Analysis of the conical piezoelectric acoustic emission transducer

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A conical transducer is a highly sensitive wide–band device (operating up to several MHz) for measuring a vertical component of displacement of a small area on the surface of a body. This transducer is designed for a wide region of applications, e.g., for testing by means of acoustic emission, to be used as a standard transducer, and the like. The scheme of a conical transducer is shown in fig. 1. The basic characteristics of the transducer are as follows:

1) The active element is of piezoelectric ceramics and is conical and its polarization is parallel with the axis of the cone;

2) The greater base of the cone with scalded silver or gold electrode is soldered on a relatively great cylindrical backing block made usually from brass;

3) The smaller base of the cone with scalded silver or gold electrode is connected through the medium of as thin binding layer as possible with the part of relatively large surface on which is measured the vertical component of displacement;

4) The output voltage is measured between the brass cylindrical backing block and the surface of the active element.
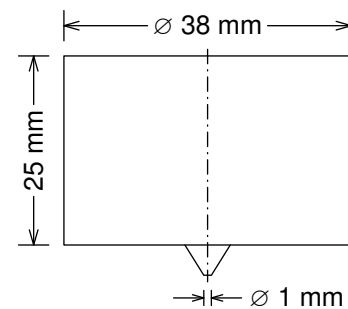

Fig. 1 A conical transducer.

5) The output voltage signal of a conical transducer is directly proportional to the normal surface displacement at the contact area with frequency up to few MHz.

The conical transducers were developed by Proctor [2] in the 1980s for quantitative acoustic emission at the National Bureau of Standards (NBS), USA.

FEM analysis of this transducer was presented. FEM calculations were performed in the environment COMSOL Multiphysics. Both the frequency response characteristic of the transducer and his time response on pulse excitation were studied. All of computations were done for various cone angles of piezoceramic (PTZ–H5) element and various sizes of the cylindrical brass backing of transducer.

The frequency response analysis was performed both for whole transducers and for separate piezoelectric elements. It was always done for nine shapes of cone. The influence of the backing size was studied on four various examples. Because some very similar jobs were performed, we used advantageously MATLAB for scripting these tasks of COMSOL. We created three scripts. The first one was for whole transducers, the second one for separate elements and the third one was for transducer with four various sizes of backing. We defined in those scripts mapped mesh, materials, boundary conditions, damping and excitation frequency. The problem was solved for particular shapes of geometry, which we changed in loop.

The FEM analysis showed necessity of using the large transducer backing. The influence of backing shape on the frequency response is shown in fig. 2. Note, the radius of backing influences more the frequency response of transducer than the height of backing.
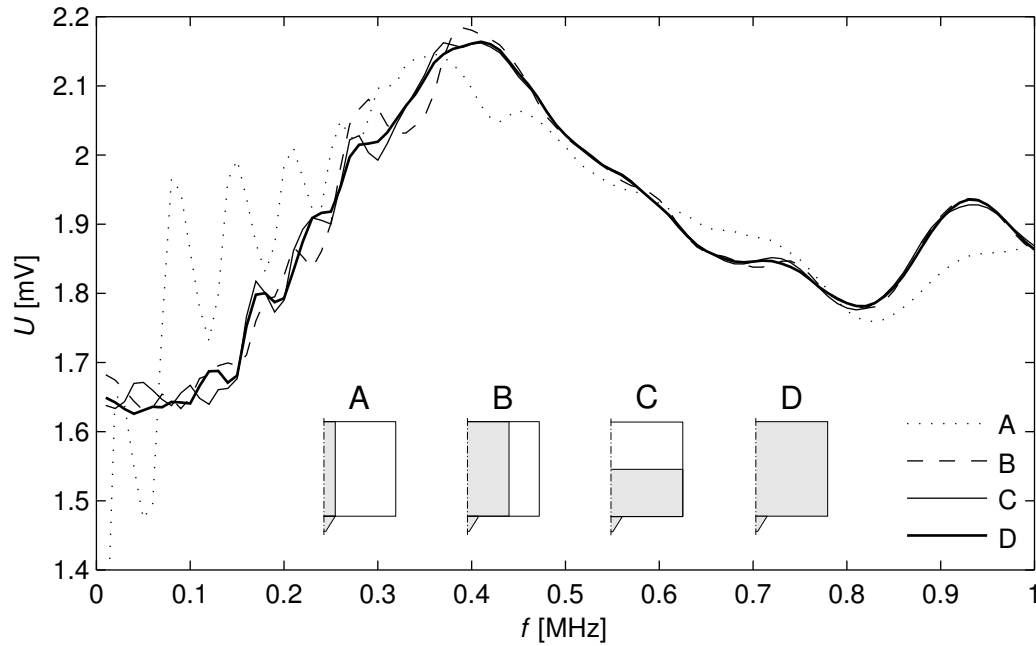
Fig. 2 Influence of backing geometry on the frequency response.

The prescribed displacement on boundary for time dependence analysis was given by a function or a data file. The sinus–pulse–displacement function had amplitude 1 pm, frequency 2 MHz and width 0.5 μs. The data file with the prescribed displacement on boundary included the vertical displacement on surface of half–space in distance 2 cm from the step–point–force source, [1]. The force amplitude was 10 N. A relative frequency response can be determined by dividing the Fourier transform of the time waveform produced by the transducer by the Fourier transform of the prescribed time waveform. It was shown in the time dependence analysis that the conical transducer signal is almost exactly as predicted by theory.

A transducer for measuring tangential dynamic displacement of a transient nature at a point location on the surface of a mechanical body was patented by Proctor [3]. Our next goal will be the FEM analysis of this transducer. Further we consider supplementing FEM analysis of the conical transducer by horizontal excitation. Both of these tasks require full 3D analysis, which poses considerable claims of the computer technique parameters.

References

[1] Mooney,H.M., Some numerical solutions for Lamb's problem, B. Seism. Soc. Am. 64 (1974), 473–491.

[2] Proctor, T.M., Jr., An improved piezoelectric acoustic emission transducer, J. Acoust. Soc. Am. 71 (5) (1982) 1163–1168.

[3] Proctor, T.M., Jr., Transducer for measuring transient tangential motion, United States Patent, Patent Number: 4782701