Comparison of two shock mitigation suspension

Abstract

Keywords: Suspension, Seat, Shock, Mitigation, Spinal, g force, Drop test

1 Introduction

High speed boats are used worldwide by Navies, coastguards, in rescue operations, and for recreational activities. In recent decades increasing demand for high speed boats has led to several studies performed by different governmental agencies and research institutes to assess the effect of the shock impact to the human body (Bovenzi & Hulshof, 1999; Dobbins et al., 2008; Gollwitzer & Peterson, 1995; Hinz, Menzel, Blüthner, & Seidel, 1998; Howarth & Griffin, 1991; Lewis & Griffin, 1998; Matsumoto & Griffin, 1998; Myers et al., 2012). All studies indicate that the Vibration Does Value (VDV) experienced by the crew on-board can substantially affect their health and can cause harm to the spinal cord and lower back. Due to the constant impact during the operation of high speed craft it is necessary to use better shock mitigation seats which can reduce the shock impact to the body. In this study a new shock mitigation unit has been tested using a drop tester at the University of Canterbury. Shark Seating's 'Flexanite(R)' spring is an injection moulded product, which has an additional shock absorber in the centre of the spring. The shock can be mounted in different positions depending on the application and the length of the shock. In this study we validated the test equipment with a readily available suspension-seat which other researchers have used in similar testing. We then tested the Flexanite suspension fitted first with two stainless-steel ("dual shock") shock absorbers and secondly with a height-adjustable Fox shock. For further benchmarking, we also tested two readily available pedestal suspensions as well as a fully rigid seats. Vibration Does Value (VDV) has been calculated according to British Standard BS 6841(Howarth & Griffin, 1991) using formula $\left\{\int_0^T a^4\,(t)dt\right\}^{1/4}$ where a (t) is the frequency weighted acceleration. This formula can be implemented to determine the reduction of the shock after impact (BSI6841, 1987; Howarth & Griffin, 1991).

2 Experimental Methodology

Each suspension unit must experience the shock after some period of free fall, with impulse transients having a duration of 0.1 seconds and peak values of 40, 60, 80 or 100 ms^{-2}. After attaching the suspension to the platform, the platform was lifted up using a chain hoist with a quick release magnet. To obtain different peak decelerations, it is necessary to lift the platform to different heights. Each suspension has been tested for 4, 6, 8, 10 g with three different loads, 40, 70, 100 kg.

A schematic of the drop tester is shown in figure1. Item 1 is the pit with a height of 750 mm and diameter of 720 mm and one third of the pit is filled with a special decelerating medium. It must be noted that, traditionally sand has been used as decelerating material in the pit, however the new medium has an advantage against sand that it does not suffer compaction. In the experiments performed with sand, the sand had to be aerated after each experiment to produce consistent decelerations. Using the new medium this problem has been solved completely. However for consistent impact duration the shape of the wedge in the pit must be adjusted. The relationship between the shape of the wedge and deceleration is not linear thus for each seat and weight several tests must be performed to ascertain the required height and shape of the wedge. Item 2 is the suspension platform, it is made of steel with the thickness of 10 mm. The wedge of the platform is also constructed from 10 mm steel sheet. Item 3 is the lifting frame which is made out of steel box section 70 mm × 70 mm and a height of 3600 mm. Item 4 is the magnetic latch which can be released manually by lifting a handle. Item 5, is the chain hoist with a capacity of 3 tonnes. Item 6 is the suspension which can be attached to the platform using its original fastening bolts.

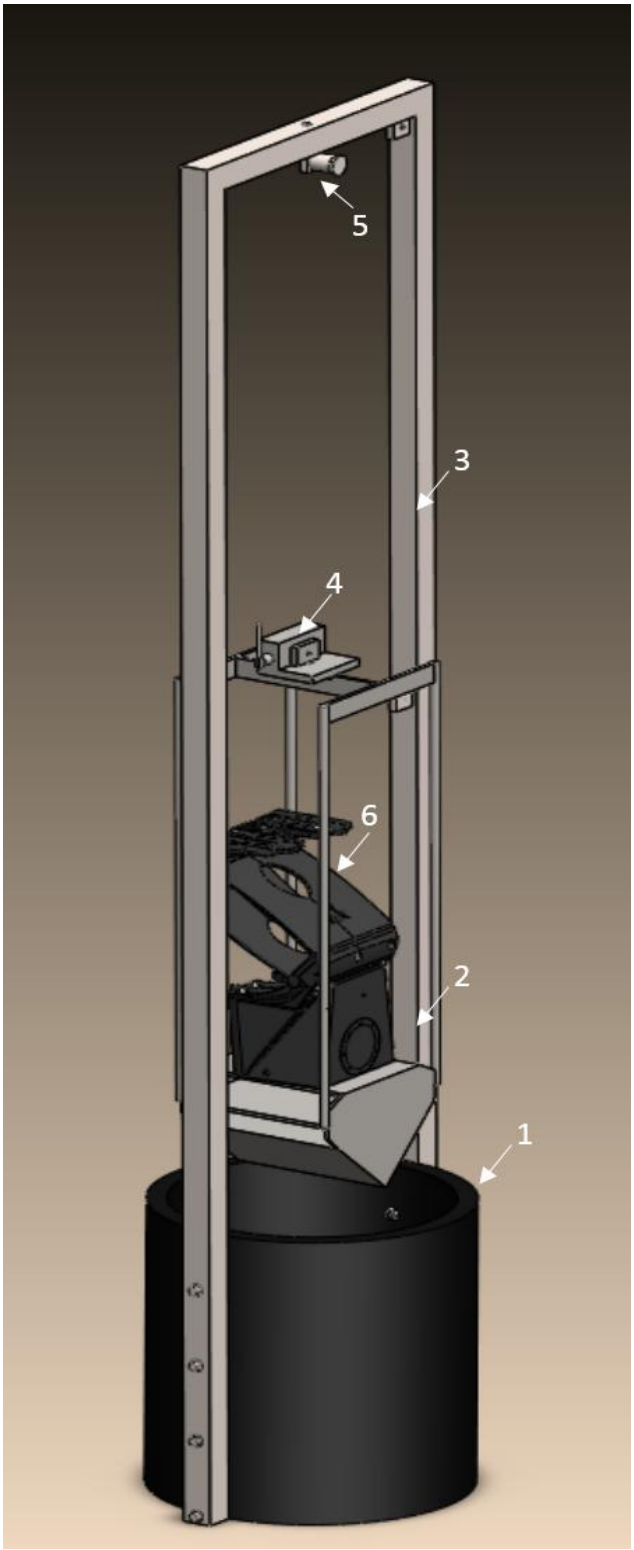


Figure 1- Testing apparatus developed at University of Canterbury in November 2013: 1-Pit, 2- Platform, 3- Lifting frame, 4-Magnetic latch, 5- Chain hoist, 6- Suspension

3 Data analysis

- Sensors position and signal processing:

Deceleration measurements were performed in two places as shown in figure 2. To measure the deceleration on the platform one triaxial accelerometer was attached to the base of the platform (green rectangular figure 2.). This accelerometer was able to measure deceleration up to 50 g. A second triaxial accelerometer with the maximum load of 6 g was mounted at the top of the suspension to ascertain the performance of the suspension (red rectangular figure 2.). The accelerometers are DC-coupled types so that they can measure static acceleration (gravity) as well as dynamic accelerations. The position of the accelerometer in different products shown figure 2.

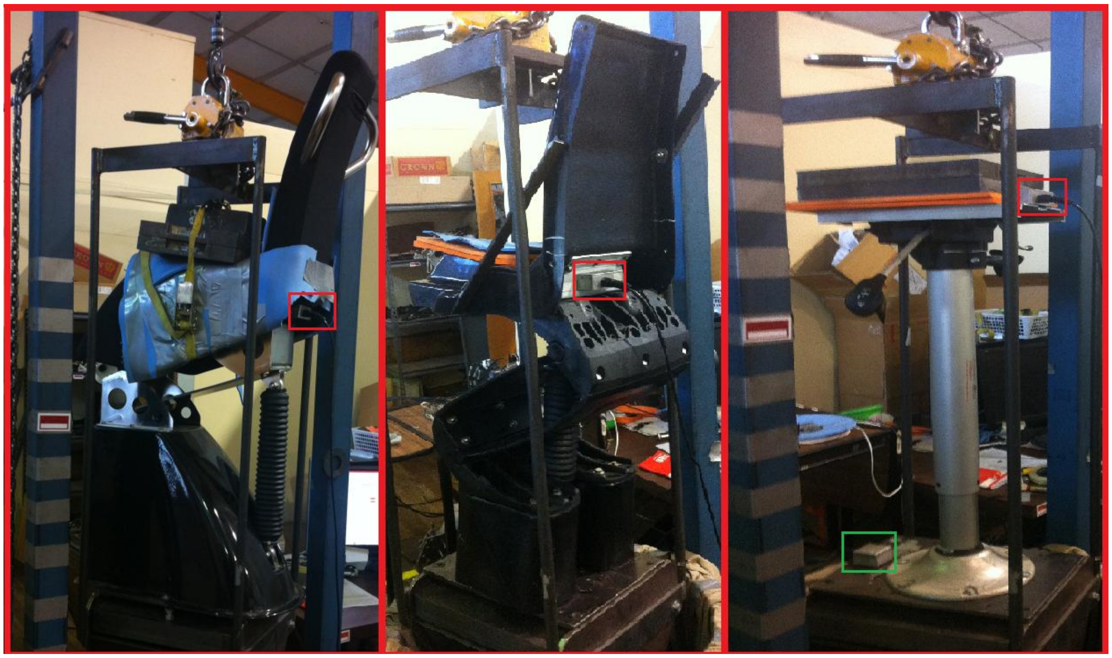


Figure 2- Position of the sensors

In order to make sure that both sensors are calibrate equally, both sensors were installed in parallel and a drop test performed. The key parameter of performance is the ratio of these two measurements, called "SEAT" ratio which is described in the next section and with both accelerometers at the same site, a ratio of 100% was measured as expected. A programme has been written in LabVIEW to read the signal through National Instrument interface modules. The sampling rate of 2000 Hz was used for all measurements. To make sure that the drop was vertical, acceleration in the X and Y axis must be practically zero. An example of the signal obtained during the test can be seen below

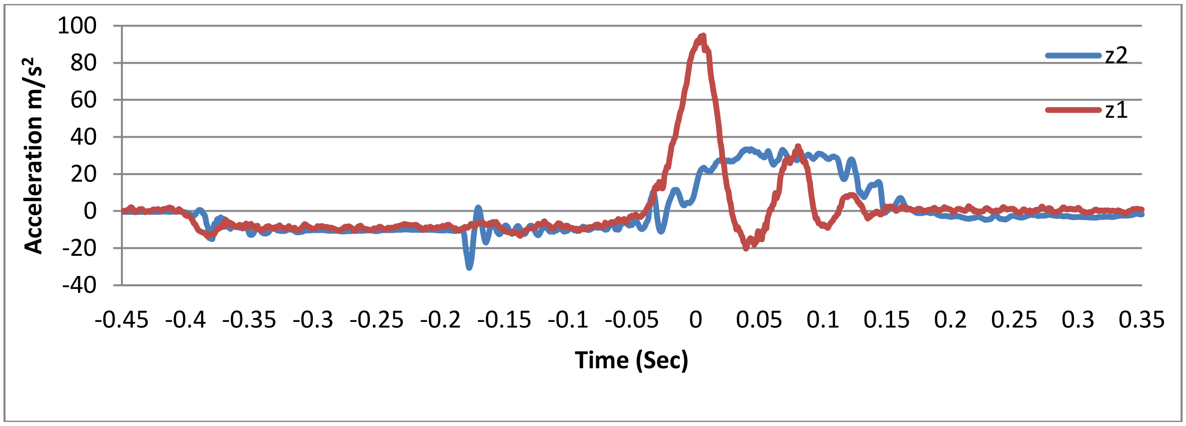


Figure 3: unprocessed Signal

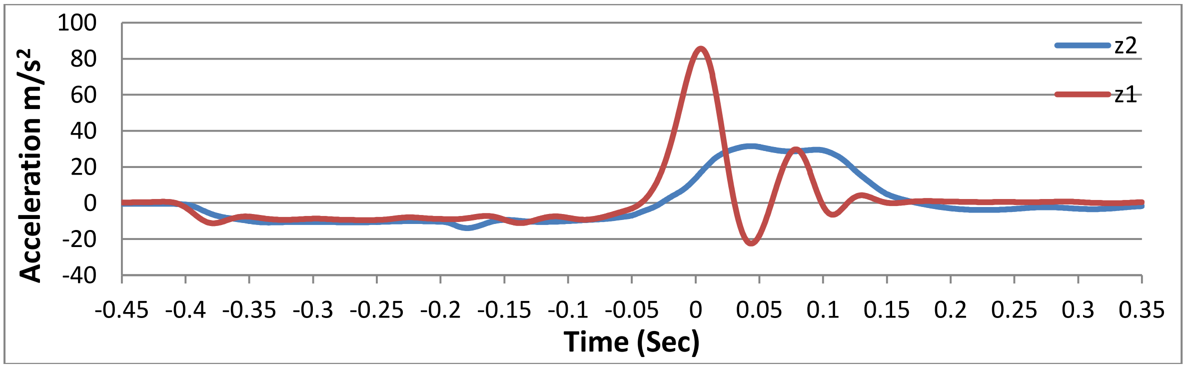


Figure 4: Processed signal

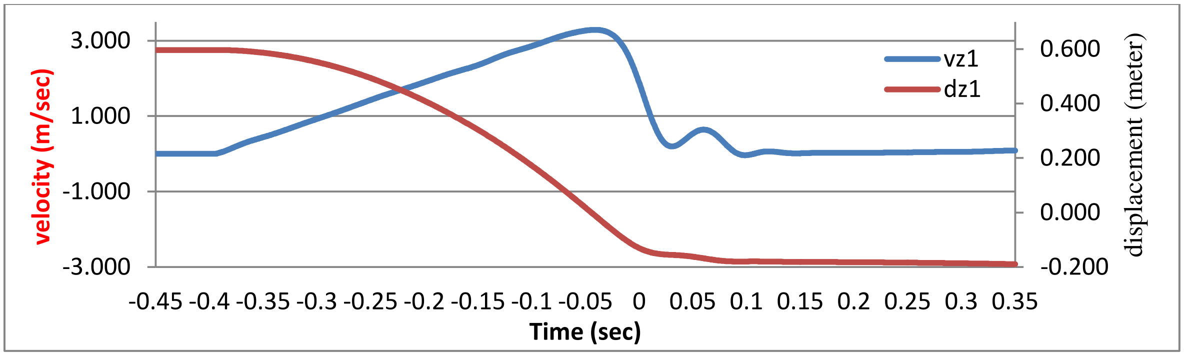


Figure 5: **Velocity and displacement**

Above we show an unprocessed graph and a processed graph as well as a graph showing velocity (ms-1) and displacement (metres) of the wedge.

Key features include; [a] release from steady state at t=-0.4, [b] relaxation of the suspension appears as a brief (0.02 second) delay between the vertical accelerations at the bottom (z1) and top (z2) of the suspension, [c] freefall before impact (-1G), [d] input peak impact (8G) and output peak impact (3G), [e] input pulse duration (0.1 second) and output pulse duration (0.2 second), [f] secondary oscillations after the initial pulse decaying to zero.

Key signal processing features include; filtering to remove noise from both accelerometers, calculation of each waveform, ratio of values (output:input and simulation:input). The "SEAT" ratio of peak values is sometimes used by other authors and in this example that ratio is 3/8 or 37.5%. However in this paper the SEAT ratio of VDV values has been used which is a much more 'conservative' measure of shock mitigation performance.

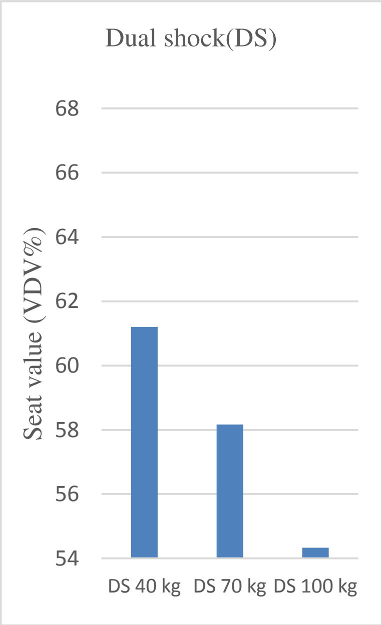
Some degree of filtering is necessary since the calculation of ("vibration dose value") raises the impact waveform to the fourth power before averaging it and taking the fourth root. This amplifies the impact of any transients or high-frequency noise which metal structures are prone to create and which accelerometers are sensitive to. Types of filtering used have included moving-average, Butterworth filtering (up to 4 pole) and also forward-and-backward Butterworth filtering (up to 4 pole). Only the last type adds no delay to the waveforms, although if all waveforms are processed using the same filter, this delay becomes equal and therefore irrelevant. The attenuation of frequencies above the cut-off frequency of the filter greatly affects the VDV value, but the SEAT ratio is largely unaffected by minor variations in the filter because the effects on input and output waveforms are very similar.

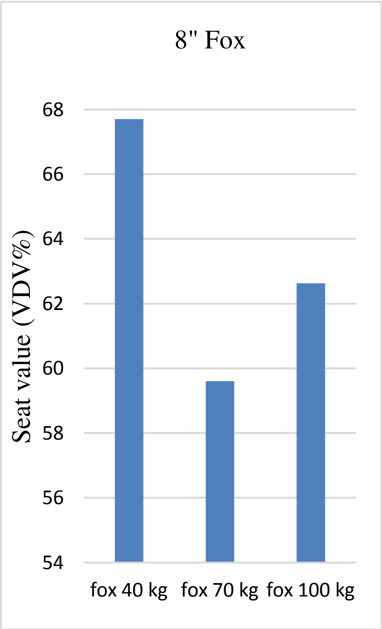
Analysis has shown that the dominant factor influencing the SEAT ratio ("Seat Effective Amplitude Transmissibility") is the width of the input pulse. This is because of the low-pass characteristic of the suspension which is less able to attenuate the lower frequencies present in wider pulses. Peak amplitude and the occupant mass also have a noticeable effect on the SEAT ratio, but it only becomes substantial when the suspension has inadequate travel so that bottoming of the suspension finally occurs.

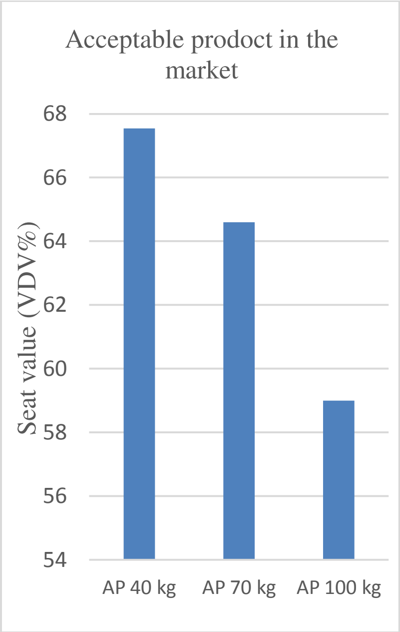
The SEAT ratio is commonly assigned an overall value by researchers in this field, by combining the results of multiple impacts with differing payloads and impact magnitudes. This information is not provided in this paper due to the lack of consensus at this point on the make-up of that moving average and the test parameters upon which it is based.

4 Results

Error! Reference source not found. shows the results of Shark suspension unit with two different shock absorbers. The left graph presents Dual Shock (DS) and the right is the 8" Fox shock. As can be seen the performance improves as the passenger weight increases from 40 kg to 100 kg. The average overall SEAT ratio (of VDV) for DS was 58% which decreased from 61% to 54% respectively with payloads reducing from 40 to 100 kg. However the Fox shock shows a different trend. The best performance of the Fox shock was at 70 kg. The overall average of SEAT ratio (of VDV) for the Fox shock was 64%. It must be noted that the SEAT ratio (of VDV) of the rigid body seat without the suspension is 100% or more and the shock can actually be magnified if the structure is not shock-absorbent. The market bench marked product has the overall SEAT ratio (of VDV) of 67, 64, 59% respective for 40, 70, 100 kg of weight. The overall SEAT ratio (of VDV) for this product was 63%.







One of the most common types of the boat seat is the pedestal shock absorber seats. Our tests on two types of pedestal suspension shows that after each impact the available travel distance decreased. For 40 kg load the unit produced its best performance with a SEAT ratio (of VDV) of 74%. The performance of pedestal units then worsened as the load was increased. By increasing the load to 100 kg the available travel of the shock sagged to zero and the unit was behaving like a rigid body with zero shock mitigation ability (100% or worse SEAT value) this observation also has been reported by different private boat owners. These results strongly suggest that in order to protect the crew on the board of high speed crafts it is necessary to use shock mitigating seats.

5 Conclusions

The dynamic response of different suspension units were compared by measuring VDV. The Shark suspension unit with the double-shock has the best performance compared with the Fox and the pedestal suspension unit. The rigid body seat had the SEAT ratio (of VDV) of 100%. The pedestal shock with 100 kg weight bottomed before the test began, thus the SEAT ratio (of VDV) was 100%. The results of this study shows that the performance of the new product with double-shock and fox are very close and even better than the standard shock mitigating seat available in the market. Also this study shows how important is the usage of the shock mitigation seats to protect the crew on the board. The results also suggest that pedestal suspensions with loads exceeding 70kg can bottom-out and amplify the impact, thus causing worse impacts to the user than rigid seats without the suspension.

6 References

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