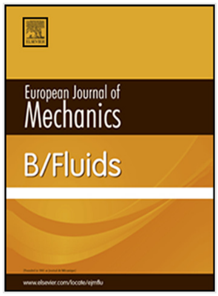

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The influence of pipeline supports stiffness onto the water hammer run

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Abstract

Water hammer (WH) phenomenon may produce various undesired effects in pipelines. Dynamic interaction between the liquid and the structure is known to influence the transient pipe flow parameters in non-rigid systems. One can expect that due to basic energy conservation considerations the energy outflow from the liquid to the elastic structure would result in lowering of WH pressures. However, this effect is not unambiguous and is not clearly and uniquely explained in literature. Thus, its proper understanding is of great practical importance.

In the paper the authors try to examine these effects mainly on the basis of experimental results acquired from measurements at a special test rig designed and constructed at the Institute of Fluid-Flow Machinery in Gdansk. The main part of the rig is a cooper pipeline of the length of about 59m, fixed to the floor with a number of elastic supports. WH runs were generated, measured and analyzed for supports of varying stiffness. Pipeline free vibrations induced by mechanical shock were measured as well. The conclusions have been found and they are presented in the paper. Still, a very important part of the job was to find the physical interpretation and explanation of the results, which allows for understanding of that phenomenon.

Keywords

Pipe transient flow - Water hammer - Fluid-structure interaction - Elastic pipe supports

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INTRODUCTION

Water hammer (WH) appears when a (steady) pipe flow conditions are disturbed by any reason, e.g. valves operation or hydraulic machinery load variation. The essence of WH phenomenon is the transfer of liquid kinetic energy to the potential energy of elasticity, which, for weakly compressible liquid may produce high pressure variations. They propagate through the pipe system as elastic waves and may induce perturbations in system functioning. For rigid or quasi-rigid structure (pipeline, supports) these behaviors are well described by the classic WH theory [1] which uses two hyperbolic partial differential equations (PDE) for modeling of the liquid pressure and velocity variations in time and space along one-dimensional pipeline. For elastic structure, which takes part in the energy transfer process the dynamic fluid-structure interaction (FSI) occurs [2]. When the longitudinal pipe motion is going to be taken into account the liquid equations has to be adequately modified. Additional two PDEs are formulated for the pipe motion which finally produces the four equations model of WH-FSI [3]. For a more precise description of the pipe motion additional ten equations are formulated for the transversal and rotational pipe vibrations to form finally the fourteen equations standard model of WH-FSI [3,4]. FSI can be considered to give an opportunity to lower the liquid pressures, just due to general energy conservation consideration. But, as pointed by scientists [5,6,7] this effect is not unambiguous and pressure increase may also happen.

Three main FSI coupling factors are pointed in the literature. The weakest is the friction between the pipe-wall and the liquid. The second is the Poisson effect that introduces coupling between the liquid pressure variation and pipe longitudinal strains. The third mechanism is the junction coupling (JC) effect that occurs at pipe bends, ends, valves, flow throttling elements and other places where strong FSI can appear. The JC effect is especially important if the pipeline has the ability to move as a whole body, which happens for elastic pipe supports. This pipe motion produces the possibility of energy outflow from the liquid to the structure, especially supports, and dissipation there. Finally this effect can result in additional pressure changes and lowering of pressure magnitudes can be expected. Other causes of energy dissipation like pipe-wall friction [8,9] or pipe material damping [10,11] will also influence the WH-FSI phenomenon.

In order to examine experimentally the influence of elastic pipe supports onto WH run a special test rig was designed and constructed at the laboratory hall of the Institute of Fluid-Flow Machinery of the Polish Academy of Sciences (IMP PAN). A series of measurements of WH runs for various pipeline supporting systems were conducted. Other auxiliary measurements were performed as well. The results were preliminary analyzed and compared with theoretical and numerical investigations. The basic conclusions on the effects produced by elastic supporting system of the pipeline have been formulated. Further analyses are still intended.