Impact of a rigid sphere on a highly compressible porous layer imbibed with a Newtonian liquid

M D Pascovici*, **C S Popescu,** and **V G Marian**
Faculty of Mechanical Engineering, Department of Machine Elements and Tribology, University POLITEHNICA of Bucharest, Bucharest, Romania

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Abstract: The process of liquid flow takes place inside a highly compressible porous layer (HCPL) many times. In these cases, elastic forces of the HCPL solid phase are negligible, compared with hydrodynamic (HD) forces. Such processes were named ex-poro-HD (XPHD). A study of the impact process under XPHD conditions for circular and rectangular aligned plates was recently performed and presented by the authors. The impact of a rigid sphere on an HCPL, imbibed with a Newtonian liquid, under XPHD conditions, is analysed in the present paper. The Kozeny–Carman equation was used to compute the permeability variation as a function of compacticity/porosity. The Bowden and Tabor model for squeeze under impact was extended for XPHD conditions. The obtained model gives the impact pressure and force variations as the layer thickness decreases, so the damping capacity of the HCPL was evaluated. The maximum value of the absorbed energy, given by the optimal compacticity/porosity of the HCPL, is established. A comparison with the impact of a rigid sphere on a Newtonian liquid film under HD conditions is also done, keeping the same geometry and same kinematic and dynamic parameters, inherited from the XPHD model. The damping capacity of an HCPL is several orders of magnitude greater than that of the Newtonian liquid layer. The theoretical model was validated by two experiments, in which the HCPL is impacted by free falling ball tests.

Q1 **Keywords:**

1 INTRODUCTION

Very often, in nature as in technique, the process of liquid flow takes place near or inside extremely porous compressible layers. This structure could be represented by unwoven and woven textile materi-
Q2 als, as felt, similar materials used as wash-cloth, the endothelial surface glycocalyx that uniformly coats the mammals' microvessels and articulates cartilage. A synthesis of these studies can be found in reference [**1**]. In these processes, elastic forces of the solid phase of the porous layer are negligible in comparison to the hydrodynamic (HD) forces. These flow processes were named ex-poro-HD (XPHD) in 2001 [**2**]. Theoretical and experimental studies refer to couples in tangential and normal motion. Recently, a study of the impact process under XPHD conditions was performed [**3**] for circular and rectangular aligned plates. The impact of a rigid sphere on a highly compressible porous layer (HCPL), placed on a rigid plate, under XPHD conditions, is presented in this paper.

**Corresponding author: Faculty of Mechanical Engineering, Department of Machine Elements and Tribology, Polytechnic University of Bucharest, 313, Splaiul Independentei, 060042 Bucharest, Romania.*
email: mircea@meca.omtr.pub.ro

2 ANALYTICAL MODEL

The analysed configuration is presented in Fig. 1. The squeeze phenomenon for a similar geometry was studied in a previous paper [**4**] by maintaining a constant force during the process. The following assumptions are used for the impact process model.

1. The elastic forces of the HCPL are negligible compared with the liquid flow resistance [**2**, **5**].
2. The HCPL permeability (ϕ) variation is correlated with the porosity ε or with the compacticity (σ)