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# Quality Analysis and Investigation into Cutting Tool Breakage at Hindustan Machine Tools, Bangalore Complex (MBX)

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## Abstract

*In today's time, every industry tries to reduce its cost through possible ways and one of the main areas of concern would be equipment and tools. A look into the tool breakage at Hindustan Machine Tools (HMT), Bangalore Complex (MBX), has provided the project with considerable data to suggest improvement methods and ways in which they could reduce the cost incurred due to breakage. Only five departments incurring the highest cost towards tool breakage chosen were High Technology Centre (HTC), Die Casting Bed (DCB), Rounds (R), Spindles (S) and Radial Drilling (RD). All the five departments showed highest loss during January. Among the five departments, DCB revealed the highest loss in tool breakage while the department of Spindles showed the lowest. Few workers in the range of 3–5 among the 26 sample size studied were involved in more tool breakage. A reliable questionnaire to interview the selected workers was designed as per the requirement and the interview revealed the actual cause for the tool breakages. The quality control tools and inferential statistics used in the present study helped to strengthen the suggestions and could prove effective methods to the company. The suggestions were drawn to reduce the cost of tool breakage to the company that included proper training to amateur workers; making them to work with veteran workers; use of good-quality raw material for tool designing; proper insulation to high-cost electricity-run equipment of HTC and spindle departments; proper maintenance of equipment and so on.*

***Keywords:*** *tool breakage, inferential statistics, Hindustan Machine Tools*

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## INTRODUCTION

Cutting tools are used for machining operations. These include lathe, drilling machine, milling machine and so on. The common factor of these tools is early breakage during operation. Due to lot of breakages in cutting tools, the loss accounts so much that it affects economy of the industry. The present study has been taken up in Hindustan Machine Tools (HMT), Jalahalli, Bangalore, to find the types of cutting tools used, operation and about the mechanics who work on them and the survey may probably help to reduce losses caused by shop floor workers by building up awareness in them to increase the life of such tools in order to improve the economy of the industry.

Cutting tools must be made of a material harder than the material which is to be cut, and the tool must be able to withstand the heat generated in the metal-cutting process. The angle of the cutting face is also important, as is the flute width, number of flutes or teeth, and margin size. In order to have a long working life, all of the above must be optimized, plus the speeds and feeds at which the tool is run [1].

The cutting tools need to be capable to meet the growing demands for higher productivity and economy as well as to machine the exotic materials which are coming up with the rapid progress in science and technology.

The cutting tool material of the day and future essentially require properties such as high mechanical strength, fracture toughness, abrasion resistance, chemical stability, thermal conductivity, low cost and so on to resist or retard the phenomenon leading to random or early tool failure [2].

Cutting tools are often designed with inserts or replaceable tips (tipped tools). In these, the cutting edge consists of a separate piece of material, either brazed, welded or clamped on to the tool body. Common materials for tips include tungsten carbide, polycrystalline diamond, and cubic boron nitride. Tools using inserts include milling cutters (endmills, fly cutters), tool bits, and saw blades [3].

Cutting tool materials can be divided into two main categories: stable and unstable. Unstable materials (usually steels) are substances that start at a relatively low hardness point and are then heat treated to promote the growth of hard particles (usually carbides) inside the original matrix, which increases the overall hardness of the material at the expense of some of its original toughness. Since heat is the mechanism to alter the structure of the substance and at the same time the cutting action produces a lot of heat, such substance is inherently unstable under machining conditions. Stable materials (usually tungsten carbide) are substances that remain relatively stable under the heat produced by most machining conditions, as they don't attain their hardness through heat. They wear down due to abrasion, but generally do not change their properties much during use. Unstable materials, being generally softer and thus tougher, can stand a bit of flexing without breaking, which makes them much more suitable for unfavorable machining conditions, such as those encountered in hand tools and light machinery [4, 5].

Tool life generally indicates the amount of satisfactory performance or service rendered by a fresh tool or a cutting point till it is declared failed [6]. Mostly, tool life is decided by the machining time till flank wear, $V_B$ reaches 0.3 mm or crater wear, $K_T$ reaches 0.15 mm. Dimension tool life can be characterized by the time within which the tool works without adjustment or replacement (Tc–l); by the number of parts produced (Np–l); by the length of the tool path (Lc–l); by the area of the machined surface (Ac–l) and by the linear relative wear (hl–r).

Cutting tools generally fail by:
(i) Mechanical breakage due to excessive forces and shocks. Such a kind of tool failure is random and catastrophic in nature and hence is extremely detrimental.
(ii) Quick dulling by plastic deformation due to intensive stresses and temperature. This type of failure also occurs rapidly and is quite detrimental and unwanted.
(iii) Gradual wear of the cutting tool at its flanks and rake surface.

The first two modes of tool failure are very harmful not only for the tool but also for the job and the machine tool. Hence these kinds of tool failure need to be prevented by using suitable tool materials and geometry depending upon the work material and cutting condition [7, 8].

All lathe operators must be constantly aware of the safety hazards that are associated with using the lathe and must know all safety precautions to avoid accidents and injuries. Carelessness and ignorance are two great menaces to personal safety as well as tool breakage and proper machine maintenance of tools and equipment should be the part and parcel of the organization [9].

## Introduction to Hindustan Machine Tools Ltd. (HMT)

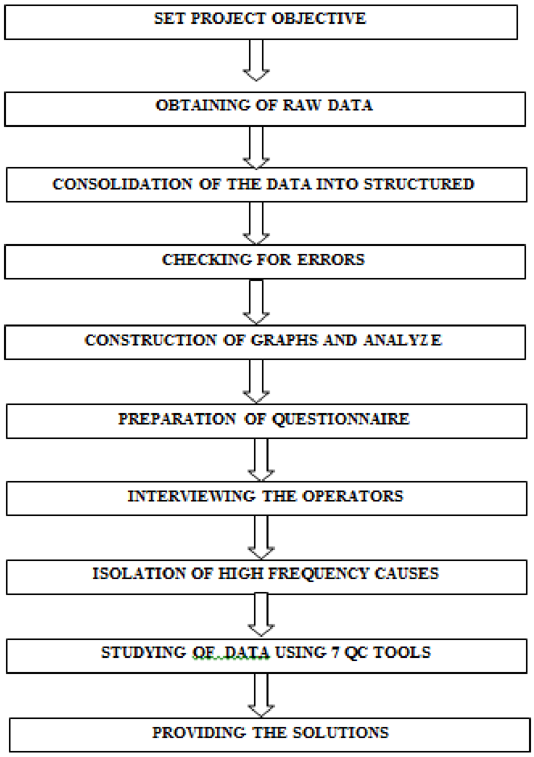
Hindustan Machine Tools Ltd. (HMT) was established in 1953 by the Government of India as a machine tool manufacturing company. Over the years, it has diversified into watches, tractors, printing machinery, metal forming presses, die casting and plastic processing machinery, CNC systems and bearings. Successful technology absorption has been achieved in all product groups through collaborations with world renowned manufacturers and further strengthened by continuous inhouse R&D. Today, HMT comprises five subsidiaries under the ambit of a holding company, which also manages the tractor business directly. The major manufacturing facilities of HMT include experienced design expertise and latest design facilities; can handle machining of components of variety weighing up to 20 ton; up-to-date tool room and inspection facilities; machine shop to build huge structures with stress-relieving facilities; machine shop to manufacture small and heavy components; facilities for assembly and retrofitting of heavy machine tools; heat treatment facilities; foundry with facilities to produce heavy, small and medium castings of ferrous metals with facilities like pattern shop and fettling shop; captive foundry of capacity 1500 MT per annum – size of grey cast iron casting up to 9 MT and S.G. iron up to 5 MT; can handle machining of components and assemblies of tool room class precision machine tools; measurement and inspection facilities with precision machines, viz., coordinate measuring machine; material testing laboratory; all facilities required for plated-through hole (PTH) PCB assembly like preparation/insertion/assembly and component soldering; facilities for cleaning of electronic PCBs, and so on.

The quality analysis and investigation into cutting tools at HMT, Bangalore complex-560 013 (MBX), is a sincere effort towards reducing costs incurred by the company due to tool breakages. In order to study the breakage history of five critical departments over the calendar year 2011, we collected the data pertaining to department, employees (with maximum breakages) and tools broken, analyzed the causes and effects, and finally provided feasible solutions to HMT to overcome or minimize tool breakages. The project allowed to touch upon subjects such as quality engineering, material science, manufacturing processes, enterprise resource planning, human resource management, organizational behavior and most importantly statistical analysis, on which this project is essentially based upon.

The objectives of the present project are:

- To reduce the cost incurred due to cutting tool breakage at HMT, MBX
- To find out the root causes leading to tool breakage
- To provide possible solutions and suggestions to improve the working methods to reduce the cost

## MATERIALS AND METHODS




### Raw Data Collection

The data was collected to find out the root causes leading to tool breakage in HMT, Bangalore complex. The company has tool issue slip, which contains information on the tool that was issued to the worker and when the tool is returned. In case the tool was broken or damaged it will be mentioned in this tool issue slip at the time of return and this will be sent to the quality department. Since there was a record for each tool that is broken in the various departments, one year data was consolidated and entered in an ERP module The information on the person breaking the tool, the month in which it was broken, the loss that the company incurred due to this breakage and the quantity of tool broken was collected. Only five departments incurring the highest cost were chosen, these were High Technology Centre (HTC), Die Casting Bed (DCB), Rounds (R), Spindles (S) and Radial Drilling (RD).

### Consolidation of Data

The data collected had to be input into a format which was easy to read and analyze. Hence, data was put into Excel sheets and graphs were drawn to find out the areas of concern.

There were four kinds of graphs drawn for each department

- Tool no. versus quantity
- Ticket no. versus quantity
- Tool breakage versus month
- Cost incurred versus month

Also pivot tables were used to find out the relationship between any of these parameters.

### Checking for Errors

The data collected was checked for errors. It was cross checked from the ERP module and the data sheets. This was done so as to obtain accurate results and no approximate or inaccurate results would be accepted.

### Construction of Graphs and Analysis

The graphs constructed in step 3 were analyzed to provide information on:

- Which employees to interview
- The months in which the tool breakage was the most
- Which tools have broken the most
- The cost incurred in each month

### Preparation of Questionnaire

A questionnaire was prepared to interview the cutting tool operators so as to find out the root causes of the tool breakage and obtain suggestions on improvement of tool life. The sample size chosen (26) is actually 26% of the total number of operators working on the cutting tools. There are nearly 600 employees at HMT, MBX, out of whom 100 operators work on cutting tools. Twenty-six operators were chosen throughout the five departments and asked for feedback. The questionnaire consisted of six sub-departments to concentrate on:

- Working environment
- Operations
- Tools
- Machine
- Material
- Human Resource

Operators were interviewed on the job-floor itself after permission of the department supervisors was obtained. The operators were given full freedom to choose the answers they wanted to give and suggest some possible solutions to increase tool life.

### Study of Data Using 7 QC Tools

Inferential statistics were carried out to find out various relationships and to provide conclusions. The quality control tools were used for descriptive statistics mainly except the Ishikawa which also helped in inferring the areas of main concern causing tool breakage. The QC tools that were used were:

- Ishikawa
- Check sheet
- Pareto chart
- Histogram
- Scatter diagram
- Flow chart

### Providing the Solutions

Solutions to reduce the cost were provided on the basis of inferential statistics that we used. The statistical techniques used in the present study to get solutions were:

- Correlation and regression
- Reliability test
- Chi-square test

Feasible and possible solutions were suggested to the company to reduce the cost incurred due to tool breakage.

## RESULTS AND DISCUSSION

### Descriptive Statistics

The data in the ERP module of HMT happened to be with respect to the months that the breakages occurred in. These data were collected in Excel sheets using pivot tables and made more user friendly. Each department had its own data which could be viewed with respect to all of the following parameters: Tool no., Ticket no., month, quantity of tools broken, and cost incurred.

### Department-Wise Analysis

By formulating graphs for separate departments, the issues pertaining to the particular departments were addressed. Graphs suggesting dependencies between workers and quantity of breakages, type of tools and quantity of breakages, trends of breakages over the whole year of 2011 in the department and the costs incurred due to breakages were looked at. One example for the department of HTC (High Technology Care) has been provided below. Finally, annual data were analyzed and suggestions were drawn based on that.

Figure 1 depicts the number of tools broken by all the employees working in HTC over the entire year. From the graphs, it can be determined that a handful of workers (5 nos.) have caused the maximum loss to the company. These employees were later interviewed to get to the bottom of the issue. Employees bearing ticket numbers 10561, 10053, 10212, 10934, and 9881 were taken into consideration.

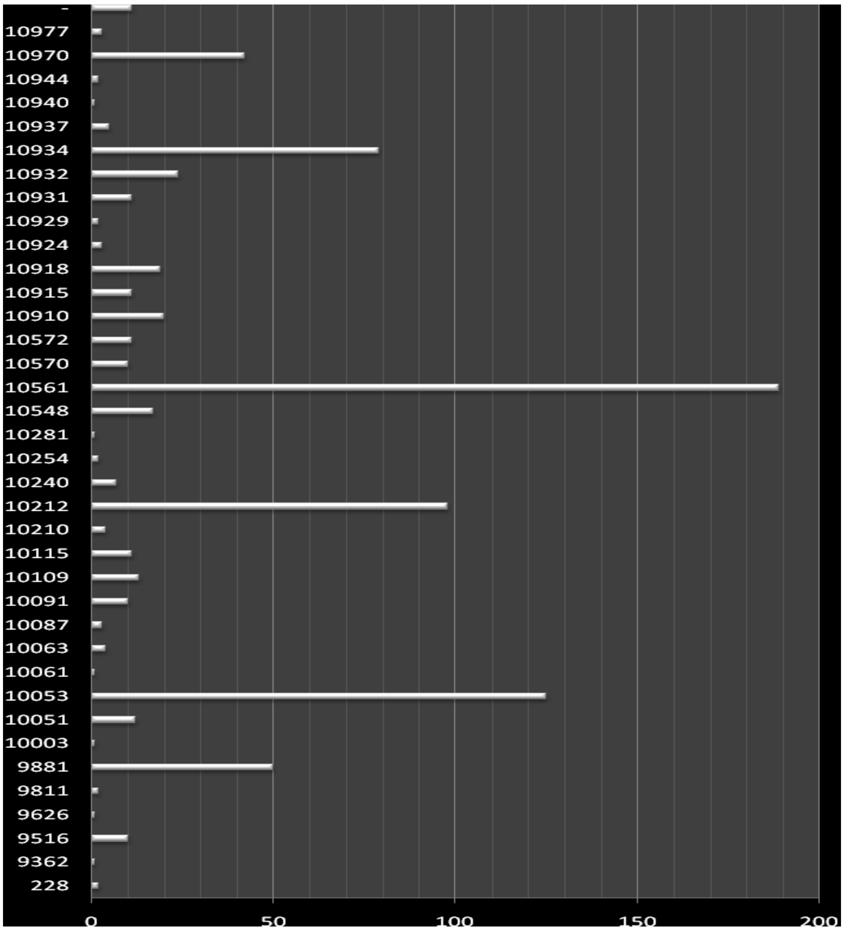



***Fig. 1:*** *High-Technology Centre: Quantity of Tools Broken versus Employee Ticket Nos.*

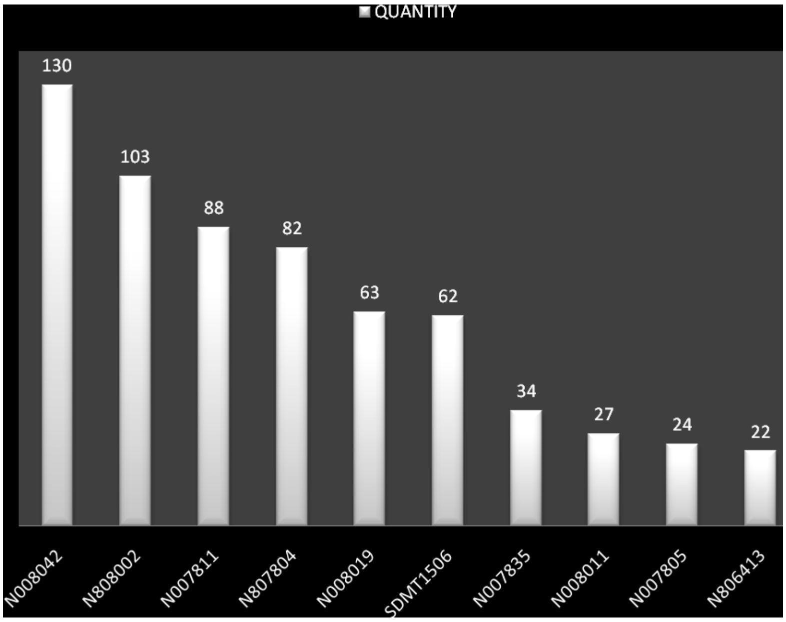



***Fig. 2:*** *Tools with Maximum Breakage.*

As is evident from the title, this Pareto chart (Figure 2) depicts tool codes on the X-axis against the number of times they were broken in a year in HTC. Tools N008042 and N808002, both being carbide tip inserts seemed to be breaking most often.

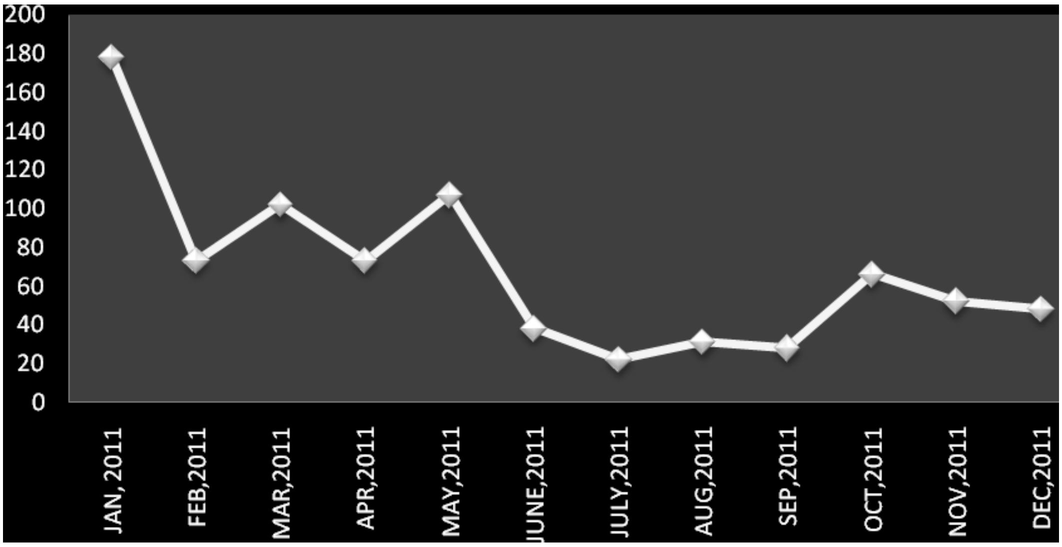



***Fig. 3:*** *Tool Breakage over the Year.*

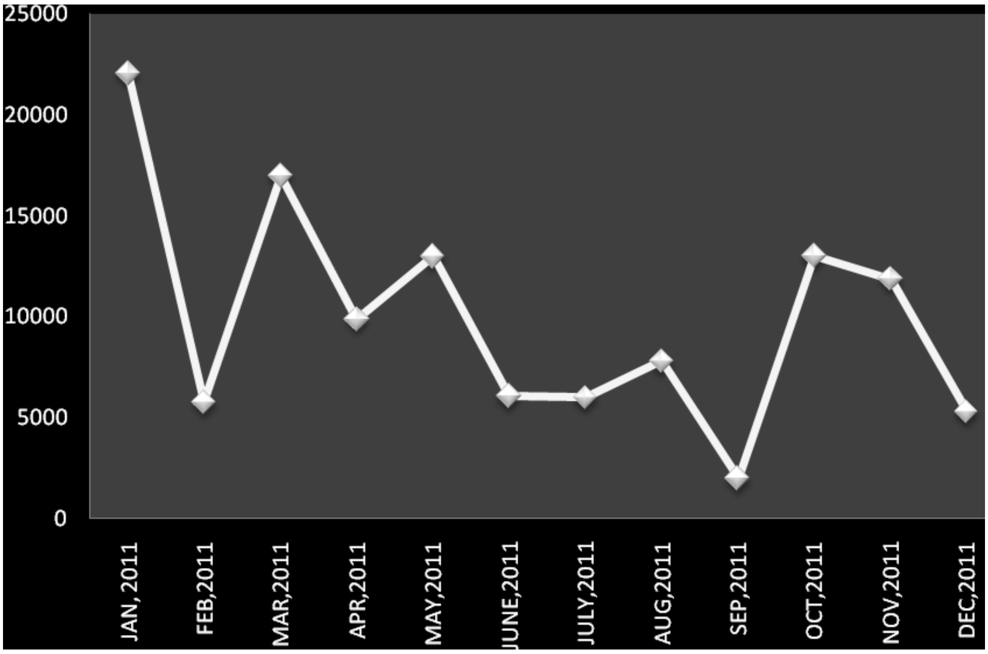



***Fig. 4:*** *Cost Incurred over the Year.*

From these trend graphs (Figures 3 and 4) of tool breakages and costs incurred respectively over the entire year, it is quite evident that the months of January, March and October have the maximum tool failures and costs incurred to the company. One strong reason would be that these were the months when production was at its peak for HMT. Extra care and precaution exercised might see the breakages significantly reduced if not completely avoided at HTC.

The employees working in Die-Casting Bed (DCB) bearing ticket numbers 9847, 9848, 9670, 10711 and 9849 were taken into consideration as they showed more breakage. Carbide tip inserts (CTIs), seemed to be breaking most often. The Die-Casting Division cost HMT the maximum when it came to tool breakages, as observed from the annual data when compared with the rest of the departments. Months like January, March, May and November, especially, all experience losses of over Rs. 22000. The number of tools broken was the maximum in January, taking the count to more than 250.

Employees bearing ticket numbers 10069, 10450, 10938, 10925 and 8619 were taken into consideration in the department of Rounds. The department also experienced a lot of breakages in the months of January and March due to high production. July and December too seem to cost the company a lot. Some of the tools broken in December, as observed from the ERP modules, happen to be diamond dressers, which are of very high cost as opposed to CTIs.

Spindles employees bearing ticket numbers 10289, 8766 and 10456 were taken into consideration. The carbide tip inserts seemed to be breaking most often. The months of January, February, June, August and December have all been very expensive for Spindles. Unlike Rounds, this department did not suffer losses in July. Breakage of cutting tools happens to be the least among all the five departments under consideration in Spindles. But this consistent rate, at which tools break in this department, needs to be tackled with proper planning and scheduling.

The employees working in Radial Drilling (RD) bearing ticket numbers 9506, 9507, 9822 and 10444 were taken into consideration due to high breakages. Carbide tip inserts seemed to be breaking most often. Tools in Radial Drilling department have been breaking most often in the months of January, June and September. Consequently, the company suffered losses in these months as well as in the month of May.

***Table 1:*** *Department-Wise Breakup of Costs Incurred to HMT due to Tool Breakage.*

| Section # | SECTION | Total (Rs.) |
|---|---|---|
| 371 | **DCB MFG.** | **153578** |
| 228 | **H.T.C** | **119732** |
| 251 | **ROUNDS** | **111634** |
| 302 | **R.D** | **107199** |
| 255 | **SPINDLES** | **98154** |
| 256 | GEARS | 76946 |
| 391 | PSB MFG. | 64303 |
| 252 | Non-ROUNDS | 44388 |
| 225 | BORING | 35109 |
| 380 | BALL SCREW | 33626 |
| 201 | TOOL ROOM | 32729 |
| 223 | PLANNING | 30605 |
| 263 | GRINDING ASSY. | 17745 |
| 273 | L-45 ASSY. | 17101 |
| 372 | DCB AASY. | 8849 |
| 195 | RECONDITIONING | 2261 |
| 258 | CUTTING | 1051 |
| 150 | INSPECTION | 468 |
| 276 | ELECTRICAL ASSY. | 385 |
| | **TOTAL** | **955863** |

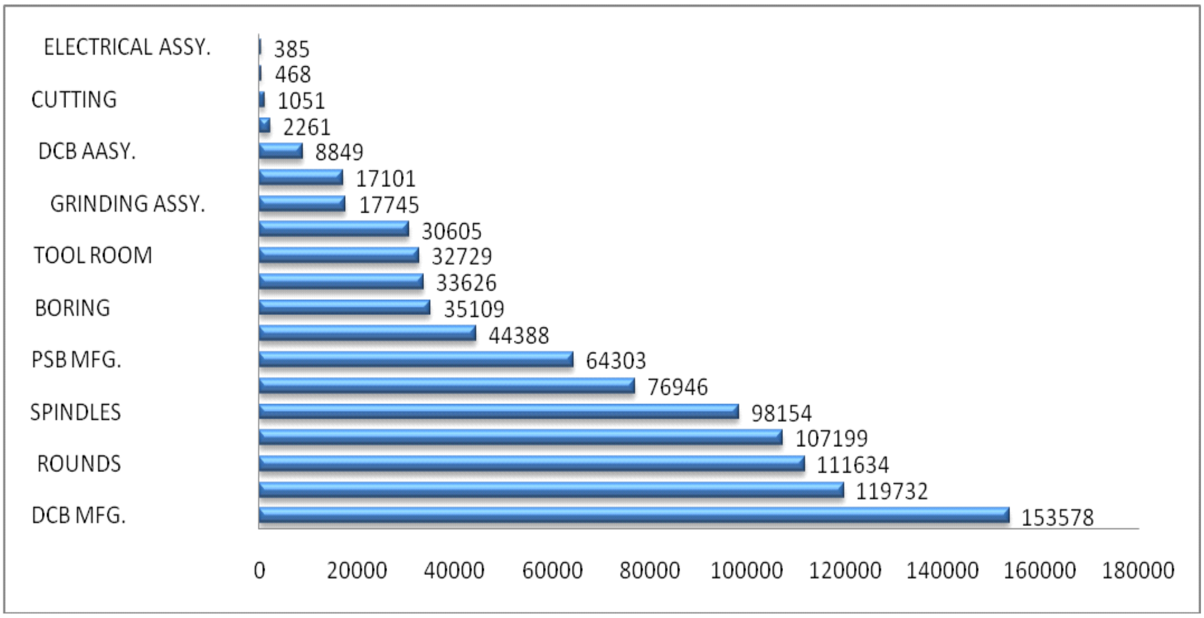



***Fig. 5:*** *Department-Wise Breakup of Costs Incurred to HMT due to Tool Breakage.*

Among the five departments studied, DCB revealed the highest loss in tool breakage while department of Spindles showed the lowest as depicted in Table 1 and Figure 5.

***Table 2:** Reasons and Months that Contributed the Most to Breakage at HMT.*

| Sl. No. | Br. Due To | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | CARELESSNESS | 18246 | 16676 | 9895 | 9917 | 22539 | 7914 | 10196 | 6978 | 2941 | 7718 | 9348 | 424 |
| 2 | LOSS | | | | | | | | | | | 0 | |
| 3 | DEFECTIVE MATERIAL | 10858 | 2268 | 6190 | 483 | 5228 | 1750 | 162 | | 150 | 27 | 1454 | 4940 |
| 4 | JOB COMPLEXITY | 380 | | 0 | | | | | | 228 | 3769 | 1461 | 692 |
| 5 | DEFFECTIVE TOOL | 1419 | 0 | 1419 | | | | 936 | 1040 | 153 | 0 | 1768 | 936 |
| 6 | EXPERIMENTAL | | | | | | | | | | | | |
| 7 | POWER SHUTDOWN | 849 | 2371 | 16769 | | 2777 | | 187 | 1026 | | | | |
| 8 | MWCH. TROUBLE | | | 5757 | 104 | | | | | 0 | | | |
| 9 | NORMAL USAGE | 106365 | 49802 | 93888 | 39047 | 64883 | 61302 | 53355 | 49606 | 68081 | 49022 | 74331 | 47198 |

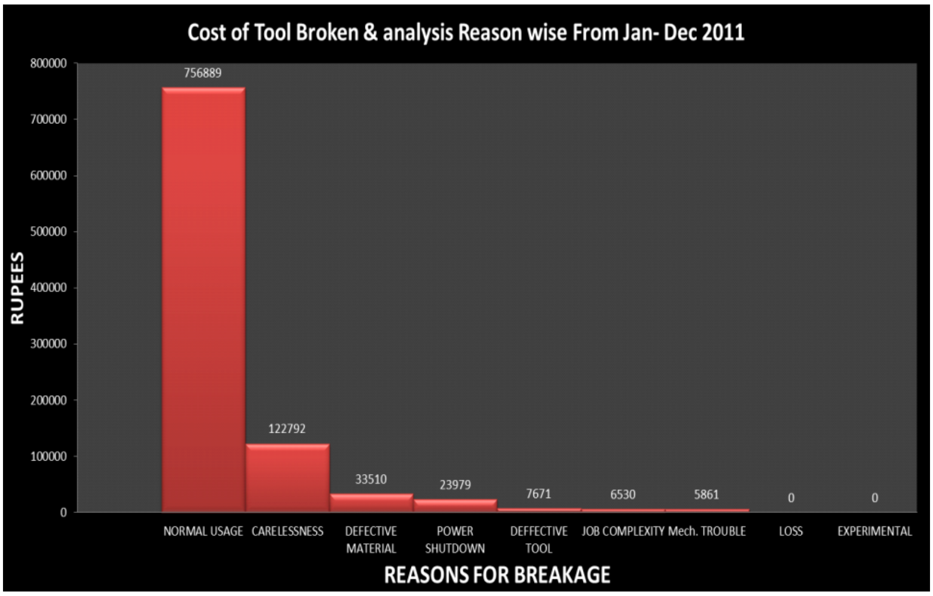



***Fig. 6:** Reasons and Months that Contributed the Most to Breakage at HMT.*

The departments incurring the highest cost chosen were High Technology Centre (HTC), Die Casting Bed (DCB), Rounds (R), Spindles (S) and Radial Drilling (RD) and all the five departments showed highest loss during January as indicated in Table 2 and Figure 6. The reasons were the carelessness of the worker followed by defective material used for the designing of the tools and repetitive usage of the tool.

## Reliability Tests on The Questionnaire

- The questionnaire consisted of 26 subjects, each was handed out a survey check sheet consisting of 18 questions.
- Reliability analysis was performed to check whether the survey conducted was conclusive or not, i.e., whether the feedback received by the subjects was reliable to the question asked.
- From the calculation, it was found that the question in relation to the subject

had a Cronbach's alpha value of 0.8811 as depicted in Table 3.

- This suggested that there was strong evidence pertaining to the questionnaire being reliable.
- The other value obtained through the analysis work:
  - Mean = 63.8461
  - Standard deviation = 8.2447

***Table 3:*** *Screenshot of Reliability Calculator.*

| | A | B | C | D | E | F | G | H |
|---|---|---|---|---|---|---|---|---|
| 1 | Cronbach's Alpha | 0.881124037 | | Reliability Calculator | | | | |
| 2 | Split-Half (odd-even) Correlation | 0.918799015 | | created by Del Siegle (dsiegle@uconn.edu) | | | | |
| 3 | Spearman-Brown Prophecy | 0.957681349 | | | | | | |
| 4 | Mean for Test | 63.84615385 | | | | | | |
| 5 | Standard Deviation for Test | 8.244776004 | | | | | | |
| 6 | KR21 | 3.591799115 | | Questions | Subjects | | | |
| 7 | KR20 | 3.61896813 | | 18 | 26 | | | |
| 8 | | | | | | | | |
| 9 | | Question 1 | Question 2 | Question 3 | Question 4 | Question 5 | Question 6 | Question 7 |
| 10 | Subject1 | 3 | 5 | 3 | 3 | 5 | 5 | 3 |
| 11 | Subject2 | 4 | 4 | 5 | 4 | 5 | 4 | 4 |
| 12 | Subject3 | 4 | 3 | 4 | 3 | 3 | 4 | 4 |
| 13 | Subject4 | 3 | 3 | 3 | 3 | 4 | 5 | 3 |
| 14 | Subject5 | 3 | 4 | 4 | 3 | 4 | 5 | 3 |
| 15 | Subject6 | 4 | 4 | 5 | 3 | 5 | 5 | 4 |
| 16 | Subject7 | 4 | 4 | 3 | 3 | 5 | 4 | 3 |

## Cause and Effect Analysis

A cause and effect analysis was necessary to evaluate all the causes that lead to tool breakage in the company. The causes with their sub-causes were furnished onto an Ishikawa or Fishbone diagram to illustrate the effect these causes had on the company in the form of losses due to tool breakage. The nine reasons HMT recognizes as potential threats to the life of machine tools were grouped under six parameters, namely, people, tools, machines, electricals, process and materials as a means to isolate the problems with respect to the aforementioned parameters. Identifying the important sub-causes helped to formulate the questionnaire for the shop-floor survey. It was easier to interview the employees with questions based on the causes and sub-causes mentioned in the Ishikawa diagram (Figure 7), so as not to let the analysis get unnecessarily extensive and vague.

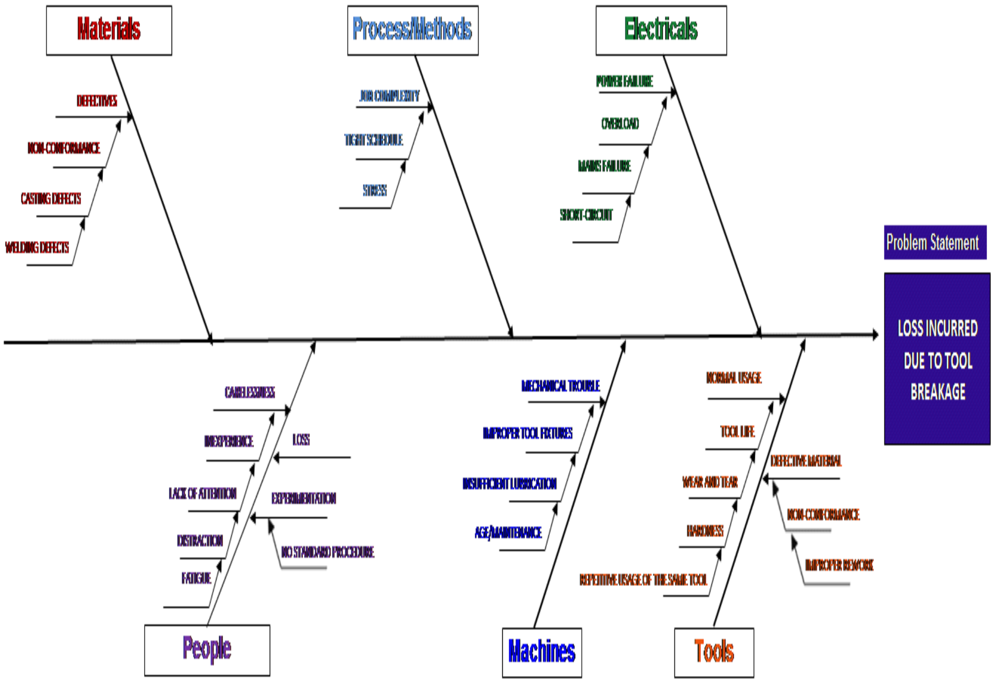



***Fig. 7:*** *Causes and Sub-causes in Ishikawa Diagram.*

## Correlations Derived

A correlation analysis was performed to check the relationship between actual hours and quantity of tools broken by a sample size of five employees individually. It was observed from the scatter diagram that employee nos. 1, 3 and 5 have positive correlation coefficients with positive linear slopes whereas employee nos. 2 and 4 have negative correlation coefficients. From this, it can be inferred that a positive correlation coefficient justifies the quantity of tools broken for the actual hours of work by the employee. The negative correlation infers that the quantity of tools broken is not dependent on the number of actual hours by that employee. This analysis was performed to provide the company with insights into the fact that long working hours lead to more quantity of tools breaking. It can be seen from the graphs that the correlation coefficients justify the above statement. Ultimately, it can safely be concluded that an employee's performance with respect to the number of tools broken by him is heavily dependent on the actual hours spent on the machine. The performance index hence is determined by the correlation coefficients where a negative slope indicates towards an abnormal phenomenon, i.e., the tools broken are due to unwanted reasons like employee negligence and carelessness. Tool failure needs to be prevented by using suitable tool materials and designing depending upon the work material and cutting condition [7, 8].

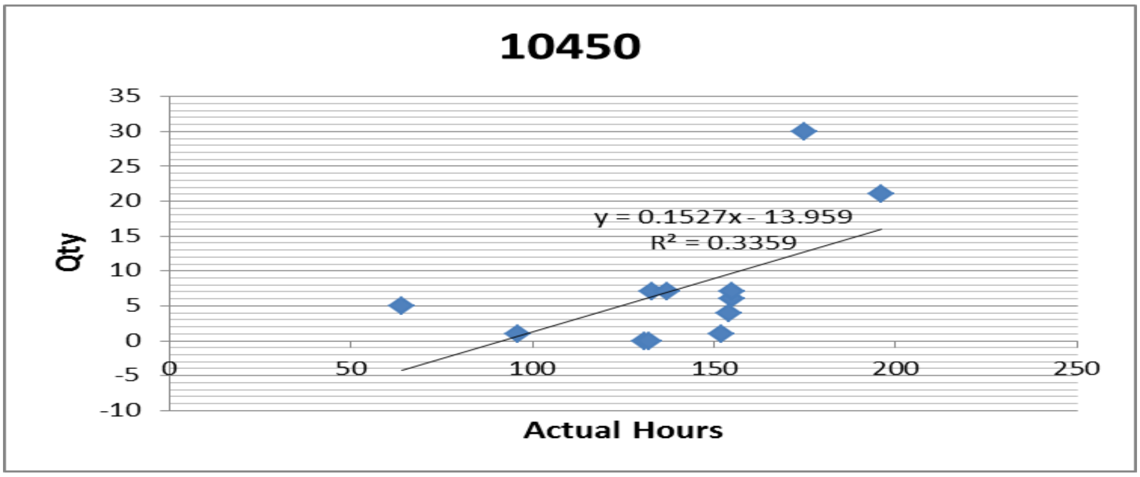
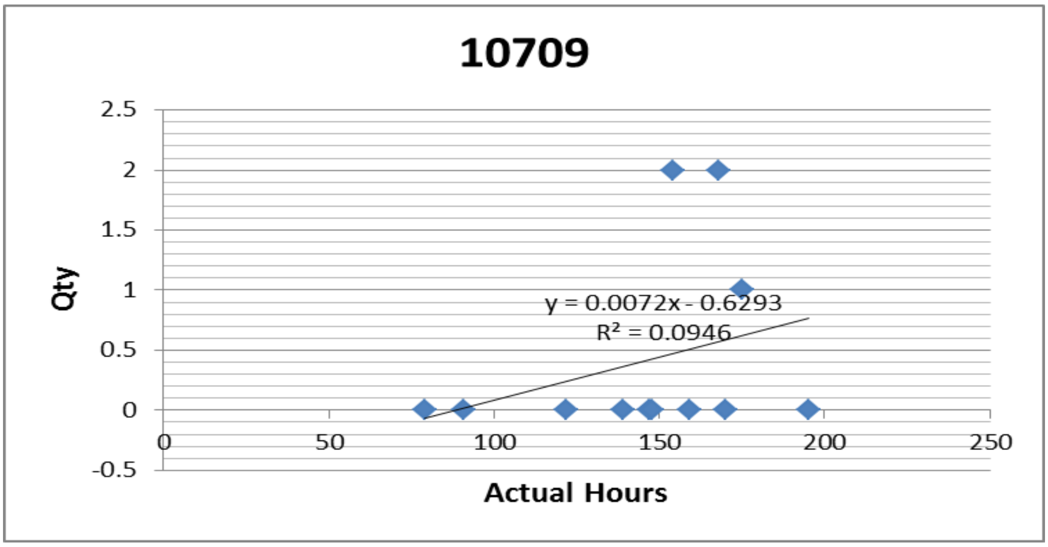
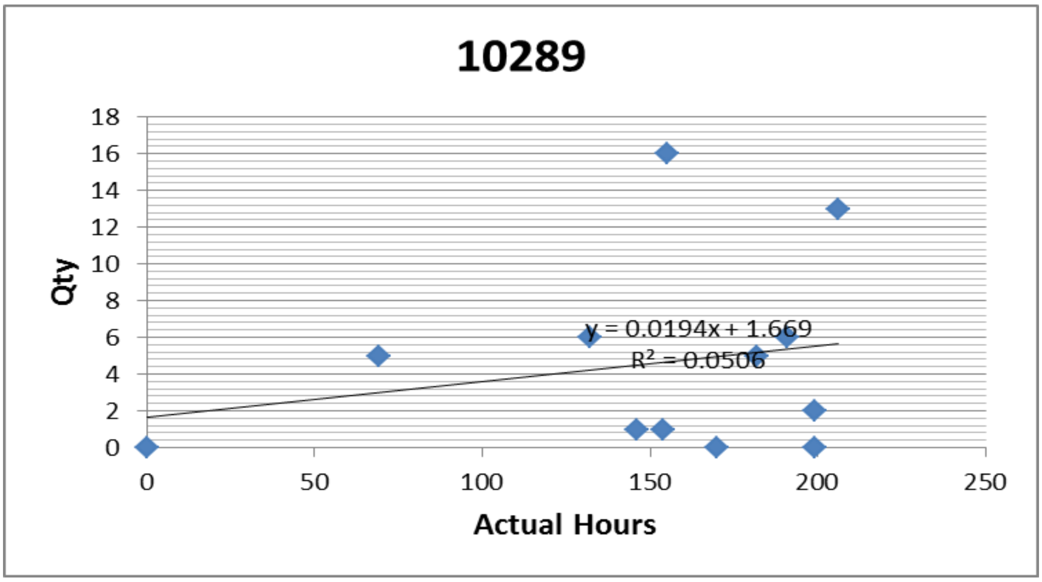


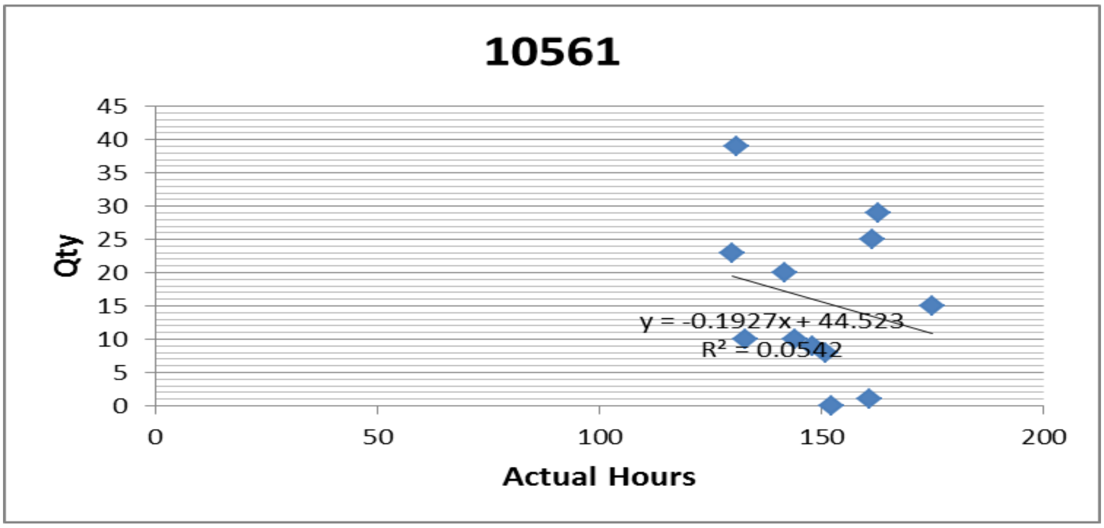

***Fig. 8:*** *Correlation Analysis between Actual Hours and Quantity of Tools Broken by a Sample Size of 5 Employees Individually.*



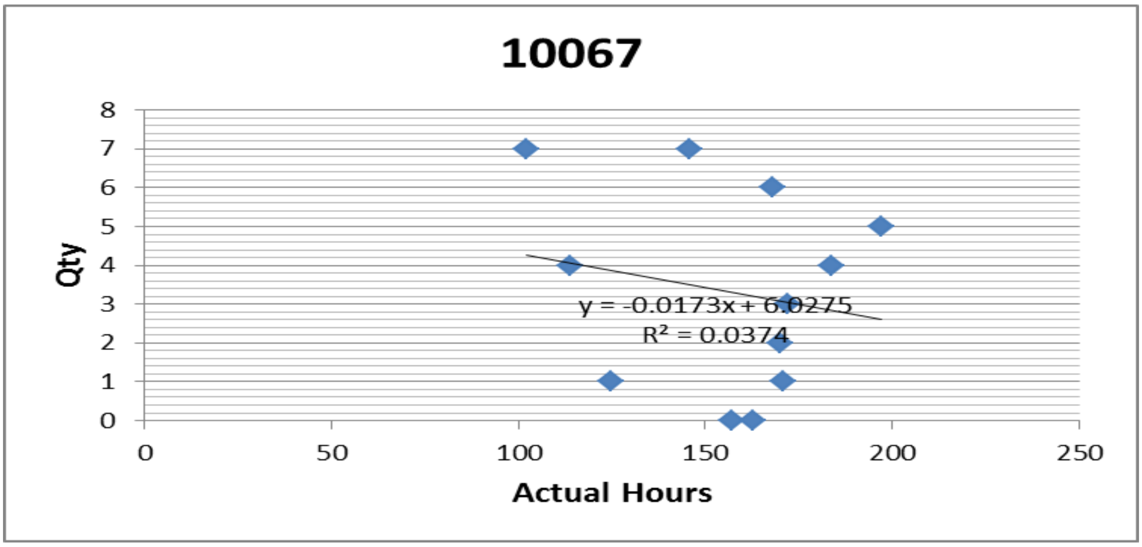

**Employee 1**




Employee 2




Employee 3




Employee 4

## Chi-Square Tests

- The Chi-square test is conducted to check for independence between departments of concern and the occurrence of the reason codes in these departments.
- The row variables were departments, the column variables were each of the nine reason codes.
- The values of certain reason codes were cumulated (1 and 2, 3–8).
- The null hypothesis is:
  - $H_0$: There is no relation between column and row variables.
- After the test was performed the Chi-square value of 221.6379, a correlation coefficient of 0.4516 and P value of 0 was obtained (Table 4)
- From the value it can be concluded that there is a strong evidence against $H_0$.

***Table 4:*** *Screenshot of the Chi-Square Test Calculator.*

| | | | | | |
|---|---|---|---|---|---|
| 5 | 15 | 14 | 117 | X | X |
| 0 | 0 | 1 | 183 | X | X |
| 22 | 0 | 4 | 133 | X | X |
| 80 | 5 | 4 | 132 | X | X |
| 53 | 0 | 0 | 97 | X | X |
| X | X | X | X | X | X |
| | | CALCULATE | CLEAR | | |
| | | **Chisquare** | 221.637999767287 | | |
| | | **Correlation** | 0.45162675988054 | | |
| | | **P-value** | 0 | | |
| **Conclusion** | | | | | |
| Very strong evidence against the null | | | | | |

## Providing Suggestions

The present study helped to draw the suggestions with respect to the reasons that HMT recognizes as potential threats to a tool.

### A. Carelessness:

- Better training.
- Ensure continuous improvement.
- Eliminate distractions caused while working.
- Pay more attention to inexperienced workers.
- Get veterans to assist the fresh recruits.
- Provide better civic amenities like drinking water and sanitation.
- Help to develop interest in the job at hand.

The two menaces such as carelessness and ignorance among operators which are the root causes of cutting tool breakage and also hazardous for health can be prevented by proper maintenance of tools and equipment and are required to be considered as the part and parcel of the organization [9].

### B. Defective Materials Used in Tools:

- The management should look to purchasing materials with better quality rather than ones with lesser cost.
- The cost factor should be given due importance but not at the expense of poor quality.
- Reduce casting and welding defects.

Breakages of cutting tools should be reduced by adopting durable tool materials and appropriate designing depending on the cutting to be done [7, 8].

### C. Job Complexity:

- Increase the standard time for each job.
- Better planning and schedule to minimize bottlenecks leading to stressful jobs.
- Defective Tools.
- Re-work of tools should be done correctly when broken.

- Care should be taken to ensure conformance to specifications.
- Customization of tools with respect to the job.

### D. Power Shutdown:

- Auxiliary power backup for critical departments like, HTC and Spindles, which involve the usage of high-cost equipment.
- Machines should be appropriately insulated or earthed to avoid short-circuits of any kind.
- The power supply should not be overloaded.

### E. Mechanical Trouble:

- Age of the machine is a critical factor. If it is not possible to purchase, maintenance and support should be provided.
- Tool fixtures should be properly engineered.
- Appropriate use of coolants and lubricants.

### F. Normal Usage:

- Repetitive usage of the same tool for the different operations should be avoided.
- Speed and feed rates should be controlled according to the job.

### G. Miscellaneous:

- Data pertaining to tool breakages on the floor should be correctly recorded and entered into the ERP database to ensure better understanding of the reasons behind breakage.

## CONCLUSIONS

Cutting tools play a pivotal role in any industry. Breakages encountered in such tools actually lead to loss of the industry. In order to assess the quantum of the breakage and reasons for the loss due to tool breakage, the present project was undertaken in Hindustan Machine Tools, Bangalore complex (MBX), among the five departments that accounted for higher loss. The statistical approach in the project led to the conclusion that proper training to workers; use of good-quality raw material for tool designing; proper insulation to high-cost electricity-run equipment; proper maintenance of equipment and normal working hours would help the company to overcome the losses incurred during the tool breakage.

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