Accounting the mechanical resistance of testing device for straight-flow branch pipe in the transverse direction

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Abstract. The flexible inserts as a rubber-cord branch pipe are used to reduce the vibrations distributed from units of a hydraulic system through the pipelines. The device with completely rigid elements is used for the experimental determination of the stiffness characteristics of the branch pipes that determine their anti-vibration properties. In the paper the study of the mechanical resistances of an experimental device construction is carried out by method of the harmonic analysis in a frequency range of 1 Hz to 1000 Hz. Then these mechanical resistances are compared with the mechanical resistance of the branch pipe with diameter 100 mm obtained experimentally. It is found as a result it is necessary to take into account the value of the device mechanical resistance when the stiffness characteristics of the rubber-cord branch pipes with diameter 100 mm in the transverse direction at frequencies above 735 Hz are determined experimentally.

1. Introduction

During the tests to determine the mechanical resistance of the branch pipes by existing methods the construction of testing device is considered to be completely rigid. Before test the mechanical resistances of the stand elements are determined experimentally (Fig. 1). According to the existing requirements they should be not less 10 times higher than the mechanical resistances of tested branch pipe in the predetermined frequency range (typically from 1 Hz to 1000 Hz). The disadvantage of this method is the reduction of accuracy of the vibration isolation properties determination of the branch pipes and in the some cases – a restriction of the frequency range of the experimental researches. The effect of these disadvantages is enhanced by increasing of the branch pipe stiffness (with increasing the pipe diameter and an operating pressure).

In consideration of the foregoing the study of the input and transfer resistance values of the device at transverse oscillations in a frequency range from 1 Hz to 1000 Hz by the harmonic analysis is carried out in this paper. The module Harmonic Response of software package ANSYS was used for calculation. The same study of the device mechanical resistances for longitudinal oscillations was carried out in the paper [1].

2. Task description

The construction of the device for experimental determination of the mechanical resistances of the straight-flow branch pipes in the transverse direction is shown in the Fig. 1 [2]. The Fig. 1 illustrates: 1
branch pipe; 2 – angle section; 3 – plane; 4 – transmission unit with force sensor; 5 – vibrator; 6 – columns; 7 – elastic suspension; 8 – support construction. The angle sections 2 and the columns 6 are mounted on a heavy plate (it is not shown on the fig.) which is attached to the basis.

Figure 1. Device scheme for determination of the mechanical resistances of the branch pipes in the transverse direction

In the tests on the transverse oscillations two identical branch pipes are mounted on the device to provide the boundary conditions. The inlet flanges of the branch pipes 1 are fixed with the plate 3 and are driven by the vibrator 5 which affects on the plate through the force sensor 4. The outlet flanges are fixed on the angle sections 2. The accelerometers mounted on the inlet and outlet flanges of the branch-pipes are intended to determine the transverse oscillations rate of the inlet and outlet flanges of the branch pipe by indirect method.

The mechanical resistances of the branch pipe are determined experimentally as a ratio of force to rate [2]. The input mechanical resistance of the branch pipe

$$Z_{22} = \frac{Q_{in}}{V_{in}} = \frac{Q_2}{V_2},$$

The transfer mechanical resistance of the branch pipe

$$Z_{29} = \frac{Q_{in}}{V_{out}} = \frac{Q_2}{V_9},$$

where $Q_{in} = Q_2$ – input force,

$V_{in} = V_2, \ V_{out} = V_9$ – the rates of the inlet and outlet flanges of the branch pipe.

Indexing corresponds to a mechanical resistances matrix of the straight-flow branch pipe, and it is given, for example, in [[1]].

Except the branch pipe the oscillations from the vibrator to the angle sections distribute through the device construction (the columns – the plate – the angle sections), which have a finite mechanical resistance. To estimate the value of this resistance in the predetermined frequency range a calculation model was made.
3. Calculation model

The calculation of the device mechanical resistance was carried out by harmonic analysis in the software package ANSYS using the module HarmonicResponse [8]. The calculation model of the device with a finite-element mesh is shown on the Fig. 2. The boundary conditions: the lower surface of the plate – an anchorage. The connections: the contact surface of the angle sections and the columns are «adhered» on the plate surface (bolted connection is used practically). Loading: harmonic force with amplitude $Q_{in} = 1000$ N acts in X-direction and is applied to the holes in the column (uniformly is distributed over cylindrical surfaces of the holes). The number of mesh cells is 104202.

![Figure 2. The calculation model of the device](image)

The frequency range of the harmonic analysis is from 1 Hz to 1000 Hz with step 1 Hz.

During the calculating the oscillation rates on the column, in the force point ($V_{a,in}$) and in the central part of the angle section vertical surface ($V_{a,out}$) are defined. The input and transfer mechanical resistance of the device were calculated by formulas:

$$Z_{in} = \frac{Q_{in}}{V_{a,in}},$$
$$Z_{trans} = \frac{Q_{in}}{V_{a,out}}.$$

4. Calculation results

The frequency characteristics of the input and transfer mechanical resistance of the device obtained as a result are shown on the Fig. 3, 4 together with the mechanical resistances of the rubber-cord branch pipe with diameter 100 mm which were obtained experimentally.
Figure 3. The input mechanical resistance of the stand $Z_{in}$ and the branch pipe $Z_{22}$

Figure 4. The transfer mechanical resistance of the stand $Z_{trans}$ and the branch pipe $Z_{29}$

5. Result discussion

On the Fig. 5 the ratio of the input mechanical resistance of the device and the branch pipe $Z_{in}/Z_{22}$ is shown. When the frequency is more than 735 Hz this ratio is less than 10. To obtain the reliable result for determination of the branch pipe characteristics it is should include accounting the mechanical resistance of the device in the experimental technique. Also a resonance of one device elements at the frequency 617 Hz takes place resulting in unreliable measurements without excluding a pliability of the stand near this frequency.

The transfer resistance of the stand in entire frequency range exceeds the transfer resistance of the branch pipe more than 10 times (Fig. 4). In the resonance points 542 and 617 Hz the ratio $Z_{out}/Z_{29}$ is respectively 25,4 and 15,5. In this case the requirements of the device stiffness are satisfied. However
accounting the mechanical resistance of the device will increase the determination accuracy of the branch pipe mechanical resistances.

Figure 5. The ratio of the input mechanical resistances $Z_{in} / Z_{22}$

Figure 6. The ratio of the transfer mechanical resistances $Z_{out} / Z_{92}$

Near the resonance the frequency step should be decreased to increase the accuracy of determination of the device resonance frequencies during the experimental study.

6. Summary and conclusion

In the process of the experimental determination of the stiffness characteristics of the rubber-cord branch pipes with diameter 100 mm at the frequencies 735 Hz it is necessary to take into account the values of the device mechanical resistances, which should be determined experimentally and a numeric calculation by the harmonic analysis is used as an evaluation (for example, in designing or modifying elements of the test device).
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