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Optimization of Pressing Force Control Limits using Taguchi Method in Automobile Industry

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***Abstract*—Taguchi method is problem-solving tool, which can improve the performance of product, process design and system. This method combines the experimental and analytical concept to determine the most Influential parameter on result response for significant improvement in overall performance. This paper presents application of Taguchi method for predicting and optimizing the pressing force control limits in transmission assembly, in which various parts like gears, bearings, bushes & synchro hub are press fitted on input & output shaft of gear box. The control factors identified for pressing force are interference between mating part, interference length, cylindricity and surface finish. The experiment is designed with four control factors and three levels (low, medium, high). It includes the effect of control factors on pressing force & signal-to-noise ratio in graphical format. At the end, this paper includes summary of results.**

***Index Terms*— Taguchi method, pressing force, pressing stroke, orthogonal array, robust design.**

I. INTRODUCTION

The present problem is from automobile industry here we have to predict pressing force control limits during the transmission assembly. In the transmission assembly on drive and driven shaft various component like gear, bush, bearings, synchro hubs are press fitted with help of servo controlled mechanical press. The machine has provision of measuring pressing force and pressing stroke. The machine shows graph of pressing force (KN) Vs pressing Stroke (mm) as shown in Fig.1.

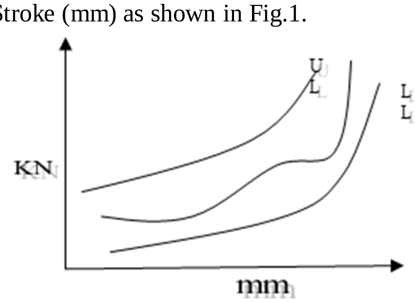

Figure 1. Graph of pressing force (KN) Vs distance (mm)

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The graph consist upper and lower limits of force, for particular gauging window the upper and lower limits of pressing force are set in machine program. If the active graph of component on that station cuts the graph of upper or lower limit then machine, reject that component by writing the data in pallet Moby. This rejected component goes into rework loop without performing any next operation. The problem in this case was with control limits of pressing force, which were set early.

II. PROPOSED SOLUTION

In this case Taguchi method is used to predict the limits and study with present parameter what will be the minimum and maximum pressing force and also study for particular limits what should be the parameter combination so this two way study. This study helps for parameter design and for predicting the pressing force control limits. The control factors for pressing force are amount of interference between mating component, interference length, surface finish, and cylindricity. All of above factors are tested at three levels as shown in table 1 below.

TABLE I. FACTORS AND LEVELS OF EACH FACTOR FOR THE JOINT

Controllable factor	levels		
Interference	Low	Medium	High
Interference Length	Low	Medium	High
Surface Finish	Low	Medium	High
Cylindricity	Low	Medium	High

There are different joints between various mating component on drive and driven shaft. We are going to consider only one joint for study. The joint between drive shaft and anterior bearing. Anterior bearing fits with the clutch housing in transmission. The specification limit for this joint is given in table 2 below.

TABLE II. COMPONENT SPECIFICATION

Component	Specification
Drive shaft OD	23(+0.015, +0.002) mm
Anterior bearing ID	22.99(+0, +0.002) mm
Interference Length	14(+0, -0.120) mm
Surface Finish	Ra 0.8 µm
Cylindricity	0.005 mm

III. THE EXPERIMENT

In this case, for three levels and four factors L9 orthogonal array is selected for experiment. Orthogonal array are a simplified method of putting together an experiment. This is shown in table 3 below. The 1,2,3 in L9 array corresponds to low, medium, high level identified for control factors.

TABLE III. L9 ORTHOGONAL ARRAY FOR THE CONTROL FACTORS

	Factors			
Runs	Interference	Length	Surface Finish	Cylindricity
1	1	1	1	1
2	1	2	2	2
3	1	3	3	3
4	2	1	2	3
5	2	2	3	1
6	2	3	1	2
7	3	1	3	2
8	3	2	1	3
9	3	3	2	1

Total set of experiments that are performed is nine here in this case. For each experiment, the pressing force is measured using specified setting of control factors. E.g. for experiment number one all factors are set at low-level setting. The result for this experiment is shown in table 4 below.

TABLE IV. L9 ORTHOGONAL ARRAY FOR THE CONTROL FACTORS

	Factors				
Runs	Interference	Length	Surface Finish	Cylindricity	Result-Force(KN)
1	1	1	1	1	2.40
2	1	2	2	2	2.61
3	1	3	3	3	2.81
4	2	1	2	3	5.90
5	2	2	3	1	6.00
6	2	3	1	2	6.28
7	3	1	3	2	6.71
8	3	2	1	3	7.11
9	3	3	2	1	7.12

IV. DATA ANALYSIS

In this experiment, Taguchi's graphical approach is used to plot the result based on mean of each level of factor to determine variation of pressing force. The average pressing force for each levels of each control factors are plotted in figure 2,3,4,5.

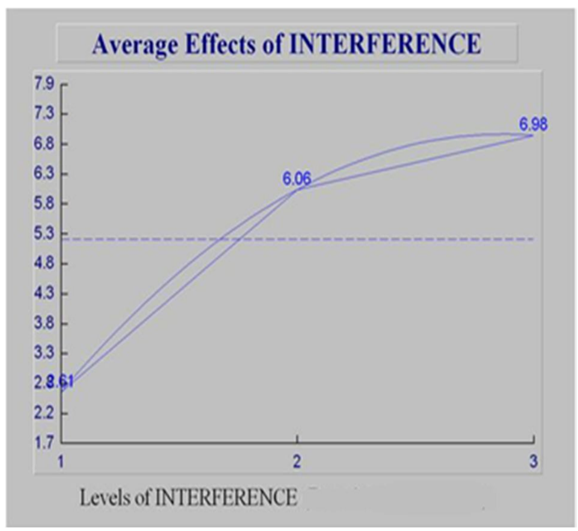

Figure 2. Effect of interference on average pressing force

These values are computed by averaging the mean pressing force for each factor for each level. For example, average pressing force for level 1 i.e. low level of interference is obtained by averaging runs 1, 2, 3 in table 4. i.e. (2.40 + 2.61 + 2.81) / 3 = 2.61. The same procedure is employed to compute the average of pressing force for each level of each control factor. Fig. 2 reveals that interference has a larger impact on pressing force. The level 3 i.e. high level corresponding to maximum pressing force while level one i.e. lower level corresponding to minimum pressing force. Therefore, it gives idea about the maximum and minimum variation of pressing force based on maximum and minimum variation of interference for this joint.

For next control factor i.e. interference length. The variation of pressing force with level low, medium & high is shown in Fig. 3 below.

It shows that as interference length increases the pressing force is also increases. The level 3 corresponds to maximum variation in length and level 1 corresponds to minimum variation of length. Fig 4 shows the impact of surface finish on pressing force with level low, medium & high.

Similarly, Fig. 5 shows impact of cylindricity on average pressing force with three levels i.e. low, medium, and high.

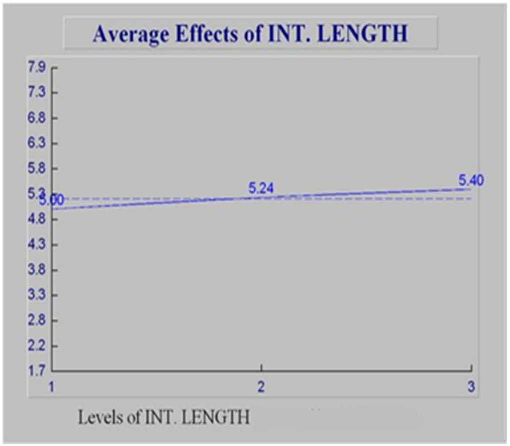

Figure 3. Effect of interference length on average pressing force

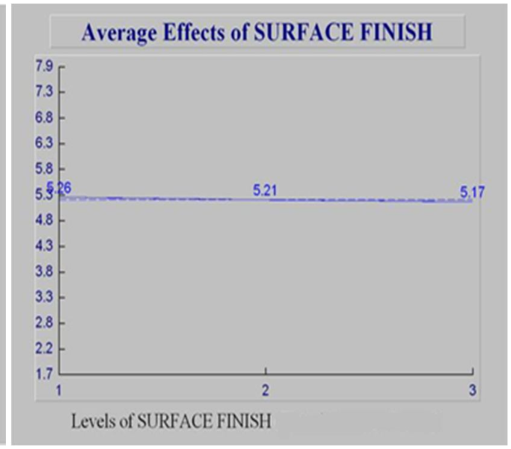

Figure 4. Effect of surface finish on average pressing force

V. Summary of results

The summary of results based on above experiment is shown in Table 5.

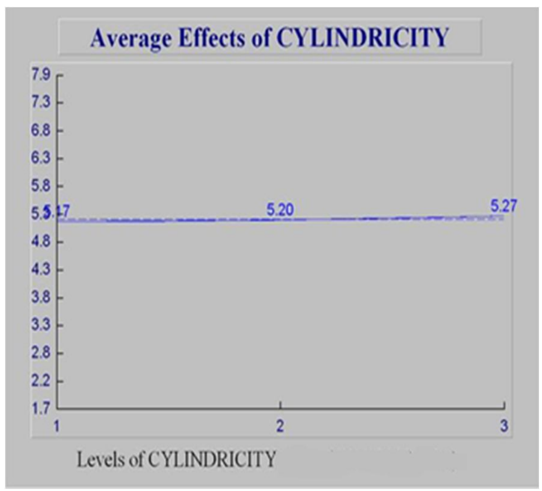

Figure 5. Effect of cylindricity on average pressing force

TABLE V. L9 SUMMARY OF RESULTS

Factors	Levels	Pressing Force
Interference	Low	2.61
	Medium	6.06
	High	6.98
Interference Length	Low	5.00
	Medium	5.24
	High	5.40
Surface Finish	Low	5.26
	Medium	5.21
	High	5.17
Cylindricity	Low	5.17
	Medium	5.20
	High	5.27

VI. Conclusion

It can be concluded from above experiments that minimum pressing force is 2.40 KN and maximum pressing force is 7.12 KN for given gauging window. Hence, for the graph, minimum limit of force is 2.40 KN & maximum limit of force is 7.12 KN. In addition, it can be seen that interference is having more impact on pressing force.

References

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