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Process Capability and Stability Analysis In Track Grinding of Taper Roller Bearings

Shrikant Jadhav, Ravi Sekhar*, T. P. Singh
Symbiosis Institute of Technology (SIT),
Symbiosis International University (SIU),
Lavale, Pune - 412 115, Maharashtra State, India
**Email: ravi.sekhar@sitpune.edu.in*
***Ravi Sekhar**
Assistant Professor,
Symbiosis Institute of Technology (SIT),
Symbiosis International University (SIU),
Lavale, Pune – 412 115, Maharashtra State, India
**Email: ravi.sekhar@sitpune.edu.in*

Abstract

The competitive natures of today's markets enforce rigid stipulations on the manufacturing industry in terms of quality and productivity. Process capability and stability analysis is a quality improvement program that helps manufacturers to improve productivity and cut losses. In the present work, inner and outer track grinding of taper roller bearings was studied. Based on the collected data of over a hundred bearings for each of the bottleneck machines, the said analysis revealed eye opening information regarding process average instability, capability crossing lower and upper specification limits, detection of non random patterns hinting at special causes etc. Results also indicated the number of defective parts per million likely to be produced by the 'diseased processes'. Such insights are vital for the manufacturer to immediately tend to the 'loss-making' processes / machines, and improve quality.

Introduction

Quality assurance is a compulsory requirement for any manufacturing industry today. Inconsistent quality of products can put manufacturers out of business. Market competition also dictates quality products to assure customer satisfaction and retention. To ensure quality, industries need to consistently produce products and components within design specification limits. Any deviation from these limits results in scrap or rework, which lowers productivity and leads to wastages and costs overruns. Deviations can be caused due to improper selection of parameters, or due to variations in the process itself [1].

Process capability analysis is a widely used tool in industry that measures the capability of any process to consistently produce parts within engineering tolerances [2]. It is a salient part of the DMAIC based Six Sigma quality improvement program. Process capability (Cp) measures the dispersion of a product quality parameter within defined limits. Process capability index (Cpk) provides an insight into the difference between the desired process mean and the actual process average output. It helps the manufacturer to realize whether the process mean is shifting upwards or downwards from the intended mean values. Too much shift in the process mean may result in a large number of rejections or rework [3].

Chalisgaonkar and Kumar [1] studied process capability in wire EDM of pure titanium. Sahoo et al [4] used DMAIC approach to minimize residual stresses in radial forging process. According to Oliviera et al [5], process reliability is a very important issue in many cases of grinding related problems. Tenera and Pinto [6] suggested a Lean Six Sigma theory to incorporate the waste minimization of lean manufacturing and process variability diminution of six sigma into a single model. Mast and Lokkerbol [7] critically examined the Six Sigma DMAIC method for its problem solving capabilities. Youssouf et al [8] used DMAIC to optimize the maintenance procedures for industrial systems.

Bearings form an integral part of any rotary machine. Properly dimensioned bearings are essential for proper functioning of the entire machinery [9]. Taper roller bearings form a vital part of gear reducers [10]. Grinding forms one of the final processes of manufacturing products having close tolerances [11]. Grinding process variations may result from disparities in grinding forces, grinding wheel wear and even work surface roughness. Force variations before and after grinding wheel dressings are also significant [12].

In the present work, the inner and outer track grinding of taper roller bearings is investigated for process stability.

Data Collection

Identification of bottlenecks

Firstly, bottleneck machines were identified out of a total of six machines on the line. For this purpose, the average cycle times in grinding 50 rings was recorded for each machine. These average cycle times were compared with the target cycle time of 11 seconds (Fig.1).

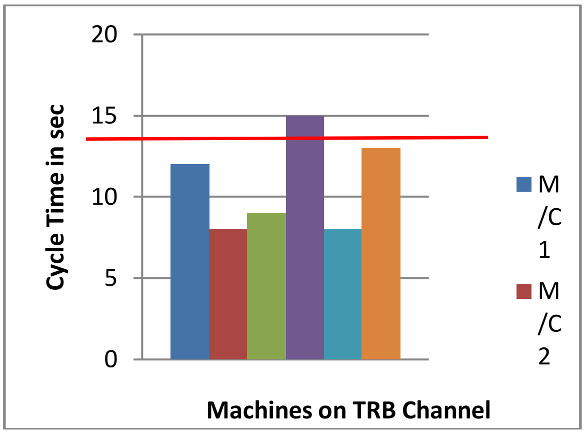


Figure 1: Average cycle times for taper roller bearing (TRB) grinding channel

As is evident from Fig.1, machines 1, 4 and 6 were singled out as the bottleneck machines contributing towards losses. Of these, machines 1 and 4 are outer ring track grinders, while machine 6 is an inner ring track grinding machine.

Baseline readings

Next step involved the collection of baseline readings for all bottleneck machines using the universal dimensioning machine (UDM). Table 1 shows baseline readings of measured track sizes of 125 bearings in inner ring track grinding machine 6. Similar readings were obtained for the outer ring track grinding machines 1 and 4.

Table 1: Baseline readings for IR track grinder 6

Sr.No.	Track size (mm)		Avg	Sr.No.	Track size (mm)		Avg
	Max	Min			Max	Min	
1	66	67	66.5	63	70	71	70.5
2	73	74	73.5	64	69	70	69.5
3	75	76	75.5	65	69	70	69.5
4	74	75	74.5	66	69	70	69.5
5	74	75	74.5	67	70	71	70.5
6	74	75	74.5	68	68	69	68.5
7	72	73	72.5	69	67	68	67.5
8	72	73	72.5	70	65	66	65.5
9	68	69	68.5	71	66	67	66.5
10	70	71	70.5	72	69	70	69.5
11	70	71	70.5	73	70	71	70.5
12	72	73	72.5	74	66	67	66.5
13	72	73	72.5	75	68	69	68.5

14	69	70	69.5	76	68	69	68.5
15	70	71	70.5	77	68	69	68.5
16	75	76	75.5	78	69	70	69.5
17	72	73	72.5	79	68	69	68.5
18	73	74	73.5	80	68	69	68.5
19	70	71	70.5	81	66	67	66.5
20	75	76	75.5	82	69	70	69.5
21	72	73	72.5	83	70	71	70.5
22	76	77	76.5	84	70	71	70.5
23	73	74	73.5	85	70	71	70.5
24	73	74	73.5	86	71	72	71.5
25	72	73	72.5	87	72	73	72.5
26	69	70	69.5	88	72	73	72.5
27	70	72	71	89	70	71	70.5
28	70	71	70.5	90	68	69	68.5
29	69	70	69.5	91	67	68	67.5
30	70	71	70.5	92	66	67	66.5
31	66	67	66.5	93	67	68	67.5
32	72	73	72.5	94	66	67	66.5
33	74	75	74.5	95	65	66	65.5
34	74	75	74.5	96	66	67	66.5
35	72	73	72.5	97	69	70	69.5
36	74	75	74.5	98	65	67	66
37	72	73	72.5	99	64	65	64.5
38	69	70	69.5	100	65	66	65.5
39	66	67	66.5	101	64	65	64.5
40	68	70	69	102	67	68	67.5
41	71	72	71.5	103	65	67	66
42	72	73	72.5	104	65	66	65.5
43	69	70	69.5	105	65	67	66
44	70	71	70.5	106	64	67	65.5
45	69	70	69.5	107	66	67	66.5
46	70	71	70.5	108	66	67	66.5
47	68	69	68.5	109	64	66	65
48	70	71	70.5	110	68	70	69
49	69	70	69.5	111	66	67	66.5
50	67	69	68	112	66	67	66.5
51	70	71	70.5	113	69	70	69.5

52	69	70	69.5	114	68	69	68.5
53	69	70	69.5	115	65	66	65.5
54	71	72	71.5	116	63	64	63.5
55	68	69	68.5	117	63	64	63.5
56	66	67	66.5	118	65	66	65.5
57	69	70	69.5	119	67	68	67.5
58	70	71	70.5	120	65	66	65.5
59	69	70	69.5	121	69	70	69.5
60	70	71	70.5	122	68	69	68.5
61	69	70	69.5	123	66	67	66.5
62	66	67	66.5	124	68	69	68.5
				125	65	66	65.5

Using the baseline readings for machines 1,4 and 6, IMR and process capability chart were obtained for each machine using Minitab software (Fig.2,3,4).

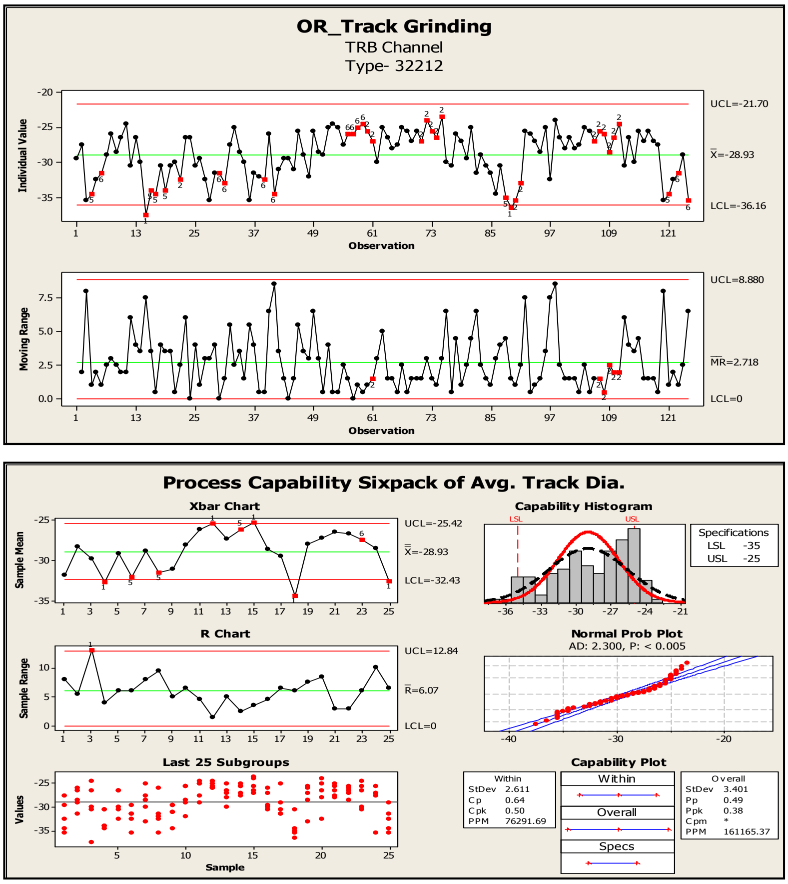
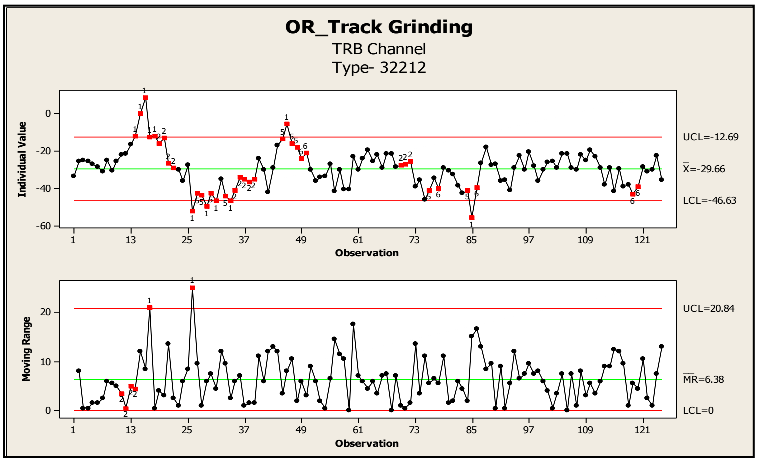


Figure 2: Process and stability charts for machine 1



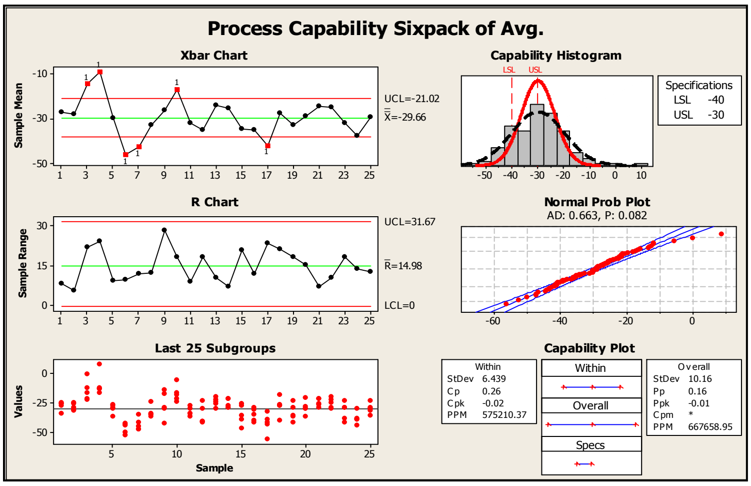
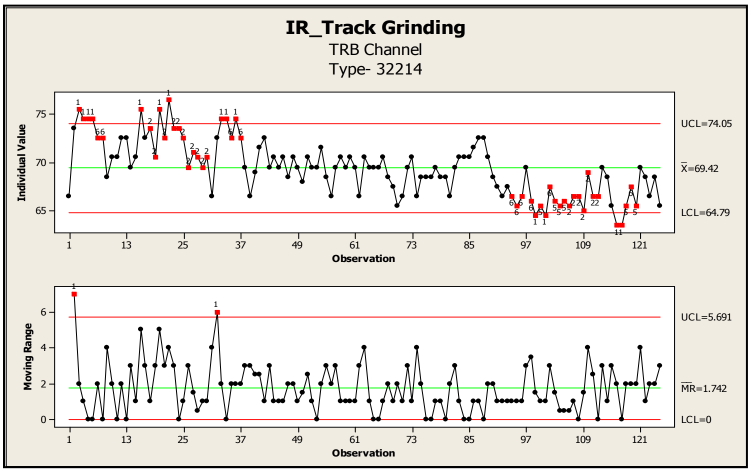


Figure 3: Process and stability charts for machine 4



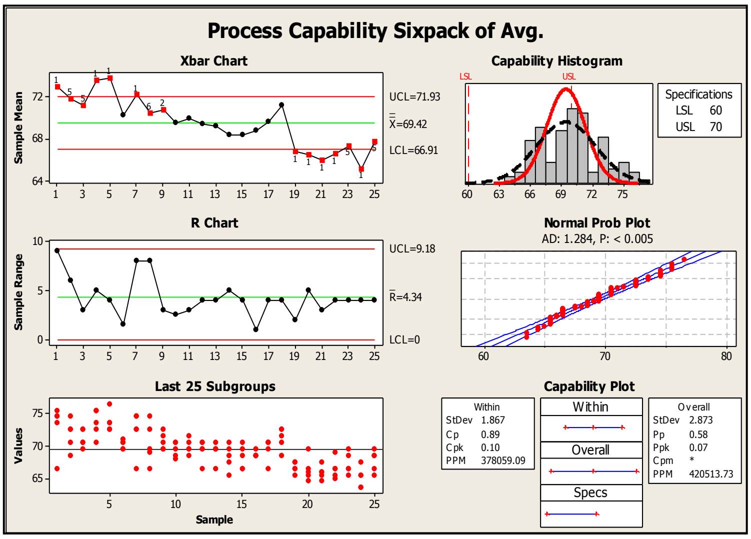


Figure 4: Process and stability charts for machine 6

Results and Discussions

The IMR chart plots individual readings (I chart) and moving ranges (MR chart) of the obtained data. This chart shows clearly whether the process under study is in control, i.e., the data variations are random, or it is out of control, i.e. variations are unusual due to some special reason(s).

The I-chart plot for machine 1 shows a number of points marked red by the software. This is to highlight that these points have failed one of the Minitab's special cause tests. For example, there are two points that have failed test 1, which means that these points are 3σ away from the centre line. Similarly, sixteen other points are found to fail test 2 (nine points in a row on same side of center line), eight points have failed test 5 (points more than 2σ away from the centre line on the same side) and twenty points have failed test 6 (points more than 1σ away from the centre line on the same side). The MR chart of machine 1 has also failed test 2. Thus, it can be concluded that the process for machine 1 is not only unstable, but is also out of control due to a number of special reasons.

Regarding the process capability chart for machine 1, it may be observed in the R chart that the third sub group fails the test 1. This again points towards some special reason that is causing variation during grinding of third sub group bearings. In X bar chart of the same machine, five points failed test 1, three failed test 5 and 1 failed test 6 implying the instability of the process. With regards to the capability histogram, the red curve indicates the overall process capability whereas the dotted line shows the within groups probability. Here it is clear that the process is producing more parts out of the upper control limit (UCL) than out of lower control limit (LCL). Due to such large process variations, the software predicts as many as 76291 defectives per million.

Regarding machine 4, similar observations can be made. The individual chart shows as many as 11 points outside control limits with 60 points inside control limits. This signifies non random variations due to special causes. In capability analysis, the X bar chart shows a hint of process instability due to a number of points failing special cause tests. However, the R chart tells a different story. The random distribution of points within the control limits in the R chart confirms the overall stability of the process. Similar random scatter can be viewed in the 25 subgroups plot as well. However, the capability histogram shows a significant deviation of the process beyond the UCL. This deviation leads to a prediction of 575210 defectives per million.

Regarding machine 6, the I chart is particularly notable. A lot of points are detected to fail Minitab’s special cause tests, indicating that the process is unstable and out of control. In capability analysis, the R chart shows all points lying within control limits, but their distribution is not random about the center line. In this machine also the capability histogram shifts towards the UCL, causing production of parts out of customer requirements. The estimated number of defectives per million is 378059.

Conclusions

In this work, process stability and capability analysis was carried out on 3 bottleneck track grinding machines. The first machine (1) was found to be unstable due to many data points failing the software’s special cause tests. However, in comparison to the other two machines (4 and 6), machine 1 was found to be more capable of producing in specification parts, with least defectives per million. Machine 4 is found to be seriously unstable and incapable with highest defectives estimated per million. Machine 6 has a moderate capability in comparison to the other 2 machines. However, the process is unstable because the data points are not found to be normally distributed. The process tends to spread beyond the UCL.

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