Study of Tool Condition Monitoring Techniques for Aluminum Metal Matrix Composite

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Abstract:- **Tool condition monitoring is one of the most important techniques to be developed in the automatic cutting processes as it can help to prevent damages of machine tools and work pieces. Researchers and engineers have been looking for ways to monitor tool conditions, but very few reliable monitoring systems exist nowadays in industry. There are various methods that are used for tool condition monitoring but only few of these are universally successful due to the complex nature of the machining processes. Tool wear monitoring plays a critical role in detecting the dimensional accuracy of work piece and guaranteeing automatic cutting process. It is essential to develop simple, reliable and effective tool wear conditions. Developing a real time tool wear monitoring system has been an intensive research topic for almost two decades and two main monitoring schemes exist.Direct measurement of tool wear using optical methods can only be applied when cutting tools are not in contact with the work piece. Indirect methods that rely on the relationship between tool conditions and measurable signals (such as force, acoustic emission, vibration, current, etc.) For detecting tool conditions have been extensively studied. Signal processing is a very important step for tool condition monitoring. Recently, wavelet transforms (WT) has provided a significant new technique in signal processing, because it offers solutions in the time-frequency domain and is able to extract more information in the time domain at different frequency bands. There have been many research activities in the applications of wavelet transforms for tool condition monitoring. In this present work Vibration signal of spindle motor and feed motor will be congregated and decomposed by continuous and discrete wavelet transformation. The signal features of tool breakage will be extracted and tool breakage will be successfully monitored by the signal features.**

Keywords-, Tool condition monitoring, Vibration signals, Wavelet transform, MMC, Stir Casting.

I. INTRODUCION

TOOL CONDITION MONITORING*:* Manyaspects of a manufacturing process must be carefully examined, controlled and measured. The various machining operations involve the contact between work piece, tool, and the chips which imposes pressure on the tool resulting in the change of shape of tool, gradual tool wear or tool fracture. The various techniques that are developed for monitoring the condition of a tool have significant importance in the manufacturing processes. The aim of the monitoring of machining operations generally are relevant to the performance of the machine tool, progression of tool wear, dimensional tolerances, surface texture (roughness, waviness), tool deflection, and other features of the work piece and the classification of chip shapes and formation. An active and effective process monitoring system should stimulate the operator and shut the NC machine down when critical and unsafely conditions are about to be reached. Effective and efficient tool condition monitoring systems (TCMs) have for more than two decades been acquiring an importance in industry and machining research. Condition monitoring not only decreases the manufacturing costs by reducing downtime and needless cutting tool changes, but also enhances the product quality by eliminating chatter, excessive tool deflection and poor part surface finish. Therefore, much study has been executed in the past 30 years.

TOOL WEAR MONITORING TECHNIQUES: Tool wear monitoring plays a critical role in detecting the dimensional accuracy of work piece and guaranteeing automatic cutting process. It is essential to develop simple, reliable and effective tool wear conditions. Developing a real time tool wear monitoring system has been an intensive research topic for almost two decades and two main monitoring schemes exist.

1. Direct tool wear monitoring

2. Indirect tool wear monitoring

1. Direct tool wear monitoring direct tool wear monitoring attempts to measure tool wear directly using some optical instrument such as video camera, which requires cutting operations to be interrupted periodically.

2. Indirect tool wear monitoring Indirect tool wear monitoring deals with indirect signals that are believed to be influenced by tool wear progression. For this type, diverse types of sensors such as cutting force and torque, motor current and effective power, vibrations, accelerations, acoustic emission or audible sound energy, sound pressure power and displacement sensor (inductive and capacitive) have been generally applied to sense a special characteristic or a combination of characteristics such as tool wear, tool deflection, tool fracture, machine vibration, etc.

Composite materials are important engineering materials due to their outstanding mechanical properties. Metal matrixcomposite (MMC) materials are one of the widely knowncomposites because of their superior properties such as highstrength, hardness, stiffness, wear and corrosion resistances.Silicon carbide particle (SiC) reinforced aluminum-based MMCs are among the most common MMC and commerciallyavailable ones due to their economical production.Metal Matrix composites are gaining the popularity in the sectors such as Automobile Industries, Aero Space Applications, and Biomedical Applications. The increase in use of Metal matrix composites particularly Aluminum Matrix composites also increase the need to develop an appropriate technology for the cost effective machining of the composites.

II. LITERATURE SURVEY

Julie Z. Zhang and Joseph C. Chen [1] presented a methodology for a tool condition monitoring for milling operation. This study demonstrates a tool condition monitoring approach in an end milling operation based on the vibration signal collected through a low-cost, microcontroller-based data acquisition system. A data acquisition system has been built through interfacing a microcontroller with a signal transducer for collecting cutting vibration. The examination tests of this developed system have been carried out on a CNC milling machine. Experimental studies and data analysis have been performed to validate the proposed system. The onsite tests showed the developed system can perform properly as proposed. The testing result showed that the prototype design was successful. The data acquisition system, mainly composed of an accelerometer evaluation board, and microcontroller was an effective, cost-competitive system that can be applied for monitoring machining processes. The interface of the hardware system and the software program was successful. The two software programs that were written in both VBA and SOFTWIRE were able to capture the machining information.

S.X. Xu et al. [2] carried out an experiment on tool breakage and undercut of a workpiece of free-form surface using wavelet analysis, both of the fault features can be extracted in a special frequency segment of wavelet decomposition. According to the feature of transient fault, the authors proposes for the first time an automatic determination technology of the threshold by the use of the adaptive filter characteristics of wavelet transformation

Erkki Jantunen [3] illustrated their work of the monitoring methods, signal analysis and diagnostic techniques for tool wear and failure monitoring in drilling that have been tested and reported in the literature. The paper covers only indirect monitoring methods such as force, vibration and current measurements, i.e. direct monitoring methods based on dimensional measurement etc. are not included. Signal analysis techniques cover all the methods that have been used with indirect measurements including e.g. statistical parameters andFast Fourier and Wavelet Transform. Fast Fourier and Wavelet Transform are more sophisticated means of signal analysis that have also been used for tool wear and breakage detection by a number of research groups. Only a limited number of automatic diagnostic tools have been developed for diagnosis of the condition of the tool in drilling. In the reported material there are both success stories and attempts that have not been so successful. Only in a few of the papers have attempts been made to compare the chosen approach with other methods, i.e. many of the papers only present one approach and unfortunately quite often the test material the study is based on is limited, especially when it comes to the cutting process parameter variation, i.e. variation of cutting speed, feed rate, drill diameter and material and also work piece material.

Xiaoli Li and Shiu Kit Tso [4] investigated tool breakage and wear condition in real time according to the measured spindle speed and feed motor currents by wavelet and fuzzy techniques. First, the continuous and discrete wavelet transforms are used to decompose the spindle and feed ac servo motor current signals to extract signal features so as to detect the breakage of drills successfully.

Manoj Singla, Lakhvir Singh and Vikas Chawla[5],
In the present study a modest attempt has been made to develop aluminum based silicon carbide particulate MMCs with an objective to develop a conventional low cost method of producing MMCs and to obtain homogenous dispersion of ceramic material.

III. OBJECTIVES

- To evaluate and monitor the tool condition through vibration data analysis.
- To acquire, visualize and analyze sample data collected in turning operation.

IV. METHODOLOGY

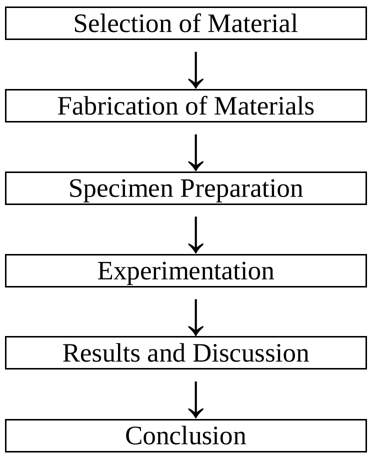

Figure 4 Flow chart for experimental Procedure

The experimental procedure adopted in the present work is shown in Fig.4.According to the flow chart the tests were carried out.

V. EXPERIMENTAL PROCEDURE

A. *Selection of materials*

i) Matrix Material: LM6

The essential characteristics of LM6 is its excellent castability, which permits the production of castings in intricate shapes. It is also having the property of high resistance to corrosion. It is used for deck casting and other marine application, Water cooled manifold, and jackets etc..

Figure 5.1Ingot Structure of LM6

ii) *Reinforcement Material: silicon carbide (400 mesh)*

Silicon Carbide is the only chemical compound of carbon and silicon. It was originally produced by a high temperature electro-chemical reaction of sand and carbon. Silicon carbide is an excellent abrasive and has been produced and made into grinding wheels and other abrasive products for over one hundred years.

Figure 5.2 Reinforcement Material (Sic)

B. FABRICATION of MMC

Manufacturing of aluminum alloy based casting composite by stir casting is one of the most economical methods of processing MMC. In the past few years, materials R&D has shifted from monolithic to composite materials, adjusting to the global need for reduced weight, low cost, quality, and high performance in structural materials Driving force for the utilization of AMCs in areas of aerospace and automotive industries include performance, economic and environmental benefits.[6]

Among the variety of manufacturing processes available for discontinuous metal matrix composites, stir casting is generally accepted as a particularly promising route, currently practiced commercially. Its advantages lie in its simplicity, flexibility and applicability to large quantity production. It is also attractive because, in principle, it allows a conventional metal processing route to be used, and hence minimizes the final cost of the product. This liquid metallurgy technique is the most economical of all the available routes for metal matrix composite production, and allows very large sized components to be fabricated. The cost of preparing composites material using a casting method is about one third to half that of competitive methods, and for high volume production, it is projected that the cost will fall to one tenth.

The composites are fabricated by liquid metal stir casting technique, where in the reinforcement material is incorporated into the molten metal by stirring. This process involves stirring the melt with solid ceramic particles and then allowing the mixture to solidify. The aluminum alloy is melted in a graphite crucible using a electrical furnace. The Sic particles are preheated to 750˚C for 2 hrs to remove the volatile contaminants on the particle surface and to artificially oxidize the surface to obtain a layer of SiO2 which could promote better wetting. The preheated particles are added to the melt with controlled feed rate, stirring speed and melt temperature. The stirring speed is in the range of 750rpm and the processing temperature is 720-740˚C.

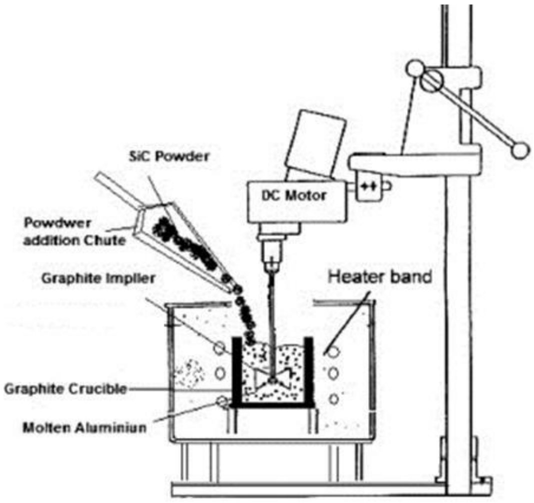

Fig 5.3 Schematic diagram of composite fabrication setup for liquid metal stir casting.

In a stir casting process, the reinforcing phases (usually in powder form) are distributed into molten Aluminum by mechanical stirring.[7] Stir casting of metal matrix composites was initiated in 1968. A typical stir casting process of Aluminum alloy matrix composite is illustrated in Fig.5.3 Mechanical stirring in the furnace is a key element of this process. The resultant molten alloy, with ceramic particles, is used for die casting, permanent mold casting, or sand casting. Stir casting is suitable for manufacturing composites with up to 30% volume fractions of reinforcement. The cast composites are sometimes further extruded to reduce porosity, refine the microstructure, and homogenize the distribution of the reinforcement. A major concern associated with the stir casting process is the segregation of reinforcing particles which is caused by the surfacing or settling of the reinforcement particles during the melting and casting processes. The final distribution of the particles in the solid depends on material properties and process parameters such as the wetting condition of the particles with the melt,

- Strength of mixing,
- Relative density, and
- Rate of solidification.

The distribution of the particles in the molten matrix depends on

- The geometry of the mechanical stirrer,
- Stirring parameters,
- Placement of the mechanical stirrer in the melt,
- Melting temperature, and
- The characteristics of the particles added.

Fig 5.4 Casted MMC

C.GEOMETRY OF SPECIMEN

The test specimen was processed by liquid metal stir casting method in the form of cylindrical billet of 25mm diameter and 180mm long.

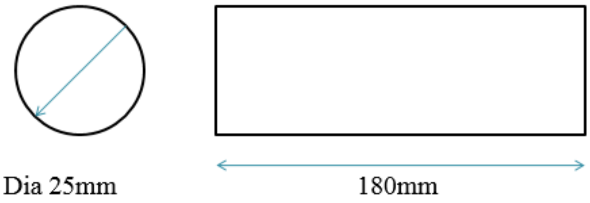

Fig 5.5 Geometry of work material

D. TOOLING DETAILS

HSS and Carbide tools have been selected for carrying out the machinability study of the Al-SiC metal matrix composites.

5.1 HSS TOOL

High-speed steel (HSS or HS) is a subset of tool steels, commonly used in tool bits and cutting tools. It is superior to the older high-carbon steel tools used extensively and can withstand higher temperatures without losing its temper (hardness). This property allows HSS to cut faster than high carbon steel, hence the name high-speed steel. At room temperature, in their generally recommended heat treatment, HSS grades generally display high hardness (above HRC60) and abrasion resistance (generally linked to tungsten and vanadium content often used in HSS) compared with common carbon and tool steels.

Fig 5.6 HSS tool

5.2 Carbide tool

Cemented carbide is the preferred material for parts that must withstand all forms of wear (including sliding abrasion, erosion, corrosion/wear and metal-to-metal galling) and exhibit a high degree of toughness.
It exhibits high compressive strength, resists deflection, and retains its hardness values at high temperatures, a physical property especially useful in metal-cutting applications. It provides long life in applications where other materials would not last or would fail prematurely.

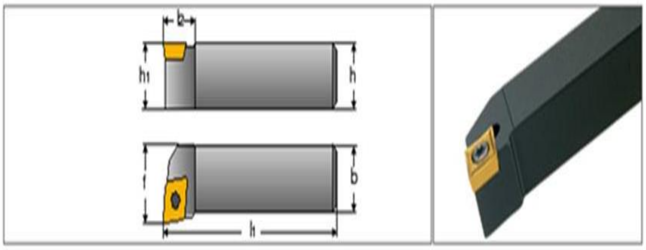

Fig 5.2 Tool holder used in present work

Tool	Melting temp in˚C	Hardness RC
HSS	1130	55-60
Carbide	2800	70-75

Table 5.3 Melting temperature and Hardness values of cutting Toll.

VI. EXPERIMENTAL DETAILS.

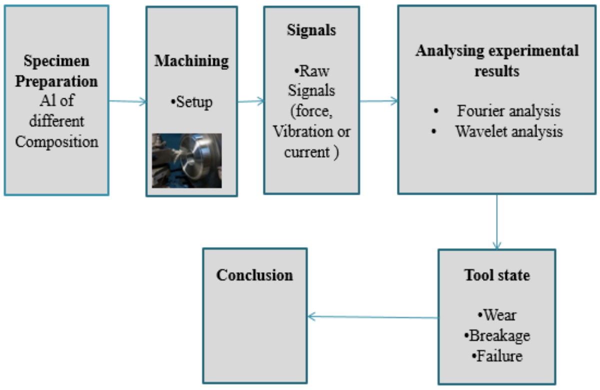

Fig. 6.1 The frame work of TCM

Signal processing feature is extracted through signal processing steps (fig.6.1) for sensitive and robust representation of its corresponding state. Wavelet transforms and fuzzy techniques are used to monitor tool breakage and wear conditions in real time according to the measured spindle and feed motor currents, respectively [4]. Different Vibration analysis and Signal processing techniques are given in paper [8].The machine condition monitoring system is composed of two components: firstly a data acquisition sub system such as signal measurement device (sensor) and signal processing algorithm secondly a decision making sub system. Those raw machining signals are then processed to extract machining characteristics features. These features can be used by thedecision making subsystem to drive the tool condition and predict part quality to determine if corrective action is necessary.

Accurate and reliable data acquisition system is a key base for machine condition monitoring. Much number of researchers has studied a variety of machining signals related to machine conditioning such as tool wear and tool breakage detection, surface roughness prediction, and dimensional quality optimization. The Kistler dynamometers were used commonly used for cutting force studies. The accelerometer sensor with data acquisition system would cost high.

STRUCTURE OF THE DATA ACQUISITION SYSTEM:

The functional information of the proposed data acquisition system is shown in Fig.6.2 . When machining is in operation, real-time vibration data in three directions will be collected through machining signal transducer (accelerometer). At this stage of raw signal processing, background will be extracted from the filtered machining signals. The extracted cutting information will be then sent to the decision making subsystem.

TOOL CONDITION MONITORING THROUGH THE DATA ACQUISITION SYSTEM:

Tool condition monitoring was implemented through the analysis of vibration data that was captured by the data acquisition system. Development of this system included hardware selection, design and implementation, computer software programming, turning process. Integration of the components in data acquisition system.

A.)VIBRATION MEASUREMENT SENSOR-Vibration signals are important for monitoring the machine condition in turning operation. A kistler accelerometer (8766A500BB) was attached to tool holder by tapping the size of the sensor to fit and X, Y, and Z directions are aligned with the conventional turning lathe axes.

B.) MICROCONTROLLER-DATA ACQUISITION-A micro controller based data acquisition device was used. This device serves to interface signal (vibration, cutting force, etc.) transducer with computer program installed in PC via USB port. Functions are described below-

- Accelerometer- converts the physical acceleration into a voltage signal.
- Signal conditioning circuit- amplifies the voltage signal and improves the resolution.
- PMD data acquisition board-carries out A/D conversion and improves the signal.
- Laptop computer- runs on data physics software, stores and displays and capture signals.

C.) SOFTWARE SYSTEM-Cutting force information is also one of the most significant cutting signals representing cutting tool features. The channels for cutting force data acquisition was programmed in the software development and were recorded using data physics and sampled using Gold Wave and frequency analyzed in Matlab.

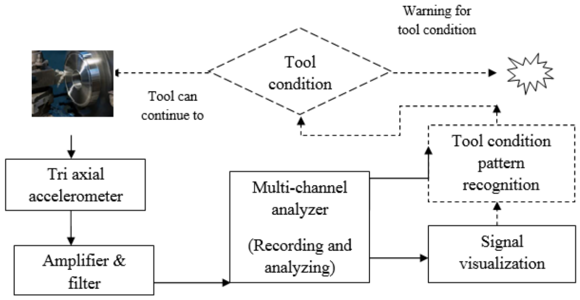

Fig 6.2 Information flow of DAS

VII. CONCLUSIONS

- Aluminum Metal Matrix composites were successfully manufactured through stir casting technique.
- The monitoring system includes tool breakage detection and tool wear detection.
- TCM is essential to distinguish between sudden and progressive failure.
- It helps effective monitoring for fault prediction.

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