VIBRATION ANALYSIS FOR FAULT DETECTION OF FLUCTUATING CUTTING TOOL BY EXPERIMENTALLY AND ANALYTICALLY

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Abstract— **The vibration analysis demonstrated to competent tool for finding mechanical defects. The main objective of this analysis is to identify a problem within a machine and then take some action. Fluctuating cutting tool has an application of the surgical sector. Due to this application type instrument, should has a smooth working feature without any disturbance. But this instrument has a problem of excessive vibration, and heat ultimately comes in the system. The use of faulty power tools will be harmful to a human being. And also, this power tool functioning for a long time, there might be a chance of fatigue failure. The finite element approach is using to validate the vibration analysis.**

Keywords— **Vibration, Vibration Analysis, Fluctuating Cutting Tool, Mechanical defects, Finite Element Approach,**

I. INTRODUCTION

Almost all machine vibration is due to one or more of these causes are Unbalance, Misalignment, Looseness, Bearing Faults and Resonance [1,2,3,4,5,6,7,8]. Monitoring the vibration characteristics of a machine gives us a better understanding of the condition of the system. We can utilize this data effectively to find out the defect that might be arising.[5,9,10] Run the system until its breaks are not affordable if the capital cost of the machinery is too high. If we carry condition monitoring, then we will find out the defects that might be arising in the system. If we do not do condition monitoring to detect unwanted vibration, then failure will occur. Condition monitoring detects probably harmful vibrations, and ultimately it saves time, money, and frustration. [5,9,10,11] And also, the finite element approach used to validate the vibration analysis. [12,13,14]

II. FLUCTUATING CUTTING TOOL

The test specimen is a fluctuating cutting tool. It is specially used for the bisection and also cutting for other hard tissue. The Cutting tool is fluctuating by the electric motor. The fluctuating cutting tool is used only for different types of surgeries. The main objective behind the design of this tool, it should be used in replacement surgery. The following are some advantages of the tool they are, dynamic, weightless, precise working, and fewer efforts required for the surgeon. The tool is electric battery-powered device, which is very practical and allow more freedom of movement due to the absence of cables. The shape of the fluctuating cutting tool is gun shape, which provide more comfortable for a surgeon to use, especially during long operations. The autonomy of battery of tool is more than other one.

III. EXPERIMENT AND RESULT

Experimental Setup and Vibration Measurement –

Experimental analysis is done to achieving the objectives of (a) Finding frequency response curves to detect the dominant frequency and related peak values. (b) Determination of overall vibration level of the system. For both purposes, we develop the proper experiment setup with the FFT analyzer and data acquisition system. The experimental system contains a tool as a test model. The tool is fixed by the gripper during the testing.

We collected the vibration data using the Piezoelectric accelerometer with a sensitivity of 10.1 mV g in a frequency range up to 2 kHz. Vibration measured in the vertical directions was dominant compared with the other two directions; hence we are only used to characterize the health of the machine tool. The accelerometer signals were taken to PC via the LAN-XI TYPE- 3050 data acquisition

card system using LabShop software. The measurement is taken on the specimen for different speeds. From the FFT and data acquisition system Frequency domain (Spectrum) graph obtained.

The peak frequencies appeared in the amplitude-versus-frequency spectrum, and all the speeds measured and they are found to be 80 Hz, 165 Hz, 185 Hz, 220 Hz, 240 Hz
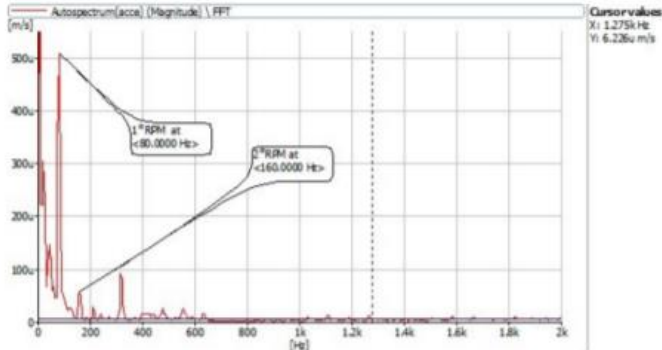

Fig. 1. Frequency domain data at 4800 rpm

Dominates frequencies are-
1*RPM at 80 Hz (4800 RPM)
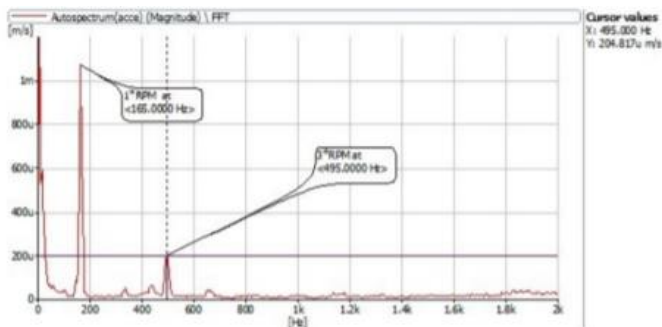2*RPM at 160 Hz (9600 RPM)

Fig. 2. Frequency domain data at 9900 rpm

Dominates frequencies are-
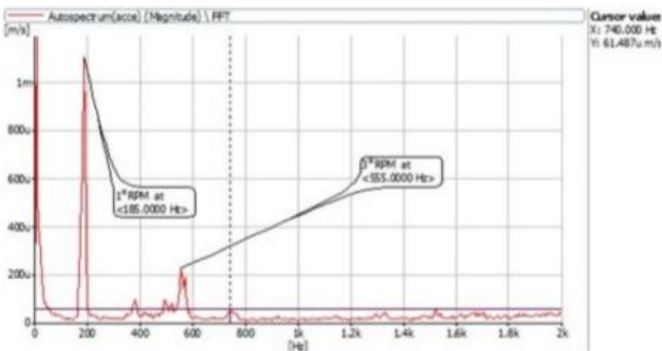1*RPM at 165 Hz (9900 RPM)
3*RPM at 495 Hz (29700 RPM)

Fig. 3. Frequency domain data at 11100 rpm

Dominates frequencies are-
1*RPM at 185 Hz (11100 RPM)
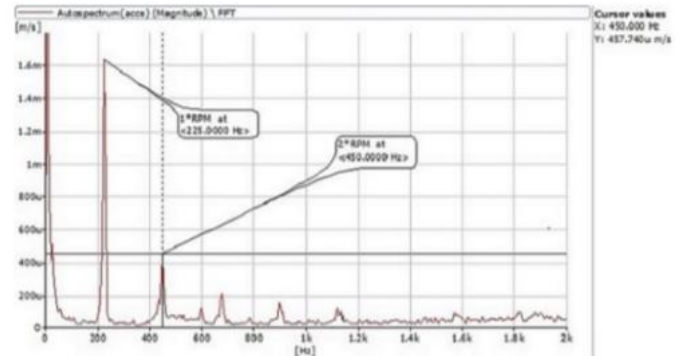3*RPM at 555 Hz (33300 RPM)

Fig. 4. Frequency domain data at 13500 rpm

Dominates frequencies are-
1*RPM at 225 Hz (13500 RPM)
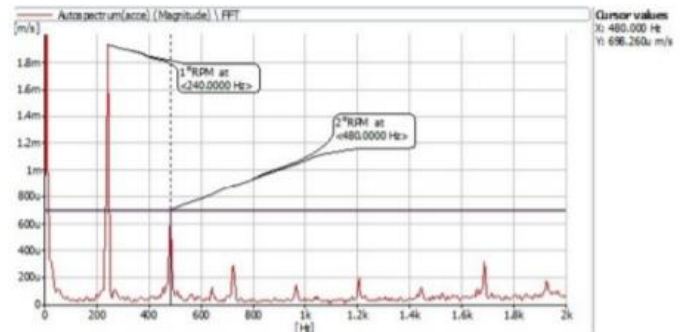2*RPM at 450 Hz (27000 RPM)

Fig. 5. Frequency domain data at 14400 rpm

Dominates frequencies are-
1*RPM at 240 Hz (14400 RPM)
2*RPM at 480 Hz (28800 RPM)

Forces generated inside the fluctuating cutting tool cause vibration. Sources of vibration in tool cloud be misalignment of couplings, unbalance of rotating components, looseness, resonance

Sr. No.	Speed	Fundamental Frequency (1* RPM) Hz	2*RPM (Hz)	3*RPM (Hz)
1	4800	80	160	-
2	9900	165	-	495
3	11100	185	-	555

| 4 | 13500 | 225 | 450 | - |
| 5 | 14400 | 240 | 480 | - |

Table. 1. Experimental readings

It is found that spectrums are same. But dominant peak is observed at 1*RPM, which shows that system has same unbalance as well as misalignment issue. Also, it is observed that, peaks are appeared at 2*RPM, 3*RPM, so it may be problem of mechanical looseness.

IV. FINITE ELEMENT APPORACH AND RESULT

To analytical calculate mode shape and natural frequency of fluctuating cutting tool the ANSYS WB 19.0 is used. First Prepared model of Fluctuating tool with and without attachment of blade by use of Solid works RX 2015.

A. Modal Analysis-

In the modal analysis, First, update the required materials in engineering data of Workbench 19.0. properly meshing the geometry and give the proper contacts between two parts. For meshing purpose triangular and quadrilateral elements are used. Then give loading condition to the model and find out Solutions in the form of frequencies and mode shape.

Result-

1) Natural Frequency of blade-

Following table shows natural frequencies values of blade of Fluctuating tool calculated by Finite element approach.

Mode	Natural Frequencies of Blade (Hz)
1	77.286
2	489.73
3	565.32
4	1406.2
5	1630.2
6	1806

Table. 2. Natural frequencies of blade

2) Frquencies of Fluctuating Cutting Tool

The following table shows the natural frequencies of Fluctuating Cutting tool calculated by FEA.

Mode	Natural Frequencies of Fluctuating tool (Hz)
1	1351.8
2	1703.6
3	2528.3
4	3443.7
5	3952.4
6	4096.1

Table. 3. Frequencies of Fluctuating cutting tool

B. Rotor dynamics analysis-

In the rotor dynamic analysis, we check whether the all modes are stable/ balance or not. For that we applied the rotational velocity to the eccentric shaft. The two bearings of the shaft are replaced by the virtual bearing with standard bearing stiffness.

Result-

Result of rotor dynamics analysis are shown in following table,

Mode	Direction of Mode	State of Mode
1	Undetermined	Stable
2	Backward	Stable
3	Backward	Stable
4	Forward	Stable
5	Backward	Stable
6	Forward	Stable
7	Backward	Stable
8	Forward	Stable
9	Backward	Stable
10	Backward	Stable

Table. 4. Results of rotor dynamics analysis

V. COMPARISON OF EXPERIMENTAL APPORACH AND FINITE ELEMENT APPPORACH

From results of modal analysis of fluctuating cutting tool with blade, note that 77.286 Hz (4637.16 RPM) is a natural frequency of tool. Which is Calculated by Ansys Workbench 19.0

To validate the results, we compare calculated natural frequency of blade by FFT Analyser (Experimentally) with analytical(FEA) work result.

Experimental Result (FFT)	Analytical Result (FEA)	Error in Percentage
75 Hz	77.286 Hz	-3.048%

Table. 5. Comparision of FEA And Experimental results

The comparison of Experimental modal analysis result and Analytical Results (Ansys Workbench 19.0) of the blade is shown in the above table with a percentage error below ±10% which is quite acceptable as per benchmark. It is shown that experimental modal analysis done on experimental setup is valid.

VI. RESULT DISCUSSION

The fluctuating cutting tool driven with revolution of 15589 RPM. So, the excitation frequency of the tool is 259.81 Hz (15589 RPM).The Natural frequencies of the Tool in both conditions are away from the operating excitation frequency's range (From Table of modal analysis result), this shows that resonance is not coming in the tool. So, the resonance is not responsible for the vibration.

From the result of rotor dynamic analysis and Campbell diagram, we conclude that all modes of the eccentric shaft assembly are stable. So, there is no issue of unbalance.

VII. CONCLUSION

From the results and discussion, we can conclude that the factor which is responsible for the vibration of the fluctuating cutting tool could be misalignment and mechanical looseness.

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