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ANALYSIS OF THE DYNAMIC BEHAVIOR OF THE CNC MACHINE CENTER BY FEM

RÓBERT KISS–ATTILA SZILÁGYI

University of Miskolc, Department of Machine Tools
3515 Miskolc-Egyetemváros
robert.kiss9405@gmail.com, szilagyi.attila@uni-miskolc.hu

Abstract: This note is the first part of an extended research-analysis work, where our aim is to summarize the concepts of the methods and measurements, which we will present in the later articles. The research is focusing on the dynamic behavior of the DMU 40 5-axis CNC machine center, which can be found in the workshop of the Department of Machine Tools. This means that we would like to determine the magnitude of the dynamic stiffness of the machine tool, by calculating the value of the natural frequencies by final element method (analytically, and with software), and with the help of an experimental test.

Keywords: *natural frequency, DMU 40, FEM, analytical method, dynamic stiffness, ANSYS WB 19.1*

1. INTRODUCTION

The dynamic test was based on a 5-axis CNC machining center, which located in the department's workshop. The *Figure 1* is shown the machine tool catalogue picture, and the figure of the machine tool without paneling. We will perform the differential mechanical tests on the machine tool shown in this picture. The analysis may be performed by calculation or measurement, which are detailed in the followings.

Figure 1. DMU 40 CNC machine center catalogue image, and without paneling [1]

Basically, we can distinguish between three types of tests:

- Final element method in an analytical way,
- Final element method by software (ANSYS WB 19.1),
- The experimental determination of natural frequencies.

2. A BRIEF PRESENTATION OF EACH TYPE

In this chapter we present the fundamentals of the different types, on the basis of which we carry out the subsequent examinations. It is explained in more details later in the article.

2.1. Analytical method

Because of the complexity of the physical world, models need to be set up to describe the phenomena, embodying important properties for the analysis. The most important models in the mechanics like the rod, plate, point and rigid body models. In the mechanical vibration fields, more abstract models can be set than in other areas of mechanics. Establishing the motion equation system is the most difficult task in this process, after the setting up a vibration model. *Figure 2* shows the process of this method.

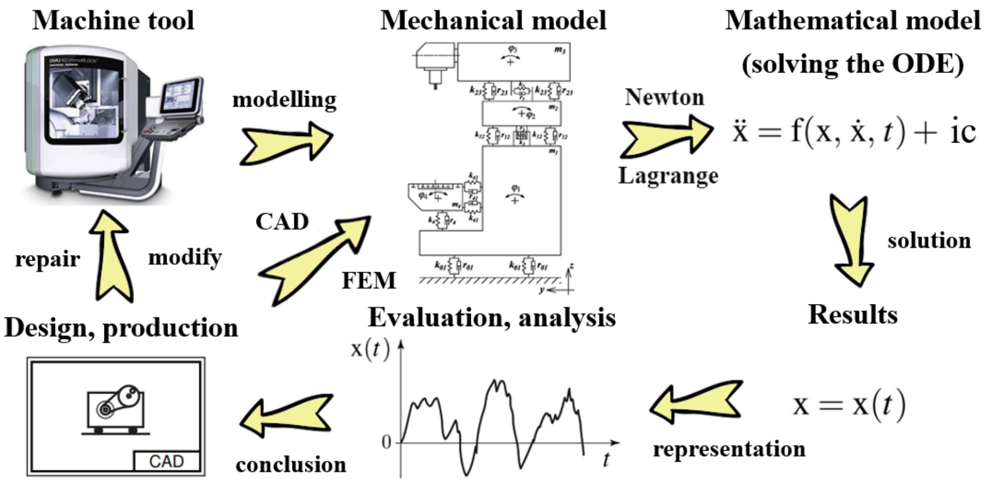

Figure 2. Process of engineering solutions for vibration problems [3]

The main steps of the process:

1. Establishing the mechanical model of the machine being tested.
2. Setting up the mathematical model based on the mechanical model (the motion equation is specified in the form of a differential equation system).
3. Solve the obtained motion equation with some mathematical method.
4. Plot the results with the help of diagrams, then analysis, evaluation.
5. Conclusions, modification of the machine or technical plan under examination based on the results of the examination.

During the analysis we can check the results obtained and the correctness of the mechanical model. Many of the unknowns in the FEM model make it difficult to track the effects of the parameters.

In the first phase of the product design, kinematic and dynamic analysis of the motion of each machine is essential. Even with simple models, the motion equation of the system is complicated. Typing and solving of the mathematical model with classical methods (Newton–Euler, or Lagrange equations) for systems with higher complexity is almost impossible. Therefore, in recent decades, multi-body procedures have spread to deal with such cases, as they are suitable for creating a computer code that automatically writes and solves motion equations for a particular machine system.

2.2. Final element method by software – ANSYS WB 19.1

One of the most commonly used finite element method (FEM) for solving mechatronic tasks is the structural analysis. Mechanical engineering refers to the examination of mechanical elements during structural analysis, which may be a part of a machine, a lathe or a whole vehicle. In the calculations, the unknown displacement is calculated primarily and the additional quantities, elongation, tension and reaction force, can be derived for instance.

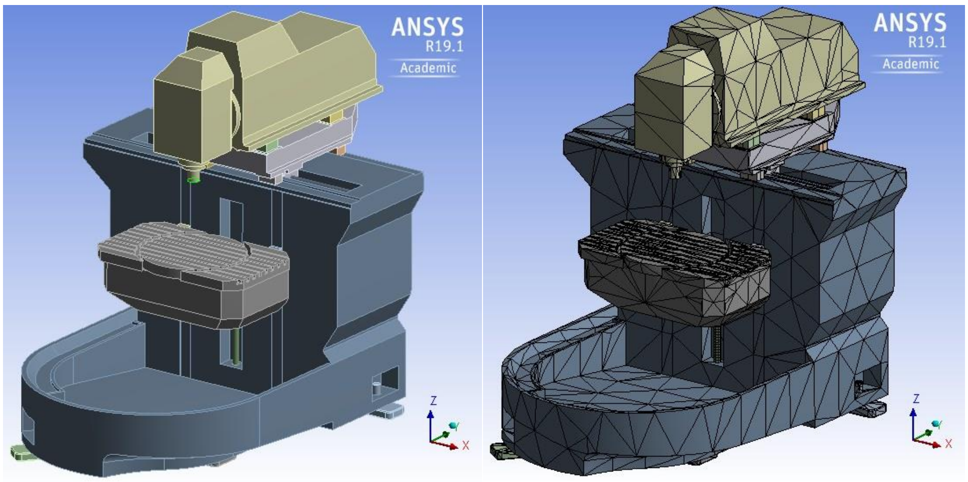

Figure 3. The 3D model in ANSYS

<u>Possible types of the most important FEM analysis:</u>

- <u>Static analysis:</u> It can be used to calculate permanent deformation or tension due to time-independent loading. However, the model may include time constant inertial loads (like angular velocity, or gravity), time varying effects (slow change of load) or time-dependent change of material (crawl).
- <u>Modal analysis:</u> It can be used to calculate the vibration characteristics of the test structure and to calculate the individual natural frequencies and to represent their oscillations, more detailed dynamic studies (e.g. transient dynamic, harmonic or spectral analysis) can serve as a basis.

- Harmonic response: It is used to determine a steady response to cyclically variable excitation in time. The analysis ignores transient phenomena the beginning of the load. It can predict the long-term dynamic behavior of the examined structure, examine the phenomenon of fatigue and resonance. The results of the test are summarized in the amplitude-frequency diagram.
- Spectrum analysis: An extended version of modal analysis. Determines the stress, response spectrum, or deformation given to the input of random vibration.

2.3. The experimental determination of natural frequencies

The determination of the frequencies of the different machines and equipment is important from several points of view, as the resulting error can be recognized in time and it can help to repair and re-design the equipment under examination, as well as to clarify the diagnosis established during the vibration test. On the basis of machine vibration, we can get a comprehensive idea of the machine state and the current state of each machine part.

In the field of vibration diagnostics, three typical test procedures have spread:

- bearing vibration test,
- resonance test,
- motion animation test.

In the future, we will deal with the resonance test, the other two types of which can be distinguished in practice by the applicability procedure. One type is the stop-ups analysis, which is the resonance frequency determination method for rotating machines, while the other is the external excitation study, which is used for machine tools, and applicable to motor vehicles. *Figure 4* shows the compilation of the above-mentioned external excitation study, which will be described in detail later.

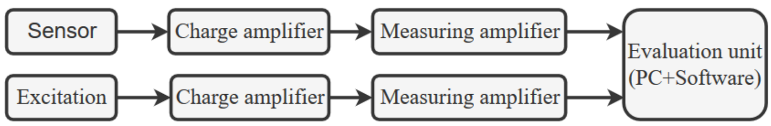

Figure 4. Sketch of a measurement assembly

3. Summary

Based on the methods described above, various tests can be performed to determine the dynamic stiffness of the selected machine tool. In order to achieve the most precise production and to achieve the best surface quality, it is necessary to avoid the operation of the machining center at its natural frequencies and in their surroundings during machining.

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