

## PRIMARY CALIBRATION OF SHOCK TRANSDUCERS LASER POSITION INFLUENCES MEASUREMENT RESULTS

*Dr. Martin Brucke, Philipp Begoff, Michael Mende, Frank Schulz*

SPEKTRA GmbH, Germany, [sales@spektra-dresden.com](mailto:sales@spektra-dresden.com)

**Abstract:** For the primary calibration of shock transducers according to ISO 16063-13 on a calibration system with Hopkinson-bar shock exciter a laser vibrometer is used as a reference sensor. Earlier publications have shown that the waves in the Hopkinson-Bar seem not to propagate exactly as plain waves and that it thus matters where the laser spot is positioned on the surface of the bar. However, in these investigations the shock duration could not be changed in a controlled way. This paper presents results from measurements by means of a special Hopkinson-bar that allows to vary the shock duration precisely and thus allows to measure the frequency dependency of such effects.

**Keywords:** primary calibration of shock transducers, Hopkinson-bar, laser vibrometer, ISO 16063-13

### 1. INTRODUCTION

For the primary calibration of shock transducers according to ISO 16063-13 [2] a laser vibrometer is used as a reference sensor. Furthermore the standard suggests two types shock exciters, a hammer anvil type of exciter or a Hopkinson-Bar type of exciter. While the hammer anvil type is used for calibration at shock lower amplitudes, the Hopkinson-Bar is the best exciter for higher amplitude ranges. In earlier investigations we could show that a modern laser vibrometer is a very reliable reference sensor that allows low measurement uncertainties even at acceleration amplitudes up to 2000 km/s<sup>2</sup> and shocks as short as some  $\mu$ s on a Hopkinson-bar exciter. However, publications from other groups showed that the waves in the Hopkinson-Bar seem not to propagate exactly as plain waves and thus it matters where the laser spot is positioned on the surface of the bar (see also section 4.3 in [2]). But in these earlier investigations the shock duration could not be changed in a controlled way and thus a frequency dependency of this effect could not be measured well. With a Hopkinson-bar with piezo-actuator as force input device invented by SPEKTRA some years ago we could not only measure the local dependence but also the frequency dependence by varying the shock duration while keeping the amplitude fixed.

### 2. HOPKINSON-BAR WITH PIEZO-ACTUATOR

Common shock exciters based on the hammer-anvil principle allow only a limited control of shock amplitude

and pulse width. Pulse width and amplitude cannot be chosen independently from each other. Although there is no analytical model available, experiences as well as numerical models show that with increasing amplitude the width of the generated shocks decreases. A similar behaviour can also be observed with a Hopkinson-Bar shock exciter which uses the hammer-anvil principle (e.g. impact of a projectile on the front surface of the bar) to generate the input force pulse. In this case acceleration amplitude is additionally depending of the time differentiator of the force input and thus the relationship between shock duration and amplitude is even stronger than in a hammer-anvil exciter [1].

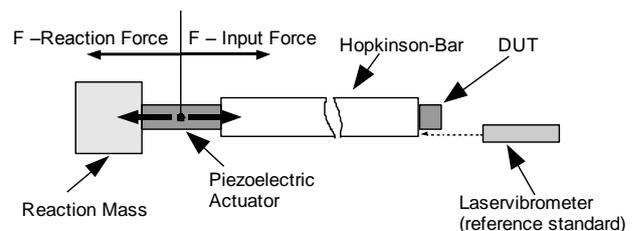


Fig.1 Principle drawing of the SPEKTRA HOP-MS Shock Exciter with a laser vibrometers as reference (patent [4])

Using a piezo-actuator as force input device instead of a classical projectile allows to overcome this dependency between amplitude and shock duration (patent [4]). The advantage of this solution is that it can be controlled completely by electrical signals and does not have any mechanical wear parts. Since also the transfer function between force input and acceleration output of the Hopkinson-bar can also be determined it is possible to vary shock amplitude and duration independently and the shock can be repeated quite precisely (see example in fig.2).

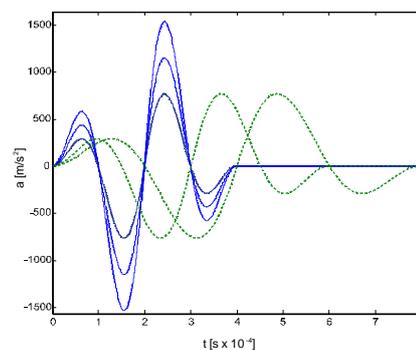


Fig. 2 Independent variation of amplitude and pulse width

### 3. MEASUREMENT RESULTS

For the measurements a SPEKTRA primary shock calibration system CS18P MS was used equipped with a Hopkinson-bar SE-220 (diameter 20 mm, material titanium) and a Polytech laser vibrometer. Two devices under test (DUT) were calibrated on this system, an Endevco 2270M8 (diameter 13.7mm, weight 16.5.gram) and a PCB 352A60 (diameter 10.7 mm, weight 6 gram). The shock duration of the positive half wave of the shock was varied between 200  $\mu$ s and 25 $\mu$ s and thus covered an equivalent frequency range from 2 kHz to 20 kHz. The amplitude was kept constantly at 2000  $m/s^2$ .

In one measurement setup the laser spot was first positioned close to the DUT and then in a distance of about 5 mm from the DUT. The difference between the DUT sensitivity determined at the outer position minus the sensitivity at the inner position divided by the sensitivity at the inner position is shown in fig. 3. Apparently the deviation between both measurement spots is increasing with a decreasing shock duration (higher Frequency). The maximum deviation was about 3%. Thus the acceleration amplitude at the outer position is lower than the amplitude at the DUT position. This increase can be well fitted with a second order polynomial (red line in fig. 3).

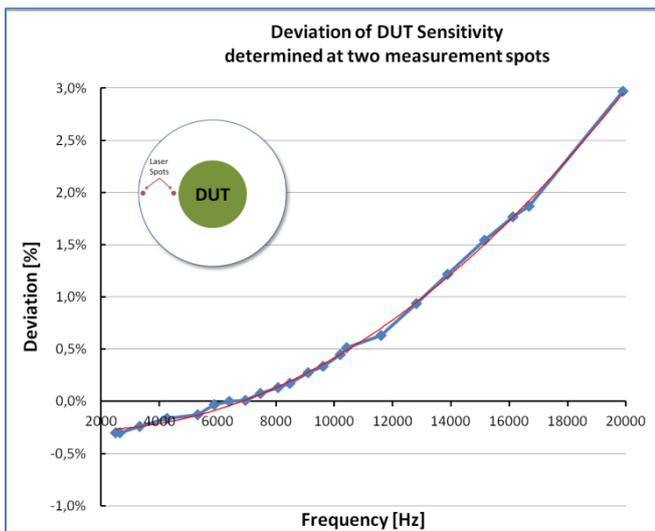


Fig.3 Comparison of the measured DUT (PCB 352A60) sensitivity with one laser spot positioned close to the DUT and the other in a 5mm distance

In a second measurement setup the laser spot was positioned at opposite sites close to the DUT. Again the relative deviation of the measured sensitivity at opposite spots was plotted over the equivalent frequency of the shocks. Here the absolute maximum deviation stayed below 1.5 % but the sign of the deviation changed over frequency indicating that some complex modes spread over the DUT coupling surface at the end of the Hopkinson –bar that change with the frequency.

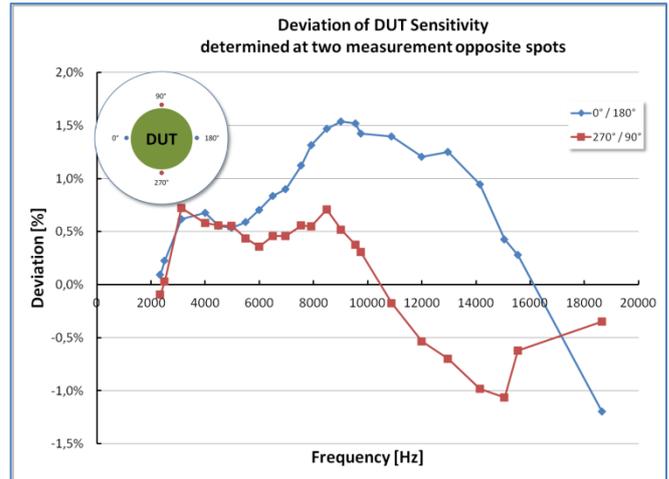


Fig. 4 Comparison of the measured DUT (Endevco 2270M8) sensitivity with one laser spot positioned close to the DUT and the other laser spot on the opposite side.

### 4. CONCLUSIONS

The measurement results show that as long as the shock duration is longer than 100  $\mu$ s the measured DUT sensitivity stays within a reasonable low range of 0.5% independent from the laser spot position. The shorter the shock duration becomes, the higher the deviations between different laser spot positions can become. At least the results show that it is mandatory to repeat the calibration with the laser spot positioned at different places around the DUT and average the determined sensitivities.

Currently more investigations are on the way to find out how stable these effects can be reproduced and how big the impact on the measurement uncertainty of a primary shock calibration system based on a Hopkinson-bar will be.

### REFERENCES

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