Identification of Parameters of the Piezoelectric Transducer Model

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***Abstract* - The paper describes simulation of time and frequency characteristics of a piezoelectric transducer model and presents a comparison of those characteristics to the ones of a real transducer. Evaluation of the model applicability to correct conversion errors is also presented.**

I. Introduction

Measurements performed on real objects as well as a correction of measuring errors are time-consuming tasks. Simulations that are presented in the paper make possible to correct the errors at the designing stage of a measuring circuit.

Measurements and simulations have been performed using as an e example a piezoelectric transducer applied to measure dynamic load under impact conditions.

II. Determination of Frequency and Time Characteristics of a Measuring Transducer Model Using This Template

Simulations of piezoelectric transducer operation have been performed with the application of the SPICE 8.0 software [2].

Electric diagram of the model presented in Fig.1 has been used in the simulations. Its parameters have been determined on the basis of laboratory measurements.

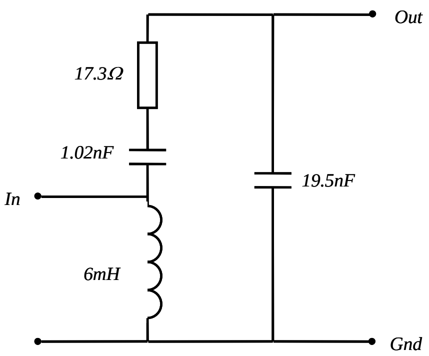

Fig. 1 Diagram of the transducer model that has been used in the simulations with values of component elements given.

Frequency characteristics of the piezoelectric transducer model have been determined with the use of a diagram presented in Fig.2. Connection of the transducer model input to the generator has been made by means of an adequate impedance (Cz, Rz), which makes the generator effect on the model operation during the simulation insignificant. It particularly concerns the generator effect on the resonance amplitude and resonance frequencies of the transducer model. The impedance substitutes an electromechanical coupling coefficient, which is one of the piezoelectric transducer parameters

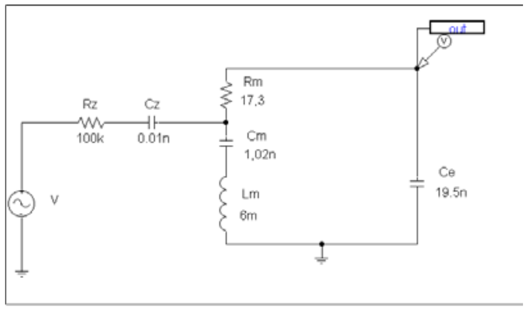

Fig. 2 Circuit that makes possible to simulate frequency characteristics of a piezoelectric transducer.

Fig.3 presents the obtained frequency characteristic of the piezoelectric transducer model.

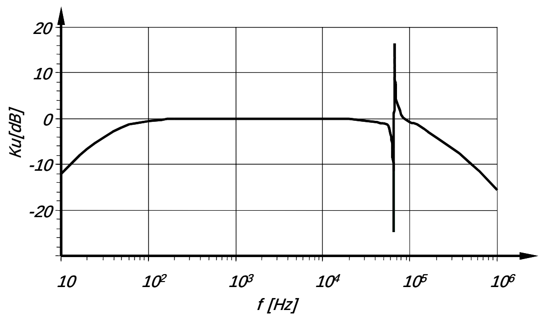

Fig. 3 Frequency characteristic of the model circuit

The presented frequency characteristic of the piezoelectric transducer model considers only the first resonance frequencies of the transducer, voltage and current resonance. They are located close to each other (64kHz, 67kHz) as it is in the case of a real transducer characteristic (64kHz, 65,5kHz) that is presented in Fig.4.

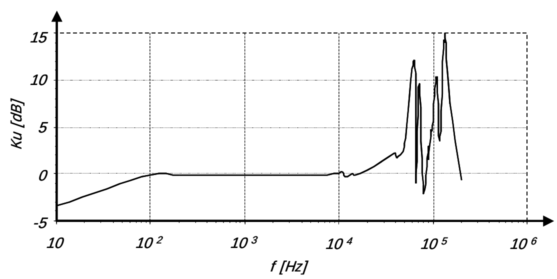

Fig. 4 Frequency characteristic of a piezoelectric transducer

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Till the moment when resonance occurs the model frequency characteristic only slightly differs from the one of a real transducer. In the real circuit higher resonance frequencies occur, which can be seen in Fig.4. However, they should not be taken into account as the first resonance of a transducer limits its application to that or lower frequency.

A response of the piezoelectric transducer model to a unit pulse has been obtained in the circuit that is presented in Fig.5. A voltage source of a rectangular characteristic has been connected to the transducer model input by impedance composed of Rz and Cz.

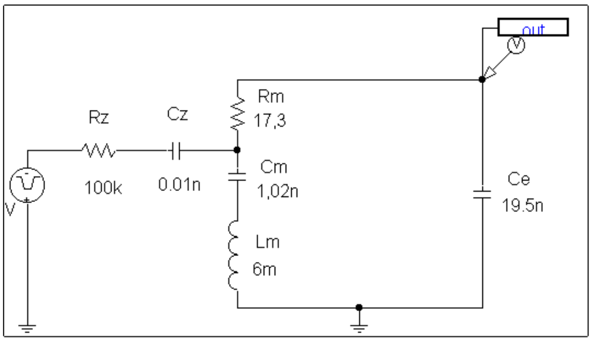

Fig. 5 Circuit to simulate a response of the piezoelectric transducer model to a unit pulse

Fig. 6 presents a response of the piezoelectric transducer model to a unit pulse

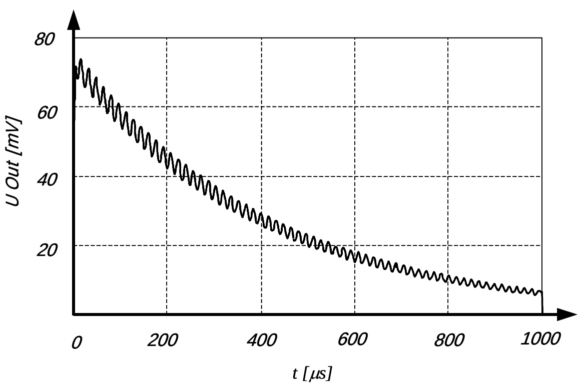

Fig. 6 Response of the piezoelectric transducer model to a unit pulse

In the obtained time characteristic of a transducer response to a unit pulse damped oscillation of high frequency (self-resonance of the transducer model) occurs. The model response to a unit pulse does not include damped oscillation beat frequency as it is in the case of a real transducer response to a unit pulse, which is presented in Fig.7. It follows from a simplification introduced to the model that consists in the lack of higher resonance frequencies that occur in a real transducer.

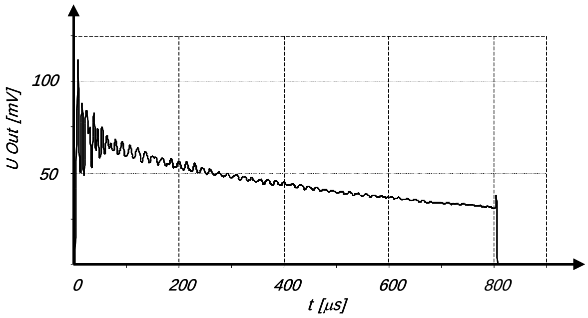

Fig. 7 Response of a piezoelectric transducer to a unit PULSE

Signal rise time in the transducer model has been determined by a graphical method. It is longer than in the case of a measuring transducer and amounts to Tm=1.6s, while the respective value for a real transducer is Tp=1.2s. It follows from the lack of higher resonance frequencies in the transducer model that are responsible for the signal rise time.

III. Determination of the Transducer Model Response to a Sinusoidal Pulse

When checking the transducer model response to a sinusoidal pulse, whose course corresponds to the one of a force pulse of elastic impact, a deviation from theoretical curves has been observed. The deviation consist in the fact that the calculated restitution coefficient is greater than unity:

$$k = \frac{S^{''}}{S^{'}}, \tag{1}$$

where: k - restitution coefficient,
S' - pulse of instantaneous force of the first impact phase,
S'' - pulse of instantaneous force of the second impact phase [3,4]

It indicates a conversion error of the transducer model and suggests that the same error can occur during measurements performed in a real circuit. Fig. 8 presents a circuit where an example simulation of a transducer response has been performed, while the transducer model responses to elastic impact are shown in Fig.9.

While performing the simulations it has been noticed that external resistance connected in parallel to the output terminals of the transducer model reduces a measuring error of the restitution coefficient value.

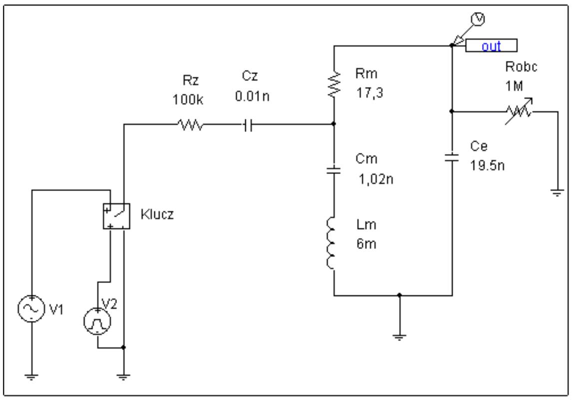

Fig. 8 Circuit to simulate transducer operation under impact conditions

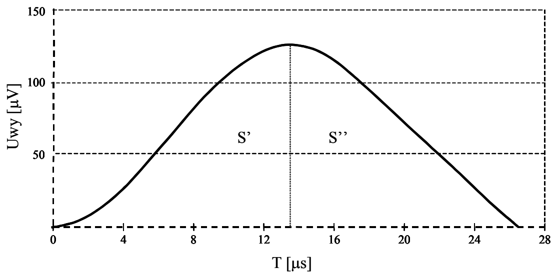

Fig. 9 Response of the transducer model to an impact pulse

A series of simulations has been performed in order to test the effect of external resistance, varied within the interval from 0.5kΩ to 1MΩ, on the restitution coefficient value. Fig. 10 presents the effect of resistance loading a piezoelectric transducer on the restitution coefficient value.

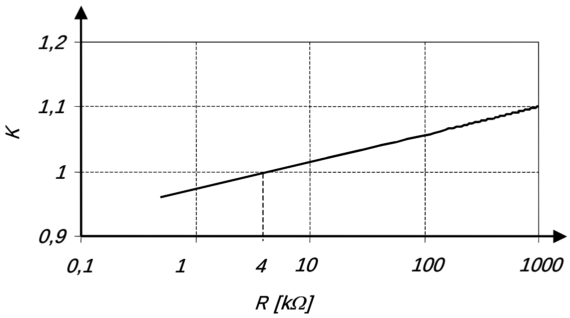

Fig. 10 Loading resistance effect on the restitution coefficient value for the transducer model

On the basis of Fig. 10 it can be stated that the restitution coefficient measuring error (for an elastic impact *k*=1) can be minimized by an adequate selection of the value of external resistance that loads a transducer. It follows from the figure that the value should be of ca 4kΩ

Results of measurements performed in a real circuit that is presented in Fig.11 indicate that for an elastic impact, at various values of parallel resistance (varied from 300Ω to 1 MΩ) it is also possible to minimize the restitution coefficient measuring error [1]. On the basis of impact measurements it has been established that its optimal value is 2kΩ. Fig. 12 presents the effect of external resistance on the measured value of a restitution coefficient.

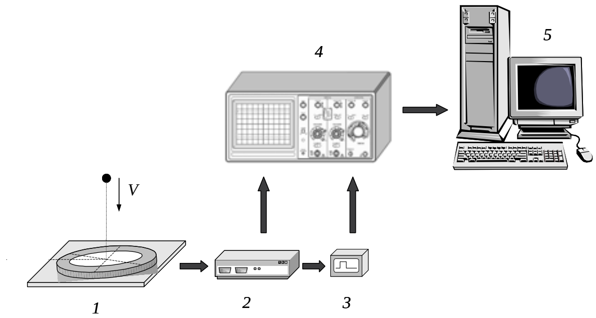

Fig. 11 Block diagram of a circuit to measure impact force and duration

1 - hitting object, 2 - piezoelectric transducer, 3 - measuring amplifier, 4- trigger circuit, 5- digital oscilloscope, 6 – computer

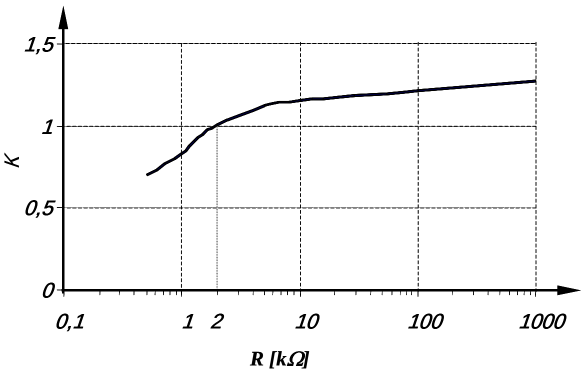

Fig. 12 Parallel resistance effect on a readout error of the restitution coefficient k

IV. Conclusions

- Electrical model of a piezoelectric transducer makes possible to simulate frequency responses, time responses and the operation of a piezoelectric transducer under impact conditions.
- Simulation tests make possible to correct errors at the designing stage of a measuring circuit.
- Simulations have made possible to establish the effect of resistance connected in parallel to output terminals of a transducer on the restitution coefficient measuring error.

References

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