IMPACT LOADING AND TRANSIENT RESPONSE OF PIPES TRANSPORTING GAS OR LIQUID

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2.*Mohammad R, Kotousov A, Codrington J. Analytical modelling of a pipe with flowing medium subjected to an impulse load. International Journal of Impact Engineering. 2011; 38(2–3):115–122 (see Appendix B).

3.Kotousov A, *Mohammad R. Analytical modelling of the transient dynamics of pipes with flowing medium. Journal of Physics: Conference Series. 2009; 181 012082, 8pp.

Conference Papers

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ABSTRACT

This thesis focuses on the investigation of the effect of flowing medium on the transient response of a pipe due to dynamically applied loading. The topic is very important in many industrial and military applications including offshore structures, oil and gas, power stations, petrochemical and defence industries where critical pipe components transporting a gas or liquid can be subjected to impact loading due to an accident. In many previous studies, such effects were largely ignored, simplified or considered negligible. The conducted study demonstrated that in many practically important cases, the influence of flowing medium on transient response is not small and has to be taken into consideration.

In the current work, the classical Bernoulli-Euler beam theory is adopted to describe the dynamic behaviour of an elastic pipe and a governing equation of a slender pipe transporting gas or liquid was derived. This governing equation incorporates the effects of inertia, centrifugal and Coriolis forces due to the flowing medium. This equation can be normalised to demonstrate that only two non-dimensional parameters govern the static and dynamic responses of the system incorporating a pipe and flowing medium. Therefore, these non-dimensional parameters can be utilised to investigate various dynamic phenomena using reduced size or scale physical models. Such scale models would be adequate if the values of these parameters were kept the same for the scale model and the real system. This is expected to result in substantial benefits if the experimental approach is adopted for the investigation of the problem under consideration.

The main effort in this thesis is devoted to the development of an analytical procedure utilising the perturbation method and numerical approach adopting a central finite-difference scheme to analyse the dynamic response of the system due to impulsively applied loadings. This is then followed by a validation study against previously published data as well as between both approaches, analytical and numerical. Further, a detailed investigation was carried out on the effects of the flowing medium on the transient response. It revealed two principally different types of behaviour of a pipe subjected to impulse loading: stable decay and unstable associated with so-called pipe whip.

Special attention is given to the above phenomena, pipe and flow characteristics, which cause growing unlimited displacements of the pipe regardless of how small the value of the applied loading is. Experiments were also conducted to support the theoretical results and were found to follow the theoretically predicted tendencies. The developed theoretical methods provide a framework for analysis of many other dynamic problems of pipes with flowing media subjected to arbitrary boundary and loading conditions. Lastly, the overall conclusion of the conducted research was provided and future work was identified for further investigations, which follows from the obtained results.

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GLOSSARY

Nomenclature

λ_f	density of the flow per unit length (kg/m)
λ_p	pipe density per unit length (kg/m)
V	velocity of the , gas or liquid or their mixture (m/s)
E	Young's modulus (Pa)
I	second moment of inertia of the pipe (m^4)
μ	mass per unit length (kg/m)
τ	characteristic time (s)
L	length of the pipe (m)
$\bar{F}(\bar{x},\bar{t})$	driving force per unit length (N/m)
$F(x,t)$	dimensionless (normalised) function of the position and time
$W(x)$	dimensionless (normalised) displacement
t	time (s)
γ	specific heat ratio of the gas
$\delta(x-u)$	Dirac delta function
ε and β	two parameters
Y_k	a set of normalised eigenfunctions
A_k	normalisation constants
x^*	position along the pipe
Δx	spatial grid size
Δt	temporal grid size
N_x	The upper bounds of the grid point in the spatial direction
N_t	The upper bounds of the grid point in the temporal direction
$\mathbf{A}$	global evolution matrix
$\mathbf{I}$	identity matrix
$\mathbf{R}$	applied loading