Theoretical Analysis of the Reduction of Pressure Wave Velocity by Internal Circular Tubes

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ABSTRACT

Since the maximum pressure rise during the water hammer phenomenon is directly proportional to the pressure wave velocity, the reduction of wave celerity is likely to be beneficial in controlling the transients. One of the methods of reducing pressure wave velocity is to lay flexible tubing inside the pipeline. Inserted tube lowers the effective bulk modulus of the system and lowers the pressure wave velocity. This study presents a theoretical analysis of the influence of the insertion of circular tubes into a pipeline on the rapid water hammer phenomenon. Three types of circular tubes are distinguished: a thin-walled tube, a thick-walled tube and a solid cylindrical tube – (Fig. 1)

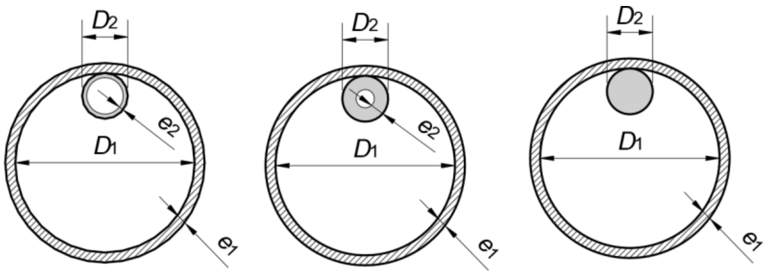

Fig. 1. Scheme of the thin-walled, thick-walled and solid cylindrical tubes inserted into the pipeline.

For each case, by applying the energy principle, a formula for the constant pressure wave velocity is derived. It allows to calculate maximum pressure increase during the rapid water hammer phenomenon using Korteweg-Joukowsky model. The differences between the derived formulas are analyzed. It is shown that the insertion of a tube with a low bulk elastic modulus may have a damping effect on the water hammer phenomenon, i.e., it reduces the pressure wave velocity and maximum pressure increase. The damping properties of the tubes are higher when the Young's modulus and wall thickness are lower. It was shown that the values calculated for thin-walled tubes are smaller than those calculated for thick-walled tubes. The formula for the pressure wave velocity in a pipeline with a thick-walled tube has a wider application because by substituting $e_2 = D_2/2$, it transforms into a formula for the velocity of pressure wave with a solid cylindrical tube.