INVESTIGATIONS ON SHOCK-ABSORBERS FOR SMALL AIRDROP SYSTEMS

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1. Introduction

The problem of efficient and robust impact mitigation is still an attractive field of research and industrial development. Numerous examples of shock-absorbers can be found, e.g. landing gears, suspensions of vehicles, bumpers of trains or cars, road barriers, etc. A passive solution is still the most appropriate for some applications from the economic point of view and the requirement of high system reliability. Nevertheless, a current significant progress in the field of sensors and smart materials allows to design more effective semi-active and active devices. Practical implementation of smart absorbers is becoming more and more common. The paper is aimed at discussion of various impact absorption techniques developed within a research project "Innovative systems for safe airdrop DROPs". The work is based on a number of innovative devices elaborated in order to ensure extremely high performance of impact mitigation during touchdown of small cargo dropped from the aircraft.

2. In search of shock-absorber for small airdrop system

The comparison of shock-absorbers based on completely different operation principles can be very difficult and some measureable quality indices have to be defined, e.g. specific energy being the ratio of dissipated energy to the absorber mass [1]. Objective evaluation of the best solution for implementation in the small airdrop system, first requires optimization of the considered absorbers. Mathematical formulation of the corresponding optimal impact mitigation problem takes the form:

$$\begin{cases} \max\limits_{\mathbf{u}(t)}(F_{abs}(t) - F_{ext}(t)) = \min \\ \int_d \mathbf{F_{abs}} d\mathbf{s} = E_{init} + \int_d \mathbf{F_{ext}} d\mathbf{s} \end{cases} \quad (1)$$

where $\mathbf{u}$ is the control vector (control variables depends on the device type), $\mathbf{F_{abs}}$ is the absorber reaction force, $\mathbf{F_{ext}}$ is the external force acting on the excited system, d is the absorber stroke and E_{init} is the initial kinetic energy of the object amortized by the shock-absorber.

Within conducted research various adaptation strategies have been elaborated and two different types of systems have been distinguished:

- adaptable absorbers, which are automatically adjusted to predicted loading conditions at the beginning of impact absorption and they are not controlled during remaining part of the process, e.g. Safe-Pack [2], pneumatic absorber Soft-Drop [3],
- adaptive absorbers, which requires on-line control but instead they are capable of re-adaptation during entire impact absorption process, e.g. pneumatic absorber with piezo-electric valve [4], hydraulic absorber with magneto-rheological fluid [5] or smart inertial shock-absorber [6].

Developed and analysed systems are shown in Fig. 1. One of the considered concepts is the Safe-Pack device equipped with a number of gears driven by racks during cargo touchdown. Decentralization of the damping forces and lengthening the displacement on which energy is dissipated increases the energy dissipation capabilities of the system. Similar concept of linear move conversion into rotation was applied in the so-called

Spin-Man shock-absorber. Nevertheless, in contrast to the first device in which the desired inertia of rotating parts should be minimal, the inertia of the Spin-Man's components should be relatively high. The device can be easily adapted by the control of energy conversion from translation to rotation and activation or deactivation of damping interface between rotating components of the absorber. Unfortunately, technological issues cause that the device is hard to be miniaturized. The promising alternative is the Soft-Drop pneumatic shock-absorber, which ensures efficient and reliable impact absorption by single reconfiguration of the release valve. The concept of Soft-Drop was proved by both the numerical simulations and the experimental tests [3].

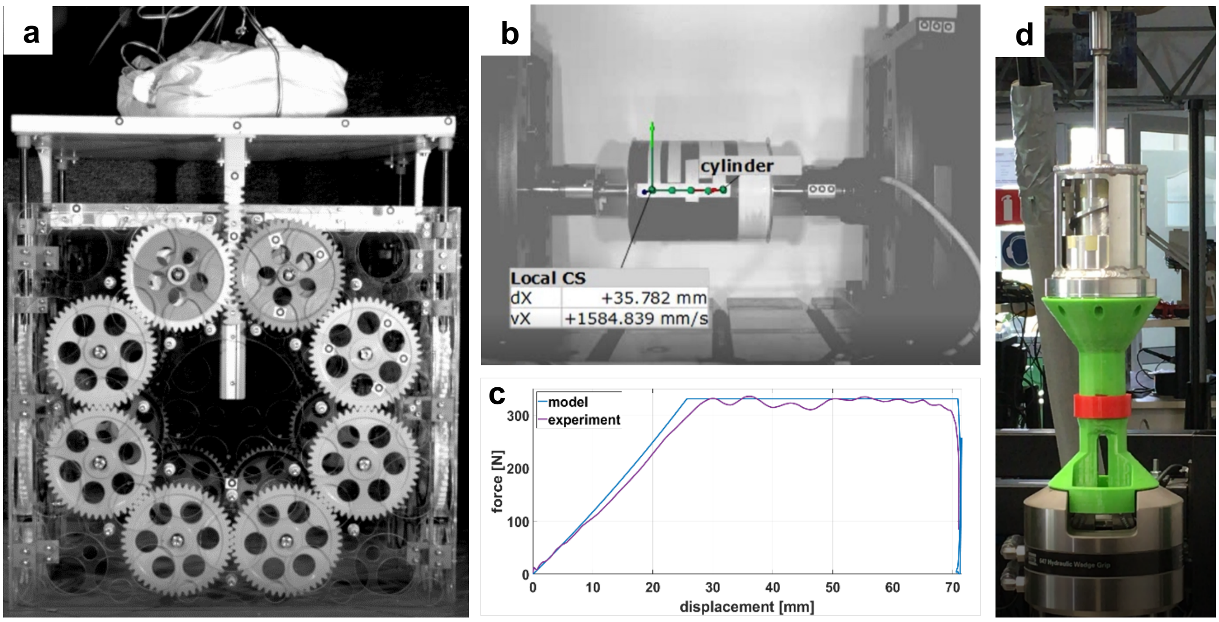

Figure 1. a) fast-camera image taken during drop test of Safe-Pack demonstrator, b) fast-camera image taken laboratory test of Soft-Drop shock-absorber, c) comparison of model and demonstrator response of the Soft-Drop system, d) demonstrator of the Spin-Man inertial shock-absorber tested at the MTS stand.

3. Conclusions

The conducted research was devoted to elaboration of efficient shock-absorbers for small airdrop systems. Simultaneously, control methods and adaptation techniques were developed in order to ensure optimal impact absorption in case of different excitations and unknown loading conditions. Numerical models were used for design of demonstrators and comparisons of experimental measurements with modelling results were conducted. The main challenges during shock-absorbers design and possible applications are indicated.

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