DEVELOPMENT OF HELICOPTER SAFETY DEVICES

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Abstract

Recent investigations indicate that improvement of helicopter occupant safety can be obtained by the optimisation of energy absorbing seat properties, specifically the introduction of variable load/stroke attenuators and the reduction of overall seat stroke length. This paper reviews these devices and investigates the feasibility of forward sliding seats and airbags in the helicopter environment.

Results indicate that seat attenuators vastly reduce occupant lumbar loads in crash scenarios. Moreover, analysis has shown that the introduction of forward sliding seats coupled with seat attenuators improved occupant safety by translating crash loads to the forward axis, reducing vertical loads. Finally, the introduction of airbags was found to increase the available space for stroking devices, improving energy absorption of the safety system and acted to reduce the potential for hard contact between the occupant and instrument panel.

1 General Introduction

Crashworthiness can be defined as the capability of an aircraft to provide the occupants protection from serious injury or death in the case of accidents that are potentially survivable. Crashworthiness is a major issue for helicopter manufacturers and its subsidiaries. Statistics show that in the majority of helicopter accidents, the helicopter impacts the ground from a substantially low altitude but with a high vertical descent rate.

Modern helicopter structures are designed to absorb the impact forces and prevent the collapse of the cabin. Additionally, helicopter floor structure are generally thin, thus the overall crash energy absorption through structure is limited. The design of the seat and its attachment to the structure therefore plays a significant role in the survivability of the crew member, and the level of injury he/she sustains.

This study investigates introduction of variable stroking seat profiles, in additional to forward sliding seats and the improvements or otherwise on occupant injury.

2 Energy absorbing seat and cabin environment

The objective of energy absorbing seats is to attenuate excessive acceleration forces by sliding downwards on their supporting structure (or stroking) along vertical tracks, limiting the loads transmitted to the occupant to acceptable levels. The majority of seat energy absorption is conducted by the stroking of the seat and controlled by seat attenuators.

However, the room available to stroke is generally limited, thus in severe crash loads, the seat may bottom (reach end of stroking ability), causing detrimental injury to the occupant when this occurs. The introduction of forward stroking seat may therefore be advantageous, in that the crash energy can be transferred from the vertical axis to the forward axis (of the helicopter cabin).

The complication of forward sliding seats is that there is an increased potential of impact injuries with the surrounding environment. A helicopter pilot must be able to reach the controls easily, the implication of which is that the seat must be located in close proximity to the controls. Consequently, the introduction of forward stroking seats will increase the probability of impact with the control column and instrument panel. In horizontal crash conditions, the probability of impact is increased by an even higher magnitude. But this can be countered by the introduction of airbags, similar to that of automobiles.

2.1 Modelling

Crash test simulations are preferable to experimental testing due to the low cost, repeatability and time constraints. The software package MADYMO (MAthematical DYnamic MOdel) [1] was utilised due to its capability in simulating the dynamic behavior of physical systems and assessing injuries sustained by passengers. Seat and cabin models were developed in the MADYMO environment and used to assess injury criteria.

2.3 Model setup

The study utilised the conditions as specified by FAR/JAR requirements in FAR Part 27 [2] coupled with the 50th Hybrid III FAA dummy model. The software dummy model has been correlated experimentally and is assumed to behave as physical dummy.

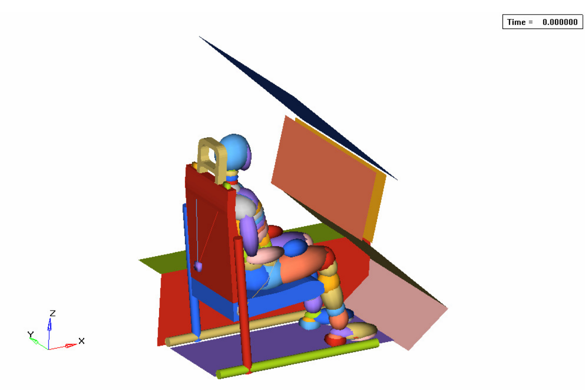

Figure 1- Helicopter cabin environment

The occupant seat was developed based on a generic helicopter crew seat [3] and exhibited real –life geometry but with rigid material properties. Experimental tests were conducted with rigid seats so the software model was correspondingly rigid to correlate to tests. The helicopter cabin was generated based on a generic model and was a generalised representation with rigid planes.

2.2 Correlation

Experimental tests [4] were conducted with a rigid seat and according to FAR Part 27 test conditions. The objective of correlation was to improve the reliability of the simulation model in regard to reality. The results are shown in Figure 2. The results show a reasonable level of correlation. The major objective of this study is to reduce the lumbar loading of the occupant. The injury to the spine is considered utmost.

The correlation indicates that the simulation over-estimated the experimental results of the lumbar loading, which is favorable as this allowed a margin of error. The thorax and head acceleration is under-estimated by the simulation. Thus, injuries in the thorax and head injuries may be greater than was predicted in the simulation model. But as the focus of this study was to reduce lumbar loads, the correlation level is acceptable. The under-estimation of injury levels to the thorax and head are noted.

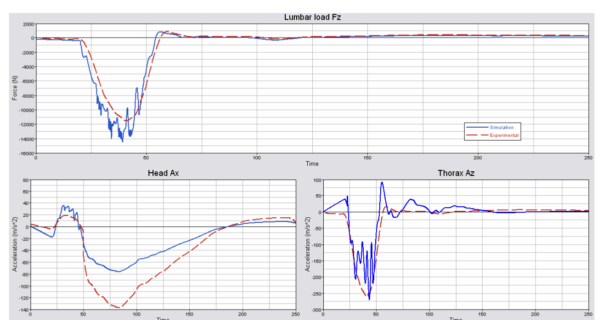

Figure 2- Correlation results

3 Effectiveness of seat attenuator

Energy absorption was introduced into the seat-system corresponding to the seat stroke and seat attenuator. The idealised stroking and attenuation was modelled by a singular translational joint allowing only vertical movement and the characteristics of the joint (representing the seat attenuator) varied. The characteristics of the seat attenuator were investigated to produce the lowest maximum lumbar loads.

At low constant load/stroke levels, it was noted that a phenomenon referred to as ‘dynamic amplification’ or ‘dynamic overshoot’ occurred. The effects were highly detrimental to the occupant survivability. Dynamic overshoot occurred as a result of the seat system responding quicker to deceleration forces than the occupant. The occupant must therefore decelerate at a faster rate than the airframe/seat/restrain systems to compensate. As a result, the occupant was exposed to higher ‘g’ loading than the airframe/seat/restraint systems and consequently higher lumbar loading. Dynamic overshoot occurred at low values of attenuator loading and was avoided by increasing the stiffness of the attenuator.

Additionally, at low load/stroke level the increase of second peak was caused by a phenomenon called bottoming. Bottoming refers to the exhaustion of available stroking distance. The effects of bottoming were severe and results in extremely high lumbar loads.

Conversely, at high load/stroke levels although high peaks of energy were absorbed, the seat did not stroke and the total amount of energy absorption was limited. The initial loads applied to the occupant due to the acceleration forces were extremely high. The high loads were transferred to the seat and absorbed by the seat attenuator. But the high loads transferred to the seat attenuator were of relatively short duration. The seat therefore did not stroke significantly enough to attenuate the forces applied to the occupant. The entire stroke length was not utilised and bottoming occurred prematurely.

The optimised attenuator properties was therefore a compromise between high and low stiffnesses. The optimised attenuator was attained and the resulting injuries curves were contrasted to the rigid seat and sliding seat in Figure 3.

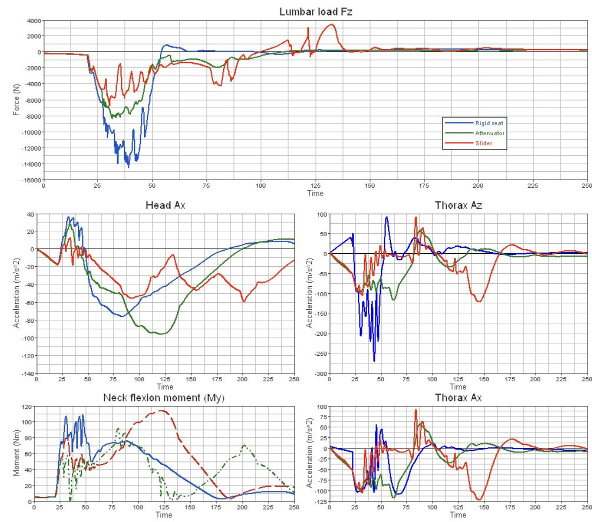

Figure 3- Contrasting optimised results

Results indicated a significant reduction (50%) in injury to the lumbar spine. The plots indicate no significant increase in injuries to the head, thorax or neck with the introduction of the optimal attenuator.

4 Effectiveness of seat displacement along helicopter axis

The seat slider was modelled in a similar method to the seat attenuator but rotated to along the helicopter axis. The translation was idealised and modelled by a singular translational joint allowing only horizontal movement. The characteristics of the seat slider were investigated to produce the lowest maximum lumbar loads. Initially, the seat attenuator was fixed at the optimal load prescribed earlier in the study.

At low load/stroke levels, the seat translated along the slider at a high rate, essentially absorbing little energy and resulted in hard contact between the occupant and the instrument panel. At low stroke levels, the occupant exhibited similar lumbar loading to that of the optimal seat attenuator. But increasing the stiffness of the slider joint reduced the lumbar loading. The crash energy was transferred from the vertical axis to the horizontal axis, thus reducing lumbar loading but increase injury to the head and thorax.

The optimal configuration was therefore a stroke profile which avoided hard contact with the instrument panel but utilized the maximum available space. The optimised slider was attained and the resulting injuries curves are contrasted to the rigid seat and attenuator seat in Figure 3.

Results indicate a 20% reduction of lumbar loading for the seat slider/attenuator coupling in contrast to the singular attenuator seat and a significant reduction of lumbar loading in contrast to the rigid seat. The head, thorax and neck moment increases at 120 ms due to slider reaching the end of its stroke. The sudden stop in seat slider and consequently energy absorption caused the injuries to increase. Overall, the reduction in injury to the occupant by the introduction of the seat attenuator was evident.

5 Effectiveness of airbags to reduce occupant injury

The helicopter cabin environment modelled in this study was a generic and idealised cabin and exhibited adequate available space below the seat and along the helicopter axis. In reality, available space in a helicopter cabin is at a premium, thus the stroking, particularly along the helicopter axis is limited.

Helicopter pilots are generally equipped with helmets but hard contact with the instrumental panel must still be avoided. Thus, the introduction of airbags may increase available space by increasing the seat slider travel and additionally couple with the chest and further absorb crash energy.

A generic airbag was modelled with the target of applying loading to the chest. The helicopter occupant (with helmet), was generally well protected, hence by applying force to the chest (higher loads can be applied to chest than to the occupant face) the bag was targeted to stop the occupant from impacting the instrument panel

The airbag was introduced into the seat attenuator/ slider model as shown in Figure 4. Results indicate an overall reduction to lumbar loadings and no hard contact with the instrument panel. The added stroking distance resulted in increased energy absorption and the deployment of the airbag reduced the potential of hard contact with instrument panel.

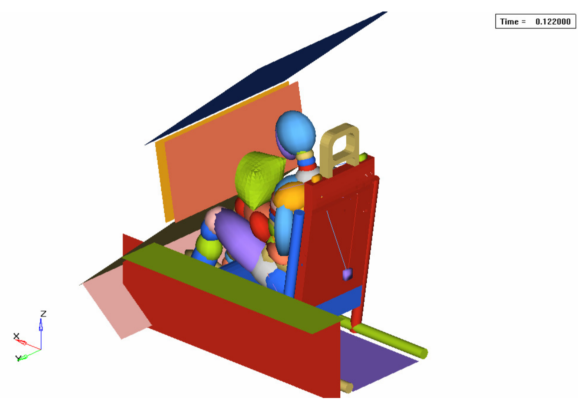

Figure 4- Airbag in helicopter environment

6 Future development

The findings and recommendations of this investigation are based on current research and the findings of an analysis conducted by computer simulations in MADYMO. The analysis is a basic representation of cabin safety systems and is idealised. The idealisation of the models is validated to a degree by experimental data. The level of validation is sufficient for preliminary parametric and optimisation studies. The reader must note that the investigation is a preliminary study and the limitations of findings and recommendations. Ideally, the findings would now be verified and finalised by experimental data.

7 Conclusion

The study has shown that seat attenuators vastly reduce occupant lumbar loads in crash scenarios. Moreover, the study has shown that the introduction of forward sliding seats coupled with seat attenuators improved occupant safety by translating crash loads to the forward axis, reducing vertical loads. Finally, the introduction of airbags was found to increase the available space for stroking devices, improving energy absorption of the safety system and acted to reduce the potential for hard contact between the occupant and instrument panel.

References

[1] TNO MADYMO BV, MADYMO V 6.2 Theory Manual, TNO Automotive, The Netherlands, 2004

[2] FAR Part 27, Code of Federal Regulations Title 14 – Part 27 Airworthiness Standards: Normal Category Rotorcraft, Office of the Federal Register, Washington DC, 19 February 1996.

[3] Staines, Richard, Crashworthy seats, Martin Baker Aircraft Company, United Kingdom, 2004

[4] P.Astori, Numerical Optimisation of a Seat Energy Absorber, Delft University of Technology, March 2003.

[5] JSSG-2010-7, Crew Systems Crash Protection Handbook, U.S. Department of Defence, Joint Service Specification Guide JSSG-2010-7, 30 October 1998.