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APPLICATION OF DESIGN OF EXPERIMENTS IN TROUBLESHOOTING OF ROLLING REJECTIONS IN OUTER BALL JOINT PIN

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ABSTRACT

This paper aims to eliminate the rejections of outer ball joint pins in the thread rolling process by finding out the appropriate remedies of the rejections and eliminating them. The appropriate causes for the rejection of outer ball joint pins were identified using QC tools. The Design of Experiments involves conducting the experiments with the new parameters to verify the results. The desirable results can be obtained only with the standard parameters. By implementing these standards on regular production planning the rejections of the components are eliminated.

Keywords: Ball Joint, Rack and Pinion, Taguchi, Degrees of freedom, Rejection, Stratification

1. INTRODUCTION

Rack and Pinion steering gears consist of the Outer Ball Joint (OBJ) pin shown in Figure.1, which is fixed to the tie rod end of the Rack and Pinion steering gear assembly. The outer ball joint pin consists of various machining process like turning, Ball turning and burnishing, thread rolling etc. During the manufacturing process of outer ball joint pin, rejections of ball joint pins have been carried out due to various causes, results in poor quality of the component, increase in the cost of production and manufacturing time. One of the major causes for the rejection of the outer Ball Joint Pin is improper threading operation in the thread rolling.

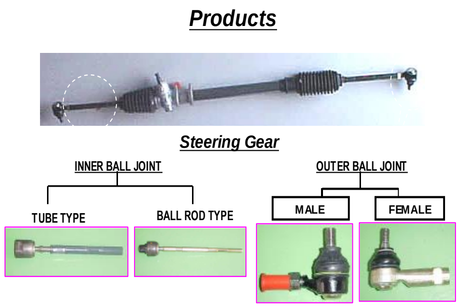

Figure 1 Steering Wheel Components

The steering gear converts the turning motion of the steering wheel into the to-and-fro motion of the link rod of the steering linkage shown in Figure.2. Moreover, it also provides the necessary leverage so that the driver can steer the vehicle without fatigue.

Figure 2 Steering Mechanism

2. PROBLEM IDENTIFICATION:

Ball pins are rejected due to the following reasons

- NO GO gauge answers to the ball pin thread
- GO gauge does not answer to the ball pin thread

Rejections data of ball pin can be analyzed by Pareto chart.

3. PARETO DIAGRAM:

A Pareto diagram is a graph that ranks data classification in descending order from left to right. In this case, the data classifications are types of coating machines. Other possible data classifications are problems, complaints, cause, types of nonconformities, and so forth. The vital few are on the left, and the useful many are on the right. It is sometimes necessary to combine some of the useful many into one classification called other. When this category is used, it is placed on the far right. Pareto diagrams are used to identify the most important problems(1). Usually, 75% of the total results from 25% of the item. The most important items could be identified by listing them in descending order. However, the graph has the advantage of providing a visual impact, showing those views a few characteristics that need attention. Resources are then directed to take the necessary corrective action.

- Determine the method of clarifying the data: by problem, cause, non-conformity, and so forth.
- Decide if dollars or both are to be used to rank the characteristics.
- Collect data for an appropriate time interval or use historical data.
- Summarize the data and rank order categories from largest to smallest.
- Construct the diagram and find the vital few.

The following Pareto represents the overall **SSLP** line rejection:

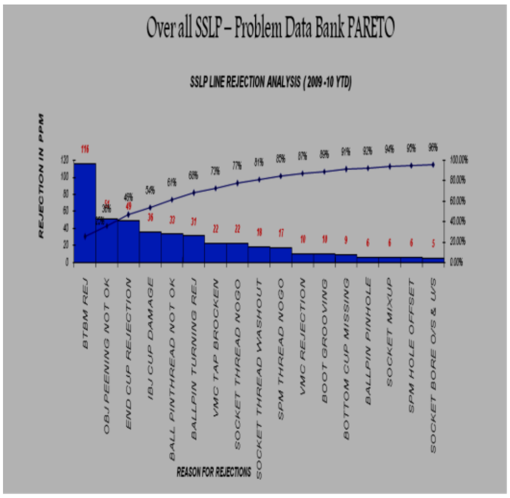

Figure 3 SSLP Problem definition sheet

Then need to concentrate more on this trouble for further improvement.

4. IMPORTANCE OF PROMBLEM:

The importance of the problem may be finding out by the following trend graph of ball pin thread shown in Figure.4 not ok for an overall PPM.

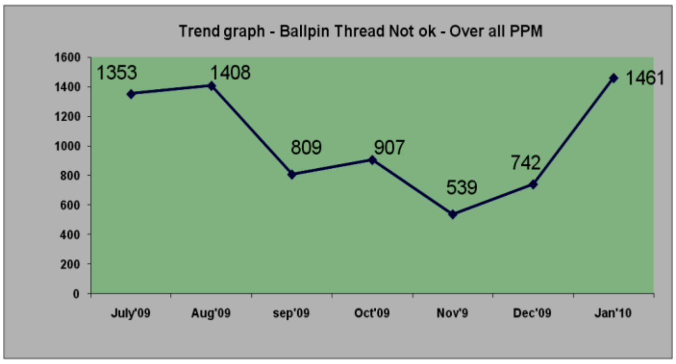

Figure 4 Trend Graph

Theme:

Eliminate Thread not ok problem in OBJ Ball pin thread rolling

Target:

From AVG 1031 to 100 PPM shown in Figure.5.

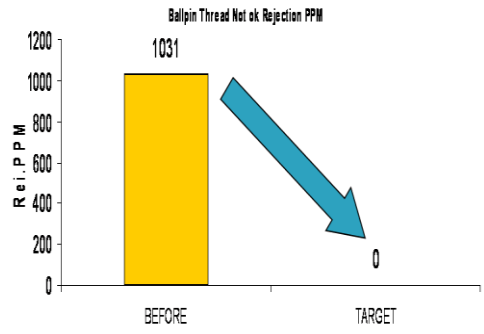

Figure 5 Achieving the Target

5. STRATIFICATION

Stratification is a method of analysis of data by grouping it in different ways. Stratification means segregating a group of measurements, observations or any other data into several sub-groups based on certain characteristics. These stratified data are used for identifying the influencing factors. Machines, suppliers, operators, tools, gauges or time-dependent sources like shifts, pre-post lunch, start or end of shifts, etc are strata concerning which the study of variations is conducted for diagnosis and possible control/prevention of variations. Both Go not answering and No go shown in Figure. 6 answering occur in all the machines.

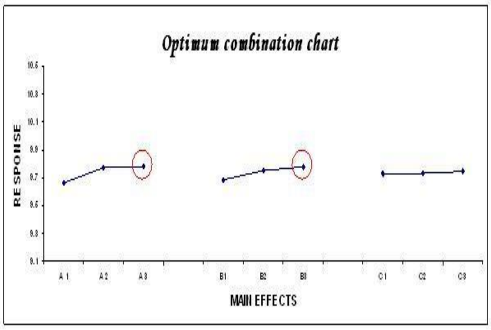

Figure 6 stratification

6. PROCESS CAPABILITY

Control limits are established as a function of the averages-in other words, control limits(2) are for averages. Specifications, on the other hand, are the permissible variation in the size of the part and are, therefore, for individual values. The specification or tolerance limit is established by design engineers to meet a particular function. The control limits, process spread, distribution of averages, process, whereas the specifications have an optional location. Control charts cannot determine if the process is meeting specifications. The true process capability cannot be determined until the X-bar and R charts have achieved the optimal quality

improvement without a substantial investment for new equipment or equipment modification. When the process is in statically control, process capability is equal to 6σ,
Where σ = R0/d2.

6σ = 6(R0/d2) = 6(0.079/2.059) = 0.230

It is frequently necessary to obtain the process capability by a quick method rather than by using the X-bar and R charts. This method assumes the process is stable or in statistical control, which may or may not be the case. The procedure is as follows:

- Take 25 subgroups of size 4, for a total of 100 measurements.
- Calculate the range R, for each subgroup.
- Calculate the average range:
- R=∑ R/g
- Calculate the estimate of the population standard deviation:
- σ=R/d2
- The processing capability will equal 6σ.

Remember that this technique does not give the true capability and should be used only if circumstances require its use. Also, more than 25 subgroups can be used to improve accuracy. The relationship of process capability and specifications. Tolerance is the difference between the upper specification limit (USL) and the lower specification limit (LSL). Process capability and tolerance are combined to form a capability index, defined as

$$Cp = \frac{\mathrm{USL} - \mathrm{LSL}}{3\sigma}$$

Where

USL-LSL= upper specification-lower specification, or tolerance

6σ = process capability

and distribution of individual values is interdependent. If the capability index is greater than 1.00, the process is capable of specification; if the index is less than 1.00, the process is not capable of meeting the specifications. Because processes are continually shifting back and forth, a Cp value of 1.33 has become a de facto standard, and some organizations are using a 2.00 value. Using the capability index shown in Table.1, the concept, we can measure quality, provided the process is centred. The larger the capability index, the better the quality we should strive to make the capability index as large as possible. This result is accomplished by having realistic specifications and continual striving to improve the process capability. The capability index(3) does not measure process performance in terms of the nominal or target value. This measure is accomplished using Cpk, which is

$$Cpk = \frac{\min\{(\mathrm{USL} - \mathrm{X})\mathrm{or}\ (\mathrm{X} - \mathrm{LSL})}{3\sigma}$$

A C_{PK} value of 1.00 is the de facto standard, with some organization using a value of 0.6198.

7. ORTHOGONAL ARRAY

Orthogonal arrays (OA) are a simplified method of putting together an experiment. The original development of the concept was by Sir R.A.Fischer of England in the 1930s. Taguchi added three O as to the list in 1956, and the National Institute of Sciences and Technology (NIST) of the United States added three.
An orthogonal array is shown in the table.2

FACTORS AND LEVELS								
S.NO	FACTORS	CODE	LEVEL -1	LEVEL -2	LEVEL -3	UOM	DOF	REMARKS
1	Dwell time	A	2	4	6	Sec	2	
2	Blak Dia	B	8.92	8.94	8.96	mm	2	
3	Rolling pressure	C	12	16	20	Bar	2	
	Interactions							
4	A X C						4	
5	B X C						4	
6	A x B						4	
						TDF	18	

The 8 in the designation OA27 represents the number of rows, which is also the number of treatment conditions (TC) and the degrees of freedom. Across the top of the orthogonal array is the maximum number of factors that can be used, which in this case are seven. The levels are designated by 1 and 2. If more level occurs in the array, then 3, 4, 5 and so forth are used. Other schemes such as -, 0 and + can be used. The orthogonal property of the OA is not compromised by changing the rows or the columns. Taguchi changed the rows from a traditional design so that TC I was composed of all level It's and, if the team desired, could thereby represent the existing conditions. Also, the columns were switched so that the least amount of change occurs in the columns on the left. This arrangement can provide the team with the capability to assign factors with long setup times to those columns. Orthogonal arrays can handle dummy factors and can be modified.
To determine the appropriate orthogonal array, use the following procedure:

- Define the number of factors and their levels.
- Determine the degrees of freedom.
- Select an orthogonal array.
- Consider any interactions.

The no. of factors and their levels can be determined by the following table shown in Table.2.

8. DEGREES OF FREEDOM

The number of degrees of freedom is a very important value because it determines the minimum number of treatment conditions. It is equal to the sum of

- (Number of levels – 1) for each factor.
- (Number of levels – 1) (Number of levels – 1) for each interaction.

- One for the average.

8.1. To find Degrees of Freedom

Number of levels = 3(for each factor)

Number of level = 4(for each interaction)

The total degrees of freedom is 18

8.2. Selecting an Orthogonal Array

Once the degrees of freedom are known, the step, selecting the orthogonal array (OA), is easy. The number of treatment conditions is equal to the number of rows in the OA and must be equal to or greater than the degrees of freedom.

Minimum no experiments = TDF+1

= 18+1

=19

Selection of orthogonal array = 27 (in the orthogonal array for 3^n series)

L 27 - Experimental layout			
Experiment no	1	2	3
	Dwell Time A	Blank Dia B	Rolling pressure C
1	1	1	1
2	1	1	2
3	1	1	3
4	1	2	1
5	1	2	2
6	1	2	3
7	1	3	1
8	1	3	2
9	1	3	3
10	2	1	1
11	2	1	2
12	2	1	3
13	2	2	1
14	2	2	2
15	2	2	3
16	2	3	1
17	2	3	2
18	2	3	3
19	3	1	1
20	3	1	2
21	3	1	3
22	3	2	1
23	3	2	2
24	3	2	3
25	3	3	1

26	3	3	2
27	3	3	3

Orthogonal array =L_{27}

8.3. Interaction table:

Confounding is the inability to distinguish among the effects of one factor from another factor and/or interaction. To prevent confounding, one must know which columns to use for the factors. This knowledge is provided by an interaction table, which is shown in Table.3. After completion of the experiments, the results have to be verified. The Standard specification of the external diameter of the thread is 9.770 to 9.78 shown in Table.4.

FACTORS	A	B	C						
	Dwell time (sec)	Blank dia (mm)	Rolling pressure (bar)	External diameter of the thread (mm)					Average
Expt. No	1	2	5	1	2	3	4	5	
1	2	8.92	12	9.959	9.615	9.484	9.49	9.51	9.6116
2	2	8.92	16	9.636	9.602	9.556	9.564	9.62	9.5956
3	2	8.92	20	9.628	9.618	9.517	9.628	9.564	9.591
4	2	8.94	12	9.624	9.675	9.625	9.674	9.662	9.652
5	2	8.94	16	9.702	9.665	9.668	9.67	9.667	9.6744
6	2	8.94	20	9.799	9.737	9.625	9.697	9.697	9.711
7	2	8.96	12	9.775	9.668	9.688	9.595	9.626	9.6704
8	2	8.96	16	9.67	9.713	9.672	9.766	9.766	9.7174
9	2	8.96	20	9.767	9.667	9.755	9.815	9.719	9.7446
10	4	8.92	12	9.735	9.733	9.74	9.726	9.713	9.7294
11	4	8.92	16	9.71	9.735	9.74	9.475	9.709	9.6738
12	4	8.92	20	9.691	9.711	9.74	9.731	9.757	9.726
13	4	8.94	12	9.768	9.784	9.774	9.79	9.77	9.7772
14	4	8.94	16	9.799	9.804	9.801	9.792	9.766	9.7924
15	4	8.84	20	9.774	9.809	9.79	9.774	9.765	9.7824
16	4	8.96	12	9.7	9.8	9.7	9.8	9.8	9.810

				83	35	6	51	23	4
17	4	8.96	16	9.806	9.83	9.803	9.83	9.802	9.8142
18	4	8.96	20	9.809	9.847	9.826	9.839	9.834	9.831
19	6	8.92	12	9.759	9.72	9.717	9.726	9.744	9.7332
20	6	8.92	16	9.774	9.71	9.749	9.75	9.727	9.742
21	6	8.92	20	9.73	9.745	9.773	9.748	9.735	9.7462
22	6	8.94	12	9.726	9.778	9.808	9.776	9.785	9.7746
23	6	8.94	16	9.774	9.804	9.79	9.794	9.8	9.7924
24	6	8.94	20	9.771	9.777	9.804	9.806	9.761	9.7838
25	6	8.96	12	9.834	9.784	9.833	9.83	9.818	9.8198
26	6	8.96	16	9.825	9.728	9.802	9.82	9.798	9.7946
27	6	8.96	20	9.809	9.774	9.777	9.833	9.851	9.8088

Dwell time parameter**:**

Using 2 sec, the Mean External Diameter of the thread obtained is = 9.6686 mm

Using 4 sec, the Mean External Diameter of the thread obtained is = 9.7770 mm

Using 6 sec, the Mean External Diameter of the thread obtained is = 9.777 mm

Blank diameter parameter:

Using 8.92 mm, the Mean External Diameter of the thread obtained is = 9.6832 mm Using 8.94 mm, the Mean External Diameter of the thread obtained is= 9.748 mm
Using 8.96 mm, the Mean External Diameter of the thread obtained is = 9.779 mm

Rolling pressure parameter:

Using 12 bars, the Mean External Diameter of the thread obtained is= 9.730 mm **Using 16 bar, the Mean External Diameter of the thread obtained is= 9.778 mm** Using 20 bars, the Mean External Diameter of the thread obtained is= 9.747

Optimum Combination:

The parameters are:

- Dwell time (A) : 6 sec
- Blank diameter (B) : 8.96mm
- Rolling pressure (C) : 16 bar

The optimum combination chart is shown (Figure.8). ("Mean is the best"-thread major dia)

9. RESULT AND DISCUSSION:

The rejection of outer ball joint pins has been eliminated by following the standard parameters, which has been determined by performing the Design of Experiments (DOE). Thus it has been concluded that the Design of Experiments (DOE) is a good procedure to find out the standard parameters of manufacturing components which may improve the Quality of the component.
By eliminating the rejection of outer ball joint pins, the following criteria have been obtained

- The productivity of the component has been increased
- Time loss has been eliminated
- The quality of the component has been improved
- Operator morale can be improved by eliminating frequent adjustments.

Before the process, the rejection of the OBJ pin is average 1031ppm After the completion of the process the rejection is reduced to average 100ppm The rejection cost is average Rs.28,169 per month and Rs.3.4 lakhs per annum. By this process, the rejection cost is saved by Rs.25,436 per month and Rs.3.05 lakhs per annum

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