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Reduction of Standard Cost of Ball Bearing

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Abstract: A bearing manufacturing line is complete flow of rings from material to finish in form of one piece flow from one machine process to another sequentially placed one after another connected by conveying manufacturing lines. A production manufacturing line is "factory within the factory" with dedicated machines, assortment and people, forming a well-structured flow of products by the bottleneck operations. Management of bottleneck is very important as it determines the production capacity, production capacity determines the output and output determines income, the output influence the cost per product, the income and cost determine the result and result finally determines future.The lost minute in the bottleneck is a lost minute for the entire manufacturing line and for all future.Managing the bottleneck is the most important activity in the entire production manufacturing line.

Keywords: Cycle time, Standard cost, Bottleneck machine, hard turning.

I. INTRODUCTION

Globalization, increasing cost pressures and stringent regulatory requirements are driving manufacturers to focus on methods to gain operational efficiencies. To overcome this situation proactively decided as one of key factor in performance of group was strong implementation of specific programmed called a 3C.The 3 Cs stand for Customer Cost Cash. In Cost reduction one of focus in reduction of manufacturing cost and manages downturn. To understand manufacturing line costing it is first necessary to understand manufacturing line concept which in turn supports the Temple of Manufacturing Excellence i.e., promoting higher quality and better service at lower cost.

II. BASIC CONCEPTS

Manufacturing Line Concept

A bearing manufacturing line is complete flow of rings from material to finish in form of one piece flow from one machine process to another sequentially placed one after another connected by conveying line. A production manufacturing line is "factory within the factory" with dedicated machines, assortment and people, forming a well-structured flow of products by the bottleneck operations. Management of bottleneck is very important as it determines the production capacity, production capacity determines the output and output determines income, the output influence the cost per product, the income and cost determine the result and result finally determines future. Managing the bottleneck is the most important activity in the entire production manufacturing line.

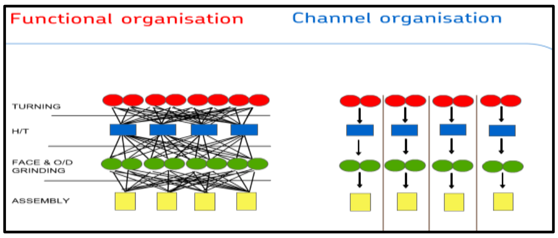

Fig.1. Manufacturing Line Concept

Manufacturing Line Cost

To run a manufacturing line resources are required to achieve production goals these resources are called manufacturing line resources or manufacturing line cost. Manufacturing line cost consists of

People in terms of wages for workers and salaries for staff employees.

Machines and equipment in terms in initial capital as assets and depreciation for cost of wear.

Raw Material and components required to produce bearings bought out from external or internal as rings, balls, cages, seals etc.

Shop Supplies are material not directly used in or as part of a product such as abrasives, tools, packing, oil, etc.

Utilities are resources as gas, electrical power, heating and water.

Manufacturing Line Efficiency

The purpose of manning a production manufacturing line and keeping it open for production is obviously to produce output. Manufacturing line efficiency is the measurement of how well the manufacturing line is utilized to produce output during the manned hours, and is calculated as a ratio between running hours and manned hours.

Manufacturing Line Efficiency= Running Hours /Manned Hours

The capacity of the bottleneck operation sets the limit of the manufacturing line output. The delivery of finished products will never be higher than the volume produced by the bottleneck. The performance of the bottleneck decides the output (income) of the manufacturing line. To control how the manned hours are used in the bottleneck is the key to controlling the manufacturing line efficiency. A high manufacturing line efficiency will obviously generate a higher output (income) for the manufacturing line.

Bottleneck Machine

The bottleneck operation is determined by longest cycle time of the products allocated to the manufacturing line. The bottleneck determines the production capacity.

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The production capacity determines output. The output determines the income. The output influences the cost per product. The income and cost determines the result.

Standard Cost

An estimated or predetermined cost of performing an operation or producing a good or service, under normal conditions. Standard Cost (SC) is the local standard for raw material, components and operation cost in the manufacturing process. They all add up to standard cost for the finished product. A unique value to measure volumes, flows and inventories of production material and products within a manufacturing unit. SC is the base for many Key Performance Indicators (KPI) in each manufacturing unit.

III. STANDARD COST BREAKUP & ANALYSIS

Standard cost mainly consists of direct material cost and the production cost required for producing good or service.

Basic Cost elements in standard cost= Direct Product cost (Material and sub-contracting) + Indirect variable costs allocated to each product (Variable VA Cost per hour in the bottleneck) +Indirect fixed costs allocated to each product (Fixed VA Cost per hour in the bottleneck)

Production cost is the cost incurred in the actual manufacturing of the product, tooling cost, cost required for utilities & shop supplies, manufacturing line efficiency, cycle time of operation, setup hours, etc.

Basic Cost elements in standard cost= Manufacturing line efficiency + CT + Setup hours + Overhead cost + Operation yield

Overhead cost is the expense directly associated with the production of goods or services such as for lighting, maintenance, and rent of a business premises.
All Cost structure factors cannot be improved at one time. So, there is need to identify critical parameters and prioritize the factors to be improved. Method to analysis used is Sensitivity Analysis Design for understanding contribution of individual cost breakup parameters.

Pareto Chart

Pareto chart of the effects to compare the relative magnitude and the statistical significance of both main and interaction effects. It displays the:

- Absolute value of the unstandardized effects when there is not an error term
- Absolute value of the standardized effects when there is an error term

Pareto chart shows the effects in decreasing order of the absolute value of the effects. The reference line on the chart indicates which effects are significant. From fig. 2 it is concluded that the main factors affecting the standard cost of ball bearing are

- Material Cost
- Efficiency
- Overhead value
- Cycle time

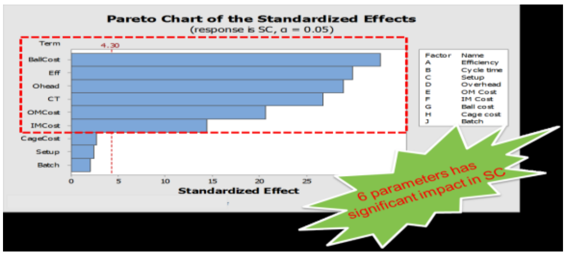

Fig. 2. Pareto Chart

Percentage Contribution of Parameters

The main effects plot (fig. 3) is most useful when you have several categorical variables. We can then compare the changes in the level means to see which categorical variable influences the response the most. A main effect is present when the mean of the response changes at the different levels of the variable. For a variable with two levels, the mean is higher at one level of the variable than at another level. The main effects plot is created by plotting the fitted mean for each value of a variable in the model. When the line is horizontal (parallel to the x-axis), then there is no main effect present. When the line is not horizontal (parallel to the x-axis), then there is a main effect present. Different levels of the categorical variable affect the response differently. The greater the difference in the vertical positions of the plotted points, the greater the magnitude of the main effect.

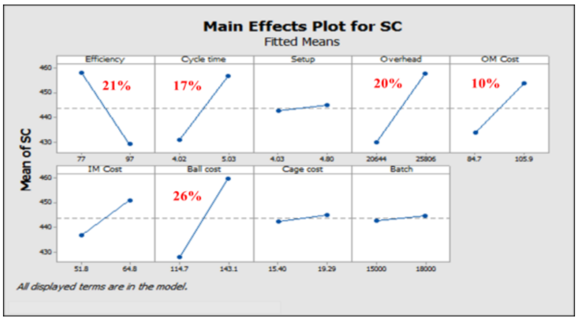

Fig. 3. Main Effect Plot

Pareto Chart for Factors Signifying Priorities

A Pareto chart (fig. 4) ranks defects from the largest to the smallest contributor, which can help us separate the "vital few" problems from the "trivial many." The right Y-axis shows the percent of the total defects and the left Y-axis shows the count of defects. The blue line indicates cumulative percentage, which can help us to judge the added contribution of each category. The bars of the histogram show the count for each category. The counts, percent, and cumulative percent are listed for each category.

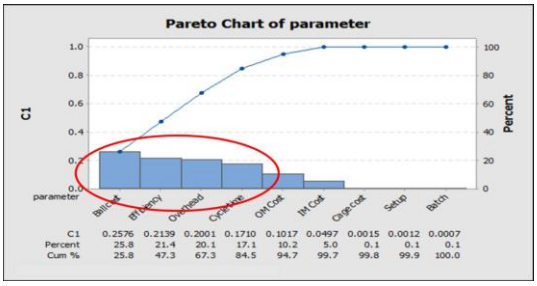

Fig. 4. Pareto Chart for Factors Signifying Priorities

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The main key factors identified from analysis need to be improved are

- Overhead cost
- Material cost
- Cycle time of the bottleneck machine

In this paper we are discussing about how to reduce cycle time to reduce the cost of the bearing.

IV. CYCLE TIME REDUCTION

Cycle time is time taken by machine to process one ring. As seen in manufacturing line concept, manufacturing line is made of no. of machines laid down as per process layout for mass production, here it is called as one piece flow, ring flow from one process to anther with addition of value in ring. Ring flow is slowest at Bottleneck machine which has high cycle time which determines the complete output of manufacturing line.

To identify real bottleneck machine we use sensitivity analysis tool using Process Simulator software. Sensitivity analysis tool is used basically to find out real losses in manufacturing line with respect to cycle time deviation, machine adjustment downtime, machine downtime, waiting time, idle time, scrap, rework etc.

Process Simulation & Analysis

Process simulation is used for the design, development, analysis, and optimization of technical processes such as chemical processes, complex manufacturing operations, biological processes, and similar technical functions. Process simulation is a model-based representation of chemical, mechanical, biological, and other technical processes and unit operations in software. Basic prerequisites are a thorough knowledge of the actual process to allow the calculation of a process in computers. Process simulation software describes processes in flow diagrams where unit operations are positioned and connected by product or educts streams. The software has to find out the uncertainty in the output of a mathematical model or system can be apportioned to different sources of uncertainty in its inputs.

The development of models for a better representation of real processes is the core of the further development of the simulation software. To develop the simulation model thorough knowledge of the actual process is required. For this model we have knowledge of machine cycle time, machine downtime, machine idle time, machine availability percentage, scrap percentage, etc. for each and every machine utilized in manufacturing process on the manufacturing line.

From simulation it is concluded that

- The main cause of loss of productivity and increase in standard cost of ball bearing is the cycle time deviation of bottleneck machines.
- To reduce cycle time and improve manufacturing line efficiency the hard turning process of manufacturing is used instead of grinding process.

Hard Turning

Producers of machined components and manufactured goods are continually challenged to reduce cost, improve quality and minimize setup times in order to remain competitive. Frequently the answer is found with new technology solutions. Such is the case with grinding where the traditional operations involve expensive machinery and generally have long manufacturing cycles, costly support equipment, and lengthy setup times. However, the grinding process itself may require several machine tools and several setups to finish all component surfaces. Because grinding can be a slow process with low material-removal rates, there has been a determined search for replacement processes.

The newer solution is a hard turning process, which is best performed with appropriately configured turning centers or lathes. Hard turning really started to develop at the beginning of the nineties. The reason for this was the availability of new tool materials and the capability of designing a turning machine that was rigid, stable and accurate enough to successfully finish hard turn. The result of these developments have made finish hard turning a viable alternative to grinding, as an accurate finishing operation.

Fig.5. Hard Turning

Process

Hard turning is defined as the process of single point cutting of part pieces that have hardness values over 45 RC but more typically are in the 58- 68 RC range. Hard turning is performed using a variety of tipped or solid cutting inserts, preferably CBN. Although grinding is known to produce good surface finish at relatively high feedrates, hard turning can produce as good or better surface finish at significantly higher material removal rates. Although the process is performed within small depths of cut and feedrates, estimates of reduced machining time are as high as 60% for conventional hard turning.

Multiple hard turning operations may be performed in a single setup rather than multiple grinding setups as shown in fig. 6. This also contributes to high accuracy achieved by hard turning.

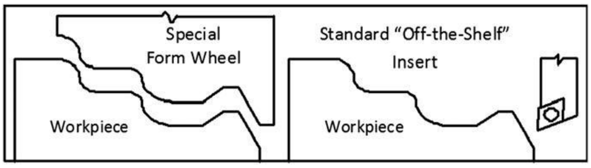

Fig.6. Grinding vs Hard Turning

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From an applications standpoint, hard turning is very much a part specific process. It excels at cutting complex geometries that contain intricate arcs, angles, and blended radii. Instead of having to buy a form wheel for the grinder, you can program the lathe's single point much faster and cheaper. Hard turning can eliminate several types of grinding, as well as lapping and other finishing operations. Not only is removing steps from the process money in the bank, but, for some, it can also mean bringing outsourced work back under their roofs and under their own control. Hard turning is a way to achieve high machining efficiency in anenvironmentally-acceptable manner and a new technology to machine hardened parts processed by forging or casting. Compared with grinding, hard turning can machine some complex workpieces in one step. The machining cycle time of hard turning can be up to three times faster than grinding. Hard turning also consumes about one-tenth of the energy per unit volume of metal removed than grinding and is more environmental friendly.

Hard turning is best accomplished with cutting inserts made from either CBN (Cubic Boron Nitride), Cermet or Ceramic. Since hard turning is single point cutting, a significant benefit of this process is the capability to produce contours and to generate complex forms with the inherent motion capability of modern machine tools. High quality hard turning applications do require a properly configured machine tool and the appropriate tooling. For many applications, CBN tooling will be the most dominant choice. However, Ceramic and Cermet also have roles with this process. The range of applications for hard turning can vary widely, where at one end of the process spectrum hard turning serves as a grinding replacement process, and can also be quite effective for pre-grind preparation processes.

Commonly processed hard turned materials would include:

- Steel Alloys such as
- Bearing steels
- Hot and cold-work tool steels
- High speed steels
- Die steels
- Case hardened steels

Machining Requirements for Hard Turning

- Machine rigidity
- Part rigidity
- Solid work holding
- Rigid location
- Vibration damping
- Rigid tools

Advantages of Hard Turning

- Soft turn and hard turn on the same machine
- Smaller floor space requirement
- Lower overall investment
- Metal removal rates of 4-6 times greater
- Can turn complex contours
- Multiple operations in a single setup
- Low micro finishes
- Easier configuration changes
- Lower cost tooling inventory
- Higher metal removal rates
- Easier waste management (chips vs swarf)

Limitations of Hard Turning

Although hard turning is an impressive process due to its ability to replace grinding as finishing process, which is a costly process due to machine cost, setup cost, lubricant cost and hazards, but as far as the surface integrity of the product is concerned, there are few limitations of the process as mentioned below.

- Low magnitudes of compressive residual stresses and the stress profile with the position of maximum stress at a certain distance beneath the surface. In general, the residual tensile stresses exist at the surface.
- The process-induced white layer leading to substantial variations in component service performance.
- Dimensional, geometric form and surface roughness errors resulting from tool wear. The other error-drive factors are high cutting forces and thermal expansion on workpiece and cutting tool.

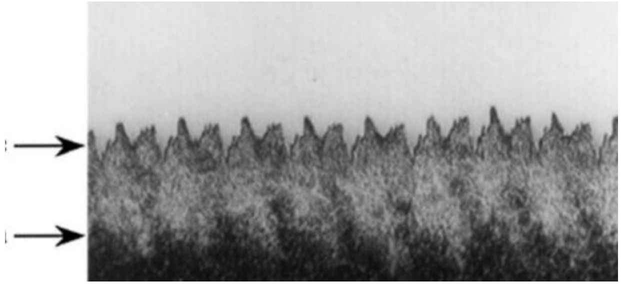

Fig.7. White Layer in Hard Turning

In spite of its limitations the process is very attractive on shop floor as it replaces grinding for finishing the hardened work parts like ball and roller bearings, crank pins, turning of small bores during manufacturing of injection nozzles for gasoline engines and other automotive components.

Accuracy of the Process

For any process to be accepted by the industry it should be robust and accurate as far as the performance is concerned. Few researchers have investigated process accuracies and the sources of errors to establish the reliability of the hard turning process as a substitute to finish grinding. The possible error driver factors and error sources (Fig. 8) were analyzed in a precision hard turning.

Tool wear, cutting forces and temperature induced by the cutting process on the cutting tool and workpiece are found to be the major error drive factors in hard turning. In an attempt to analyze the geometrical accuracy achievable in hard turning investigations were performed in a working environment in order to determine the attainable size, form and positional accuracy obtained with hard turning. In the parts produced in series, size deviations, out-of-roundness, cylindricity error and parallelism error of the bore’s generatrices were measured. It was observed that as compared to grinding, cylindricity error, like out-of-roundness, was higher for hard turning but still

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workable, while the parallelismwas better in hard turning. But on the entering side, the diameter is smaller due to insufficient conduction of the intensive heat. Flatness error, while being adequate in hard turning, was very high in grinding. Also the axial run out was much higher in grinding. From above it is evident that with effective control on error sources, hard turning can achieve the level of accuracies desired for the finishing levels. It can even surpass the grinding capabilities if executed carefully. That is why hard turning is now increasingly replacing finish grinding of the components.

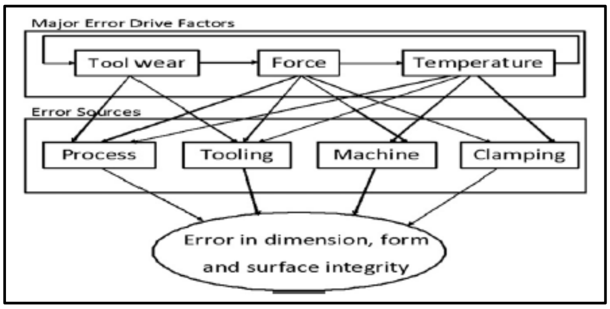

Fig.8. Major Error Driver Factors and Error Sources in Precision Hard Turning

Hard Turning vs Grinding

GRINDING	HARD TURNING
Long set up times	Short set up times
Multiple clamping operations	Single clamping operation
Long cycle times	Cycle times up to 80% faster
Low chip volume	High chip volume possible
Profiled grinding wheel	Single point tool tip
Non-productivedressing operations required	No dressing, effectivecutti ng time
High investment costs	Low investment costs
Environmental unfriendly due to grinding sludge	Dry cutting, thus clean process

Table1. Hard Turning vs grinding

Hard turning is competitive in many cases compared to grinding but the white layer formation is detrimental for the component life. Properties of white layers from both the processes are fundamentally different in four aspects namely surface structure characteristics, micro-hardness, microstructure and chemical composition. A turned white layer is much more strained than the ground white layer. The thickness ratio of dark to white layer for a ground layer is much larger than for the turned surface shown in fig. 9. The micro-hardness profile for both the processes may be the same but the ground white layer can be40% harder than the white layer in turning. A turned white layer is etching resistant while the ground white layer is not. A turned white layer has much more retained austenite than a ground one.

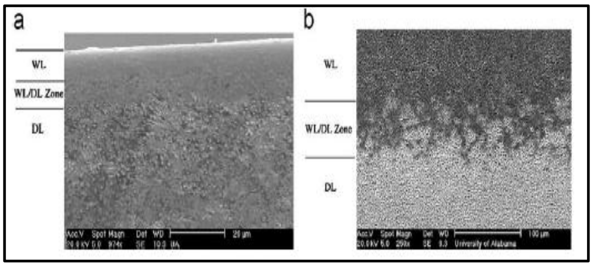

Fig.9. Surface Structures of (a) Hard Turned and (b) Ground Surfaces

V. CONCLUSION

We understand manufacturing line costing, manufacturing line concept, manufacturing line efficiency, etc. which in turn supports the Temple of Manufacturing Excellence i.e., promoting higher quality and better service at lower cost. From standard cost breakup analysis it is concluded that the main key factors affecting the standard cost of the ball bearing. From process simulation and analysis we verified the SC breakup analysis results. Process simulation analysis gives us the main cause of loss of productivity and increase in standard cost of ball bearing.
To reduce cycle time and improve manufacturing line efficiency the hard turning process of manufacturing is used instead of grinding process. From comparison of grinding and hard turning it is concluded that due to incorporating the hard turning process in the ball bearing manufacturing process we can reduce the cycle time required for bearing manufacturing. As the cycle time reduces the standard cost of ball bearing get reduced by approximately 15% to 20% because of hard turning.

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