Bottom-up modal analysis of a small size machine tool

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Abstract

A bottom-up modal analysis methodology was adopted to specify the performance of a small size machine – the µ4. The modal properties were simulated using Finite Element Method (FEM), measured and analysed in order to improve the mechanical and control design. The goal of this research is to allow free-form manufacturing based on high dynamic performance and sub-micrometre accuracy of the µ4 machine.

The Integ-µ4 machine was conceived in 2008 (Shore and Morantz, 2007) by Cranfield University Precision Engineering Institute as a 6 axes CNC micro-milling machine. The machine specification was aimed to be around the leading capability of diamond turning and micro-milling machines. The overall size of the machine was set as a European scale washing machine in the range of 0.6×0.6×1m volume. The µ4 motion axes were split into two near identical modules thus; each one of the modules can be used as a test rig.

The analysis methodology is a bottom-up process (Figure 1) in which the lowest level components are tested and simulated first, then used to facilitate the testing of higher level components. The modal properties of one of the motion axes modules were simulated using Finite Element Method (FEM), measured and analysed using modal measurement equipment specified and procured for this research. Each component and assembly was supported in free-free conditions (Ewins, 2000) and frequency response functions measured using hammer excitation. The free-free boundary condition was approximately achieved by supporting the components and assemblies on a floating table and a bubble wrap mattress. This method of supporting will allow operating the motion module while measuring, which is more practical than using bungee cables suspension. The body modes were synthesised using stabilisation diagrams choosing the frequency and damping values.

Comparison and correlation between measured and simulated modes was carried out (Figure 2). Each measured mode was identified based on animation movie, which showed the main characteristics of that mode. The identified measured and simulated modal properties of the motion axes module were shown to have a good correlation with less than 15% discrepancy of the frequency values. The results of the modal measurements and simulation will be used to improve the mechanical and control design for a high-dynamic motion control goal.

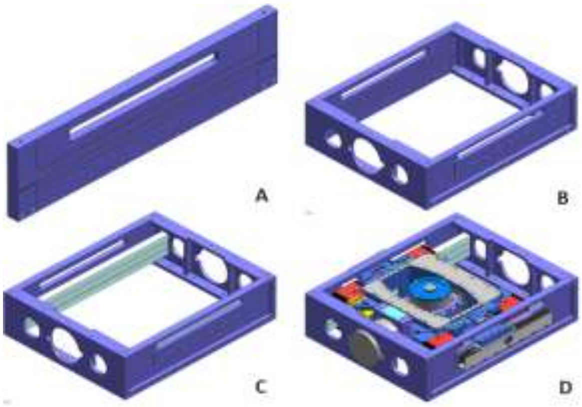

Figure 10 Bottom-up process

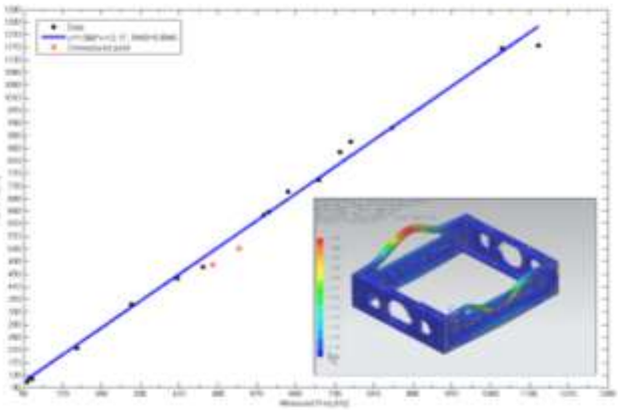

Figure 11 FEM and measurements comparison and correlation

1. Shore, P. and Morantz, P. (2007**)** Integrated Knowledge Centre in Ultra Precision and Structured Surfaces.EP/E023711/1.
2. Ewins, D. "Modal testing: theory, practice and application, 2000", Research Studies Press LTD., Baldock, Hertfordshire, England.