	3,71	3,13	21,53	6,89	6,23	2,93	18,72	6,38	6,41
912_45	46	19	- 0,0001	RIGHT	130	11,05	28,31	24,39	1,09	3,36	3,09	1,65	1,71	5,78	3,38	2,47	1,99	9,58	4,82	3,06	2,11	10,19	4,84	3,11
912_46	47	22	0,0002	LEFT	145	13,70	28,00	23,53	1,67	8,15	4,88	3,02	2,04	9,28	4,55	3,24	2,84	32,08	11,28	5,42	2,58	33,83	13,09	5,65
912_47	48	10	0,0002	RIGHT	70	12,75	28,22	22,60	1,21	4,38	3,61	1,85	1,54	4,97	3,23	2,32	1,68	9,56	5,68	2,70	1,50	7,03	4,69	2,32
912_48	49	76	- 0,0005	LEFT	519	11,87	28,13	24,51	2,35	11,41	4,85	4,46	2,40	10,56	4,40	4,10	4,00	39,31	9,82	7,52	3,50	37,99	10,86	6,90
912_49	50	92	- 0,0009	RIGHT	679	15,53	31,77	26,49	1,65	9,05	5,50	2,95	2,38	11,33	4,76	3,94	3,60	37,90	10,52	7,40	3,84	35,42	9,22	7,82
912_50	51	60	0,0007	LEFT	427	15,19	32,74	25,38	1,78	9,44	5,29	3,28	2,37	9,92	4,19	4,34	3,44	50,29	14,61	6,99	3,16	44,34	14,02	7,05
912_51	52	49	- 0,0006	RIGHT	382	19,29	32,32	27,74	1,58	8,40	5,33	3,05	2,31	9,08	3,94	3,51	3,36	23,89	7,12	5,39	3,52	24,67	7,00	5,97
912_52	53	23	0,0002	LEFT	180	19,11	29,56	27,35	2,06	7,36	3,57	2,89	2,59	9,14	3,54	3,75	3,93	42,90	10,92	5,35	3,59	44,00	12,25	5,35
912_53	54	27	- 0,0004	RIGHT	227	23,10	32,47	29,64	1,65	9,52	5,77	2,91	2,39	11,86	4,96	4,11	3,57	36,92	10,34	7,03	3,62	27,40	7,58	5,91
912_54	55	36	0,0003	LEFT	297	22,73	32,20	28,97	2,36	9,65	4,08	3,76	2,77	10,47	3,78	4,25	5,01	33,16	6,62	9,03	4,47	30,07	6,72	7,42
912_55	56	60	- 0,0000	RIGHT	570	24,38	46,00	33,77	1,72	8,15	4,74	3,37	2,57	10,97	4,26	4,01	4,03	34,58	8,59	7,25	4,29	34,63	8,08	7,66
912_56	57	37	0,0002	LEFT	313	25,50	32,75	29,76	2,44	11,61	4,76	4,99	2,44	12,02	4,92	3,91	4,40	28,88	6,56	7,86	3,86	24,32	6,29	6,87
912_57	58	48	- 0,0004	RIGHT	419	23,74	40,82	30,93	1,29	5,46	4,24	2,20	2,01	9,82	4,89	3,62	3,08	34,13	11,07	5,11	3,30	33,82	10,24	5,63
912_58	59	24	0,0002	LEFT	197	23,71	31,94	28,67	2,37	11,26	4,76	4,31	2,34	9,80	4,19	3,72	4,76	34,57	7,27	9,15	4,07	32,48	7,98	7,81
912_59	60	48	0,0002	RIGHT	308	9,42	33,40	22,68	1,25	8,00	6,38	3,19	1,61	8,92	5,54	3,42	2,07	23,19	11,22	5,12	2,23	26,47	11,90	5,61

Test n.11 – 2nd October 2010 – HYERES

						Speed (km/h)			a_{wx} (m/s²)				a_{wy} (m/s²)				a_{wz} (m/s²)				a_{wroll} (m/s²)			
File Name	#	sec	Main Direction	Side	Total Distance	Min	Max	Ave.	RMS	RMS Peak	Crest Factor	MTVV	RMS	RMS Peak	Crest Factor	MTVV	RMS	RMS Peak	Crest Factor	MTVV	RMS	RMS Peak	Crest Factor	MTVV
1002_01	1	51	0,0037	RIGHT	418	10,51	33,82	29,46	2,38	16,73	7,04	3,96	2,56	12,90	5,03	4,30	6,81	53,44	7,85	14,01	12,08	122,55	10,15	27,31
1002_02	2	14	-0,0010	LEFT	121	14,77	34,11	29,85	1,73	7,95	4,58	3,29	1,77	6,59	3,73	2,74	4,41	31,76	7,20	9,82	7,64	58,00	7,59	15,85
1002_03	3	20	0,0014	RIGHT	163	18,83	32,43	28,49	1,88	8,09	4,29	3,36	2,36	8,88	3,77	3,55	5,07	36,89	7,28	9,99	9,05	68,78	7,60	17,78
1002_04	4	63	-0,0048	LEFT	543	15,96	34,53	30,85	2,33	12,28	5,27	3,88	2,44	12,41	5,09	4,16	6,92	72,89	10,53	13,64	12,63	157,57	12,48	27,57
1002_05	5	48	0,0033	RIGHT	377	15,60	35,28	28,15	2,39	10,79	4,52	4,20	2,56	10,52	4,11	3,74	6,08	36,75	6,04	11,41	10,81	76,16	7,05	20,19
1002_06	6	59	-0,0048	LEFT	548	19,95	40,04	33,04	2,86	11,64	4,07	4,68	2,81	11,88	4,23	4,04	8,30	60,28	7,26	14,27	15,02	128,38	8,55	28,04
1002_07	7	68	0,0050	RIGHT	575	20,71	34,90	30,18	2,71	13,55	5,01	4,79	2,92	12,58	4,31	4,78	7,12	54,65	7,67	13,65	12,90	114,37	8,86	25,56
1002_08	8	60	-0,0049	LEFT	548	15,01	48,42	32,77	2,50	14,61	5,85	4,75	2,71	12,50	4,61	4,40	7,74	56,73	7,33	16,38	14,25	134,05	9,41	28,38
1002_09	9	89	0,0052	RIGHT	596	12,98	32,45	24,08	1,92	12,00	6,24	3,84	2,36	14,59	6,19	4,64	4,52	46,30	10,25	11,41	8,34	101,05	12,11	21,83
1002_10	10	108	-0,0069	LEFT	774	16,58	30,89	25,69	2,05	10,82	5,28	3,78	2,59	10,97	4,23	4,41	4,14	50,77	12,25	8,99	7,65	108,34	14,15	17,05
1002_11	11	65	0,0043	RIGHT	497	15,14	31,49	27,32	2,15	10,55	4,90	3,44	2,67	11,79	4,41	4,58	5,23	49,06	9,39	9,27	9,69	99,74	10,30	16,39
1002_12	12	51	-0,0042	LEFT	477	17,31	43,42	33,58	2,49	11,47	4,60	4,17	2,60	10,46	4,03	3,72	7,15	54,32	7,59	11,55	13,17	123,28	9,36	23,37
1002_13	13	52	0,0039	RIGHT	445	16,61	36,50	30,52	2,96	25,80	8,72	6,85	2,92	13,28	4,55	5,08	7,34	81,64	11,12	14,35	13,03	146,07	11,21	25,22
1002_14	14	44	-0,0038	LEFT	430	21,20	38,02	34,72	2,89	13,06	4,52	4,75	3,14	11,60	3,70	4,84	8,63	56,76	6,58	15,07	15,82	116,78	7,38	28,59
1002_15	15	80	0,0067	RIGHT	771	16,21	46,23	34,57	2,38	13,56	5,70	3,95	3,21	13,63	4,24	5,38	7,82	60,20	7,70	16,50	14,81	158,08	10,68	28,82
1002_16	16	63	-0,0044	LEFT	504	16,42	33,74	28,68	2,21	11,77	5,33	3,76	2,39	13,91	5,82	4,28	4,64	44,95	9,70	10,17	8,37	104,23	12,45	20,36
1002_17	17	63	0,0043	RIGHT	491	12,07	34,64	28,07	2,37	12,68	5,36	4,48	2,70	18,42	6,82	6,30	5,30	49,62	9,36	10,66	9,32	106,46	11,43	17,91
1002_18	18	48	-0,0036	LEFT	403	17,48	34,98	30,03	2,29	11,05	4,83	5,14	2,39	11,14	4,67	4,42	5,66	45,12	7,98	13,32	9,88	94,15	9,53	21,55
1002_19	19	41	0,0028	RIGHT	322	14,46	33,23	28,03	2,15	12,74	5,91	4,50	2,45	10,70	4,36	4,13	5,55	46,12	8,30	11,52	9,88	95,41	9,66	20,80
1002_20	20	16	-0,0011	LEFT	129	15,34	33,92	28,57	1,89	10,61	5,63	3,84	2,33	9,10	3,90	4,07	4,57	38,55	8,43	10,21	8,11	74,43	9,18	16,99

1002_21	21	41	0,0030	RIGHT	341	15,47	34,02	29,57	2,25	18,05	8,03	5,72	2,53	16,69	6,58	4,94	5,61	79,67	14,20	13,52	10,76	179,12	16,64	27,41
1002_22	22	39	-0,0030	LEFT	353	14,60	36,01	32,32	2,68	17,18	6,42	5,45	3,22	24,75	7,68	11,41	6,62	80,21	12,12	13,63	12,12	202,31	16,70	28,08
1002_23	23	29	0,0017	RIGHT	201	16,20	29,12	24,60	1,55	17,46	11,28	4,85	1,72	13,60	7,91	4,28	2,83	38,28	13,53	7,86	5,01	51,72	10,32	12,17
1002_24	24	54	-0,0033	LEFT	388	17,21	31,28	25,58	1,85	11,64	6,30	4,92	2,47	11,59	4,68	4,96	4,50	45,68	10,16	12,24	7,95	91,50	11,51	21,88
1002_25	25	19	0,0010	RIGHT	119	13,44	26,02	22,23	1,66	6,75	4,07	3,09	2,04	8,18	4,01	3,13	2,94	18,38	6,26	4,86	5,30	36,31	6,86	9,31
1002_26	26	11	-0,0007	LEFT	87	16,81	30,84	26,84	2,98	17,00	5,70	5,11	2,66	12,45	4,68	4,49	6,80	64,10	9,42	14,54	11,93	146,78	12,30	24,05

Test n.12 – 3rd October 2010 – HYERES

						Speed (km/h)			a_{wx} (m/s²)				a_{wy} (m/s²)				a_{wz} (m/s²)				a_{wroll} (m/s²)			
File Name	#	sec	Main Direction	Side	Total Distance	Min	Max	Ave.	RMS	RMS Peak	Crest Factor	MTVV	RMS	RMS Peak	Crest Factor	MTVV	RMS	RMS Peak	Crest Factor	MTVV	RMS	RMS Peak	Crest Factor	MTVV
1003_01	1	42	0,0023	RIGHT	270	14,34	29,02	22,85	1,60	8,36	5,23	3,00	1,89	7,15	3,79	3,26	3,89	27,94	7,19	8,88	6,79	51,49	7,58	14,77
1003_02	2	36	-0,0027	LEFT	309	14,52	36,58	30,69	2,11	20,63	9,76	7,08	2,05	7,99	3,90	3,10	6,67	68,78	10,31	23,92	11,52	119,62	10,38	38,21
1003_03	3	47	0,0041	RIGHT	474	14,59	45,59	36,33	2,75	11,89	4,33	4,53	2,95	12,29	4,16	5,09	11,59	73,31	6,33	24,37	19,93	124,75	6,26	37,23
1003_04	4	52	-0,0045	LEFT	513	13,86	45,46	35,42	2,33	14,41	6,18	4,44	2,60	11,23	4,32	4,51	9,69	92,86	9,58	20,46	17,69	187,18	10,58	36,39
1003_05	5	63	0,0052	RIGHT	591	14,33	40,22	33,73	2,25	12,17	5,41	4,29	2,27	9,51	4,19	3,73	7,86	65,74	8,37	14,26	13,99	86,73	6,20	23,45
1003_06	6	54	-0,0056	LEFT	634	12,67	53,62	42,45	2,48	16,01	6,45	5,09	2,69	12,60	4,69	4,32	11,32	82,47	7,28	20,46	20,93	142,61	6,81	36,26
1003_07	7	94	0,0060	RIGHT	675	14,10	31,36	25,80	2,06	11,57	5,61	4,85	2,11	11,27	5,34	4,64	5,24	82,93	15,82	13,12	9,53	165,54	17,38	22,85
1003_08	8	74	-0,0048	LEFT	547	14,21	35,75	26,38	2,07	12,95	6,26	4,35	2,37	10,69	4,51	4,71	5,88	52,07	8,85	16,28	10,08	103,14	10,23	28,57
1003_09	9	66	0,0033	RIGHT	369	12,81	24,51	20,01	0,99	5,11	5,16	1,71	1,46	7,04	4,83	2,72	2,21	19,39	8,79	5,19	4,28	29,61	6,92	9,99
1003_10	10	60	-0,0040	LEFT	458	16,60	36,31	27,29	1,46	9,41	6,46	3,75	2,02	8,84	4,37	3,30	3,58	56,03	15,64	14,34	6,29	105,09	16,71	24,49
1003_11	11	49	0,0031	RIGHT	357	16,22	30,39	25,96	1,32	6,21	4,70	2,36	1,91	7,92	4,15	3,21	3,27	30,54	9,35	6,81	6,49	67,06	10,34	12,44
1003_12	12	37	-0,0020	LEFT	224	10,42	27,89	21,46	1,25	5,87	4,68	2,88	1,69	6,53	3,86	2,88	2,39	25,08	10,50	7,86	4,40	45,63	10,37	13,63
1003_13	13	58	0,0025	RIGHT	279	13,03	21,22	17,04	0,98	4,50	4,58	1,87	1,44	7,15	4,95	2,85	1,52	13,09	8,60	3,06	2,88	27,51	9,55	5,96
1003_14	14	53	-0,0029	LEFT	335	14,16	28,46	22,55	1,30	5,44	4,20	2,16	1,82	8,33	4,59	3,22	2,54	22,90	9,00	4,67	4,66	38,35	8,23	8,08
1003_15	15	51	0,0043	RIGHT	494	13,51	50,48	34,87	2,22	12,03	5,43	4,67	2,77	12,50	4,52	4,74	7,40	86,73	11,72	14,87	13,79	139,79	10,14	27,04
1003_16	16	69	-0,0065	LEFT	738	14,65	48,21	38,57	2,09	10,73	5,13	4,00	2,76	14,22	5,15	5,08	8,61	71,75	8,33	18,37	15,92	125,39	7,88	31,85
1003_17	17	56	0,0052	RIGHT	590	19,90	46,62	37,77	1,97	8,81	4,48	4,14	2,25	9,23	4,11	3,92	7,66	68,90	8,99	16,31	14,30	128,48	8,99	29,05
1003_18	18	45	-0,0036	LEFT	413	15,93	42,27	33,02	1,78	8,92	5,01	3,34	2,05	8,29	4,05	3,48	5,24	52,51	10,02	11,56	9,80	103,56	10,57	22,46
1003_19	19	44	0,0042	RIGHT	472	20,90	43,60	38,44	1,78	7,40	4,15	3,08	1,81	8,32	4,60	3,28	7,41	36,90	4,98	12,90	13,90	77,24	5,56	23,43
1003_20	20	41	-0,0040	LEFT	456	17,48	47,81	40,04	1,92	12,22	6,36	3,90	2,04	9,30	4,56	3,75	8,04	73,03	9,08	18,82	14,72	144,99	9,85	35,01
1003_21	21	98	0,0058	RIGHT	658	16,76	34,57	24,05	1,22	8,29	6,80	3,27	1,85	8,63	4,68	3,91	2,75	102,12	37,09	11,14	5,15	140,75	27,32	17,20
1003_22	22	82	-0,0067	LEFT	759	16,81	42,71	33,19	1,71	10,04	5,89	3,21	2,26	11,03	4,88	4,09	4,93	45,28	9,18	10,82	9,26	109,20	11,79	21,24
1003_23	23	51	0,0041	RIGHT	462	14,18	40,68	32,68	1,28	8,28	6,47	2,80	1,74	8,15	4,69	3,52	4,17	27,62	6,63	10,56	8,04	57,58	7,16	18,56
1003_24	24	58	-0,0047	LEFT	537	15,35	38,27	33,23	2,27	25,19	11,08	10,21	2,73	22,91	8,40	10,14	4,61	52,29	11,35	13,30	7,97	82,18	10,32	20,84
1003_25	25	52	0,0034	RIGHT	388	13,02	31,67	26,80	1,61	7,68	4,78	2,68	2,11	9,22	4,38	3,71	4,60	37,00	8,04	8,24	8,97	82,27	9,17	17,45
1003_26	26	46	-0,0037	LEFT	418	16,02	37,03	32,54	1,89	8,00	4,22	2,91	2,47	10,74	4,35	4,13	5,48	70,11	12,80	12,04	10,08	132,49	13,15	21,20
1003_27	27	67	0,0037	RIGHT	421	14,13	27,35	22,40	1,14	4,95	4,35	1,95	1,85	7,23	3,90	3,00	2,49	19,62	7,90	4,46	5,00	42,12	8,43	8,99
1003_28	28	62	-0,0059	LEFT	663	20,70	52,48	38,33	2,25	12,54	5,57	5,38	2,67	11,07	4,15	4,07	9,75	77,49	7,95	27,24	17,16	145,07	8,45	43,19
1003_29	29	60	0,0050	RIGHT	567	14,63	39,97	33,90	2,45	10,79	4,40	4,66	2,50	10,78	4,30	3,69	8,63	67,43	7,81	15,65	15,89	157,31	9,90	30,01
1003_30	30	83	-0,0051	LEFT	578	10,49	35,53	24,95	1,41	8,60	6,09	2,51	2,25	13,88	6,18	4,52	3,43	51,97	15,15	9,09	6,20	95,92	15,47	16,99
1003_31	31	80	0,0047	RIGHT	531	13,10	31,07	23,85	1,32	5,34	4,04	2,17	1,92	8,22	4,28	3,77	3,54	27,33	7,73	7,00	7,01	50,21	7,16	13,38
1003_32	32	41	-0,0042	LEFT	478	16,12	48,21	42,13	2,09	10,38	4,96	4,34	2,27	8,90	3,93	3,71	8,85	61,35	6,93	16,93	16,18	114,33	7,07	28,53
1003_33	33	52	0,0045	RIGHT	514	16,54	42,79	35,62	2,21	10,56	4,77	4,03	2,18	11,26	5,16	3,92	8,18	64,27	7,86	15,71	14,89	127,53	8,57	28,05
1003_34	34	44	-0,0045	LEFT	519	19,94	54,60	42,37	2,08	11,05	5,31	3,74	2,42	10,81	4,46	4,09	8,81	94,86	10,77	17,01	15,99	137,64	8,61	30,67
1003_35	35	77	0,0059	RIGHT	661	15,15	54,47	30,86	1,86	8,13	4,36	3,53	2,16	8,74	4,04	3,72	5,48	32,19	5,88	11,28	10,31	76,90	7,46	19,04