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Paper

SYSTEM OF CHAMBERS FOR ACTIVATION OF MODULATION OR PULSATION IN WATER JETS

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ABSTRACT

The paper is aimed at the development of the function model of the system of resonating chambers for generation of modulated or even pulsing jets. These jets are to be applicable for descaling of metal sheets in rolling mills. The design of the system and some results of measurements are presented in this contribution.

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1. INTRODUCTION

Pulsing and/or modulated liquid jets are the tools boosting destruction effect of energy impact on material. As the up-to-date modulated and/or pulsing jets are developed primarily for relatively low liquid pressures and great flow rates, the width of their footprints are several times larger than the ones of the jets generated upon high pressures and low flow rates. Moreover, it was recognized that for a development of the sufficient effects of modulated and pulsing jets there is necessary to assure some minimum stand-off distance between the jet outlet from the nozzle and the impingement point at the material surface. This stand-off distance is several times longer than the effective one for the continuous jets generated from high pressures. So, the broadening of the footprints of the modulated and/or pulsing jets is caused also by the effect of divergence of jets after the nozzle outlet.

In years 1995 to 1997 I'd trying to win a project aimed at research of pulsing liquid jets gained from the system of chambers that due to resonation effects generate modulated jets. Therefore, a large retrieval work was carried out. When the project FB-C3/05 of the Ministry of Industry and Trade had been started in 2000, its investigator asked me for participation in this research as a co-investigator of the project part solved at the Mining and Geology Faculty of the VŠB - Technical University of Ostrava. The primary task was the development of a device producing either pulsing or modulated jet applicable for descaling of metal sheets in rolling mills. Based on the analyses of the up-to-date published theoretical results, my own configuration of the system of resonation chambers was designed.

2. THEORETICAL BASE

The design was subordinated to the demands of the investigator of the project mentioned above. The flow rate through the system was determined by the desired operation pressure (15 MPa ± 10MPa) and the construction of the outlet nozzle (cylindrical orifice with diameter 2 mm). The design of the system is presented in Figure 1. I had created it by a virtue of the investigator's demands and using the knowledge acquired from published works to the problem (Chahine et. al. 1983, Rockwell & Naudascher 1978, Sami & Ansari 1981, Sami & Anderson 1984, Shen & Wang 1988, Vijay 1994). The advantage of the design was the feasibility of changes in height (length) of the estimated essential resonation chamber, even during operation, and so induced changes of its volume. Expected effects were, as a matter of course, changes of the resonation frequency of the system, and so, the tunability of the modulation frequency of the water outflow - the jet. The design should offer at least the potential for further research of the behavior of the system of resonating chambers.

I had specified the following dimensions of the appropriate parts of the designed chamber (system of chambers) for the assignment mentioned above:

D_1 = 22 mm, diameter of the initial part of the system, higher part of the pipe;

L_1 = 140 mm, length (height) from the cover of the chamber marked **1** in Figure 1 to the conversion to smaller diameter;

D_2 = 18 mm, diameter of the subsequent part of the system, lower part of the pipe;

L_2 = 38 mm, length (height) of the chamber marked **2** in Figure 1;

R_1 = 3 mm, diameter of the fillet;
D_3 = 4 mm, diameter of the connecting aperture between chambers marked **2** and **4** in Figure 1;
L_3 = 3 mm, thickness of the wall between chambers marked **2** and **4** in Figure 1;
D_4 = 30 mm, diameter of the essential resonation chamber with changeable length (height);
L_4 = 0 to 50 mm, changeable length (height) of the chamber marked **4** in Figure 1;
D_5 = 2 mm, diameter of the outlet nozzle marked **5** in Figure 1;
L_5 = 20 mm (or 30 mm), length (height) of the body of the outlet nozzle marked **5** in Figure 1.

The best tuning was detected for the length (height) of the essential resonation chamber (marked **4** in Figure 1) about 1 mm (between 0.9 mm and 1.1 mm). The initial experiments showed dependence of the modulation frequency and gain on resonation upon water pressure. Simultaneously, the potential for tuning of modulation frequency by change of the height of the chamber marked **4** in Figure 1 was not confirmed. Therefore, I proposed a modification of the system of chambers as evident in Figure 2. The rigid cover closing the cylindrical part marked **1** in Figure 1 was replaced by a piston enabling change of their length (height) L_1.

3. EXPERIMENTAL RESULTS AND THEIR DISCUSSION

Selected experimental results aimed at measurement of generated frequencies are presented in the form of graphs demonstrating the count of frequencies detected in the analyzed signal. The analyzed signal is a time depending value of the electrical discharge induced in the force sensor through the piezoelectric phenomenon. The force is induced by impact of the water jet at the target plat mounted to the sensor. Frequency spectrum of the signal obtained after impingement of the jet formed by the system depicted in Figure 1 for presented dimensions and water pressure 15 MPa (L_5 = 20 mm) is shown in Figure 3.

Frequency spectrum of the signal gained after impingement of the jet produced by system presented in Figure 2 onto the force sensor target plat is displayed (for the same dimensions and water pressure) in Figure 4. Unfortunately, the spectrum in Figure 3 is obtained processing the signal gained during performance of the initial tests with the old version of the program. As the signal is unworkable in the later program release, the spectrum range is unchangeable and, therefore, a bit different (larger) from the rest of spectra processed later. Nevertheless, it is evident that the peak of the resonation frequency is almost at the same value – it implies that the resonation frequency was not affected by changes implemented modifying the system shown in the Figure 1 into the one shown in the Figure 2. Visual comparison of spectra presented in Figure 3 and Figure 4 obtained through the FFT of the time dependent record of the force of the jet (impinging the sensor) makes clear that the modification of the system did not disturbed resonation behavior of the basic dimension configuration. Therefore, shift of the resonation frequency value indicated in the frequency spectra of jets generated by the system presented in Figure 2 with either shortened or extended length (height) L_1 of the chamber marked **1** (and documented in Figure 5 and Figure 6) are caused by changes of this changing parameter.

As it is evident from the spectra of signals there was not proved that geometrical changes can influence the resonation frequency of the system substantially. Neither the water nozzle length (L_5) influenced the resonation frequency significantly as it is evident from the spectra presented in Figure 6 and Figure 7. The most important geometrical factor remains, according to the primary expectation, the length (height) L_4 of the chamber that has this parameter flexible just in the initial design. Generally, the most important factor at all seems to be the pressure of the water delivered by the pump, as it is clear from the results summarized in the graph in Figure 8.

The pressure itself, of course, is not a source of the frequency. The fluctuations caused in the pressure by the cyclic loading through the pump are the source of the frequency fluctuations. The significant frequencies are introduced into the water flow through the piston frequencies derived from the motor revolutions. Those are lower for lower pressures and hence the frequencies in the water flow are lower too. The frequency induced into the water flow by alternating motion of pistons increases with increasing water pressure. It is evident that except the tuning of the chamber 4 the resulting frequency of chambers is influenced significantly by the pump generated frequency, i.e. by forced vibrations. This fact, however, can be proved using more pumps with the equivalent parameters of flow but different frequencies of piston revolutions at the same conditions. This experiment could not been realized in our laboratory up-to-date.

Because we want to use the system of resonating chambers for amplification of the signal enforced into the flow by the magnetohydrodynamic (MHD) effect (Hlaváčová & Hlaváč 1999), it can be considered as proved that the resonating system can amplify the modulation induced by the MHD. Simultaneously, it is considered as proved that it is possible to tune the system appropriately.

4. CONCLUSIONS

Research of behavior of the system of resonation chambers with passing through water continues in projects of the Grant Agency of the Czech Republic No. 105/06/1516 and No. 103/07/1662. Actually there are implemented such modifications of the system of chambers that a flow rate will be reduced. This modification should enable the studies of chamber system behavior for diameters of the outlet orifices around 1 mm. Simultaneously, the project of the system of chambers for high pressures has been prepared based on the analysis of the up-to-date experiments with the existing one. Manufacturing of the function model of such system is planned for the year 2007.

5. ACKNOWLEDGEMENTS

The author thanks to the Magistrate of the Statutory City of Ostrava (project 1/2005) and to the Grant Agency of the Czech Republic (projects 105/06/1516, 103/07/1662) supporting presented research.

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7. GRAPHICS

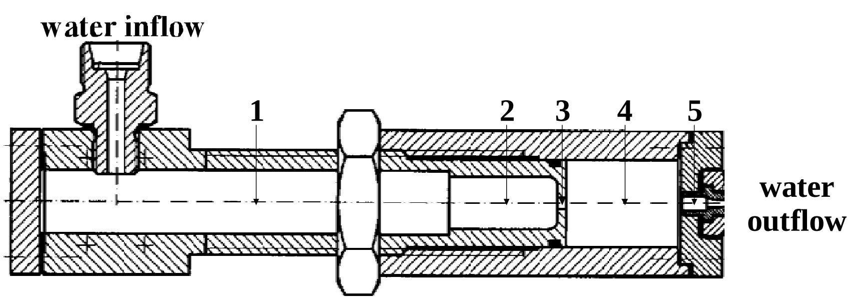

Figure 1. Scheme (design) of the system of resonation chambers.

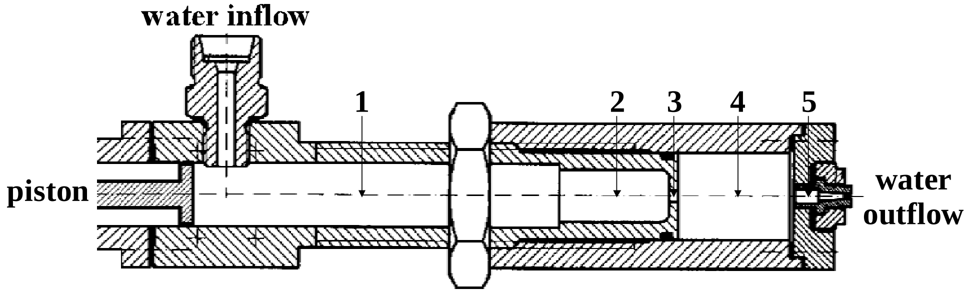

Figure 2. Scheme (design) of modified system of resonation chambers - the piston added.

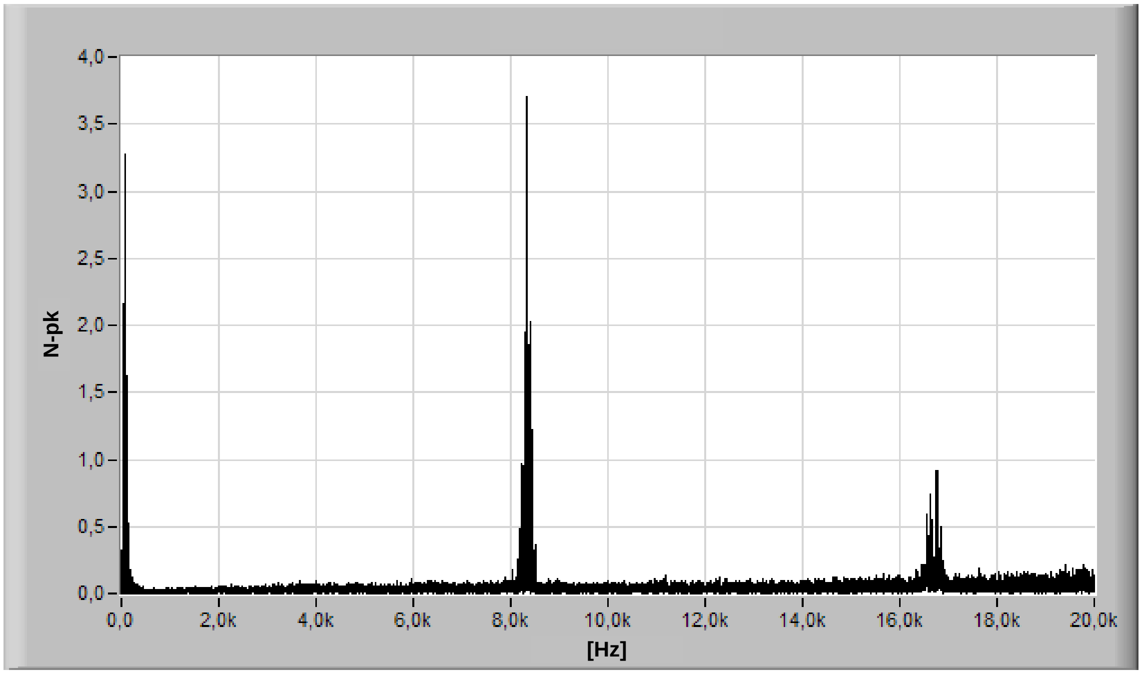

Figure 3. Frequency spectrum obtained through the FFT transformation of the signal induced by an impact of the water jet generated by the system of chambers (presented in Figure 1) onto the force sensor. Dimensions are conformable with presented design of D_i, L_i, R_i, L_5 = 20 mm, water pressure inside the system was 15 MPa.

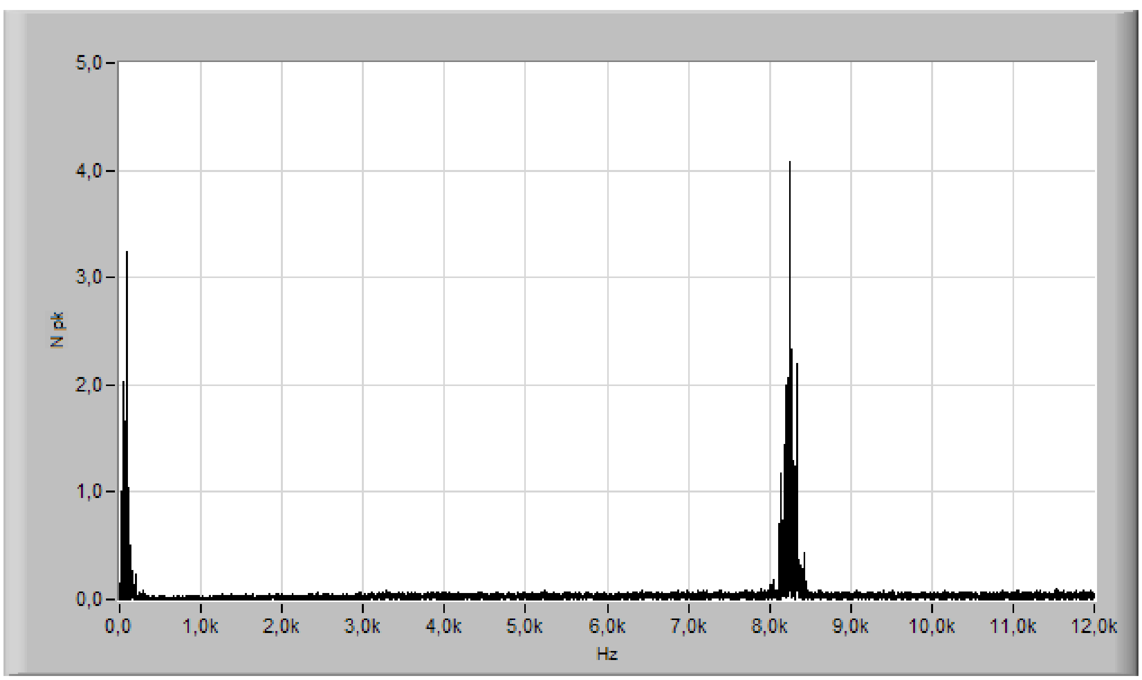

Figure 4. Frequency spectrum of the signal caused by impingement of the water jet generated by system of chambers drawn on Figure 2 (with piston in the position equivalent to the

position of the cover of the part 1 in the system presented in Figure 1) onto the force sensor. Geometrical dimensions of chambers and the water pressure were identical to the ones in Figure 3.

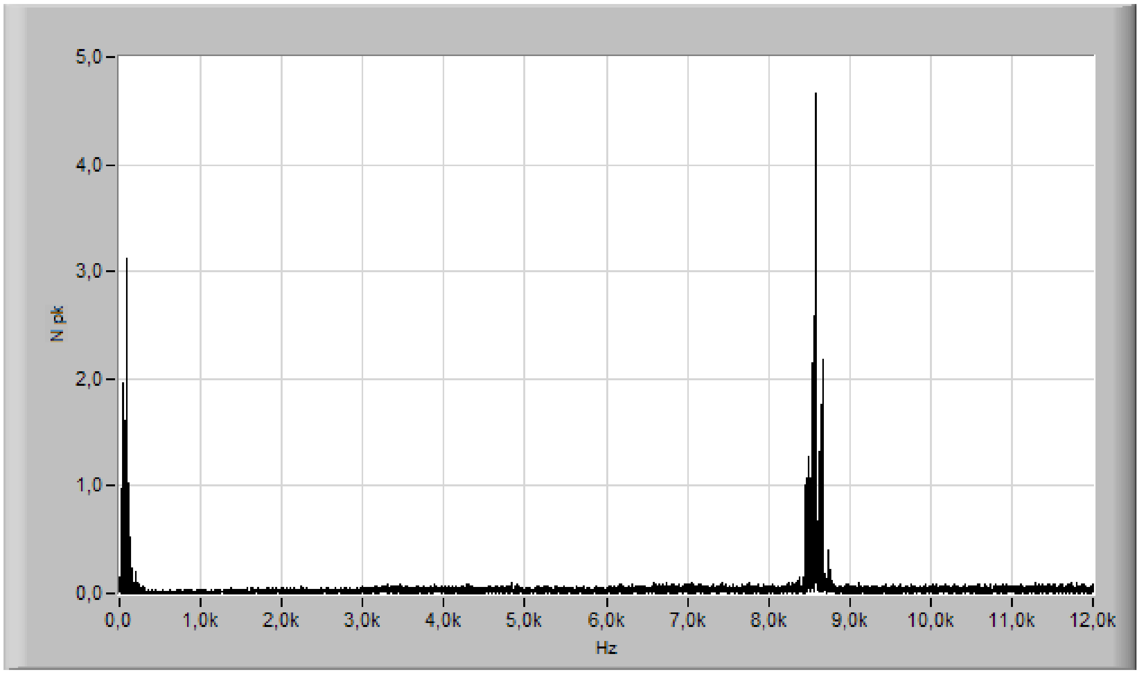

Figure 5. Frequency spectrum of the signal caused by impingement of the water jet generated by the system of chambers drawn on Figure 2 (with the piston in the position equivalent to the shortest possible length of the part 1 in the used function model) onto the force sensor. The rest of the geometrical dimensions of chambers and the water pressure were identical to the ones used for generation of jet which spectrum is in Figure 4.

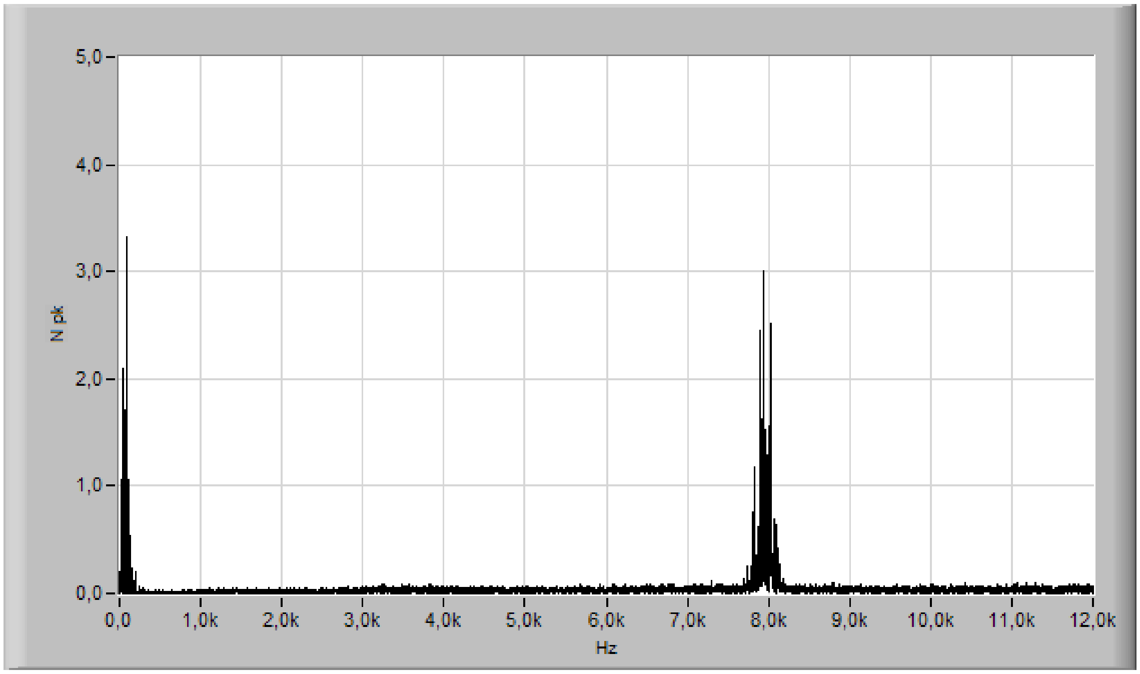

Figure 6. Frequency spectrum of the signal caused by impingement of the water jet generated by the system of chambers drawn on Figure 2 (with the piston in the position equivalent to the longest possible length of the part 1 in the used function model) onto the force sensor. The rest of the geometrical dimensions of chambers and the water pressure were identical to the ones used for generation of jet which spectrum is in Figure 4.

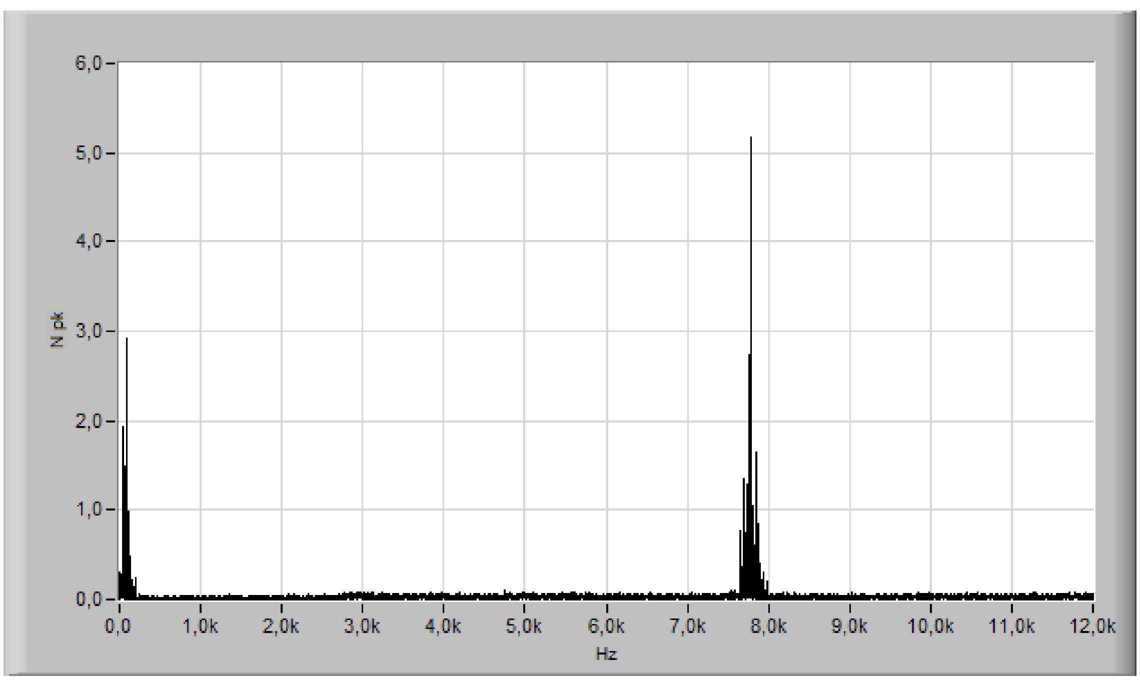

Figure 7. Frequency spectrum of the signal caused by impingement of the water jet generated by the system of chambers drawn on Figure 2 (with the length of the outlet nozzle

L_5 = 30 mm) onto the force sensor. The rest of the geometrical dimensions of chambers and the water pressure were identical to the ones used for generation of jet which spectrum is in Figure 6.

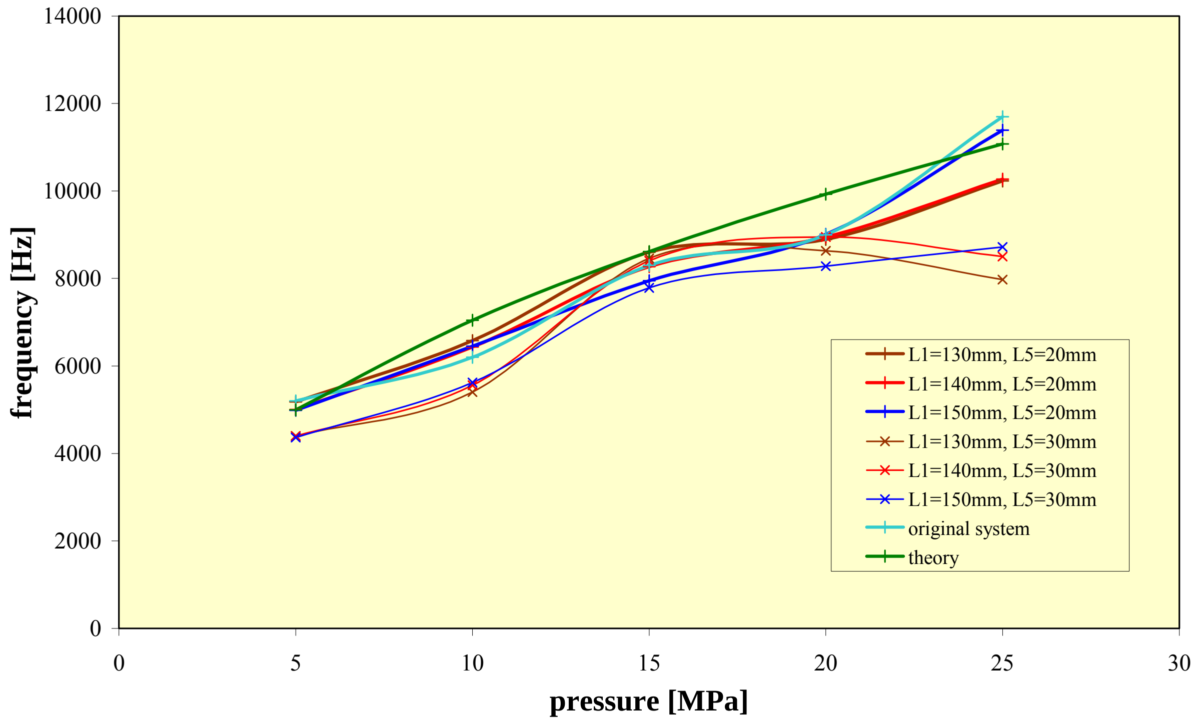

Figure 8. Dependency of the frequency spectrum of the signal, generated by impingement of the water jet from the system of chambers onto the force sensor, on the water pump pressure. Correlation for all measured configurations – pressures 5, 10, 15, 20 and 25 MPa, length L_1 equal to 130, 140, 150 mm and length L_5 equal to 20 and 30 mm.