SOFTWARE DEVELOPMENT FOR DYNAMIC BEHAVIOUR ENHANCEMENT OF MILLING PROCESS

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Abstract. *Chatter vibrations can appear in machine tools under determinate cutting conditions and are a limiting factor to increase the productivity of machining processes. These vibrations reduce the tool life, worsen the superficial finishing and can damage the machine. To avoid them, machine operators reduce the spindle rotation speed or the axial depth of cut, resulting in diminished operation productivity. The objective of this work is the development of computer software to help the non-specialist machine dynamics user to get the experimental data to implement a method to predict the emergence of these vibrations in milling operations, enabling him to select cutting conditions with stable cutting end maximum productivity.*
Keywords*: Milling, vibration, chatter, software.*

1. INTRODUCTION

Machining operations are applied to remove material from the workpiece. The most common are milling, turning and drilling, followed by special operations like boring, forming and broaching. Due to the cutting forces and machine movements, summed with the lack of material homogeneity and machine compliance, vibrations naturally appear during the operation. If these vibrations achieve excessive amplitude, become one of the more critical factors relating to the lack of machining process productivity. The excessive vibrations are called chatter and accelerate the cutting tool wear, cause bad workpiece surface finishing, produce noise and can also damage machine tool components, like spindle and bearings. In order to avoid chatter, operator use to reduce spindle rotation speed or the depth of cut, diminishing the productivity. Nevertheless, it is known by decades that increasing the spindle rotation speed can eliminate the problem. Obviously, this procedure not always works and in some cases can aggravate the problem. The ideal condition is to work at these high speeds where the cut is stable, because the productivity increases. The question is: how to know the ideal cutting conditions?

The objective of this work is to develop software, called FRESAMAX, which will help its user to get the various experimental data in order to discover these stable high speeds. The user doesn't need to be a machine dynamics specialist, because all the calculation is transparent to him.

2. CHATTER

Machine tool chatter vibrations are due to a self excitation mechanism which occurs during the chip generation in machining operations under certain conditions. This phenomenon is easily reckoned because leaves characteristic marks in the workpiece surface or by the generated noise. Figure 1 helps to understand its cause: one of the vibration structural modes of the system composed by milling machine, tool and workpiece is excited by a periodic cutting force. A waved surface is produced by one tooth, which is removed by the next tooth, which also leaves a waved surface. The chip has a dynamical thickness, resulting in oscillatory cutting forces, whose amplitude depends on the instantaneous chip thickness. The growing vibration increases the cutting forces and the system becomes instable and chatters till operator stops the machine to avoid tool breakage, due to the excessive forces. So, chatter continues to be a limiting factor to achieve higher material removing rates in machine tools. Regarding chatter, the most important cutting parameter is the depth of cut a_p, according to Smith and Tlusty (1990). Using small values, the cut is stable, free of chatter. Increasing the depth of cut, chatter securely will appear above a value, which is called limit depth of cut (a_{plim}). Above this value, chatter tends to grow continuously. According to Budak and Altintas (1998), Tobias (1965) and Koenigsberger and Tlusty (1967), chatter is caused by two main mechanism: mode coupling and "waviness regeneration". In the most of machining operations, the second one appears firstly, as explained in Altintas (2000). It is regarded the most important in milling, because several teeth cut the workpiece during one revolution of the tool, increasing the effect of waviness regeneration and creating favourable conditions to start chatter.

3. FRESAMAX VERSION 1.0

The following methodology was applied to the software creation using Java® language, divided into four stages. Firstly, the main interface was elaborated, containing general information, menus and links to the help section and modules which compose the software. The second stage was the development of KMAT module, whose function is to

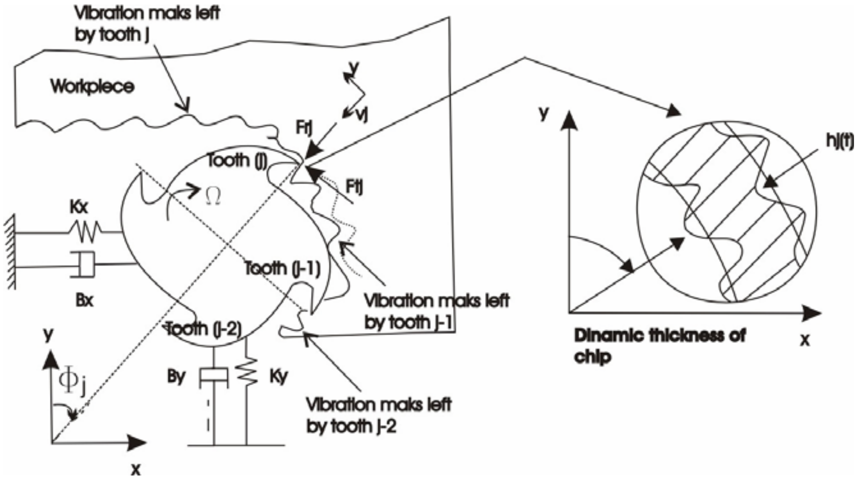

Figure 1 - Two degree of freedom milling model with self excited vibrations. Extracted from Altintas (2000).

get the specific cutting pressure of the workpiece material and the tool geometric constant. It has an assistant to guide the user during the experimental data acquisition with Lab/view® software. The raw data are processed and the constants are calculated without user interference. The third stage consisted in the creation of the KDIN module, whose function is to get modal parameters of the system formed by workpiece, tool and milling machine. There is an assistant to guide the user during the experimental data acquisition with Lab/view® software. The fourth stage utilizes these data in order to generate the stability chart to the specific combination of workpiece material, tool and milling machine. The calculation is performed with the GNU Octave mathematical program (http://www.octave.org). These stages were planned in order to automate to the maximum all the steps presented in Lima (2003). This author manually implemented the method of Budak and Altintas (1998b) utilizing LabView® and Matlab® software. This method requires solid knowledge from machine dynamics, system parameters identification and mathematical analysis. The objective of this software is to help an engineer to get all the experimental data and to show him the final result, a graphic depth of cut versus spindle rotation speed, called stability chart. This chart indicates cutting parameters where coexist stability and high productivity. Data processing and calculation are invisible to the user.

3.1 Interface and Modules

The software presents a simple and friendly interface with a link to the Help section, which explains in detail each module function and also contain equipment manuals in pdf format. There are also links to the four modules, called KMAT, KDIN, KFT and CALC, as can be seen in the Figure 2. When the user passes the mouse pointer over one of the boxes, a short explanation is given about that module. The text inside some figures is in Portuguese because it is Brazilian software. The translations are given in the figure captions.

The modules KMAT and KDIN conduct the user into the data acquisition stages to get important data for analysis and prediction of milling chatter. The LabView® software is started automatically into virtual instruments specially created to make easy each task. The acquisition parameters have default values which can be altered by the user, if necessary. The user indicates the combination of machine, tool and material which is being tested. The experimental data are acquired, processed and the results are stored in a data bank for future consultation.

Clicking on the “KMAT” box in Figure 2, appears the screen shown in the Figure 3. This module has the function to help the user to get the specific cutting pressure (K_r) of the workpiece material and the tool geometric constant (K_t), previously cited. More details about these constants can be found in any book about machining, like in Trent (1984). Figure 4 show two screens from the “Help” of KMAT module. There are detailed step by step instructions to help the user to make the test specimen and to assemble and setup the equipment. There are also photos and schemes to avoid errors in order to easily get reliable data. Observe in Figure 4(b) the button which starts LabView® software to initiate the data acquisition with the virtual instrument shown in Figure 5. The test specimen milling is started by machine operator. The cutting forces in the X, Y and Z directions are measured by the dynamometer which sends a voltage signal to the data acquisition board inside the computer. The values are stored in a data file for posterior processing. Figure 6 shows the calculated constants. Following, there is a confirmation to save the results in the data bank.

Figure 2- User Interface, with links to the four modules and Help. Translation: "Initializing FresaMAX…Choose one of the options: / Modules description: In KMAT module, the constants K_t (specific cutting pressure) and K_r (tool geometric constant) are obtained. / Exit. Help. KMAT. KDIN. KFT. CALC".

Figure 3 - KMAT module main screen. Translation: "Fill data for constants K_t and K_r acquisition./ Material: name and specification./ Tool: type, teeth number, diameter, specification, type of milling: up milling or down milling./ Back, Clear, Next stage".

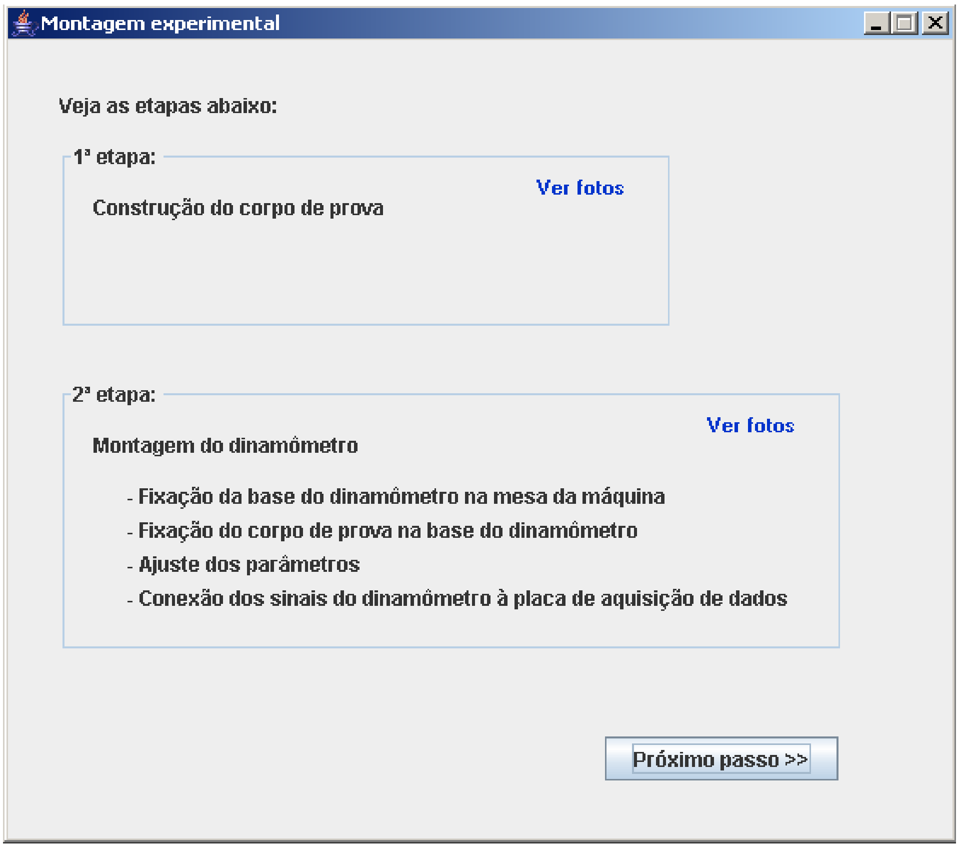

Figure 4(a) - KMAT module “Help” screen. Translation: “Experimental assembly. See the following stages: /1st stage: Test specimen fabrication (See photos). /2nd stage: Dynamometer assembly./ - Dynamometer base assembling on machine table; - Test specimen attachment on dynamometer base; -Parameters setup; - Dynamometer signals connection to the data acquisition board. / Next stage”.

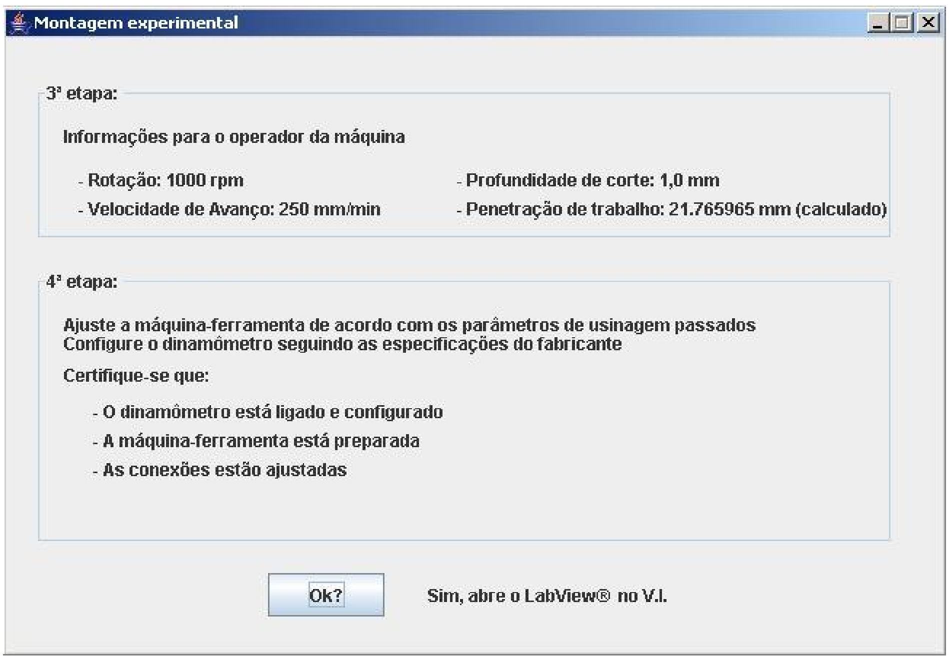

Figure 4(b) - KMAT module “Help” screen. Translation: “Experimental assembly. / 3rd stage: Information for machine operator: - Rotation speed: 1000rpm; - Feedrate: 250mm/min; - Depth of cut: 1.0 mm; Radial immersion: 21.8 mm (calculated). / 4th stage: Setup the milling machine accordingly with the informed machining parameters. Setup the dynamometer following the dealer instructions. Certify that: - The dynamometer is on and fitted; - The milling machine is ready; - The connections are fitted. OK? Yes, open LabView® on the proper virtual instrument.”

Figure 5 - LabView® virtual instrument. Translation: "Virtual instrument for milling forces acquisition".

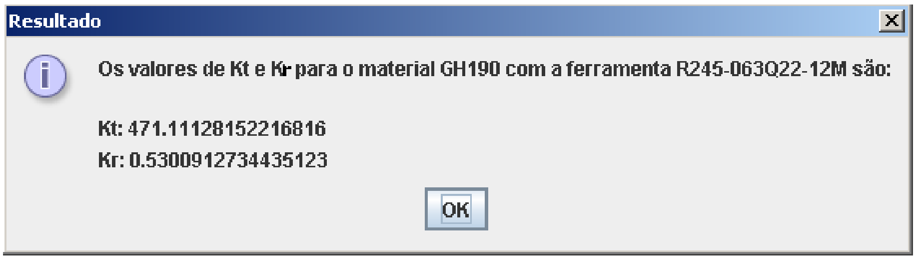

Figure 6 - KMAT module results. Translation: "The results of K_t and K_r for GH190 material and R245-063Q22-12M tool are:"

The KDIN module does the acquisition of the impulsive force signal applied by the impact hammer and the resulting structure vibration, measured by an accelerometer, using the LabView® software. The identification procedure consists in an impact tests sequence. The chosen points for hammer impacts and vibrations measurement are the tool tip and the spindle main bearing, because they have good sensibility for vibration analysis, as pointed in Sousa (1998). Clicking in the box called "LabView" at the module interface, a virtual instrument is open, giving clear instructions to the user in order to initiate the procedure. There are various default acquisition parameters which can be altered by the user, if necessary. Each impact test generates the corresponding data file.

Figure 7 shows an impact being applied with the hammer at the tool tip. Figure 8 contains an example of the measured impulsive force and one example of the resulting acceleration is shown in Figure 9.

The KFT module utilizes data acquired with KDIN module to calculate the natural frequencies, damping factors and residues of the milling machine / tool adaptor system, using a method called RFP (Rational Fraction Polynomials), whose details can be found in Richardson and Formenti (1982). The calculation is made by a program created with GNU Octave software.

Figure 7 - Impact applied at the tool tip.

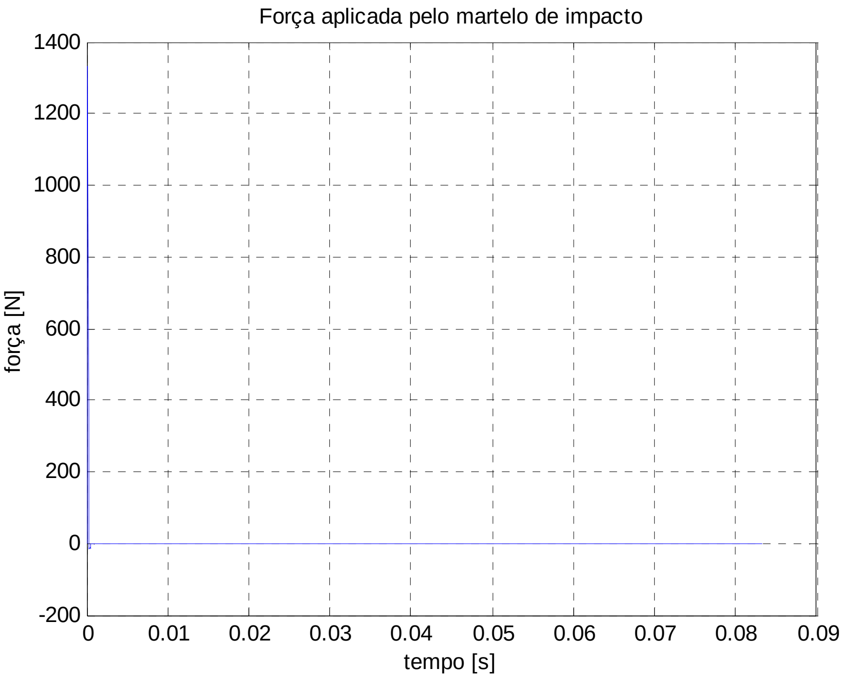

Figure 8: Impulsive force applied by impact hammer.

The program is started by a computer system call and the generated LabView® file is passed on as a parameter. The GNU Octave works in background and doesn't call the user attention. In order to store data, the freeware tool "Prevayler" (http://www.prevayler.org) was used with success. It dispensed the use of data bank software, simplifying FRESAMAX. The module CALC utilizes experimental data and calculation results to compose the stability chart to the milling machine – tool adaptor – workpiece system, using the method described in Altintas (2000).

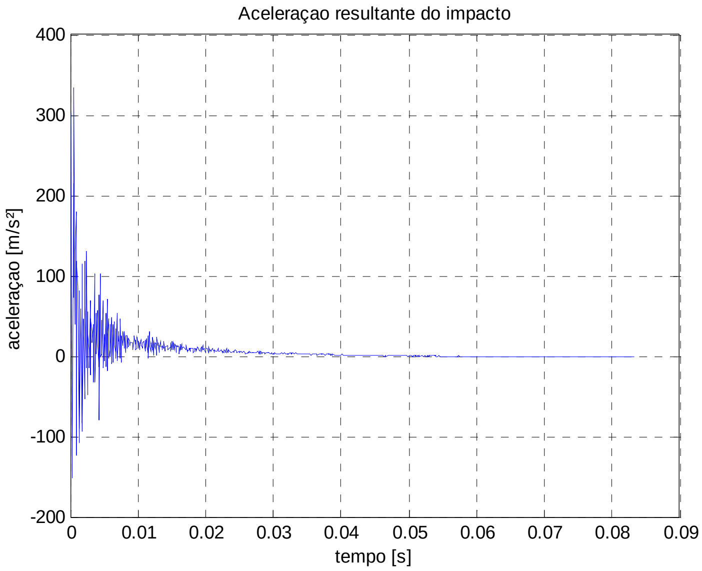

Figure 9 - Resulting acceleration.

4. CONCLUSION

The software was developed using modules to improve its efficiency and to facilitate its implementation. There was also a requirement to have a friendly and easy interface. The Java® language was used with the concepts of the object oriented programming in its construction. The data processing and other calculation were made through GNU Octave programs. Before using FRESAMAX, it is necessary to acquire a computer with a data acquisition board and LabView® software. It is a disadvantage, but the authors had no alternative. All the results can be retrieved by the user, dispensing the repetition of the tests to the same combination of milling machine – tool adaptor – workpiece. It is important to remember that the stability chart is valid only to this combination. All the experimental data was seamless acquired and the results were obtained correctly. The milling machine dynamic characterization was partially automated. This stage needs posterior research in order to give more easiness to the user. The actual stage is the software testing.

5. ACKNOWLEDGEMENTS

The authors express gratitude to FAPEMIG (Minas Gerais State Fundation for Research Support) for financing this research, project TEC_930/2003. The first author thanks CNPq (National Council for Scientific and Technological Development) for financial support. The second author thanks CNPq for financial support through PIBIC/UFU/CNPq program.

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