CAPSULES FOR SAFE AIRDROP AND EFFICIENT TOUCHDOWN MITIGATION

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1. Introduction

Novel systems for specialised airdrop operations are still elaborated and used in military, commercial, rescue and humanitarian applications. Each application implies different requirements for the system construction and its performance. Moreover, the touchdown conditions can significantly vary, and the airdrop system should be robust to possible disturbances. This paper discusses development of a new general-purpose airdrop capsule. The proposed system guarantees efficient mitigation of impact during capsule touchdown and enables efficient protection of the transported cargo.

2. The concept of adaptable absorber

According to the analysis presented in [1-2] an efficient reduction of the loading transmitted to the airdrop capsule can be obtained by using adaptable pneumatic shock-absorber. The concept is based on application of two concentric cylinders (Fig. 1a) - the upper with vent of optimized shape and the lower with narrow longitudinal slot. During touchdown the relative cylinders' motion provides compression of the gas and initial increase of reaction force, while overlapping of the slot and the vent provides proper release of gas and maintaining constant reaction force level (Fig. 1b). As a result, the obtained change of generated force enables stopping vertical motion of the capsule with minimal value of deceleration. Adaptation of the system to various loading conditions is executed with the use of specially adjusted shutters [3], which change both the compression distance and the vent shape.

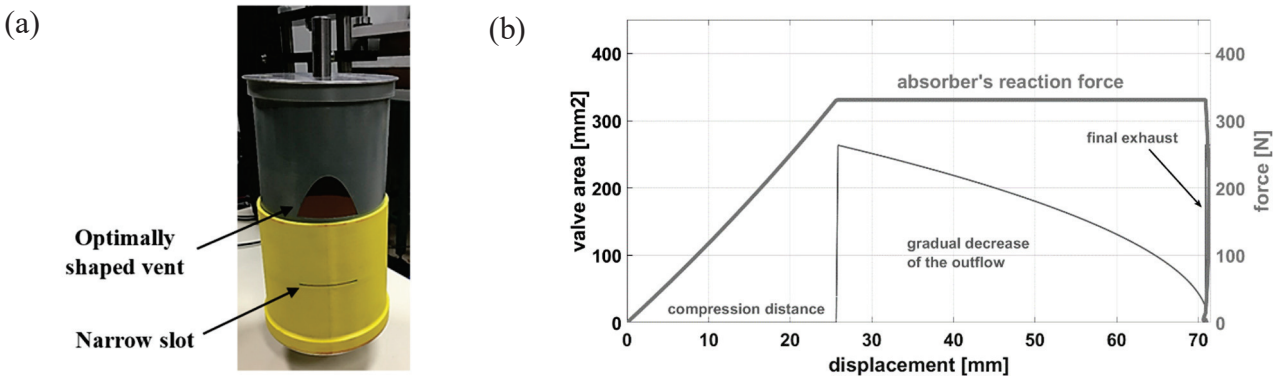


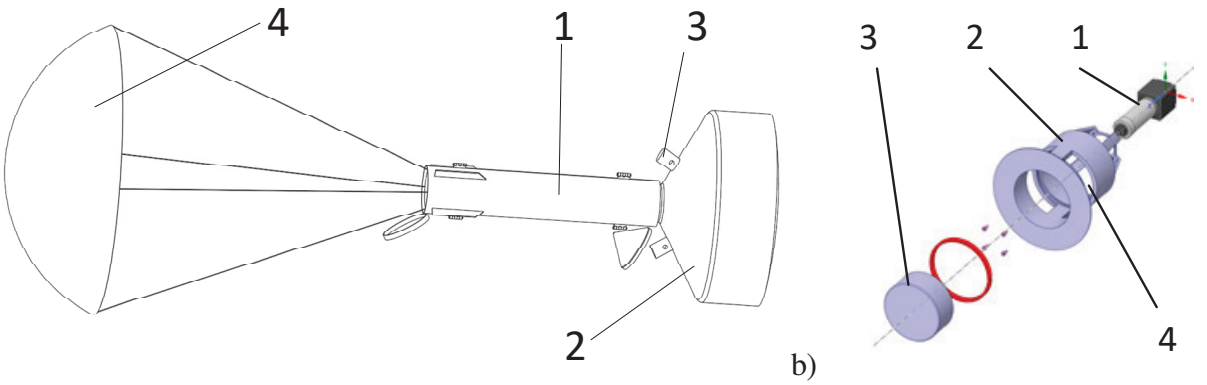
Figure 1: a) adaptable pneumatic shock-absorber, b) basic characteristics of the adaptable absorber

3. The airdrop capsule with adaptable valve

In another solution based on a similar operating principle, the airdrop capsule is equipped with a parachute, self-deployable airbag with highly elastic internal skeletal structure and adaptable valve (Fig. 2a). The airbag is deployed and inflated just before touchdown using gas from external accumulator or ambient air flowing through specially designed holes located in the envelope. The adaptable valve is used to control the outflow of air from the airbag during touchdown in a predefined manner. The valve is composed of external housing with

an optimally designed vent and a mobile piston (Fig. 2b). The motion of the piston, which is driven by pressure of internal gas, causes gradual overlapping of the vent and change of the gas outflow area. Due to appropriate shape of the vent in the valve housing, it is possible to obtain desired change of gas pressure inside the airbag and maintain constant value of total reaction force acing on the capsule.

The adaptation to various touchdown conditions can be provided by modification of valve characteristics before the touchdown process. This can be achieved by change of stiffness of the spring supporting the valve piston, adjustment of the mass of the valve piston or modification of the friction force acting between the valve piston and the housing. In an alternative solution, the supporting spring can be replaced by micro-actuator, which allows to obtain semi-active system with full control of the gas outflow and wide range of system adaptivity to different touchdown conditions.



a) b)

Figure 2: a) airdrop system composed of: capsule (1), airbag (2), adaptable valves (3) and parachute (4), b) components of the discharge valve in a version with micro-actuator: (1) micro-actuator, (2) valve housing, (3) valve piston with a sealing, (4) optimally shaped vent

The paper presents numerical analyses aimed at optimal design of the shock-absorption system for the airdrop capsule. The special attention will be paid to the adaptable valve which can be considered as a crucial component in providing efficient touchdown mitigation. The proposed mathematical model of the airdrop system will be used to determine optimal change of gas outflow from the airbag for various capsule mass and touchdown velocity. Further, the model of the adaptable valve will be applied to compute optimal shape of the vent for the assumed range of touchdown scenarios. Finally, we will present the results of system adaptation obtained by modification of valve spring stiffness, valve piston mass and piston-housing friction coefficient.

4. Conclusions

The paper discusses the innovative airdrop system equipped with airbag and discharge valve. The authors propose novel design of the shock-absorption system based on adaptable valve with optimally shaped vent and methodology of its adaptation to different touchdown scenarios. The proposed solution is expected to ensure safety of the touchdown process and efficient protection of the cargo.

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References

[1] R. Faraj, C. Graczykowski, J. Holnicki-Szulc, Adaptable pneumatic shock absorber, *J. Vib. Contr.*, 25 (3), 2018.
[2] R. Faraj, C. Graczykowski, J. Holnicki-Szulc, polish patent no. 234219, WUP 01/20 2020-01-31.
[3] R. Faraj, High performance pneumatic shock-absorbers for aeronautical applications, 31st Congress of the International Council of the Aeronautical Sciences, ICAS 2018.