What is the practical importance of pipe supports stiffness for fluid structure interaction effects under transient pipe flow conditions?

Adam Adamkowski, Slawomir Henclik, Waldemar Janicki, Mariusz Lewandowski,
Department of Hydropower, Institute of Fluid-Flow Machinery, Polish Academy of Sciences,
Gdansk, Poland

Long Abstract

Introduction

Water hammer (WH) phenomenon is the result of sudden change in pipe flow conditions due to operation of closing devices, hydraulic machinery load variation or other reasons [1]. When the pipe is flexible or it is fixed to the foundation with elastic supports, then the pipe motion during WH may influence the flow and the dynamic fluid-structure interaction (FSI) should be taken into account [2]. In case of elastic pipe supports and the possibility of motion of the whole pipeline an external mechanical shock may generate the WH as well. This happens due to the effect known as the junction coupling (JC) which is considered to be the strongest FSI coupling factor. So, JC appears mainly when the pipe can move on its elastic supports due to the influence of FSI in bends, elbows, flow throttling elements (e.g. constrictions), pipe close ends, etc. One can expect that elasticity of the pipe supports may produce an outflow of WH energy from the liquid to the structure thus lowering the WH pressures. However, this conclusion is not unambiguous [3] and a temporary pressure increase may also happen [4],[5]. In the paper, the authors examine and explain these effects on the basis of experimental results received at the special laboratory test rig designed and built at The Szewalski Institute of Fluid-Flow Machinery of the Polish Academy of Sciences (IFFM PAS) in Gdansk.

1. Methods

The general scheme of the long copper pipeline, being the main part of the special laboratory test rig is presented in figure 1.

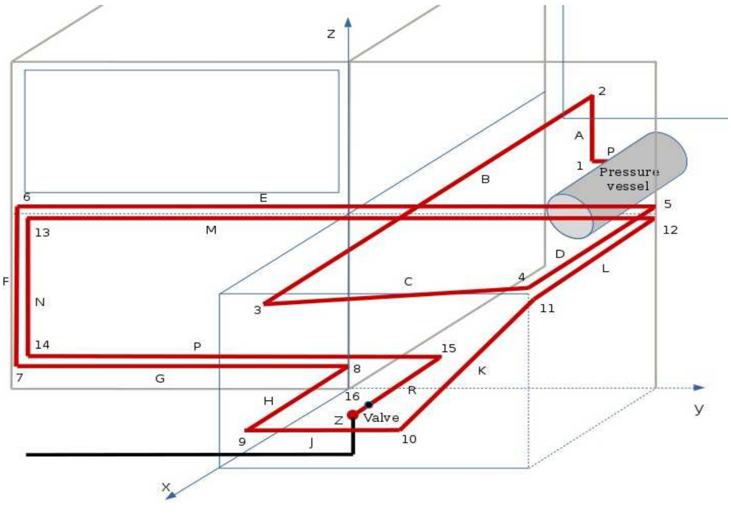

Figure 1. The scheme of the laboratory pipeline (in red)

The length of the pipeline is about *L*=60 m, its inner diameter *D*=20mm and pipe wall thickness *e*=1mm. The pipeline is consisted of several straight pipe reaches joint with elbows and fixed to the foundation with two rigid supports at both ends and 25 or 26 elastic supports (two types of configuration were used) along the pipeline. The supports were specially designed and manufactured at IFFM PAS as a kind of flat springs and their stiffness matrices were calculated for modeling of WH-FSI behaviors. Four types of supports of increasing stiffness presented in figure 2 were used.

Figure 2. The pipe fixed with various types of flat springs (from the left: FS2, FS3, FS4, FSR)

The initial steady water flow was driven by the constant pressure of the water-air vessel and adjusted by opening of the control valves. The WH was excited by sudden closure of the shut-off valve installed at the end of the pipeline. The pressures, pipe stresses and pipe displacements were recorded during the transient. Some other auxiliary quantities (pressure at the vessel, initial flow velocity, water temperature, valve closing degree) were also registered. The valve at the end of the pipe was closed with the use of a special spring drive within about 5 msec. (a series of measurements for fast, manual valve closure were also conducted). Large amount of data were recorded for various initial conditions and support configurations. Additional experiments were performed as well - the pipeline on elastic supports was excited with an external mechanical shock and the free vibrations of the system were recorded and analyzed. A water hammer wave excited in that way was also observed.

2. Results and conclusions

On the basis of measurement results and data acquired during experiments the authors describe and explain the influence of elastic pipe supports onto the run of water hammer phenomenon and dynamic fluid structure interaction. In order to find the answer to the question stated at the title of the paper the selected experimental data are presented, analyzed and concluded. The parameters of the supports were found to influence the magnitude of the pressure wave, its shape, propagation speed, column separation effects, etc. These effects are discussed in the paper. The physical explanation of the system behavior and relation between experimental results and theoretical models are also proposed.

References

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