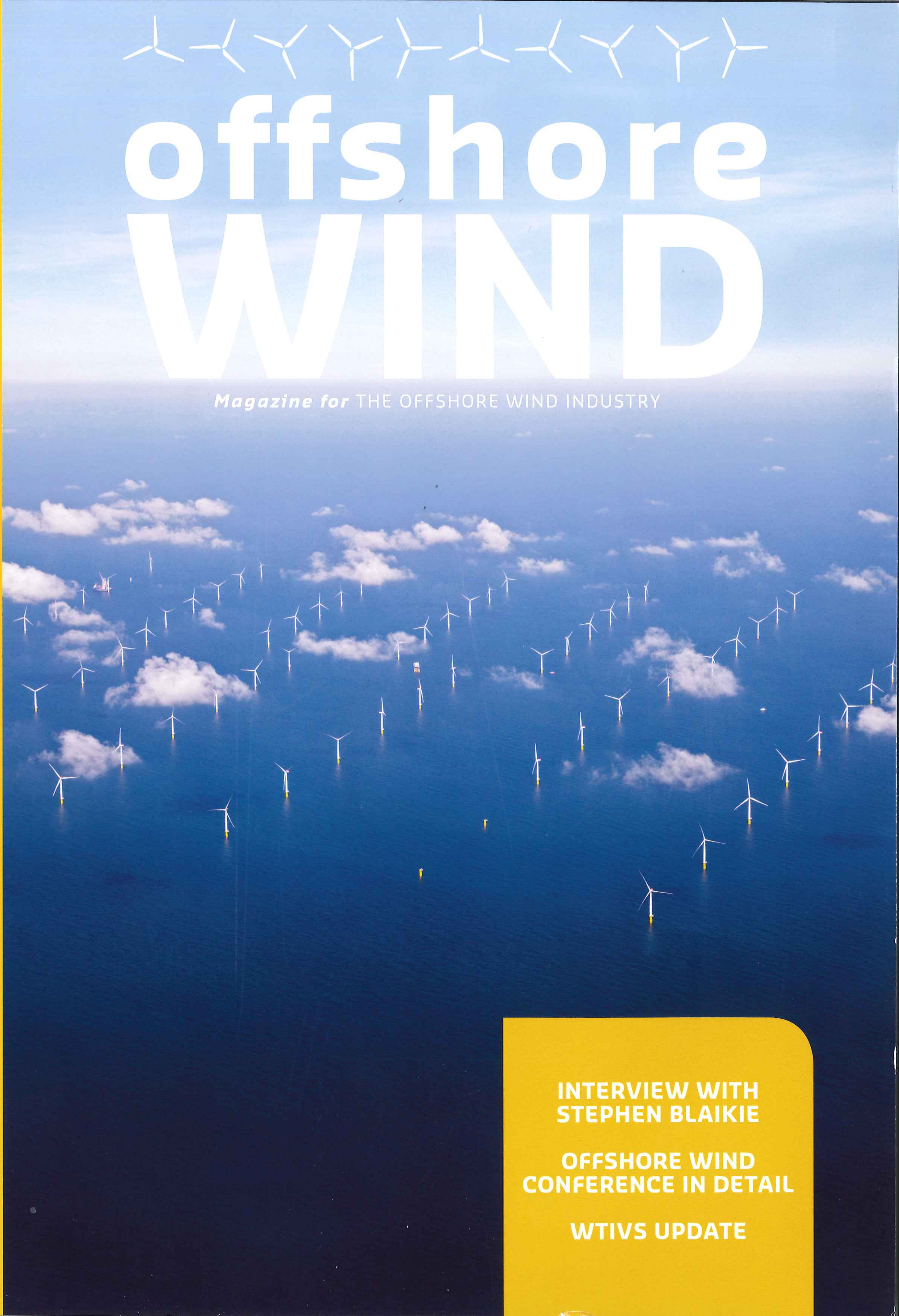
offshore WIND

Magazine for THE OFFSHORE WIND INDUSTRY



INTERVIEW WITH STEPHEN BLAIKIE

OFFSHORE WIND CONFERENCE IN DETAIL

WTIVS UPDATE

Magazine for **THE OFFSHORE WIND INDUSTRY** | VOL VII **NO 04 2016** | WWW.OFFSHOREWIND.BIZ
Price per issue € 25 Europe | € 27 Rest of the world

The test rig being placed over the quay side by the fork lift truck.

Service vessel dynamic impact study

Knowledge of impact forces is an important aspect in the design and subsequent operation of offshore wind turbines. Offshore wind turbines are typically monopile or space frame structures. In addition to their basic operational loading, these structures are designed to withstand the environmental loads experienced offshore from waves, currents and wind.

Environmental loading is typically steady and/or cyclical over periods of seconds. In addition, consideration also has to be given to the forces from service vessels used for the transfer of personnel and equipment to and from the turbine. This is normally achieved with the vessel pressing firmly onto a boat landing positioned at the water line. The transfer operation therefore leads to two additional types of loading, firstly a short period impact force as the vessel contacts the boat landing, followed by a more steady force as the vessel maintains contact in opposition to the prevailing waves, currents, and wind. In contrast to the basic environmental loading, loading as a result of impact from a service vessel can be significant and lasts for only fractions of a second. This can result in a significant peak force which must be reacted by the boat landing and structure, and in addition, this short period loading can excite multi frequency response from the turbine structure which can be damaging to both structure and installed equipment. The damage can also be cumulative as a result of frequent visits from service vessels.

Magnitude of force

Discussion has prevailed within the industry on the magnitude and form of the forces experienced by boat landings and structure, and which is complicated by the different vessel sizes and displacements, and in particular the propulsion and fender system employed on a given vessel. Typical values have been estimated by the turbine designers, vessel operators, and fender manufacturers but with little full scale quantitative assessment of these estimates.

In order to gain a better understanding of these forces an instrumented boat landing has been developed which allows direct measurement of the impact and holding force.

In order to gain a better understanding of these forces an instrumented boat landing has been developed which allows direct measurement of the impact and holding force. This has been designed and implemented by Automasjon and Data (A+D) of Sandnes in Norway in conjunction with vessel operator World Marine Offshore (WMO) of Esbjerg in Denmark.
Leaving aside the basic thrust from the vessel propulsion system, the process of identifying impact forces from basic physics is based around force = mass * acceleration. However, the mass of the vessel is made up from its physical mass, which is continually changing, plus the added or entrained water mass, a value which is generally only estimated.

VMMS

In addition, the measured longitudinal accelerations are complicated by the gravitational component of acceleration, and this changes with the rapid change of vessel attitude which can occur on impact. A+D allow for a calibrated model within their Vessel Motion Monitoring System (VMMS) in order to monitor dynamic impact during the vessels operational, and the instrumented boat landing allows for model calibration.

Extensive consideration was given to the test requirements and procedure by both A+D and WMO. The resulting test system was therefore designed to be used within the closed environment of a harbour where the environmental influences on a vessel are minimised and the measured forces will be closely related to the performance of the propulsion system, and the mass and accelerations of the vessel. It consists of two main sub systems. The first sub system is the boat landing. This conventionally consists of two vertical columns of standard diameter and separation.
For the requirements of the test system however this was simplified to a 'half' boat landing consisting of a single vertical column. This is mounted onto a triangular sub frame with load cells positioned at each corner of the triangle, with the whole assembly mounted in turn onto a rigid rectangular frame as illustrated in the photograph. The system weighs approximately 0.5 tonnes and is deployed by fork lift truck against a suitable harbour wall with height set to suit vessel configuration and tide.

This arrangement enabled the direct real time measurement of the magnitude (up to 75 tonnes) and location of the forces applied to the boat landing.
Note that the load cells had previously been independently calibrated within a dedicated calibration facility. In addition to the load cells, at the position of the red band shown in photograph B there is a hole behind which is positioned a laser to measure the distance of the bow from the landing. This was sampled at very high speed with the objective of measuring the vessel speed at the final moments prior to impact.

Vessel accelerations

The second sub system is fitted to the vessel. As a minimum, this needs to measure vessel accelerations and rotations along the three primary axes, plus some elements of the vessel propulsion system. This can be a deck mounted portable system, or simply an interface to an existing vessel performance monitoring system. For the trials described in this article, the WMO vessel was already equipped with an A+D VMMS system which had available all the necessary data plus also interfaces to the fender system.

Effectively the instrumentation gives vessel acceleration data, velocity at point of impact, together with total force of impact, with supporting engine and fender data. With the vessel accelerometer and motion data telemetered to a receiver mounted close to the instrumented boat landing, this data plus the data from load cells and laser was logged onto a computer system positioned nearby on the dockside. This data could be inspected in real time and also plots made immediately after an individual test if required.

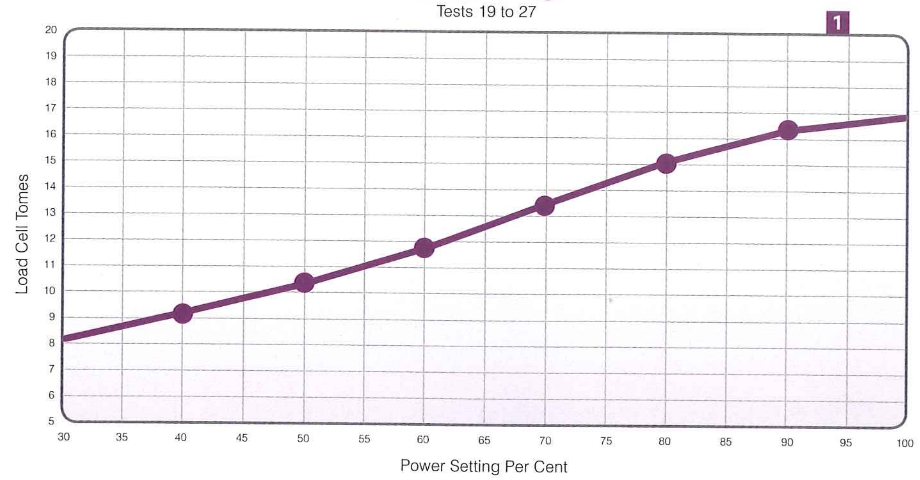

A World Marine Offshore


B The test rig

Fender settings

The trials described here were conducted in January this year in Esbjerg harbour. Overall the trials only required less than two hours to obtain all the necessary data. Conditions were calm with very little wind. The 30-metre WMO vessel used for the trials had an estimated mass of 128,000 kilogrammes. It was also equipped with an adjustable bow fender allowing the effect of fender settings to be examined. Two way radio contact was maintained between the personnel at the data logging system, and the vessel captain in order to optimise the parameters for each test. Photograph D shows the bow in contact with the instrumented boat landing.

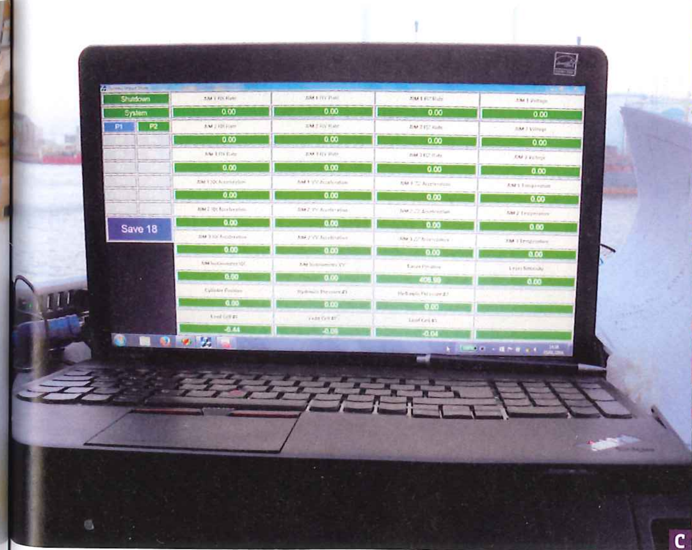
Static Loading
Tests 19 to 27



The first stage of the trials were termed 'static' trials whereby the vessel simply pressed onto the instrumented boat landing at different power settings in order to obtain the basic relationship between bollard push force and power setting. This is shown in graph 1.
Note that the vessel was equipped with a single lever control calibrated in the range 0 to 100 per cent where a power setting resulted in an idealised combination of propellor pitch and engine RPM. The tests demonstrated a maximum force of 16 tonnes.

Dynamic trials

There then followed a series of 'dynamic' trials whereby the vessel was driven into the instrumented boat landing at increasing speeds. This phase endorsed the decision made at the system design phase to conduct the trials within a controlled harbour environment; the focus of attention by the operating crew could be maintained specifically on achieving target conditions (i.e. different approach speeds and fender settings with impacts near normal to the quayside) without having to compensate for external environmental conditions.
An example of a quite complex impact trial is shown in graph 2; this was conducted at a high power setting with the bow fender set to a relatively high stiffness. The blue trace is the measured longitudinal acceleration after the component of gravity due to vessel trim has been removed. Note that the vessel trim can and does change throughout the cycle from initial impact to final settled contact. The dashed line is the corresponding velocity. At time zero, the vessel is accelerating towards the instrumented boat landing with an initial velocity of approximately 1m/s.
The point of impact is clearly seen with a sharp change in the acceleration profile from acceleration to rapid deceleration with the velocity reducing rapidly from the value at impact to zero. The corresponding force measured on the load cells (red trace) also peaks to approximately 25 tonnes, but is of very short duration, in the order of 1/10 of seconds, decaying quickly afterwards.



C


Vessel fender in test rig D

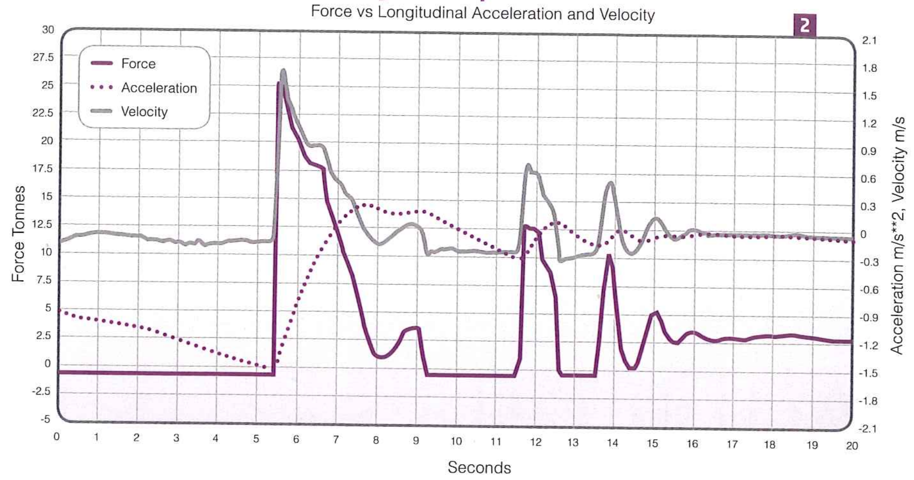
However, note that at seven seconds the velocity of the vessel is near zero at which point the fender system is compressed sufficiently to react the combination of vessel momentum and propulsive force, after which the vessel rebounds as indicated by the change of sign on the velocity and then becomes detached from the boat landing indicated by zero force only then to return a few seconds later for a second and even third impact before finally settling with a steady force of approximately four tonnes.

This is an extreme and complex example of one of the individual trials, but demonstrates the opportunity to examine a wide range of operational scenario in a controlled environment.

Graph 3 shows the consolidation from a number of individual impacts plotting the initial velocity at impact together with the resulting peak force and which demonstrates a strong correlation. The slope of the best fit straight line is 0.0705 (m/s)/tonne, with a correlation coefficient of 0.96. The intercept with the force axis is also interesting at 7.5 tonnes and which represents the typical static thrust used in making contact with the boat landing. Similar graphs were obtained for peak acceleration at impact together with peak force, and which in turn allowed an assessment of vessel added mass factor at approxiamtely 17 per cent of total mass.

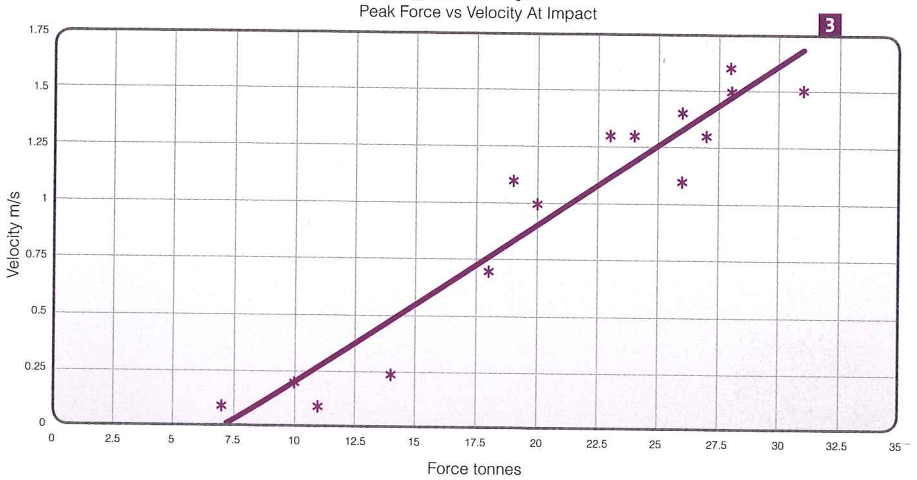
Dynamic Impact Test #34

Force vs Longitudinal Acceleration and Velocity



Dynamic Impact

Peak Force vs Velocity At Impact



No bossing around

In summary, throughout the Esbjerg trial, the equipment and instrumentation performed extremely well. The instrumented boat landing proved to be very robust, maintained position, and was not in any way 'bossed' around by the vessel. Using the fork lift approach, it proved to be easy to deploy and recover. The instrumentation performed without problems giving good results. In addition the telemetry of the vessel accelerations and motion data to the quayside data logging system operated consistently and without issue.

The trials demonstrated the very short duration of significant peak forces and which would normally be missed other than from a suitably designed measurement system capable of fast sampling. Correlation between peak impact force and peak acceleration has been established and showed linear relationship within reasonable confidence limits and allowed an estimate of the vessels added mass. Correlation between impact force and initial impact velocity also correlated well with a linear relationship.

The trials suggest that the equipment can be used successfully not only to establish the performance of individual fender systems, but also subsequently to calibrate a suitably equipped vessel for monitoring of in service impact forces with reasonable accuracy.

In summary, throughout the Esbjerg trial, the equipment and instrumentation performed extremely well.