Advanced Landing Gears for Improved Impact Absorption

G. Mikułowski
Smart-Tech Centre, Institute of Fundamental Technological Research, Warsaw, Poland
R. LeLetty
Cedrat Technologies, Grenoble, France

Abstract:
The presented project ADLAND (AST3-CT-2004-502793) dealt with evaluating the options for adaptive shock absorbers to be applied in aircraft landing gears. Analytical design procedures were developed to simulate different potential design options and a best practice solution determined. The different hardware components regarding adaptive shock absorbers were then developed and tested with regard to adaptive landing gear model. The objectives of the project were: to develop a concept of adaptive shock-absorbers, to develop new numerical tools for design of adaptive absorbers and for simulation of the adaptive structural response to an impact scenario, to develop technology for actively controlled shock-absorbers applicable in landing gears, to design, produce and perform repetitive impact tests of the adaptive landing gear model with high impact energy dissipation effect, to design, produce and test in flight the chosen full-scale model of the adaptive landing gear.

Keywords: adaptive impact absorption, piezo-actuators, magnetorheological.

Introduction

Adaptive impact absorption (AIA) is a modern control problem being solved presently for several transportation and industry branches [1-4]. The objective of the impact absorption process is dissipation of impact energy with simultaneous generation of the minimal deceleration on the protected structure. However, in many applications the exploitative impacts, which the absorbers are exposed to, exhibit a broad variety in the domain of their energies. The passive devices that are currently in usage, do not offer a proper behaviour for various impact conditions, what effects in needless overloading of the protected structures. A possible solution for minimisation of the deceleration level is using of adaptive shock absorbers that would enable adjusting theirs damping force characteristics to the actually recognised impact energy.

An an example of application, which is exhibited during regular operation to repetitive impact loadings, are aircrafts in touchdown. The problem of impact energy in this case of application is uniquely difficult as landing gears must operate properly in a wide range of conditions that may occur during landing. Civil aircraft may be endangered by a variety of weather conditions which may enforce a hard landing. Situations when the vertical landing speed at the moment of impact is higher than 1.5 m/s is undesirable, and exceeding the sink speed level of 3 m/s may cause serious increase of the relative fatigue of the aeroplane's structures. Application of adaptive landing gear (ALG) may improve the impact absorption capabilities of the existing landing gears and, therefore, to reduce the threat of damage of the fleet and to prolong the service life of the air vehicles. The economical aspect plays here a significant role since the air transport rises continuously its share in public transport during the recent years.

Except the foreseen benefits in civil aviation, the adaptive landing gears may play a key role in the case of landing systems for helicopters in the coastguards' services. The air vehicles being used in the rescue actions usually must operate in heavy weather conditions. Despite the difficult circumstances, it sometimes happens that pilots must land on a deck of a threatened ship or mining platform. Having in mind that usually such an operation must be realised in presence of a strong wind, the landing is extremely hazardous for the aircraft's and ship's crews. In these circumstances, the adaptive landing gears would play very important role as, device that improve significantly safety of landings of the air vehicles and lower the risk of accidents.

This paper is devoted to presentation of adaptive impact absorbers applied as aircraft landing gears. The presented work discusses a possibility of utilisation of active dampers based on piezo-actuators and magnetorheological fluids (MRF) as the actuator for the proposed system. Control issues of an impact absorption system are widely presented.

Requirements for the system

The control system for the adaptation of a landing gear is a challenging task to design. The designer must take into account a series of aspects that cannot be neglected, which are a result of the specificity of aircraft ground operations. The control system design must consider the following three important problems.

The first problem is related to the duration of the phenomenon. In general, the landing impact lasts between 50 and 200 ms, depending on the size of the landing gear and the landing conditions. This short time period makes it difficult to implement control strategies effectively as present actuators are not able to respond fast enough. The proposed actuating systems collaborating with the designed hardware controllers are able to execute one control loop with approximately 4 ms delay [4].

The second problem to be considered for the design of the active landing gear is calculation of the exact position of the aircraft during landing in relation to the runway. The position is important since the impact energy dissipation process must be significantly different, depending on whether the plane lands on one or both main landing gears. One method of conducting these measurements is to integrate the ultrasonic height sensors with sink speed sensors on each landing gear (Figure 4). This would enable monitoring of the 6 DoF position of the aeroplane so that the landing gears could adapt more effectively to the coming impact.

The third problem that must be considered in the design of active landing gears is the spring-back forces that occur during touchdown. Spring-back forces come from the acceleration of the wheels after contact with the runway surface and significantly influence the friction forces appearing on the seals of the strut. The influence of friction damping is very difficult to predict since it varies with each landing and is dependent on the horizontal speed of the aeroplane, the sink speed of the aeroplane, runway adhesion, temperature and the exact 6 DoF position of the aeroplane.

Piezo actuated system

A piezo valve based on a Parallel Prestressed Actuator (PPA) from CEDRAT TECHNOLOGIES has been designed and manufactured. It has been included in the shock absorber (Figure 1). The fitting of the piezoelectric valve in the shock absorber requires a careful metrology.

Figure 1 : View of the shock absorber including the piezoelectric valve.

MRF actuated system

A second technology was investigated in parallel. A magnetic circuit (Figure 2) was designed and manufactured with the aim to efficiently control the viscosity of the Magneto-Rheologic Fluid. The magnetic circuit was designed with the FLUX® software from CEDRAT.

Figure 2 : View of the magnetic head for the MRF based shock absorber.

Control system configuration

The feedback control system was designed in order to execute the sequence of tasks presented in Figure 3. These were: recognition of the impact energy on the basis of the initial velocity and mass of the falling structure (velocity sensor), determination of the optimal acceleration value for the adaptive impact absorber and execution of the control signal in the closed loop during the process (acceleration sensor feedback). The objective of the feedback control loop was to regulate the damping of the actuator in order to maintain the optimal acceleration level with reference to the identified impact energy and the stroke of the adaptive absorber. The feedback signal was acceleration of the structure. The designed and realised controller was implemented on an FPGA platform, which executed the on-off controller. Execution of the feedback loop was accelerated via introduction of an additional current control loop. This monitored the actual control current level and regulated it in order to shorten the response delay of the system. This current control loop reduced the current generation time to 500 *I s* (for 1 A level).

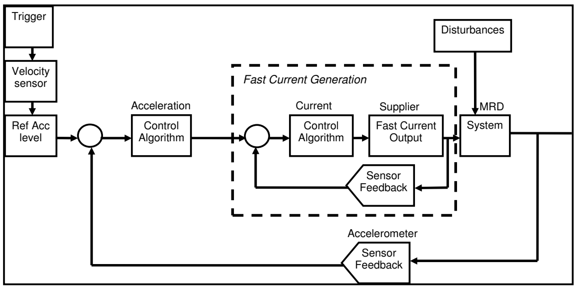

Figure 3 : Feedback control system based on acceleration signal

Figure 4 : View of the ultrasonic speed sensor.

Results of laboratory tests

The Adaptive Landing gear was first assembled and tested on the Institute of Aviation test bench (Figure 5), which allow simulating the real conditions, including the horizontal speed of the airplane.

The two technologies have been tested and compared (Figure 6 - Figure 7). It was shown that the piezo based adaptive landing gear gave good results: it was possible to obtain the same flat shock response for different sinking speeds (Figure 7).

Figure 5 : View of the landing gear on the Institute of Aviation test bench.

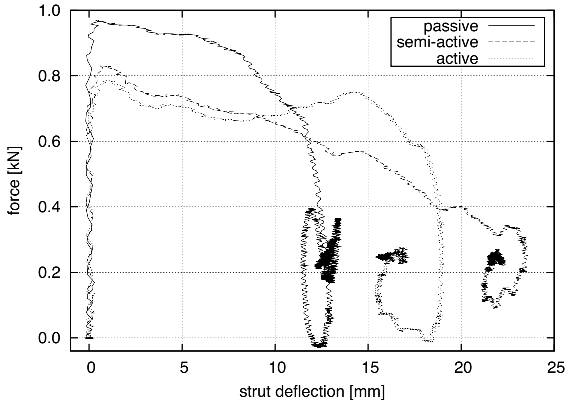

Figure 6 : Experimental force-displacement characteristics of the MRF actuated model of ALG measured in laboratory

The piezo based adaptive landing gear system was therefore selected for a flight experimental test. For that purpose, a Skytruck airplane from PZL Mielec was equipped with the experimental shock absorber, instrumented with several sensors with the aim to compare the behaviour of the passive and the active landing gear (Figure 8).

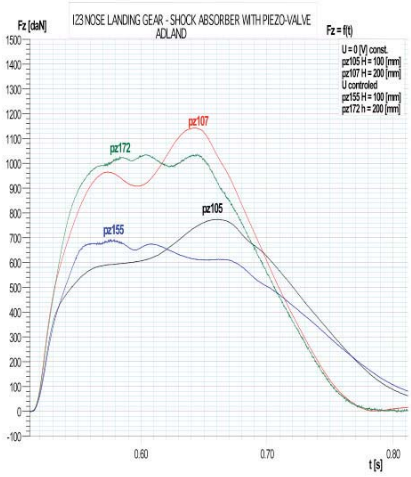

Figure 7: Experimental force-time characteristics of the piezo-actuated ALG measured in laboratory.

Results of flight tests

The flights test were organised in Mielec during the 2006 summer period. Institute of Aviation and Smart Tech centre took part to this experimental campaign.

Figure 8 : View of the PZL aircraft equipped with the adaptative landing gear.

Conclusions

Two technologies (piezoelectric and magneto rheological fluid) for adaptive landing gear have been investigated. The piezoelectric technology has given very promising results and a flight experimental test has successfully conducted. Thanks to its fast reaction, the piezo actuated valve can smooth the shock force and adapt the stiffness of the shock absorber depending on several landing conditions.

The technology is considered mature for further developments and some bigger piezo valves have been considered for larger aircrafts.

Acknowledgement

A part of this work has been performed into the frame of the FP6-STREP n°502793 'ADLAND – Adaptive Landing Gear for Improved Impact Absorption'. The European Commission is acknowledged for its support. Institute of Aviation in Warsaw is kindly acknowledged for the laboratory tests results.

References

[1] J. Holnicki-Szulc and L. Knap. Crash-worthiness of dynamically adaptive structures. In J. Rodellar, A. H. Barbat, and F. Casciati, editors, *Advances in structural control*. CIMNE, Barcelona, 1999.

[2] J. Holnicki-Szulc, P. Pawłowski, and M. Wikło. High-performance impact absorbing materials - the concept, design tools and applications. *Smart Materials and Structures*, 12:461-467, 2003.

[3] J. Holnicki-Szulc, editor. *Smart Technologies for Safety Engineering*. Wiley, 2008. in press.

[4] G. Mikułowski and J. Holnicki-Szulc. Adaptive landing gear concept - feedback control validation. *Smart Materials and Structures*, 16:2146-2158, 2007.