Aspects of Experimental Research Management to Study Water Jets Used in Sewer Cleaning

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Abstract: *Industrial cleaning is an application of water jets technology. The functioning of sewer cleaning equipment is it depends on a series of parameters that can be modified as needed. The impact force influences the cleaning process. To measure the impact forces in laboratory conditions, are required equipment for generating water jets and measuring the impact force. The full factorial design is the research method used in the experiment. In the start of the research was made a screening of the process using Taguchi method. Finally, a regression equation is obtained that calculates the value of the impact forces of the jet for the studied experimental field. The paper presents the steps necessary to achieve an experimental research management in general and for the cleaning head sewer system in particular*.

Keywords: *water jets, impact forces, design of experiment*

1 INTRODUCTION

The current knowledge on cleaning using water jets comes mainly from experiments. Adler [1] study the mechanisms that take place at the impact between a water jet with a surface. Other researchers, like Guha et al [5], Leach et al [6], Leu et al [7] analysed the distribution of the pressure in the water jet. Other papers talk about the influence of nozzle geometry [2, 3, 4].

The cleaning heads and the high-pressure pump and are the most important components of the equipment used for cleaning the sewer cleaning. Using the equipment is generated water jets at the necessary working pressure. Considering the concrete conditions from the place where the sewer cleaning takes place (the diameter of the sewer, the type of debris, the type of obstruction) and considering the characteristics of the pumps (pressure and water flow) are used different types and sizes of cleaning heads.

The water jet leaves the nozzle at a desire pressure, thus generating impact forces. The cleaning of the sewer takes place due to these impact forces.

2 DESIGN OF EXPERIMENTS

The management of an experimental research requires completing some steps corresponding to an experimental plan [9]:

1) identifying and statement of the problem;
2) choosing of the of the studied process;
3) choice the process parameters, their levels and ranges;
4) choice the type of experimental design;
5) conducting the experiment;
6) statistical analysis of the of the experimental data obtained;
7) conclusions and recommendations.

2.1 Statement of the problem

Industrial cleaning is an application of water jets technology. Starting with 1950s reliable high-pressure water pumps were built. From that moment on, water jets began to be widely used to clean pipes and sewers.

After completing bibliography of field, research question is: study the pressure water jets used in cleaning sewer considering the influence of the involved process parameters.

2.2 Establish of the response variable

The pressure water jet appears at the outlet of the nozzle (the nozzle is part of the cleaning head). These jets generated impact forces. Because of these forces occurs cleaning a drain.

In sewer system we study the force generated by pressure water jets in two directions:

a) dislocation and movement of deposits from the sewer by pushing into behind the cleaning head through free water jets (cleaning heads);
b) use of water jet force for using the cleaning head like a hammer. Cleaning head is used for fracture, dislocation and breakage deposits. There are several types of cleaning heads for this purpose such as: pointed heads, chain scrapers, gliding heads, wire rope.

Given the above, the impact force produced by pressure water jets is the response parameter studied.

2.3 Choice of factors of the process, levels, and ranges

For cleaning sewer, in the bibliography, were identified several parameters that influence the process [8].

The parameters are divided into two major categories:

1) target parameters for deposit removal. These parameters are located in the contact area between the water jet and the surface of the sewer and are directly related to the sewer deposits. Here are some of them: mass removal, cleaning with, cleaning rate, deposit thickness;
2) process parameters. These parameters are divided into 2 groups. In the first group we talk about hydraulic parameters (work pressure, volume flow, nozzle diameter). In the second group we refer to the performance parameters (impact angle, stand-off distance and traverse rate).

2.3.1 Choice of factors

Because are a multitude of parameters involved in cleaning a sewer, are study the process parameters. Is necessary to study the process parameters to be able to determine the impact forces.

Four parameters are studied:

1) The water pressure noted with p,
2) The nozzle diameter noted with D,
3) The stand-off distance noted with x
4) The angle noted with α

We don't use the parameter traverse rate v_t, because in this study was used a stationary jet. Another parameter that is not used is volume flow Q because is a indirectly parameter (results indirectly from the pressure p and the diameter D).

2.3.2 Levels and ranges of factors

To generate a pressure of water jet up to 200 bar the equipment used for cleaning sewers is used a high-pressure water pump. Usually, 120-180 bar is the pressure of water jets. This value range is chosen to avoid the damage of pipes.

The pressure pressure p varies between 120 and 200 bar with a step of 20 bar.

The maximum diameter of sewer used in this study are 400 mm.

The distance between nozzle and impact surface (stand-off distance x) is between 25 mm to 200 mm, with an increment of 25 mm.

Considering the pressures and diameters previously established, manufacturers recommend cleaning head with different diameters of the nozzle.

Taking into account the recommendations of manufacturers the values of nozzle diameter D are 1 mm, 1.5 mm and 2 mm.

To clean sewers with diameters up to 400 mm are used cleaning heads for which the usual value of the impact angle α is 75^0. If impact angle α decrease below 60^0 the impact force becomes too small to perform cleaning.

Impact angle α was set to values $\alpha=60^0$, 75^0 și 90^0.

The established experimental domain is presented in Table 1.

Table 1. Experimental domain established

Parameter	Abrev.	M.U.	Values
Nozzle diameter	D	[mm]	1, 1.5, 2
Pressure	p	[bar]	100, 120, 140, 160,180, 200
Impact angle	α	[^{0}]	60, 75, 90
Stand-off distance	x	[mm]	25, 50, 75, 100, 125, 150, 175, 200

2.4 Choice of experimental design

Experimental method used in this paper is full factorial design.

For the four previously established parameters and corresponding values, gives several 3x6x8x3 = 432 experiments.

Each experiment in this study was replicated buy 7 times [9], to be able to achieve statistical analysis of the data. At the end results the numbers of measurements required 432x7 = 3024.

If 10 minutes are allocated for each measurement, a total time of 120 days is required to perform the experiments.

Considering the time necessary to make all the measurements, in the first part of experimental research we made a screening (using Taguchi method). We made the screening to determine the percentage in which the previously established factors influence the impact force.

After screening the full factorial design is used to study the impact forces.

2.5 Performing the experiment

To performing the experiment dedicated equipment is required.

Thus, it was designed and executed a stand for generating pressure water jets to generated pressure water jet and a device to measure the impact forces.

2.5.1 Stand to generate pressure water jet

The operating scheme of the stand to generate pressure jet used in the experiments is presented in figure 1.

The main component parts of stand are: electric motor (1), a flexible coupling (2), a high pressure pump (3), a pressure regulator (4), pressure gauge (5), nozzle (6), tap water (7), water tank (8) and chassis (9).

Water coming out from water tank, enters the high-pressure pump and then goes into the pressure regulator where is adjusts the pressure desired and goes in the path of the high pressure water. This desired pressure is found at outlet of nozzle.

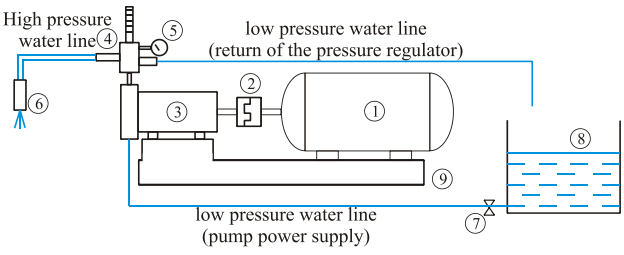

Fig. 1. The operating scheme of the stand to generate pressure jet

2.5.2 The device to measure the impact forces

In figure 2 is represented the operating scheme of the device with which it was measured the impact force of the water jet when hit a flat and rigid surface.

The component parts of device are: high pressure water hose (1), support nozzle (2), nozzle block (3), nozzle (4), pressure water jet (5), target plate (6), water

collector path (7), scaled container to measurement the flow (8), piezoelectric sensor support (9), piezoelectric sensor(10), equipment for data acquisition (11), computer for processing the obtained data (12), support (13), acrylic enclosure (14), rods used to adjust the distance between nozzle and the plat (15).

From the high-pressure pump comes water whose pressure is set to a certain pressure using the pressure regulator. Thus, at the exit of the nozzle, a pressure water jet is generated. The water jet strikes the target plate at a desire distance x in front of the plate. The water jet, when hit the target plate, generates an impact force. This impact force moves the plate axially. With the help of the piezoelectric sensor the motion is converted into electric signal. The signal is processed by data acquisition equipment (11) and DaqView soft and data results.

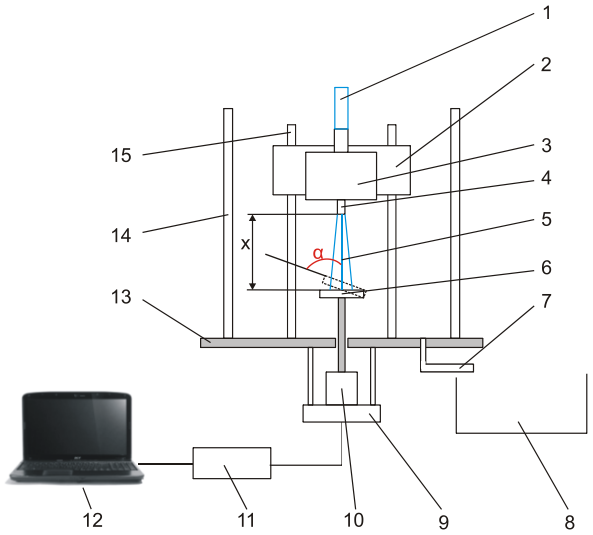

Fig. 2. Operating scheme of the device

Further, are determined the values of impact forces for the entire experimental domain established.

2.6 *Statistical analysis*

An important part of experimental research is the statistical analysis of the data obtained. The purpose of this statistical analysis is to certify that the data values measurement in the experiment are real values of process studied and these values isn't affected by system or measurement errors.

The necessary steps to make the statistical analysis of the experimental data are:

a) verifying the aleatory character of data. To do this check was used the Young test.

b) verify the normality of the experimental data distribution. For this part was used Shapiro-Wilk normality test.

c) identifying data affected by aberrant errors. In this case it is done using the Romanowski test.

After validation of the obtained data (following the statistical analysis) can proceed to processing the experimental data and obtained the mathematical model which describe the process.

In figure 3 are presented the steps taken in the D.O.E. (design of experiment) for study the pressure water jet.

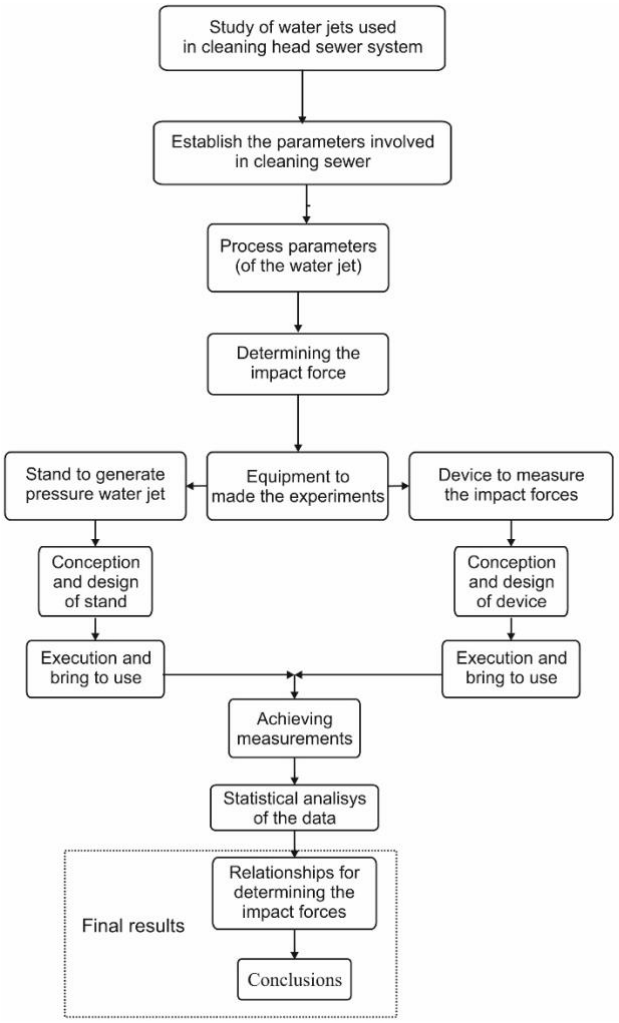

Fig. 3. Steps taken in the DOE for study the pressure water jet

3 CONCLUSIONS

Experiments have always served as means of knowledge of phenomena and processes.

Any experimental research requires a management structure for planning. The resources necessary to make the experiments are the most important. The context where development solutions to an experimental research are generally unique. This often imposes innovative solutions using components of existing structures or new systems. In this case, to study the water jets used in sewer system, was used a device for measuring the impact forces generated by water jet on impact with sewer.

Furthermore, aspects of the efficiency of a research process led to the identification of the Taguchi method as a solution to determine the fundamental influences of the process studied. This resulted in reducing the number of experiments from 3024 to 378.

Using the full factorial method itself is a process of research management as the results of experimental research have led to efficiency.

Validating the results is also a fundamental component of the management process of an experimental research.

An important part of management planning was to conduct experiments in real time while keeping the stability of the system.

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