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ScienceDirect
Procedia Engineering 176 (2017) 107 – 117
Procedia Engineering
www.elsevier.com/locate/procedia

Dynamics and Vibroacoustics of Machines (DVM2016)

Analytical calculation of hydraulic characteristics of jet-cavitation fluid mass flow stabilizers

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Abstract

The paper provides analysis of devices using cavitation mass flow stabilization effect in the working process. The object of present study is the jet-cavitation fluid mass flow stabilizer of the "pipe-pipe" type. To create the method of its calculation a new hypothesis about the causes of the cavitation mass flow stabilization effect based on the preservation of the boundary layer at the cavitation has been proposed. Verified method of calculating hydraulic characteristics of the jet-cavitation fluid mass flow stabilizer is proposed. The discrepancy with the experimental procedure is not more than 4% for the mass flow of stabilization. With the help of the method the influence of structural and hydraulic parameters on the mass flow and the width of the stabilization zone were studied. The efficiency of the proposed method was compared with numerical simulations and analytical methods of calculation.

Peer-review under responsibility of the organizing committee of the international conference on Dynamics and Vibroacoustics of Machines

Keywords: hydrodrive; cavitation; fluid mass flow stabilization; mass flow stabilizer; flow valve; hydroautomatics

1. Introduction

The development of hydraulic systems due to pressure increase, weight and size reduction and rejection of the spool valve controls require fundamentally new hydro units using effects of multiphase media mechanics.

The most promising is the effect of stabilizing the fluid flow cavitation. The effect of the cavitation flow stabilization occurs during hydrodynamic cavitation in Venturi nozzles, jet elements and is characterized by a constant, independent of the differential pressure Δp, mass flow of stabilization Q_{st}, and stabilization zone width Δp_{st}. (Fig. 1).

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Peer-review under responsibility of the organizing committee of the international conference on Dynamics and Vibroacoustics of Machines
doi:10.1016/j.proeng.2017.02.278

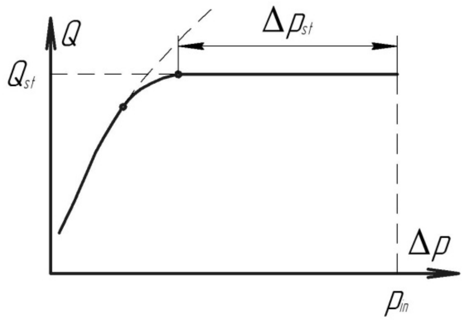

Fig. 1. P-Q characteristic of stabilizer during cavitation stabilization of fluid mass flow

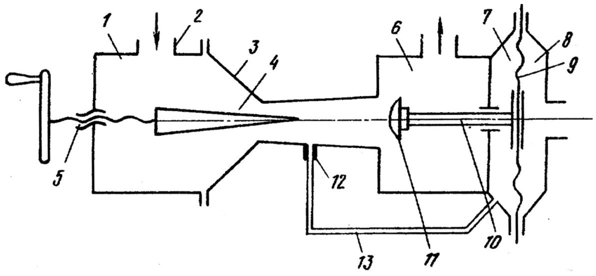

Fig. 2. Adjustable fluid mass flow stabilizer (AS SU 903816, 1980). 1 – inlet chamber; 2 – input channel; 3 – convergent nozzle; 4 – bevel needle; 5 – mechanism for moving the needle; 6 – outlet chamber; 7, 8 – cavity of pressure regulator; 9 – membrane; 10, 11 – rod with the control valve; 12, 13 – pressure feedback

The stabilization zone width Δp_{st} is determined by difference between pressure at the inlet of fluid mass flow stabilizer p_{in} and pressure drop Δp, when the effect disappears. Experimental research shows that mass flow of stabilization depends on the stabilizer's geometry and inlet pressure [10]. Mass flow of stabilization usually rises with the increase of inlet pressure and hydraulic diameter of stabilizer [13, 23]. As for the width of stabilization zone it decreases with the rise of hydraulic resistance of diffuser elements of stabilizers [14]. When the effect of stabilization of fluid mass flow occurs in the jet elements, the mass flow of stabilization is affected by the diameter of the jet pipe, the diameter of the receiving nozzle and the distance between the nozzles [4, 5, 12], and the width of the stabilization zone is affected by the aperture angle and the length of the receiving nozzle.

Using the effect of cavitation stabilization allows to create two different classes of hydro devices: flow valves and flow dividers.

Fluid mass flow stabilizers provide a constant speed of actuator motor at varying loads. They are analogous to the well-known flow valves (flow regulators). First stabilizers were created on the basis of the Venturi tubes and nozzles [10]. The main disadvantage of these stabilizers comparing with the flow valves is relation of mass flow of stabilization, supply pressure and the geometry of the element. This requires a fluid mass flow stabilizer for separately taken hydraulic system, as well as efficient methods of calculation and design. To eliminate these drawbacks complex adjustable mass flow stabilizers on the basis of the Venturi tube were created [17], enabling to set the desired mass flow of stabilization depending on the supply pressure (Fig. 2).

In 1985, Bocharov and Konovalov [18] proposed the use of a jet type element "pipe-pipe" as a fluid mass flow stabilizer [3]. Jet element "pipe-pipe", unlike the Venturi tube has a hydraulic flow gap in the jet chamber, which allows to change the stabilization mass flow by moving the nozzles. The main advantages of jet-cavitation fluid mass flow stabilizers as compared to the flow valves are small weight and size, lack of spool pairs, high precision of mass flow retention (2 – 3%), the ability to work at pressures above 300 bar.

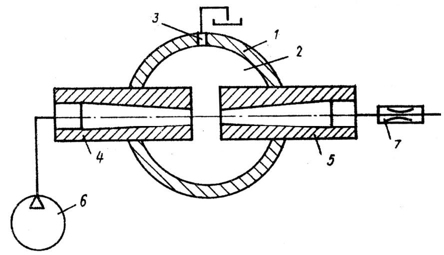

Fig. 3. The jet fluid mass flow stabilizer [18]. 1 – housing the jet chamber; 2 – jet chamber; 3 – channel of jet chamber; 4 – feed nozzle (jet pipe); 5 – receiving nozzle; 6 – pressure source; 7 – load (hydraulic motor)

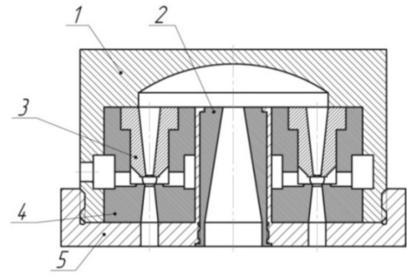

Fig. 4. Perspective jet-cavitation flow divider [22] 1 – housing; 2 – convergent nozzle; 3 – jet pipe; 4 – receiving diffuser nozzle; 5 – cover