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Optimization of Parameters in Helical Gear used in Heavy Load Vehicle to Reduce the Pitting and Scuffing Failure by using Taguchi Method

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Abstract:- The objective of this paper is to obtain the optimal parameters of the helical gear in order to eliminate the gear failure due to pitting and scuffing using Taguchi method. The investigation is done with the help of the transmission department in an automobile industry. During the investigation, the various defects that causes the gear failures are studied. The process parameters considered for the study are module, pressure angle and material at two levels. To obtain the optimal process parameter combination, optimization is carried out by DOE method.

I. INTRODUCTION

The gear damage resistance research is resulted by standard DIN 3990 part 5. The DIN standard 3990 part 5 propose the testing procedure for the materials used in gears. Many researchers are focused on gear analysis, the major gear analysis deals with the analysis of gear failures mainly pitting and scuffing. To avoid the pitting failure the strength of the gear tooth should be greater or equal to the dynamic load and the scuffing problem occurs because of the inadequate lubricant film between the gear teeth or when the lubricant viscosity is less.

M. Ognjanovic proposed that according to the pitting of teeth flanks the gear load capacity calculation is done. In service conditions a gear failure includes number of damage problems. These problems will be based on design calculations, load conditions and other several factors and he also stated that, to know the accurate reason for the gear failure, it is necessary to do more number of gear tooth failure test [1]. J. Kattelus et al states that by using traditional visual inspection documented by photographs the progression of gear micro pitting can be detected. The number of metallic particles in oil indicates the progression of micro pitting failure. He also states that macro pitting is promoted by micro pitting [2].

V. Onishchenko et al concluded that the extreme pressure additives will reduce the chance of scuffing and its negative effect, and increase the gear wear resistance significantly and also he states that with the mechanical impurities, the extreme pressure additives will perform its function by preventing scuffing, and reduce. the catastrophic deterioration to relatively calm wear conditions [3]. H. Düzcükog˘lu et al states that there will be delay in initial pitting formation meanwhile in unmodified gear the pitting effect can be seen in dedendum area, he also stated that the pitting failure will have rapid progress in high transmitting torque this can be prevented by manufacturing greater width teeth [4]. Z.Z. Julie et al states that the most important stage in manufacturing process is parameter design, selecting the proper orthogonal array (OA) is the first process in parameter design [5].

II. MATERIALS AND METHODS

A. Helical Gear

In helical gear the tooth will be cut at an angle to the face of the gear. The helical gear have more smooth and noiseless operation comparing to other gears, they create thrust load on the gear when they mesh, it's because of the angle of the tooth, but at the same time helical gear also introduces the axial force in the system. So, this will give negative effect on transmission. Power loss won't be high but still there will be power loss, and with increasing helix angle the negative effect on transmission increases. The helix angle for most of the gears will be between 10-25°.

B. Pitting

It is a surface damage cause of repeated contact stress progressed through lubrication film that is in or near the elasto hydro dynamic regime. More than 60% of gear failures are occurred by pitting. In the negative sliding region between the tooth root and pitch line that is exactly on the dedendum the damage is noticed. When the material and the heat treatment are same in the mating gear, the pitting can be first expected on the gear with less tooth because it receives the greater number of load cycles.

Surface breaking cracks are the initial cause for pitting. Then it will get advance because of the repeated contact loading. Eventually the crack that generates and reaches the tooth surface. Damaged area can change the tooth profile and increase vibrations and audible noise.

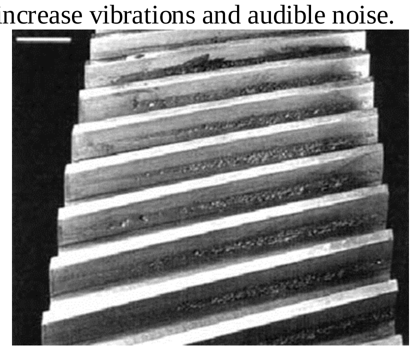

Fig 1:- Pitting in Helical Gear

C. Micropitting

The formation of small caters on the tooth surface is said to be micro pitting. It is often formed below the pitch line in the region of negative sliding. These caters will form small cracks on the gear teeth and slowly removes the surface material, similarly with abrasive wear. For this reason the micropitting is labeled as a kind of abrasive wear. The key predictor for this kind of damage is the ratio of thickness of the oil film to the surface roughness [6].

D. Scuffing

Scuffing is also termed as scoring. It is a type of failure which instantly damages the tooth surface which is in relative motion. The gear may face the catastrophic failure because of single overloading. In gear tooth, the area which have high contact pressure and sliding velocity will be affected by the scuffing. The scuffed area can be visualized by having crushed texture on the root surface. This type of failures are mostly noticed in addendum or dedendum.

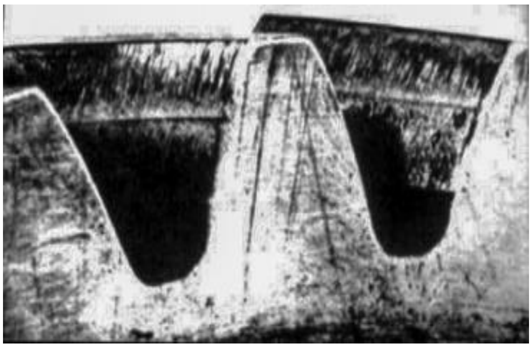

Fig 2:- Scuffing in Helical Gear

E. Helical Gear Calculation

The helical gear calculation is done by the standard ISO/DIN 6336/1-4 from 1992 and DIN 3990 [7,8]. The initial data are shown in (Table 1). In helical gears the strength of the gear tooth is find out by Lewis equation. The gear may be subjected to dynamic test when it's running in high velocity. To reduce the pitting and scuffing failure and to increase the gear tooth strength the gear parameters should be optimized.

Input data	Mark	Units	Value
Power	P	KW	242.879
Speed	n	1/min	1950
Torque	T	Nm	782
Required service life	H	H	150

Table 1. Input Data Of Helical Gear

III. EXPERIMENTAL DESIGN

A. Taguchi Method

In most of the engineering design the Taguchi techniques are used. It portrait the whole control of the process without loss function. Taguchi's orthogonal array (OA) will provide high balanced combination of input with less number of experiment run. To obtain the performance of the experiment for desired output, signal to noise ratio (S/N) is used. (S/N) ratio have three categories they are "higher is better", "nominal is better" and "smaller is better" [9].

B. Materials

Materials 20MnCr5 and EN353 are used in this study and they are used for manufacturing the helical gear. They also represent one of the considered factors in orthogonal array (OA) table. By applying Taguchi method, it is necessary to find the better solution of the factors, respectively, appropriate material, as well as optimal values of the remaining considered factors.

C. Orthogonal Array $L4(2)^3$

It is a fractional orthogonal design based on matrix calculations. It allows you to consider the selected factors at many levels. Orthogonal arrays are balanced, so that all the levels of factors are equally considered. The levels of controlled parameters are shown in (Table 2). In order to set up the experimental design, following factors are selected: module (A), material (B) and helix angle (C) and its levels. Each factors have two levels. The signal to noise ratio (S/N) for each experiment is calculated and shown in (table 3).

CONTROL FACTORS	UNITS	LEVEL 1	LEVEL 2
A: MODULE	MM	5.816	5.513
B: HELIX ANGLE	DEG	7.5	11.5
C: MATERIAL	-	20MNCR5	EN353

Table 2. Levels For Various Control Factors

MODULE	HELIX ANGLE	MATERIAL	PERMISSIBLE TOOTH ROOT STRESS	S/N RATIO
4.618	8.5	20MNCR5	689.57	56.7716
4.618	12.5	EN353	723.89	57.1935
4.5	8.5	EN353	725.19	57.2090
4.5	12.5	20MNCR5	684.71	56.7101

Table 3. Experimental Design Using L4 Orthogonal Array

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IV RESULTS AND DISCUSSION

S/N ratio means the ratio of sensitivity to the factors of goal to be optimized. In consideration of quality, higher ratio gives the better quality characteristics. The signal to noise ratio calculation is done carried out for each single experiment. This experiment can be done on three basis they are “smaller is better”, “higher is better”, “nominal is better”.

In the present study, by using the software Minitab 18 the S/N ratio is calculated by using “higher the better” criterion. In this experiment, the maximum value output is considered to have the higher safety coefficient for gear tooth strength. The equation for higher the better characteristics is as follows.

$$S/N = -10*\log(\Sigma(1/Y2)/n)$$

Y is the response for the given factor level and n is the number of measurements.

A. S/N Ratio Analysis

Only the main factors are considered for the present study. The aim is to obtain the maximum value by using “higher the better” quality characteristics. The effect of considered factors on the safety coefficient for tooth root strength can be determined based on performed Taguchi analysis, as shown in (table 3). Based on the factor ranking table, we can conclude that material has the highest influence followed by helix angle and module has the least influence. The (figure 5) shows the effect of the considered factors on the safety coefficient for tooth root stress of a helical gear. The results based on (S/N) ratios provides the optimal factor levels. Based on (figure 5), it is concluded that the optimal factor combination is (A1B1C2). So therefore, these factor values get maximum value of the safety coefficient for tooth root stress of a gear.

Larger is better

Level	module	helix angle	material
1	56.96	56.99	56.74
2	56.98	56.95	57.20
Delta	0.02	0.04	0.46
Rank	3	2	1

Fig. 3:- Response table for signal to noise ratio

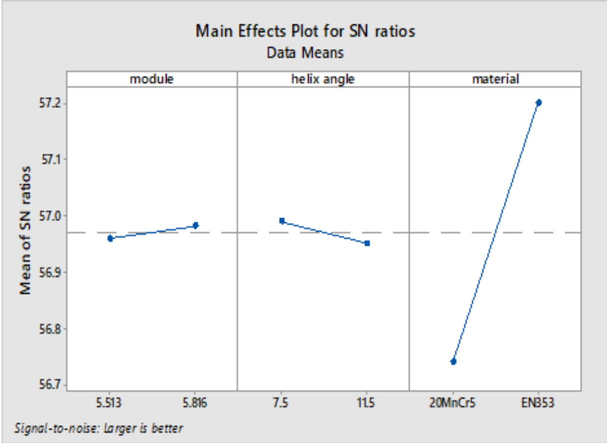

Fig. 4:- Main effects plot for S/N ratio

V CONCLUSION

Based on the analysis done by Taguchi method, it is concluded that the material has the greatest influence on the safety coefficient for gear tooth strength and the module has the least influence. The factors (A1B1C2) is obtained from the experimental research. The research shows that the material with grade (EN353), the gear module 4.5 and the helix angle of the gear 8.5° gives the better result.

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