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Analysis and Optimization of Retention Force of a Needle Roller Bearing Using Taguchi Experiment.

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ABSTRACT - *This paper reviews the various needle roller bearing parameters affecting the effectiveness of retention force. The detailed structure includes in the model, are three parameters such as needle diameter, clearance and thickness of retainer. We analysed the effect of this three parameters on retention force of needle roller bearing .The detailed mathematical model is simulated by Minitab17 and simulation results fit experiment data very well this shows that the model can be used to forecast the performance of needle roller bearing when design In this analysis, an effective approach based on Taguchi method, analysis of variance , linear regression , has been developed to determine the optimum conditions leading to higher Retention Force . Experiments were conducted by varying needle diameter, pocket clearance (Clearance = Needle diameter – Retainer Pocket size) retainer thickness using L9 orthogonal array of Taguchi method. The present work aims at optimizing Retention Force process parameters to achieve high Retention Force. It concludes that needle diameter and clearance is most influencing parameter followed by on Retention Force.*

KEYWORDS:- Push-Out Force Comparator, Retention Force, ANOVA, Regression Analysis, MINITAB 17 etc.

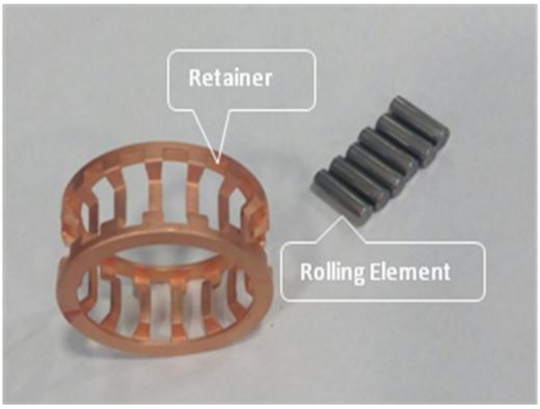
I. INTRODUCTION

The main function of a rotating shaft is to transmit power from one end of the line to the other. It needs a good support to ensure stability and frictionless rotation. The support for the shaft is known as "bearing".

Figure-1: Needle Roller Bearing

Needle Roller Bearing use small diameter of rollers. They are used for radial load at slow speed and oscillating motion. They are used in aircraft industry, live tail stock centres, bench-drill spindles; etc. A needle roller bearing is a special type of roller bearing which uses long, thin cylindrical rollers resembling needles. Ordinary roller bearings' rollers are only slightly longer than their diameter, but needle bearings typically have rollers that are at least four times longer than their diameter. Like all bearings, they are used to reduce the friction of a rotating surface. Needle bearings are heavily used in automobile components such as rocker arm pivots, pumps, compressors, and transmissions.

Figure-2: Rolling Element and Retainer



Needle retention force is nothing but how much force requires to come out the roller from bearing retainer. This is also called as push out push in force of rolling element of bearing. Needle retention is a significant characteristic hence need to analyze and needle should not fall and should be retained with bearing. If retention force is less then needle can fallen happen which cause, load carrying capacity of bearing reduces, premature failure of bearing can happen as well as L10 life of bearing. So to avoid needle fallen of needle bearing retention force study is essential for proper functioning of bearing.

II. LITERATURE SURVEY

By various research papers and failure analysis data of needle roller bearing we found following research gab:

i. Retention force of rolling element not defined clearly with specific range.

ii. Effect & influence parameter to cause needle fallen or less retention force of needle not studied in detail.

iii.Optimization of needle retention force not focused in detail.

III.EXPERIMENTAL DETAIL

i. Design of Experiments:

In this study we have consider 3 factors which affect majorly on quality characteristic such as

(A)- Needle Diameter

(B) - Clearance (Needle diameter – Retainer Pocket size)

(C)- Retainer Thickness

The design of experiment was carried out by Taguchi methodology using Minitab 17 software. In this technique the main objective is to optimize retention force needle roller bearing that is influenced by various process parameters

ii. Selection of Control Factors:

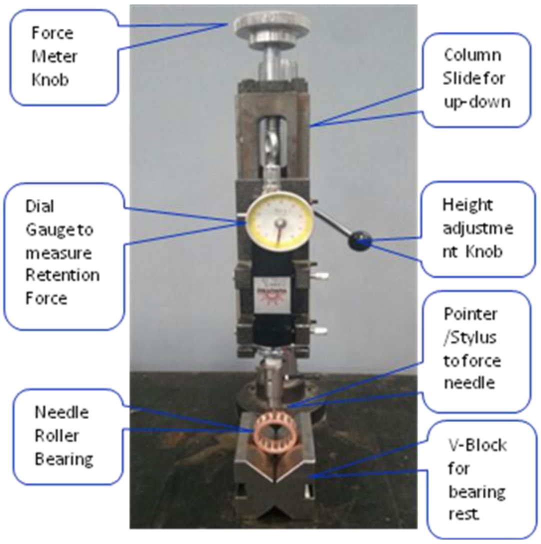
By past trouble data sheet and bearing failure data and discussion observed that retainer pocket clearance; retainer thickness and roller diameter of needle roller bearing is direct relationship with retention force of rolling element. Hence Retention forces in Newton (N) are selected as response parameter for experimentation.

iii. Selection of Orthogonal Array:

Since 3 controllable factors and three levels of each factor were considered L9 (3X3) Orthogonal Array was selected for this study.

iv. Experimental Set Up:

Figure-3: Push-Out Force Checking Comparator.



A Series of experiment was conducted to evaluate the influence of needle roller bearing parameters on retention force. The test was carried out on push-pull force checking comparator for retention force testing. The experiment was conducted by keeping all other parameter constant.

v. Experimental Conditions:

The experiments were carried out on PUSH-PULL force testing comparator for needle retention force testing. There are three input controlling factors selected having three levels. Details of parameters and their levels used shown in table.

Table-1: Process Parameters and Levels

A	Needle Diameter (mm)	3.994	3.998	4.000
B	Clearance (mm)	0.05	0.1	0.2
C	Retainer Thickness (mm)	1	1.5	2
	Code	1	2	3

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Table-2: Layout for Experimental Design by L9 Array

Exp. Order	A-Diameter	B-Clearance	C- Thickness
1	3.994	0.05	1.00
2	3.994	0.1	1.5
3	3.994	0.2	2
4	3.998	0.05	1.5
5	3.998	0.1	2
6	3.998	0.2	1
7	4	0.05	2.00
8	4	0.1	1
9	4	0.2	1.5

IV.RESULT AND DISCUSSION

i. Test Hypothesis:

$H_0: b_1 = b_2 = b_3 \ldots\ldots\ldots = b_k = 0$
(No explanatory variable is significant)
Ha: at least one $b_j \neq 0$
(At least one explanatory variable affect Y linearity)
In this case , Null hypothesis,
H_0: A = B = C = 0
(Effect of needle diameter, clearance, retainer thickness has no significant effect on retention force of needle roller bearing.)
Alternative hypothesis,
H_1 : A $\neq$ 0 or B $\neq$ 0 or C $\neq$ 0
(At least one explanatory variable has significant effect on maximum retention force of needle roller bearing.)

Table-3: Experimental Trial Result

Exp. Order	Actual Exp. Order	A-Diameter.	B-Clearance	C-Thickness.	Response: Y-Retention Force (N)
1	8	3.994	0.05	1.00	11.77
2	2	3.994	0.1	1.5	7.85
3	3	3.994	0.2	2	3.92
4	5	3.998	0.05	1.5	11.77
5	6	3.998	0.1	2	9.81
6	8	3.998	0.2	1	5.89
7	9	4	0.05	2.00	13.73
8	7	4	0.1	1	9.81
9	1	4	0.2	1.5	7.85

ii. Regression Analysis:

Table-4: Analysis of Variance (ANOVA)

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	3	71.74646	23.9215	22.89	0.002
Diameter	1	9.8986	9.8986	9.47	0.028
Clearance	1	61.8661	61.8661	59.21	0.001
Thickness	1	0.0000	0.0000	0.00	1.000
Error	5	5.2242	1.0448		
Total	8	76.9989			

Model Summary

S	R-Sq	R-Sq(Adjusted)	R-Sq(Predicted)
1.0228	93.21%	89.14%	72.31%

R^2 & adjusted R^2 is nearly 1 Thus model seems to be good.

Table-5: Coefficients

Term	Coefficient	SE Coef.	T-Value	P-Value	VIF
Constant	-1667	546	-3.05	0.028	
Diameter	420	137	3.08	0.028	1.00
Clearance	-42.04	5.46	-7.69	0.001	1.00
Thickness	0.000	0.835	0.00	1.000	1.00

We observe that P-value (Significance F) in ANOVA for needle diameter is 0.028 and for clearance is 0.001 which is much smaller than 0.05. Hence we reject the null hypothesis. It means diameter and clearance having significant effect on result. i.e. Retention Force.

Regression Equation:
Retention Force = -1667 + 420(Diameter) - 42.04(Clearance) + 0.000(Thickness)

Retention Force = -1667 + 420(Diameter) - 42.04(Clearance)

Y = -1667 + 420(A) - 42.04(B)

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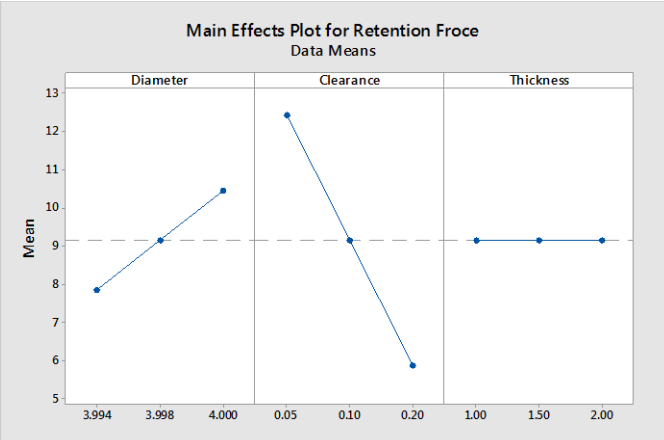
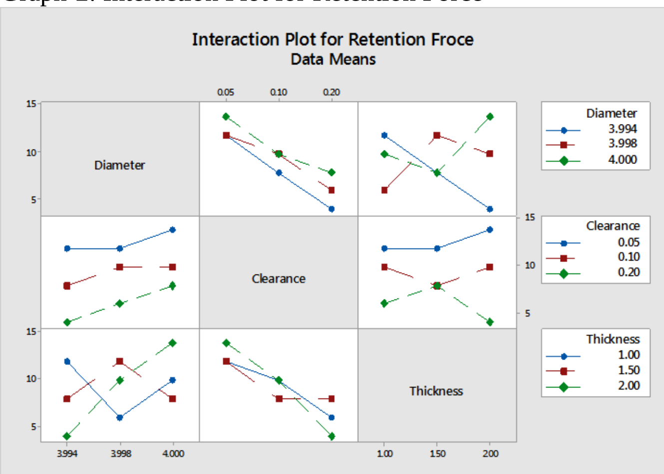
iii. Result by Graph:

Graph-1: Main Effects Plot for Retention Force.



As shown in graph it is observed that retention force increase with increase in needle diameter and also can increase with reduction in clearance but there is no effect of retainer thickness on retention force.

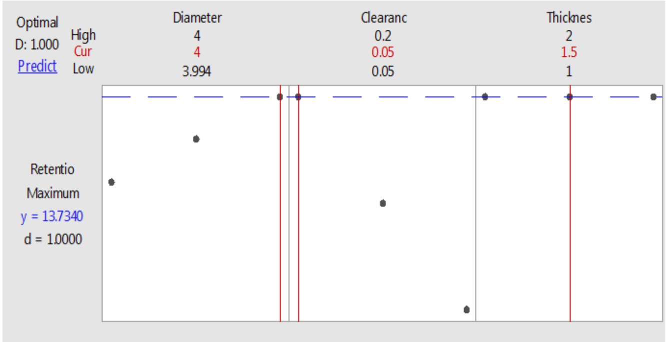
Graph-2: Interaction Plot for Retention Force



Graph shows that individual factor interaction plot on diameter, clearance and thickness of retainer.

V. OPTIMIZATION FOR RETENTION FORCE:

Graph-3: Optimization Plot for Maximum Retention Force



From graph we have observed below optimum result can achieve by keeping below factor setting.

Table-6: Optimum Factor for Maximum Retention Force

Sr. No	Factors	Level Description	Level
A	Needle Diameter (mm)	4.000	3
B	Clearance (mm)	0.05	1
C	Retainer Thickness (mm)	1.5	2

Table-7: Optimum Parameters

Response	Goal	Lower	Target	Upper Weight	Importance
Retention Force	Maximum	3.924	13.734	1	1

Table-8: Optimum Solution for Maximum Retention Force

Solution	Diameter	Clearance	Thickness	Retention Force Fit	Composite Desirability
1	4	0.05	1.5	13.734	1

Y optimal = 13.734 N

Optimal Retention Force = 13.734N

VI. CONCLUSION:

Based on above experimentations and mathematical analysis. Following conclusions are drawn:-

i. The equations derived shows that the retention force of needle roller bearing is function of needle diameter, clearance and retainer thickness.

Hence generalize regression model for this experiment become,
Retention Force = -1667 + 420(Diameter) - 42.04(Clearance)

Y = -1667 + 420(A) - 42.04(B)

ii.The equations derived from the graphs shows correlation factor 0.93 which is more than 0.85 Hence regression model is acceptable and there is linear relationship .

iii.The clearance of needle roller bearing is directly proportional to retention force. (C α Y)

iv.The Optimum solution for Retention Force is
D = 4.00 mm, C = 0.05 mm and C = 1.5 mm then
Maximum Retention Force can obtain,
Y optimal = 13.734 N

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