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Tool condition monitoring in milling using sensor fusion technique

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ABSTRACT – In this work, the response of sound pressure and cutting force during machining of Hybrid aluminium composite alloy was investigated to predict the condition of multipoint cutting tool. The machining process is carried out for fresh, working and dull tool with optimum parameters. During machining, the sound pressure and cutting force are measured using microphone and Milling tool dynamometer. The response from sensors during machining process was acquired with NI USB 6221 DAQ card and monitored using LabVIEW. The acquired signals are fused together and the fused data given as input to the fuzzy inference system and the output of which is used to assess the condition of the tool.

1. INTRODUCTION

The main aim of the industries is to produce parts with low cost and high quality in very short period of time. The prediction of tool life and tool changing strategies are based on most conventional estimates of tool life from the past tool wear data. Tool condition monitoring is essential to get a superior quality product. Tool flank wear is the most important parameter that influences the production performances [1]. Various methods employed for monitoring the condition of the tool was explained previously [2]. The condition monitoring techniques will be directly useful to the manufacturing industries. The cutting force has the direct influence on the generation of heat, tool wear, durability and quality of the machined surface, and sometimes causes shocking or even damages the tool and machine parts[3]. The cutting force, sound pressure and vibration signals has been used with fuzzy inference system[4]. The flank wear was indirectly estimated with various features like cutting force, spindle vibration, spindle current and sound pressure signals extracted from the machining zone [5]. The design of effective multi sensor based tool condition monitoring was studied [6] and its consequences are reported. The flank wear was predicted with Ls-SVM using feed cutting force, estimated from feed motor current and sound signal [7]. This paper discusses the monitoring the condition of the tool using cutting force and sound pressure data. The condition of the tool is estimated using Adaptive Neuro Fuzzy Inference System.

2. METHODOLOGY

Aluminium alloy hybrid metal matrix composite (7075 T6 85%, TiC 7.5 % and SiC 7.5%) is fabricated through two step stir casting technique. The fabricated materials is machined with fresh (0 mm wear), working (0.2 mm wear) and dull (>0.3 mm wear) tool. The sound pressure and cutting force are acquired from the cutting zone with the aid of NI USB 6221 DAQ card and stored in the computer. The acquired signals are fused together and the condition of the tool is estimated with MATLAB – FIS. Figure 1 shows the experimental setup with sensor attachments.

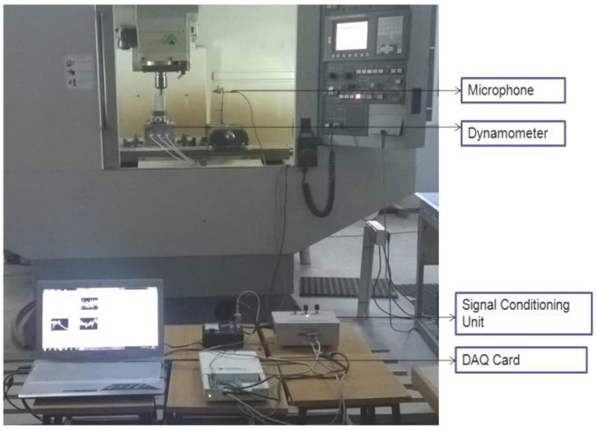

Figure 1 Experimental setup.

3. RESULTS AND DISCUSSION

Initially the free run is carried out for analyzing the influence of surrounding noise. The optimal parameter used in this work was spindle speed of 2000 rpm, feed rate of 0.08 mm/rev and depth of cut of 1 mm. The resulting sound signal is used as reference signal and further machining process was carried out with fresh, working and dull tool. From the reference signal the influence of surrounding noise was eliminated and the actual signal was used for further analysis. During the machining process, the sound pressure signal from the microphone was increased with the increase of flank wear. The sound pressure response for different tools is shown in Figure 2. It clearly indicates that wear is proportional to sound pressure.

The response of microphone for first 10 sets of experiments conducted with fresh (new) tool produces sound pressure around 0.0004pa. Next 10 set of experiments were conducted with the working tool and the microphone produces sound pressure in the range of 0.0005pa to 0.0008pa due to increase in wear of the tool. Next 10 set of experiments conducted with dull tool produces sound pressure around 0.0009pa. From the microphone response, it was observed that the dull tool produces more sound pressure compared to other tools.

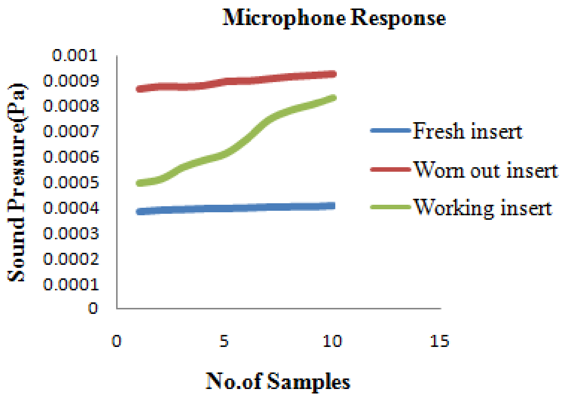

Figure 2 Response of Microphone for various tools.

The cutting force measured from dynamometer for different tools were shown in Figure 3. The cutting force for first 10 sets of experiments conducted with fresh tool was in between 10.7-11N, 4-4.8N and 54.5-61.6N in Fx, Fy, and Fz directions respectively. For the working tool, the cutting force varied from 12.6-18.4N, 5-7.4N and 62.5-73.6N for Fx, Fy, and Fz directions respectively due to increase in wear of the tool [4]. For the dull tool, the cutting force varied from 21.2-36.6N, 8.9-36.7N and 75.8-86.8N in Fx, Fy, and Fz directions respectively. The cutting force observations show that dull tool requires more cutting force.

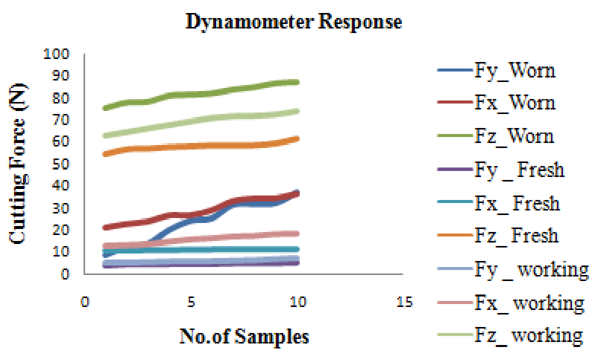

Figure 3 Cutting force signals for various tools.

From the response of sound pressure and the cutting force, the condition of the tool can be estimated. For fuzzy modeling, the sound pressure and cutting force was used as input parameter. The condition of the tool was the output parameter. For output linguistic variables range was fixed on wear value. For input and output, triangular membership functions were used. If – then rules were framed based on the experimental results. The output linguistic variables used were given in table 1.

Table 1 Output linguistic variable.

Sl. No	Output	Tool Condition
1.	<0.15	Fresh tool
2.	0.15<0.25	Working tool
3.	>0.25	Dull tool

4. CONCLUSION

This experimental work had focused on the prediction of tool condition in CNC milling machine using sensor fusion model by measuring the cutting force and sound pressure during machining of hybrid aluminium alloy using milling dynamometer and microphone. Finally, the condition of the tool was predicted using fuzzy model. If the output level was less than 0.15, the tool condition was considered as fresh tool. If the output lies between 0.15 to 0.25, the tool was considered as working tool. When the value exceeds 0.25, it indicates that the tool condition becomes dull and the tool had to be replaced for further cutting process. When it reaches the maximum threshold value the tool had to be replaced. This system enables the monitoring of the cutting process with high reliability. Fuzzy model can estimate the tool wear progress very quickly and accurately, once the maximum cutting forces and sound pressure for particular work piece and tool were known.

5. REFERENCES

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