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Abstract: This team project studied the hub machining process at Consolidated Metco. The parts selected is part no. 102198. Thickness of the parts had very large variations resulting quite a few scrap. The control charts were set up to detect the problem with the process. Special causes were identified. The economic and practical suggestions were made to monitor and control the process. The team also Pointed out that although SPC has been implemented for several years, the processes are still out of control. The control charts should be set up correctly and then the charts should truly be used for on-line control.

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QUALITY IMPROVEMENT FOR PART NO.102198 IN CONSOLIDATED METCO

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TABLE CONTENTS:

Introduction

The work group studied the hub machining process at Consolidated Metco. The parts being machined are the wheel hubs used on Class (over 30,000 lb. GVW) trucks. Typical hub machining drawings are shown in the appendix.

The group visited the plant to see the machining process and ask about possible problem areas in the machining process. Employees identified flange thickness variation as a problem needing investigation. The monthly scrap report "dirty dozen"(see appendix) shows the top two parts to be scrapped in the machine shop to be part number 102399 and 102198. We were informed that the 102399 hubs were machined at an outside source. The 102198 hub is the cause of the most scrap in the machine shop. The Pareto chart issued by plant Quality Assurance (see appendix) shows flange thickness to be the most frequent defect.

Control charts are kept for several machining dimensions. Typical control charts are shown in the appendix. Flange thickness is not a charted variable. The nominal flange thickness is 1.500"$\pm$.010" . This is not a very tight tolerance as the flange thickness is not that critical to the functioning of the part. The parallelism of the flange is critical. Both the front side of the flange and the back of the flange are held to a total runout of .006" with respect to the bearing bores. The functional reason for this is that when the hub is rotating on the axle spindle, the mounting face for the wheel is the outboard flange of the hub. A runout at the hub is amplified more than

3.5 times at the tire circumference. Excessive runout will cause tire shake and the hub will be returned under warranty.

Due to the machining sequence and the geometry of the part, the outboard flange face (the outboard side is the side of the hub facing away from the truck) must be machined in the first operation. The bearing bores must be machined in the second operation which uses the machined flange face to align the hub for chucking in the lathe. The operation uses two lathes set up in tandem to complete the turning operation. Since the mounting face and the bearing bores are turned in separate operations on different lathes, there is an opportunity for excessive runout. The flow chart shows the sequence of operations for the machining of the hubs. The part number 102198 hub is a front axle hub. Rear axle and trailer axle hubs do not have the same problem since the flange face and the bearing bores are turned in a single operation.

The drill and tap operation is the final part of the machining sequence. This is done on a CNC machine at a later time. If there is excessive runout, the flange will show uneven chamfers from one side of the hub to the other. This visual check is where the defective parts are most often detected.

The runout is difficult to check easily, so the flange thickness variation is used as a proxy. The inboard flange face is machined in the second operation with the bearing bores. The runout between the bearing bores and the inboard flange is virtually nill. Any thickness variation in the flange can be attributed to runout between the outboard flange face and the bearing bores.

manufacturing processes. We analyzed the Pareto charts provided to decide our objectives for the project. We also checked their control charts. Then, we selected product and process as the objectives; made the flow chart; used our own check sheets to collect data; set up the control charts, and cause effect diagrams using our data and the data provided by the company Pareto charts In order to make the plan to help the company to continuously improve the process for better quality, we needed to identify and prioritize the candidate processes that either has a lot of problems or is a good one which can be greatly beneficial for the company if the variance is greatly reduced. The facts about the current performance and critical problem were found by using Pareto charts.. We selected reducing scrap as our main focus. Which part has more scrap than the others? Which process causes the most problem or which characteristic has more problems than the others? These questions were answered by examining eight current machine shop scrap Pareto charts. Part no 102198 (hub) has highest rank in the number of scraps in the chart in the month updated (The other highest one is not controlled by the company). Among all of the characteristics, flange thickness problem caused most scrap. Therefore, we chose the objective process for improvement. Since significantly reducing variance in one of the bore sizes of the same part is desired by the company, we also checked the related process.

2. Flow chart

At the beginning of the project, all the members went to the shop to see the whole production process from casting to assembly lines, which helped us to better understand the sequences of the steps involved in manufacturing the parts. Then flow chart for machining the part 102198 was drawn to help us to find where the problem lies and/or where is the good or better position for measurement and control.

Although the flange thickness of the hub is machined on Machines W/S3 and W/S4, many decisions about scrap are not made until next process is finished on another machine. Clearly, if the measurement is checked immediately after finishing machining on W/S 4, another machining spending will be saved. Thus, we suggested to take measurements immediately after machining on W/S 4 and we used the data measured there for our control charts.

3. Check sheets

Check sheets were designed for collecting data. Part number, date, time, measurement locations are recorded as well as the thickness.

The specifications about the thickness includes two groups of tolerances. The nominal value of the thickness is 1.500 in. . The tolerance for the thickness is $\pm$ 0.010 in. The other group of tolerance is for the largest difference between the thickness in different positions on each hub, which is 0.006 in.

Because the thickness is different at the different locations, we chose four or five positions to take the measure. The mean of the measurements is the thickness of the part, and the range of the 4 or 5 measurements is the difference used to check against the second group of tolerances.

On the check sheets, all of the measurements and the mean, range are recorded to facilitate analyzing data in the following steps.

4. Histograms

Histograms were intended to be used for assessing process capabilities and examine the distributions of the data.

Because the processes were not in control, process capability was not assessed.

In order to set up control charts, the distributions of the thickness data and bore size data were examined by histograms. Then best fitting of the theoretical distributions to the data histogram were conducted using SIMAN program (see exibit 1-4).

According to the results, the thickness data was very close to Beta distribution or Lognormal distribution, and right skewed. The bore size data appears to follow Beta distribution , very close to normal one. Actually, when the number of data are quite large, the distributions are normal ones. Therefore if individual control charts are used for not large number of samples, bigger errors are expected than those in use of X-bar charts. Since all the data show single bell shape distribution, sample size of 4 or 5 should be enough for central limit theorem to effect for X-bar charts.

5. Control charts

Control charts are the most important tools used. They were intended to used to monitor the process, to diagnose if the process is under statistical control, to tell the operator when to leave the process alone and when to make necessary adjustment and to find special causes to the out of control points. When the charts show the process is under statistical control, the charts would be used to make process capability analysis to assess the capability to meet the requirements of the specifications; they would also used to check if the efforts work taken by management to reduce the variances of the process give a result or not.

To examine the process machining the thickness, we set up the control charts to see what happened. The first step was to collect data. No ready data was available. We must take measurements ourselves. Unfortunately, we did not have the time to perform measurement gauge and reliability studies. In order to closely examine the process, 100% inspection was done for one day process as well as the inspection with one hour interval for more than one day.

Two types of sampling were used. the first type we take 5 hubs from every layer of 16. These samplings were taken until 26 samples. Second type of sampling is 100% inspection , more than 100 hubs were measured within one shift. We spent more than two days to collect the thickness data. We did not have time to collect bore size measurements, but we have a lot of those data taken by the operators.

QCPROG was used to set up the control charts. X-bar and S charts were set up for the mean and largest difference in thickness in a hub respectively. As expected, a natural process on which statistical control has not been implemented is out of control. The control charts for both the mean and the difference were not in control (see exibit 5-7). Two extreme points were identified. Both are out of control limits and specification limits, resulting in scraps. Special causes for them were explored (this will be addressed in the next section). When these two points are eliminated out, the control charts still show out of control process (see exibit 8-9).

It seems to be desired that the control charts are set up for the thickness to control the scrap. Yet close examination of the charts shows the variation range was small. Since the variation range on X-bar charts can not be compared directly with the tolerance range, run charts were set up for individual values of each hub against time/ samples (see exibit 10). Also shown on the chart are nominal value (1.500 in.), upper specification limits (1.510 in.), and lower specification limit (1.490 in.). Apparently, although the process was not under statistical control, the variance range was much smaller than that of tolerance, and the data were close to target. And , the process was relatively stable comparing to tolerance range.

Besides that, by closely examining all the charts again (especially the run charts), we see that the out of specification points are quite unrelated to their former points. The behavior of the former points do not reveal any possible out of specification signal in the following points. Thus, it is chart are inflated, so the X-bar chart is meaningless. This fact does not seem to be noticed by some people in the company. The control charts for some other parts were also examined, which were out of control, too. We were agreed with by the company that the processes we checked were not in control

6. Cause-Effect Diagrams

To find the special causes for the scrap, a cause-effect diagram was made to list out all of possible factors resulting the problem. Unfortunately , we did not have time to set up and examine the diagram together with the operators and quality technicians who can help greatly for this work.

Among the possible causes related to the operators, machines , environment, materials, and methods, we think that machine and operator can become the causes (see exibit 14). The operators may be the main factor who failed to thoroughly clean up the chips left on the fixtures after the former parts were machined. Other causes are possible too. But, the chips may be the main causes for the two out-of-spec points detected. Hence, suggestion was made to the operators to be more cautious about the chips.

7. Summary

To summarize, the processes under the study were not under statistical control. Yet, for the thickness process, since tolerance range is much larger than that of variance of most points, and

- Redesign the chuck jaws that will not collect chips.

Long term improvements include:

- Implement TQM philosophy in the company.
- Develop a steering team that include top management, key quality persons, and project team to bring the process in control and then continuously monitor the process for continuous improvement.
- Develop flow-chart for every individual process in the company so problem can be traced easier.
- Design the hub or process that can be executed in one machine instead of two to reduce the set up time and errors.
- Advance training for operator and quality people in SPC to make them understand better in the nature of process and to improve the quality of the product.

Conclusions

The project team found two hubs that were out of specifications. These defectives were determined to be the result of special causes. These hubs were the problem that we want to investigate.

The Project Team concluded that based on the limited numbers of measurements for the flange thickness on Hub No. 102198, the process of machining the hubs for flange thickness is out of control. After eliminating those two out of specification hubs the control charts show that the process is out of control but still within the specifications

The process does not seem centered within specifications. The X-bar chart shows a significant downward trend, i.e. the thickness of the flanges were getting thinner during the period when the Project Team took their measurements We did note that even with the X-bar chart showing the significant downward trend, the individual measurements were still within the specifications as established by Consolidated Metco for the hubs.

The Project Team also concluded that we did not have enough data to fully assess the economic impact or severity of the out-of-specification flange thickness to Consolidated Metco. Since the process was not in control, we could not calculate a process capability. However, from the individual run chart, we can observe that most of the time the process would manufacture parts within specifications.

To assess the full economics a "follow-up" team should do the following:

- We recommend that Consolidated Metco review the specifications for the hubs. The tolerances of 0.010 inches variation on the thickness and 0.006 inches for the parallel faces may be too wide as the process appears capable of being out of control but still within the tolerances.
- A sampling plan for detecting out-of-specification flange thickness should be developed to detect defective hubs before the holes on the flanges are drilled. This would prevent the company from putting any more machine time into a defective hub.

- The severity of an out-of-specification hub may be worse than just the cost of 6 reject hubs per month. A test of whether a defective hub would be detected showed that not all out-of-specification hubs are removed from the final assembly process. It appears that some defective hubs are being shipped to the customers. We recommend that a "follow-up" team collect more data to determine how many nonconforming parts are being inadvertently shipped to Consolidated Metco customers.
- We also recommend that customer surveys be done to record and estimate the number of returned hubs for out of parallel faces and the cost of correcting this defect. We perceive that the economic impact to the company for the out-of-specification flange thickness may be more than the $300 per month for the cost of scrap. The true cost of this error in the manufacturing process will be needed to balance the cost of implementing a statistical process control program to monitor the thickness of the hub flanges.

At last, the Project Team would like to express its appreciation and thanks to the management and employees of Consolidated Metco for their cooperation and assistance in this study.