Estimation of Cutting Tool Life by Varying Cross Feed with the Knowledge of Actual Cutting Force Acting On It

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Abstract - *Mechanical components and machines are developed to perform their specified task allocated it, because of scarcity of raw material and from the view point of better efficiency it is essential to optimize the existing design of machines and its components. For design optimization it is essential to determine the operating load. For practical situations in many cases, it is not possible to measure directly the operating loads by any type of transducers in case of impact type. A most probable way to approach to this problem is indirect method of measurement of force acting. The indirect method of determination of force includes the determination of structure responses which can be measured by using sensors and LABVIEW, and obtaining the FRF matrix. The FRF matrix and the response of the component give us the force acting on the component which is greater than the theoretical value. The estimation of tool life is done by using the force obtained by indirect method which is lower than the life obtained by the theoretical force.*

Key Words: Time and Frequency Domain Analysis, FRF, Inverse Identification of Force, Cross Feed, Tool Life

1. INTRODUCTION

The force estimation is one of attentive inverse problems and is significant for engineering design and presentation. Information of the input force on mechanical structures is advantageous to the design and task of the system. Here are abundant instances presenting the requirements for the prediction of applied forces to mechanical structures, that is the cutting forces of mechanical structures such as machine tools, forces in engine and forces in bearings. In certain, the destruction of composite structures exposed to impact forces is not simply noticeable; hence, the estimation of the force location can short down the struggle in relating other inspection technique all above the mechanical structures. Approximating load by direct measurements for mechanical structures those are in procedure is in practice its difficult, because the impact locality is unapproachable. The problem of recognizing impact force on mechanical components is the converse of the direct problem the usage of measured reactions on a given mechanical structure to insulate the causes, that is, the apprehensive impact forces. Method needs to produce either numerically or experimentally, Transfer functions among the measurement points on the structure and the impact so as to measure the reactions, then to obtain the load by de-convolution of the signal. It is acknowledged that this type of problem is ill conditioned. To get a stable solution, it is essentially be steadied using conventional regulation techniques, such as by using Tikhonov method. Problem of describing the impact converts more complex once the impact location is unidentified so it is essential to generate the transfer functions between several impacts, and minimize the objective function, which can identify the force impact history. Inverse technique of force identification using measured structural responses is one such alternative method to identify the dynamic forces. The inverse technique has many wide verities of applications some of which are load estimation as in the case of vehicle structures and machines etc. In this paper work an attempt is made to determine the shaper machine cutting tool life by varying cross feed by the use of inverse technique for the identification of operating forces on a structure or a machine from the measured vibration responses.

2. THEORETICAL FORMULATION

The force acting on the tool is analysed as an inverse identification of impact force which leads to estimation of tool life.

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2.1 Time Domain Analysis

The time domain analysis refers to the recording of response of mechanical structure to the applied input force in correspondence to the time. The domain analysis gives the time history of response of the mechanical structure

The response of the mechanical structure to an impact can be considered to be directly dependent on the applied impact force.

In these cases the response at point on the body can be related to impact force by linear convolution integral technique as.

$$x(t) = \int_0^t h(t-\tau) f(\tau)\, d\tau \quad (1)$$

Where the h(t) is the impulse reaction function of the linear method and it is expected that f(t)=h(t)= a(t)=0 for t<0. The basic structure for de-convolution is to discretize the Equation (1) in to algebraic equations in-the time domain such as

$$a(t) = f(t) * h(t) \quad (2)$$

Where the '*' symbol specifies a mathematical convolution. The convolution sign is a short way of writing the convolution integral.

2.2 Frequency Domain Analysis

In frequency domain, the acquaintance relation to Equation (1) can be found by taking the Fourier transforms of the variables, such as.

$$\{A_j(\omega)\} = \{F_i(\omega)\} * [H_{ij}(\omega)] \quad (3)$$

Where

$$A_j(\omega) = [A_1(\omega), A_2(\omega) \ldots \ldots A_n(\omega)]^T \quad (4)$$

$$F_i(\omega) = [F_1(\omega), F_2(\omega) \ldots \ldots \ldots F_n(\omega)]^T \quad (5)$$

$$H_{ij}(\omega) = \begin{bmatrix} H_{11}(\omega), H_{12}(\omega) \ldots\ldots H_{1m}(\omega) \\ H_{21}(\omega), H_{22}(\omega) \ldots\ldots H_{2m}(\omega) \\ \vdots \\ H_{n1}(\omega), H_{n2}(\omega) \ldots\ldots H_{nm}(\omega) \end{bmatrix} \quad (6)$$

The functions H_{ij}, A_j and F_i denote the Fourier transform of the $a_j(t)$, $f_i(t)$ and $h_{ij}(t)$ respectively, and the transpose of the matrix is indicated by super script T. The ω indicates the radian frequency. Therefore convolution in time domain is converted in to exponentiation in the frequency domain. The only assessable quantity in the force identification problems is a(t) or A(ω) [2].

2.3 Frequency Response Function.

The frequency response function is basically the ratio of the output response of a mechanical structure due to an applied input force. We measure together the response of the structure and the applied force simultaneously. FRF is a complex valued function of frequency domain.

$$H(\omega) = \frac{A(\omega)}{F(\omega)} \quad (7)$$

Measuring the response of the tool during working of machine and by using the relation

$$H(\omega) = \frac{A(\omega)}{F(\omega)} \text{ finding } F(\omega) \quad (8)$$

To get Inverse force we have to perform IFFT on obtained F(ω)

3. EXPERIMENTAL WORK

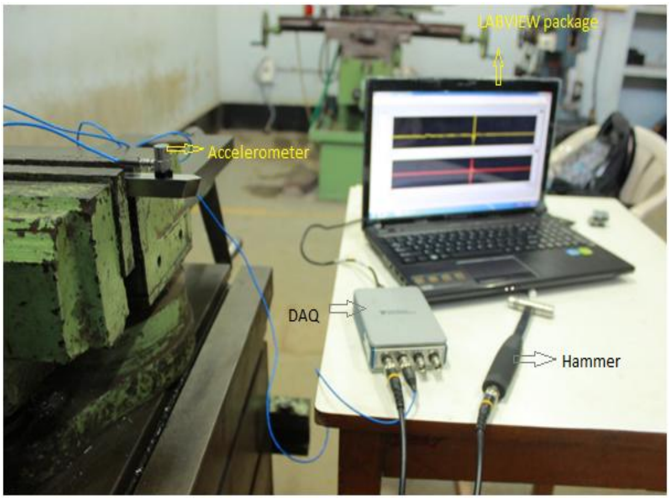

Fig -1: Experimental set-up for FRF extraction

Figure.1 shows an experimental setup for obtaining the time and frequency history of the tool. It consists of HSS cutting tool of size 12mm × 12mm × 150mm shaper cutting tool which is held firmly in the vice. An Accelerometer is firmly mounted on the tool by applying wax. Accelerometer is in turn connected to Lab-VIEW

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software through Data Acquisition System. An impact hammer which consists of sensor is also connected to Lab-VIEW software through DAQ. An appropriate circuit which reads samples is developed. Figure 3 shows the Acceleration and Force time history. A MATLAB code which performs the calculation and generates FRF is used to obtain tool FRF. Obtained FRF sample is shown in figure.4

Fig -2: Accelerometer mounted on the tool during working of machining

As shown in above figure the accelerometer is mounted at distance of 20 mm from the tip of tool. The work piece is 10mm thick and made of mild steel material. Speed of shaper machine is kept constant and depth cut is also kept constant at 1mm. By the use of Lab-VIEW software and accelerometer due to impact is recorded for 3 seconds.

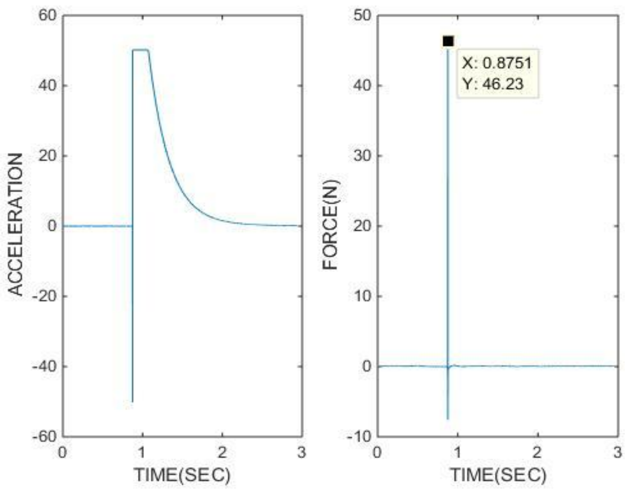

Fig -3: Acceleration and Force time history

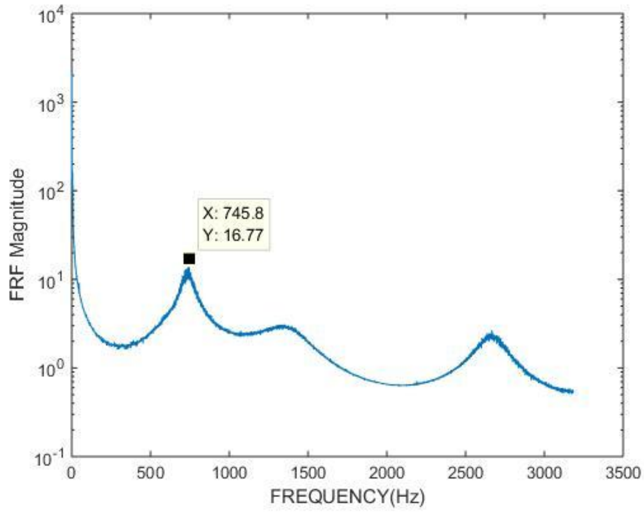

Fig -4: FRF of the Tool obtained.

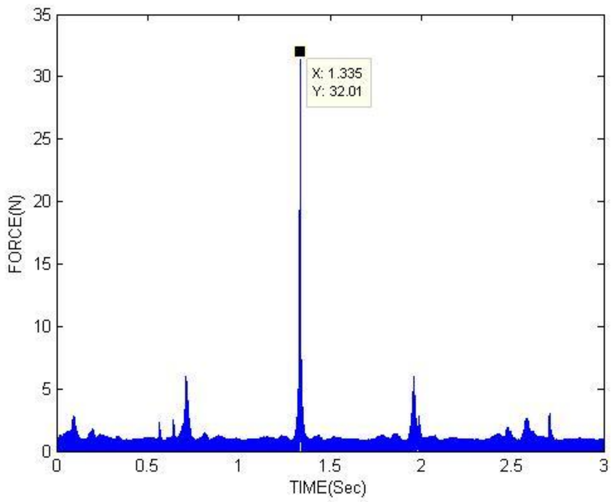

Fig -4 Predicted Force from MATLAB code.

4. RESULTS AND DISCUSSIONS

The force acting on the cutting tool is indeterminable by the direct method of determination of force. Hence the force can be estimated by the inverse technique which uses the best FRF among a set of FRFs collected from a series of experiments and acceleration response of the tool during machining. Hence we can predict the actual force acting on the tool. These obtained forces are validated by comparing it with the theoretically obtained forces as shown in below table.1

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Table -1: Comparison of Theoretical and Experimental Cutting Force

Cross feed (mm)	Depth of cut (mm)	Experimental force (N)				Theoretical force(N)	% Error in force
0.2	1	32	32.6	32.4	32	26.54	17.06
0.3	1	40.1	40.7	39.3	40	35.25	11.87
0.4	1	52.3	52.3	51.4	52	43.12	17.07
0.5	1	54.7	55.3	54.6	55	50.41	8.033

The main object in the experiment is varying the cross feed by keeping the depth and speed constant. The forces obtained from the experiment and the theoretical force the life of the tool is estimated and compared which is shown in below table. Hence an average error in force of 45% is observed

Table -2: Comparison of tool life for various feed

Cross feed (mm)	Cutting Force (N)		Tool life in strokes		Difference in tool life	% Reduction
	Theoretical	Experimental	Theoretical	Experimental		
0.2	26.54	32	9,39,723	7,34,514	2,05,209	27.93
0.3	35.25	40	8,03,526	6,94,864	1,08,662	15.63
0.4	43.12	52	6,54,379	5,94,155	60,224	10.13
0.5	50.41	55	5,57,956	5,52,896	5,060	.91

5. CONCLUSION

There is a very high difference between identifying the static force and dynamic force. Dynamic force often associated with inaccessible type, because of difficulty of direct measurement. Hence we can obtain the dynamic force by the frequency response function obtained and the acceleration caused by it. The force acting on the tool is dynamic type, because of the engagement of the tool tip with the cutting we cannot access force by placing the load cells or any devices, for measuring this type of force we can use the inverse identification technique which can be done by modal analysis which uses the FRF of the tool and the response of tool during machining by using this force life of tool is estimated. It is seen from the results obtained he experimental force is 1.9 times the theoretical force. It is observed that as the cross feed increases the tool life goes on decreases. It is observed that the tool life is reduced by 16% as compared to tool life obtained by theoretical method.

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BIOGRAPHIES

Akhil A. Deshpande is currently working as Assistant Professor in Department of Mechanical Engineering at KLS's Gogte Institute of Technology, Belagavi. He has completed his M.Tech. in Machine Design from KLS GIT, Belagavi. He has presented seven papers till date in various International Conferences and International Journals. He is presently working on LabVIEW software.

Mr. Shrinivas Laxmanrao Gombi has completed his graduation in Bachelor of Engineering in Mechanical Engineering in the year 1984 from Gogte Institute of Technology; Belgaum affiliated to Karnataka University Dharwad. He joined his Alma meter as Lecturer in the same year. He was awarded Gold Medal for having obtained the first rank in his Post Graduation in Diploma in Business Management in the year 1988. Later in the year 1990 Mr. Shrinivas Laxmanrao Gombi was awarded with Master of Technology degree from one of the most prestigious institute of India, the Indian Institute of Technology, Mumbai. Mr. Gombi is pursued his PhD in Structural Dynamics from JNNCE, Shimoga. He has chosen Design Engineering as his area of specialization. Presently he is working as Professor in the department of mechanical engineering of Gogte Institute of Technology; Belgaum.

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