529. Measurement of static characteristics of pipe fastening elements

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Abstract. It is important to possess information about static characteristics of pipe fastening elements in order to achieve good vibro-isolation parameters. Static characteristics of the same fastening element may change with regard to applied clamping force, rubber relaxation phenomenon or other reasons. Measurement system for determination of static characteristics of pipe fastening elements was developed and multiple measurements were performed. Results confirm relevance of such experiments.

Keywords: pipe vibrations, static measurement, fastening element.

Introduction

It is hard to find a building where the pipes are not used as the main tool for gas or liquid transportation. It is therefore understandable that the piping is one of the main sources of noise inside of building [3] and pipe fastening elements have significant impact on noise reduction and transmission parameters.

The purpose of this paper is to introduce to static measurements of pipe fastening elements, and to cogitate on tendency and causes of parameters variation of pipe holders.

Problem

Noise sources of piping inside the building can be divided into several components:

- noise because of pipe oscillation;
- noise produced by the wall caused by vibrations transmitted through the pipe fastening element.

One way to assess the vibro-acoustic properties of fastening element is to test the entire pipeline installation with selected holders and measure noise level inside the building. This method has a disadvantage because it is difficult or impossible to assess the characteristics of particular fastening element. This is explained by the fact that the nature and level of produced noise depends on piping installation and acoustic properties of the room and not on pipe ring alone. Therefore the measured parameter value may change while using other pipe types or even because measurements were performed at a slightly different location than before.

In order to describe the vibro-acoustic characteristics of the pipe fastening element it is necessary to highlight the parameters which could characterize this attribute, and to find effective ways to measure them.

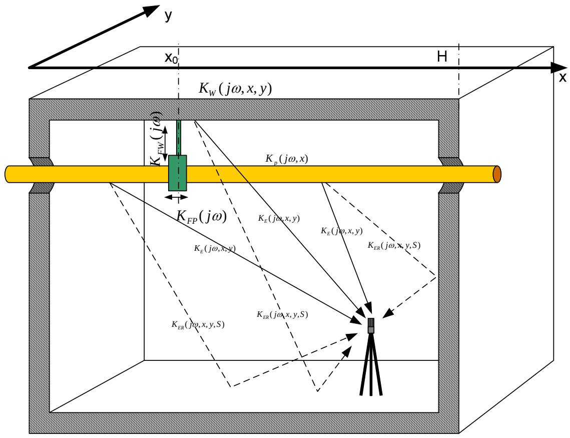

Fig. 1. Noise created by vibration of the tube reaches the sound meter either directly or reflected from the wall. Also some pipe vibrations are transferred to the wall and along the pipe over the pipe fastening element and produces noise too. Each of these media has its own vibro-acoustic characteristics, and it is very difficult to assess the parameters of fastening element from the total acoustic noise

Pipe fastening element

Pipe fastening element, pipe and wall fixing components all together are displayed in fig. 2. Vibro-acoustic property of whole system is defined by all listed components of the system.

Pipe fastening element is the key component involved in the transmission of the pipe vibrations to the wall. How pipe vibrations travel along the pipe is also partially defined by its properties. It is therefore important to know parameters of the pipe ring in order to decide on its impact on vibrations, and to assist the pipeline design process to effectively address the vibration and sound isolation issues.

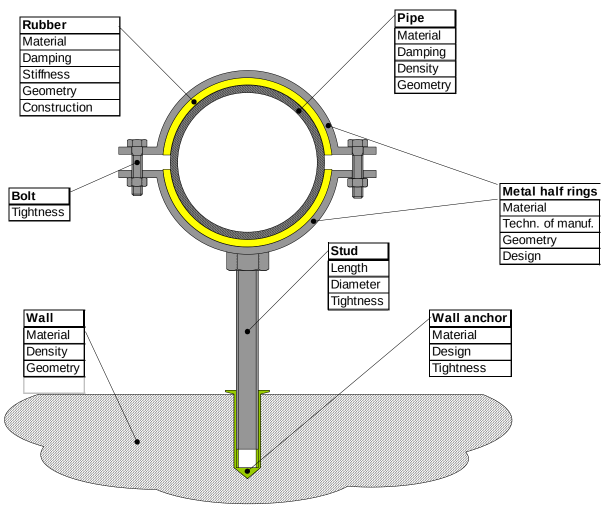

Fig. 2. Pipe holder and factors which may influence its vibro-acoustic characteristics

With the intention to make our initial research simple, we reckon that acoustic noise and vibration emitted by the pipe as well as vibration transmission to the wall are affected by four degrees of freedom of the pipe ring: the transverse and longitudinal fibrillation and circular movements on the same axis. Considering that the principle of superposition applies to the fastening element, we can identify four separate models for each of the degrees of freedom. One degree of freedom dynamic model can be described by the equation thus making it possible to model adjustments contributed to the vibration of the whole system which are caused by the pipe holder [4].

$$m \cdot \ddot{x} + k \cdot \dot{x} + b \cdot x = 0,$$

where *m* is the mass of the pipe on the holder, *k* is its stiffness, *b* – damping factor [1, 2]. If we know *k* and *b* values, for all four models the fixing element could be described in the sense of vibration. This method is attractive for its simplicity and because it is easy applied in practical calculations. Another way to describe fastening element is to measure the vibration transmission characteristics for each of its degrees of freedom. It is likely that the latter method will better describe characteristics of vibration damping and transmission of the pipe fastening element but on the other hand, measurement of such transfer function is not a simple task.

Quasi-static tests were performed on several types of pipe holders to understand the trends and causes of variation of its parameters and to find static characteristics, such as:

- stiffness vs. clamping force dependence;
- stiffness dependence on loading rate and direction;
- stiffness variation as a function of time.

A universal testing machine was used for quasi-static tests. The machine is capable of producing a force of few tens of kN and measuring load and deflection of test element. Load force is measured with a resolution of 0.00045 N and the deflection is measured with 0.002 mm resolution. Frequency of one load cycle is 0.03 Hz.

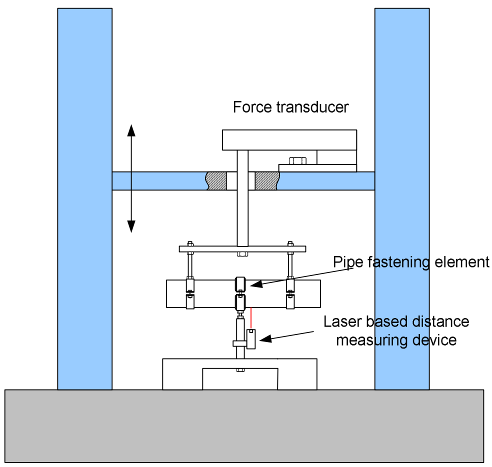

Fig. 3. Universal testing machine

Tests were performed to measure longitudinal characteristics of pipe fastening element. First experiment was made on two 35 mm pipe holders while applying different clamping force.

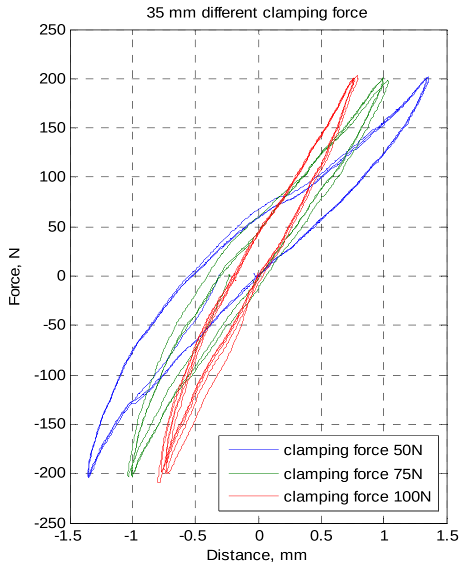

Fig. 4. Stiffness vs. clamping force

Average longitudinal stiffness of the pipe holder is linearly dependent on clamping force, but the difference of stiffness may be seen under different loads or direction of it.

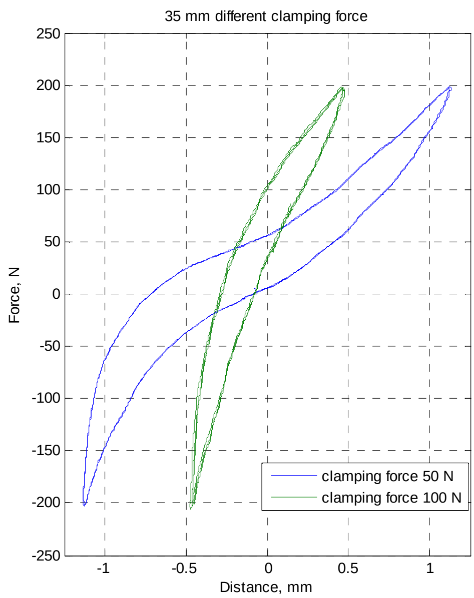

Fig. 5. For some specimens the shape of stress-strain curve heavily depends on applied clamping force

This feature became more noticeable after another pipe ring of the same diameter from other company was tested. As it can be observed from Fig. 5 static stiffness heavily depends on the load applied to the pipe ring, particularly when the clamping force is small.

It was noticed that stiffness measurements obtained immediately after the clamping force was applied, and 24 hours later were different for various pipe rings. There was no significant difference in stiffness values for specimen number one (Fig. 6). This cannot be said for specimen number two (Fig. 7).

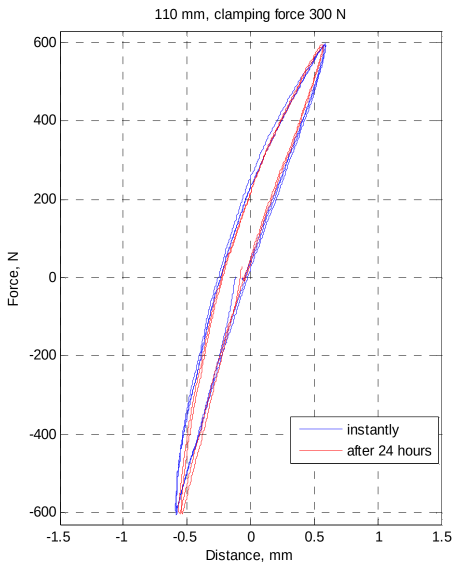

Fig. 6. No significant difference between two measurements made in different times

Separate sections of the slope of stress-strain curve which was measured 24 hours later than clamping force was applied, are less steep than ones, measured immediately after. The difference between the areas formed by the curves is also visible.

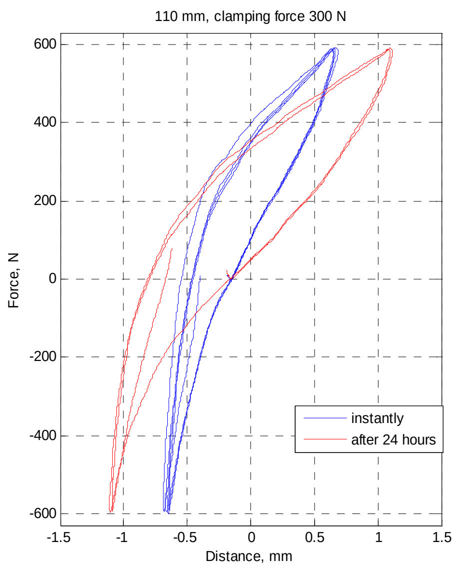

Fig. 7. Difference between instant and delayed measurements (red line) is noticeable

In all of the tests we can notice a tendency that the curve in the lower part of the plot is steeper than in the upper part. This is explained by the fact that while the pipe fastening element is stressed down it is less distorted because of the mounting element to which it is threaded. The measurements indicate that depending on how the pipe fastening element will be stressed the sound and vibration insulation parameters may differ.

Static tests were carried out with large loads, which led to strains of such size that are not possible in real world vibrations. In order to find out stiffness dependency on amplitude of strain, test was performed with smaller amplitude of strain of pipe imitator.

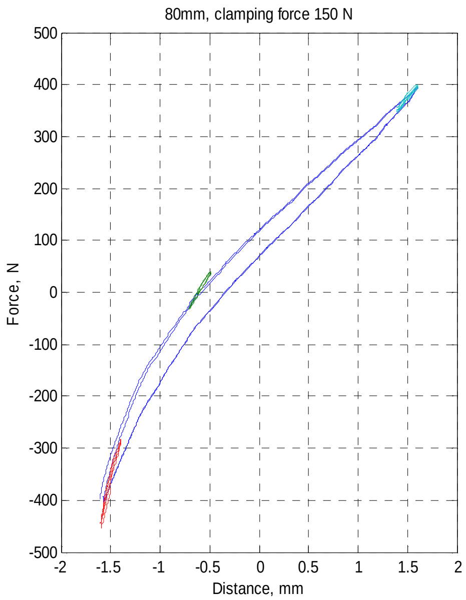

Fig. 8. Smaller strain amplitude – larger stiffness

The specimen was moved 200 μm peak to peak in three working points. The frequency of cycle was 0.03 Hz. The results demonstrate that stiffness is higher while applying small-amplitude deformations compared to the large - amplitude ones. The smallest difference between measured small and large amplitude stiffnesses was observed while larger loads were applied to the pipe holders. This trend was observed for all specimens under test.

Conclusion

Characterization of vibro-acoustic properties of pipe fastening element and measurement of those parameters is not a simple task. After initial measurements of stiffness of pipe fastening elements, several variables are determined which affect this measurement:

Clamping force;

Time after clamping force was applied;

Direction and magnitude of load;

Magnitude of strain.

It should be noted that the measurements of static stiffness may not correspond with the dynamic stiffness measurements because of the rubber properties [5, 6]. In this way, static measurements only reflect the potential trends or anomalies of stiffness variation, which depend on the above-mentioned components, but does not allow accurate estimation of parameters (including stiffness), which affect pipe vibrations inside the pipe ring.

Given the dynamic stiffness of the pipe fastening element, you can calculate what force will act on base attachment of the holder at certain amplitude of the pipe vibration. It is thus possible to calculate the transmission characteristics of the selected axis of the pipe holder and to judge on its vibro-acoustic properties. Therefore further research is necessary to analyze the dynamic parameters of the pipe holder such as: stiffness, damping and transmission characteristics.

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