Machine Tool Failure Data Analysis For Condition Monitoring Application

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ABSTRACT

With the development of modern manufacturing technology, Flexible Manufacturing Systems (FMSs) have become key equipment in factory automation. Machine tools are heart of the Flexible Manufacturing Systems. Lathe, milling and grinding machines are the general type of machine tools used by almost all the FMSs. During the operation of these machine tools, different kinds of failures are faced by the industry. A systematic study of such failures can help in identifying the critical sub-system of these machine tools. This will be useful for identifying the condition monitoring needs of the machine tools. This paper deals with the identification of critical sub-system based on the failure data analysis for different type of machine tools.

1. INTRODUCTION

Technologies have been developed rapidly in recent years and in due course the manufacturing environment is also changing its features rapidly. In machining activities, the traditional role of machine tool operators is being replaced more and more by the intelligent controllers. With the developments in manufacturing technology, FMSs have become key equipment in factory automation. This kind of manufacturing method is being used more and more widely because of its potential to improve the strategic and competitive position of firms. For advanced supervisory tasks, people usually staying away from the real machining spots, control and monitor the machining processes by means of computer terminals. However, such manufacturing environment is dependent upon the trouble-free operation of all its component parts. In order to reduce maintenance time detecting and diagnosing process failures quickly becomes a crucial task. Upto 80% of the downtime is spent locating the source of fault [1].

Machine tools are heart of the Flexible Manufacturing Systems. Lathe, milling and grinding machines are the general types used by almost all the FMSs. Machine tool maintenance is an important area for the practicing maintenance engineers. Because, it furnishes a particularly complicated system for solution, which includes electronics, electrical, hydraulic and pneumatic power drive mechanisms, control systems, measurement systems, bearings, ball screws, gears, belts, lubrication systems and coolant systems. During the operation of these machine tools, different kinds of failures are faced by the industry. For cost effective maintenance, condition monitoring is normally applied to critical sub-system. The identification of critical sub-systems could be based upon the information available on failures, their frequency and the consequent downtime. A systematic study of such failures can help in identifying the critical sub-systems of these machine tools. This identification may greatly help in adapting appropriate maintenance approach for these machine tools. Data on failures is a poorly researched area, which is of great interest to the design of condition monitoring systems [2, 3]. It is only recently that failure data have been collected in any systematic way as an offshoot of organized maintenance planning. These data are of great interest to the machine tool manufacturer who will, endeavor to design out the fault generating elements. They are also of interest to the designer of condition monitoring systems as they indicate the vulnerable elements in the machine tool system. With the presumption that these cannot always be designed out, the data will indicate on which elements the condition monitoring system should concentrate [4].This paper endeavors to focus on a study of machine tool failures. Data on failure for several machine tools (i.e. Lathe, Milling and Grinding machines) have been collected from BHEL, Tiruchirappalli for this purpose.

2. FAILURE DATA COLLECTION AND ANALYSIS

Failure is defined as the termination of the ability of an item to perform its specified function. Data on failures are considered as a health report of any machine tool system. It was difficult to collect field failure data on machine tools several years ago, because users hardly kept adequate and complete maintenance records beyond the warranty period. In this computerized maintenance environment, users feel encouraged to keep the systematic maintenance records of their machineries. Failure data were collected for a period of five years on several conventional machine tools such as lathe, milling and grinding machines. It contained the following information:

o Product name, model and size

o Product code

o Reported time & date of failure

o Failure phenomena

- o Cause of failure

- o Repair process

- o Repair time

- o Downtime

- o Date of hand-over

- o Model, size and number of breakdown components

- o Number of service engineers or repair engineers

- o Site of machine tool

Failure data analysis has been carried out for all the machine tools and the same has been presented in this section.

2.1. Failure Data Analysis of Lathe

Initially lathe has been classified into various sub-systems as shown in Fig. 1. In an earlier study [4] the frequency of failures for each sub-system and failure modes have been considered for finding out the weakest sub-system. In the present analysis, failure frequency and downtime have been taken into consideration for deciding critical sub-systems of machine tools. It can be seen from the Fig. 2 that the maximum failures took place in headstock and carriage sub-systems. These sub-systems face failures in components like gear, gearbox bearing, spindle bearing, clutch and cross-slide jib. Here it could be observed that the bearing failures cause longer downtime.
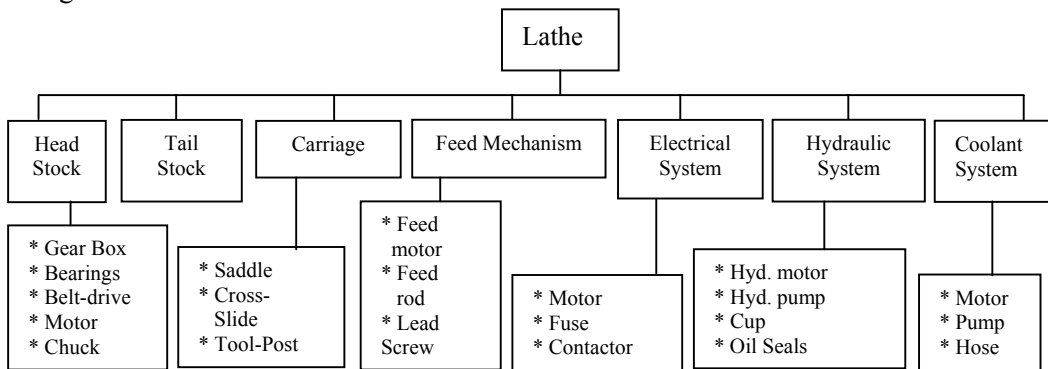

Fig. 1   Lathe sub-system Classification

Fig. 3 gives different failure modes and their relative failure frequencies. All failures have been grouped into four-failure modes viz., component damage, fuse

burnt, circuit fault and looseness. It can be observed that the dominant failure mode is because of component damage. The components are electrical, electronics and of mechanical categories. The most of the components are standard and bought-in components.

2.2. Failure Data Analysis of Milling Machine

As a first step, milling machine has been classified into several sub-systems such as spindle, table, saddle, knee assembly, electrical, hydraulic system sub systems and coolant system as shown in Fig. 4.
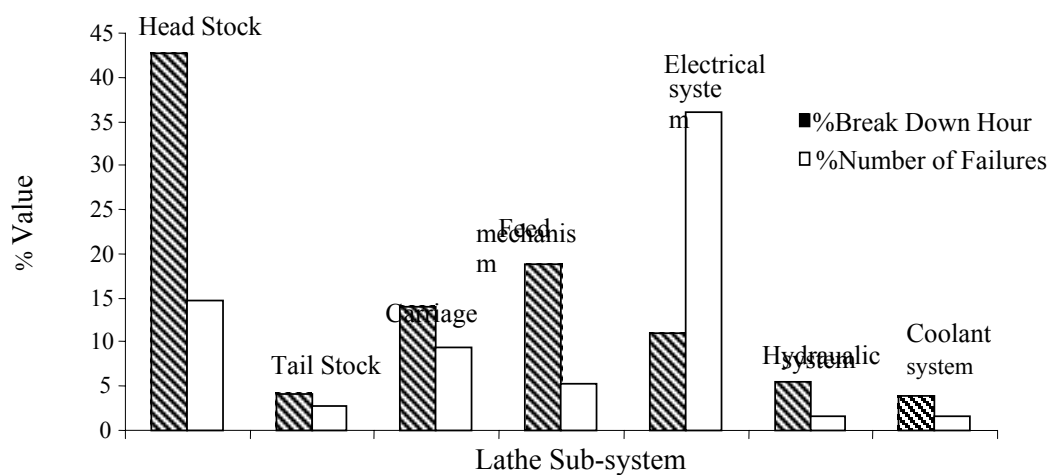

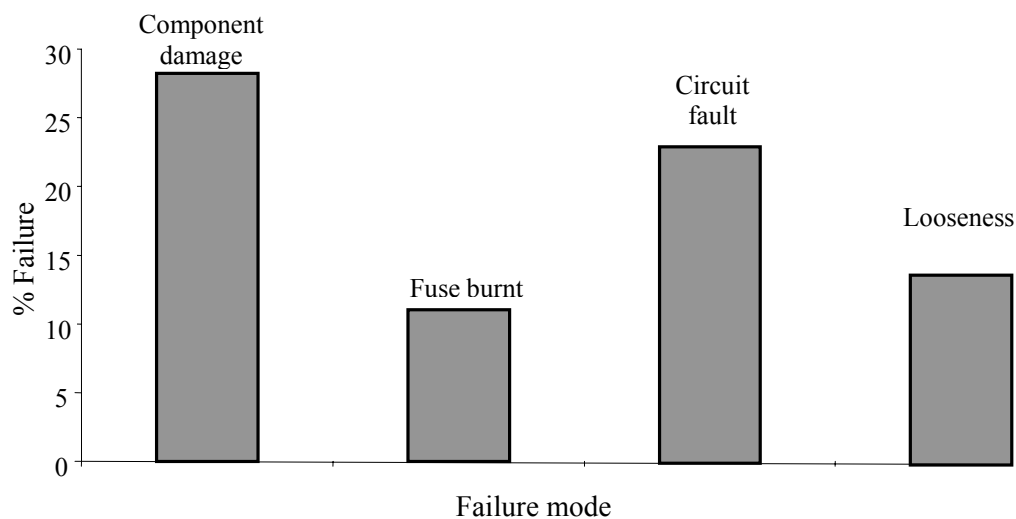Fig. 2   Lathe sub-system failure frequency and downtime

Fig. 3   Histogram of lathe failure mode

Fig. 5 shows the failure frequency and downtime of milling machine. It could be observed that the milling machine "Table" sub-system faces frequent failures and longer downtime. The different failure modes involved in milling machine are given in histogram as shown in Fig. 6. All failures have been grouped into four-failure modes viz., component damage, circuit fault, fuse burnt and looseness. It can be seen from here that the dominant failure mode is due to component damage. The damaged components include brake plate, bearings, circuit breaker, feed lever, motor coil, coolant hose etc. The most of the components are standard and bought-in components.
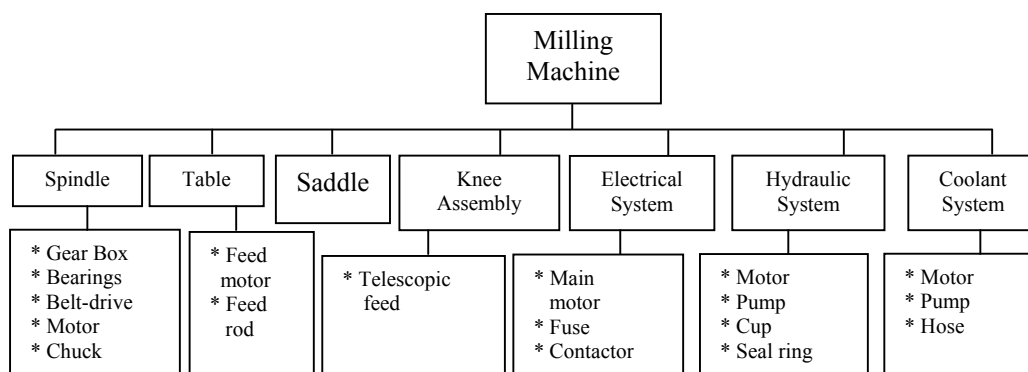

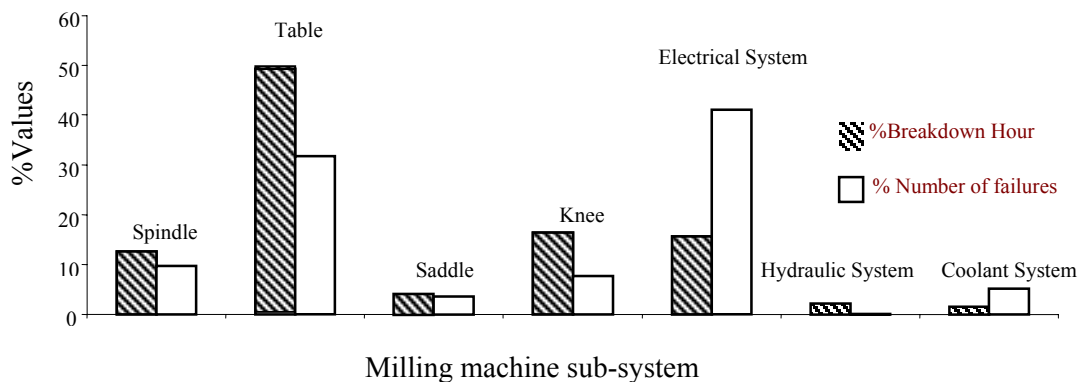Fig. 4 Milling machine sub-system classification

Milling machine sub-system

Fig. 5 Milling machine sub-system failure frequency and downtime

2.3 Failure Data Analysis of Grinding Machine

The sub-systems of grinding machine have been classified such as wheel head, work head, table, tail stock, dressing unit, electrical, hydraulic and coolant sub-

systems as given in Fig. 7. The number of failures and consequent downtime have been identified for each sub-system. From the Fig. 8 it could be observed that the maximum number of failures occur in electrical sub-system, wheel head sub system and hydraulic sub system. In electrical sub-system many failure relevant to fuse blown out and circuit fault have been recorded. On comparing the breakdown time of all the sub-systems, hydraulic sub-system was found to have longer down time. Thus it could be observed that the critical sub-systems of grinding machine are hydraulic and wheel head sub-systems.
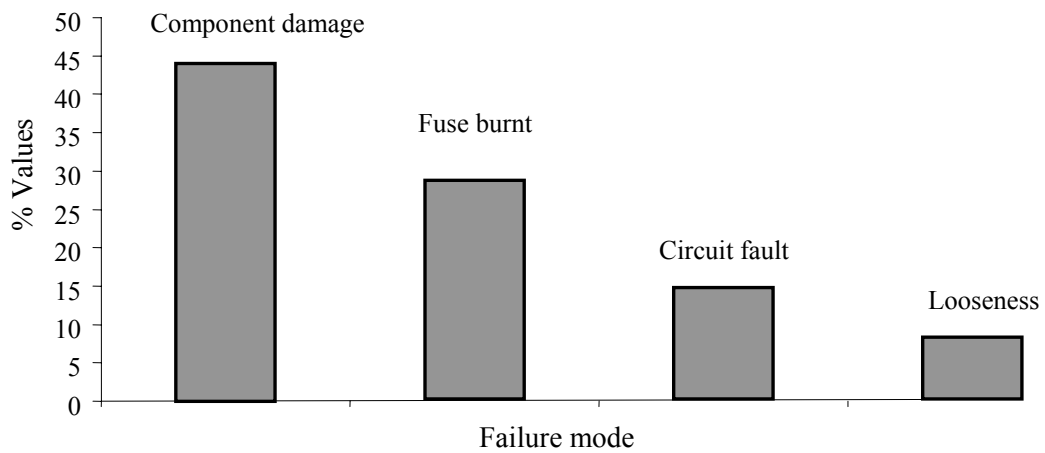

Fig. 6   Histogram of failure mode of milling machine

The common failures are identified as "U" cup damage and spindle bearing damage. Particularly in grinding machine, the spindle is made to rotate at high speed around 3000 rpm, and the wheel keeps on wearing. There may be a chance of mass unbalance in the wheel. By considering all these facts, most critical sub-system of grinding machine is found to be "wheel head" sub-system. Fig. 9 shows the histogram of common mode of failures. It could be observed that the component damage and component looseness occur more frequently.

The failures in machine tool components occur due to three causes- inherent weakness, misuse or gradual deterioration. Only failures of gradual deterioration type are most suitable for condition monitoring purpose. Condition monitoring can provide information about machine tool condition and of its rate of deterioration. This can be achieved by selecting suitable parameters for measuring deterioration and recording their values at certain intervals.

3. MONITORING PARAMETERS

Monitoring parameters are measurable variables able to display information

concerning component condition. A set of suitable parameters is a set of measurable variables, which can reflect the information about the component condition at any moment. Information regarding component failure mechanisms and their causes helps in identifying different monitoring parameters. Proper monitoring techniques could be used for measuring these identified monitoring parameters.

Table.1 gives various methods for condition monitoring of rotating machinery and their fields of application [6, 7, 8]. It is possible to monitor the entire machine tool by applying various possible combinations of these techniques as a multi-sensor and multi-parameter approach.
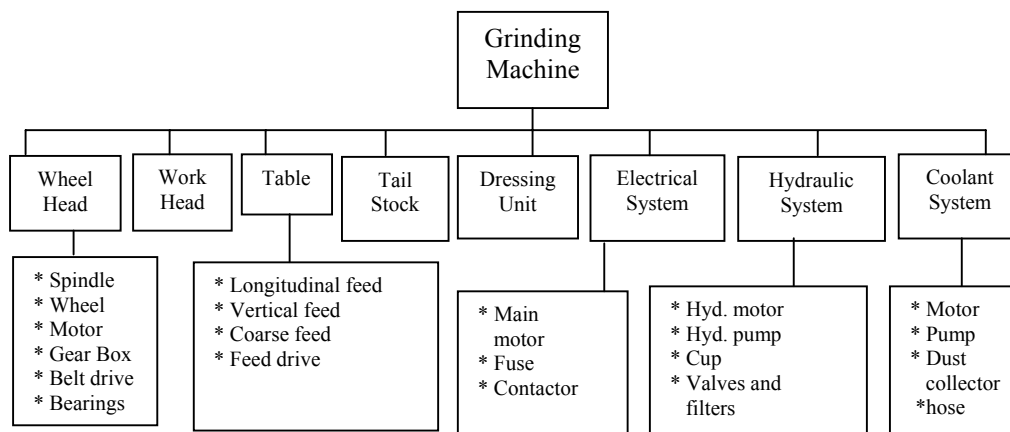

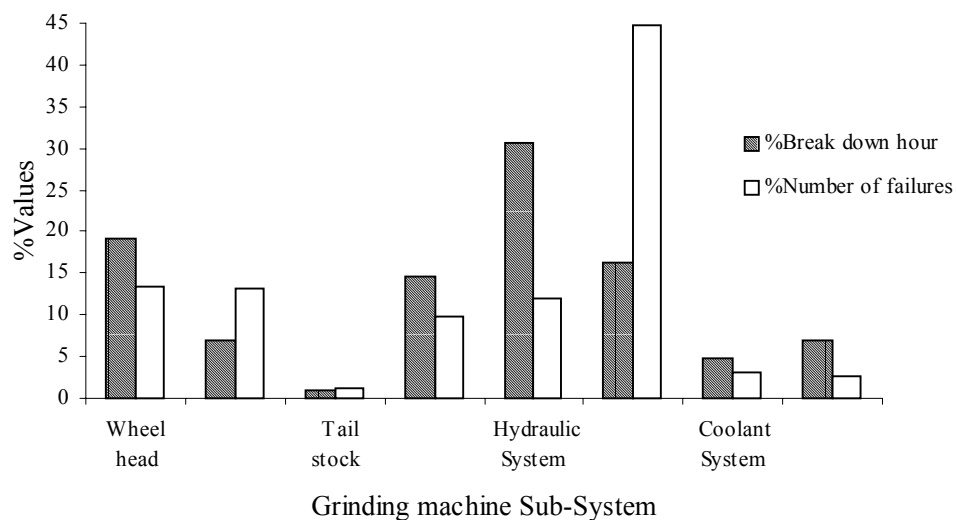Fig. 7   Grinding Machine Sub-System Classification

Fig. 8   Grinding machine sub-system classification

4. CONCLUSION

The failure data have been collected and analysed systematically for several commonly used machine tools like lathe, milling and grinding machines. The critical sub-system has been identified for each type of machine tool based on number of failures and downtime hours.

Table 1   Various methods for condition monitoring and their fields of application

	overall vibration	Frequency analysis	Kurtosis	Crest factor	SPM	Cepstrum analysis	Spectrometric oil analysis	Wear particle analysis	Particle counting	Temperature analysis	Shaft analysis	Ultrasonic measurement	Sound measurement	Acoustic measurement
Unbalance	◊	◊									0			
Misalignment	◊	◊									0			
Rolling bearing	0	0	0	0	◊	0	0	0	0	0		0	0	Δ
Sliding bearing	0	0					0	0	0	0	◊	0		0
Gears	0	◊	Δ	Δ	0	◊	0	0	0		◊	0	0	Δ
Bent shaft	◊	◊												
Oil whirl	0	◊									◊			
Electrical Unbalance	◊	◊												
Insufficient lubrication	0	0		Δ	◊		0	0		0	0	0	0	0
◊- Normally applicable, 0 = Applicable with limitations, Δ = Requires a case to case study														

The most critical sub-system of lathe is headstock. It faces frequent problems of gearbox bearing fault and high-speed locking screw loosening. In the case of milling machine the "table" sub-system has been found to be significant. Telescopic feed fault and gear damage are identified many times in milling machine table sub-system. In the case of grinding machine, wheel head sub-system has been perceived as the weakest among all the others. Bearing damage and spindle jam have been

identified to be important. Almost in all the cases the principle mode of failure is damage of component and most of them are standard and bought-in components. The use of appropriate condition monitoring technique for monitoring the above critical sub-systems of the machine tools will be helpful in identifying and predicting the failures.

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