SmartShock—Mechanical Shock Resistance of Mesoscale Parts: Semi-automatic Design Testing and Adaptation

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Miniaturization of high-precision silicon-based mechanical parts of MEMS components and devices impose increasing requirements for their reliability, and particularly for their resistance to mechanical impacts. This becomes especially important for novel application markets such as watch industry, where mesoscale Si-based mechanical parts become promising candidates to replace classical metal-based designs. The present approach to assess the mechanical shock resistance of mesoscale parts relies on qualitative analysis of slow-motion shock test videos. Within the current project we develop a unique semi-automatic system for the analysis of mechanical deformation and stress in precision mechanical parts at mesoscale level during high speed impacts, such as mechanical shocks. The system allows to overcome the main drawbacks of the present approach.

The project aims to develop a novel semi-automatic system for the analysis of mechanical deformation and stress in precision mechanical parts at mesoscale level during high speed impacts, such as mechanical shock. This allows the determination of weak points and enable optimization of the design for the structures containing mesoscale precision parts. The main areas of application of such a system is the watch industry, especially for designs where Si parts with high mechanical performances are used, as well as MEMS-based micromechanical systems. For these technologies, the evaluation of mechanical shock resistance of tiny Si parts and determination of the design weaknesses is an important issue.

The state of the art approach consists of "manual" analysis of slow-motion videos acquired with a high-speed camera. Its main drawback is related to inconsistency of the analysis due to the rather qualitative and non-quantitative approach. The proposed approach allows to overcome this limitation by implementing a semi-automated system that performs quantitative data analysis of slow-motion videos. The developed system consists of a specially-designed high-speed camera, synchronized with the existing mechanical shock testing setup (Figure 1). Acquired high-speed videos are analyzed frame-by-frame using a developed post-processing data analysis software that extracts quantitative measurements of deformations on the targeted mesoscale parts. Mechanical stress is calculated from these measurements as a function of time and mechanical acceleration up to the failure of the part. The data is then compared to the theoretical simulations.

The proposed system consists of 4 integrated components:

1) Mechanical shock testing setup that allows conducting mechanical shock test of macro- and mesoscale Si-based parts. The test parameters, such as shock acceleration and shock pulse duration are controlled and logged in-situ using a reference accelerometer.

2) FastEye high-speed camera (Figure 2) developed at CSEM that features a 1 MP image sensor which can acquire full resolution images at frame rates of up to 2 kfps. By combining high signal-to-noise ratios and global shutter pixels, the sensor captures high quality, smear-free images.

Figure 2. FastEye high-speed camera.

3) Frame-by-frame video analysis module. The module is a part of the CSEM VISARD (Vision Automation Robotics Designer) platform that is used to control the camera, to acquire and log the image data, and to perform the data analysis using a dedicated algorithm.

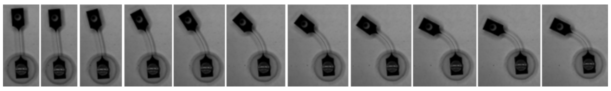

Figure 3. Deformation of a Si-part during the shock test at ~200g. Each next image is taken with a delay of 0.67 ms after the previous one (1500 fps). The total part length is 12 mm. The central beam width is 10 μm.

4) Tunable simulation module, which is applied for theoretical simulation of the behavior of the selected mesoscale parts subjected to mechanical shock. This information is used to support the experimental data and to provide suggestions on possible improvement of the mechanical resistance of the evaluated parts. .

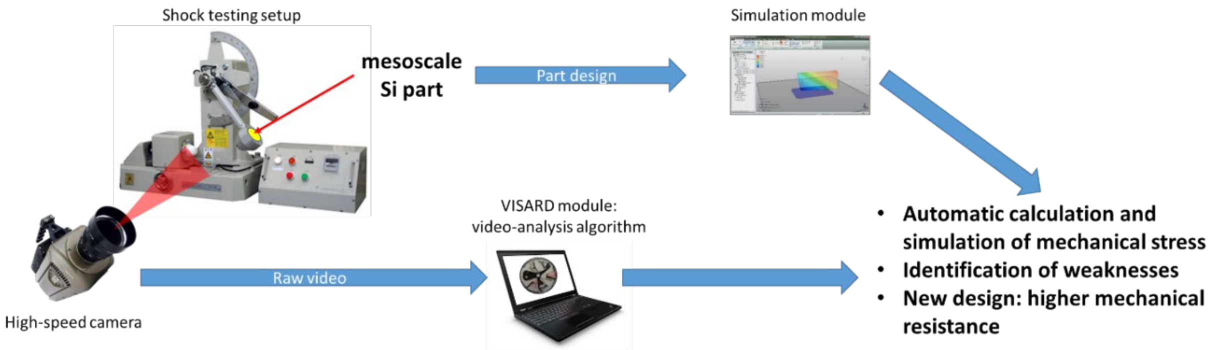

Figure 1: Schematic representation of the proposed system.