ISSN 2348-1218 (print)
International Journal of Interdisciplinary Research and Innovations ISSN 2348-1226 (online)
Vol. 6, Issue 3, pp: (176-181), Month: July - September 2018, Available at: www.researchpublish.com

TAGUCHI'S APPROACH TO OPTIMIZE STRENGTH OF GEARS: A REVIEW

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Abstract: **In this paper, strength of the spur gear was studied under the influence of module, number of teeth and speed. The optimum result was achieved in the experimental study by employing Design of Experiment with full factorial design. The ANOVA analysis was used to optimize parameters and to achieve maximum strength. Also the relation between the parameters and the performance measure were determined using multi regression equation. Further the beam strength of the helical gear was studied considering its module, number of teeth and helix angle as the design parameters and the same ANOVA analysis is done to optimize the parameters and maximize strength.**

Keyword: **module, arrays, optimization, regression.**

I. INTRODUCTION

Gears are used to transmit power from one shaft to another with zero slip. Gears are classified according to the position of axis of shaft, type of gearing and the peripheral speed of the gears.

(1)According to axis of shaft: Spur and helical gears are used to transmit power when axis of shaft are parallel. The spur gear have straight teeth whereas helical gears have curved teeth. Bevel gears transmit power when shafts are inclined at an angle ranging from 0° to 180°.When angle between shafts is 90° and velocity ratio is unity it is called mitre. Worm gears transmit power between two non coplanar shafts.

(2)According to type of gearing :External gears mesh externally and rotate in opposite directions whereas internal gears mesh internally and rotate in same direction.

(3)According to peripheral speed: The gears having speed less than 3 m/s are low speed gears and above 15m/s are called high speed gears. The gears having speed range between 3 to 15 m/s are called moderate speed gears.

The objective of the gear drive is to transmit high power with higher load-carrying and lower weight. But the gear load capacity may be limited by tooth strength. With the development of gear heat treatment technology, such as carburizing, high-frequency hardening and nitriding technology, the tooth contact strength has been significantly improved. Researchers in the gear field have proposed many solutions to tackle the problem of failure.

The strength of spur gear tooth is determined from Lewis equation which is given as:$W_s=\sigma_o\ C_v\ \pi bmy$ where σ_o =static strength of teeth ,C_v=velocity factor, b=face width, m=module and y=tooth form factor.

The beam strength of the helical gear tooth is given by Lewis equation which is:

$W_s= \sigma_o * C_v * b * m_n * y$

where , σ_o =allowable stress ,C_v=velocity factor, b=face width, m_n= normal module, m_n =m cosΦ, m=module,Φ=helix angle, y=tooth form factor based on formative number of teeth.

Fig 1a) Spur Gear

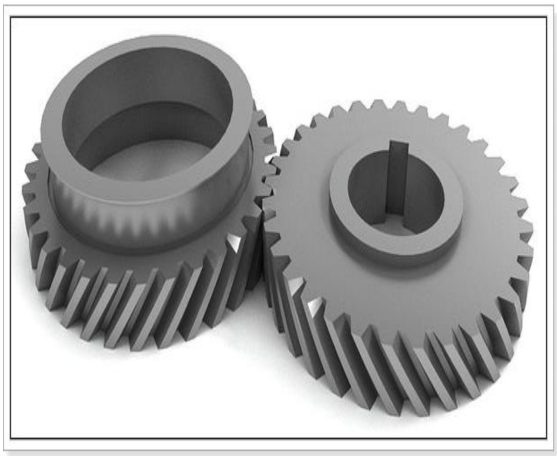

Fig.1b) Helical Gear

II. METHODOLOGY

Design of experiments (DOE) method are among the most effective and useful statistical quality control technique to investigate the individual and interaction effects of the process parameters. DOE methods can be an important part of system optimization, yielding definitive system design or redesign recommendations. These methods also involve the activity experimental planning, conducting experiments, and fitting models to the outputs. An essential ingredient in applying DOE methods is the use of experimental design can have a large influence on the accuracy and the construction cost of the approximations. Several experimental design techniques have been used to aid in the selection of appropriate points. Experimental design strategy, using Taguchi orthogonal arrays concept is used in the paper.

The following L-9 orthogonal array was applied:

Table 1: L-9 Orthogonal array with actual values for spur and helical gear

Module (mm)	No. of Teeth	Speed (rpm)	Strength
8	20	900	31366.52
8	24	1100	24583.70
8	28	1300	19656.34
10	20	1100	34972.07
10	24	1300	27926.63
10	28	900	34775.09
12	20	1300	37814.12
12	24	900	46924.84
12	28	1100	36282.89

Module (mm)	Helix angle	No.of teeth	Strength
5	20	20	13467
5	30	24	13844
5	35	26	13624
6	20	24	20410
6	30	26	20225
6	35	20	18857
7	20	26	28428
7	30	20	26090
7	35	24	26425

III. RESULTS & DISCUSSION

Observations in Taguchi Analysis:

A) Spur Gear: Strength versus Module (mm), No. of Teeth, Speed (rpm)

B) Helical Gear: Strength versus Module (mm), No. of Teeth, Helix angle

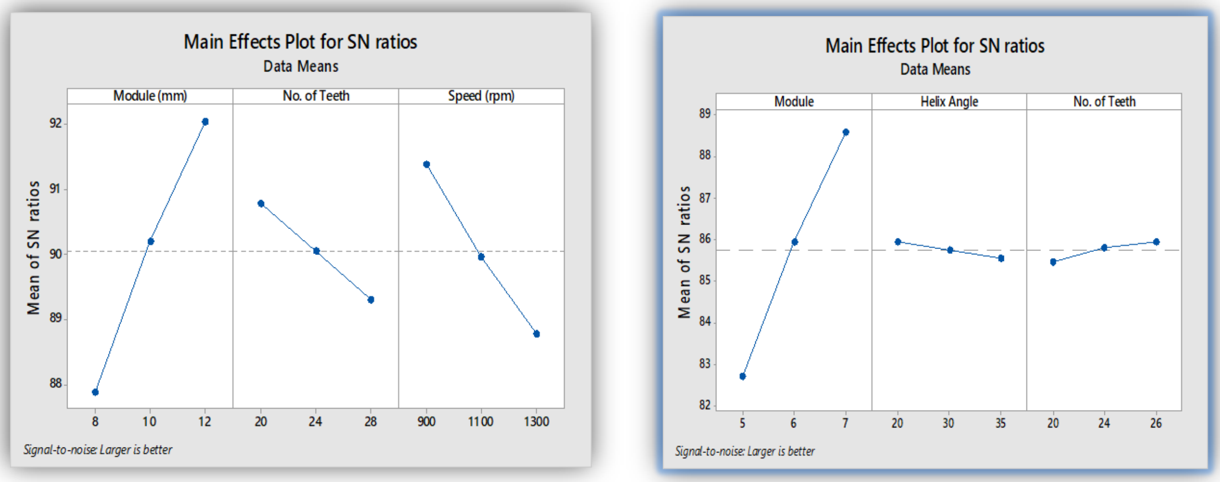

Figure 2: Main effects plot for S/N Ratio (MRR)

The above SN ratio graph was made using 3 variables i.e. module, number of teeth and speed for spur gear and module ,no of teeth and helix angle for helical gear. As observed from graph, it is clear that at 12 mm of module, 20 number of teeth and 1300 rpm speed gives the best output in terms of strength of spur gear teeth will be maximum and 7 mm of module, 26 number of teeth and 20° helix angle gives the best output in terms of beam strength of helical gear teeth will be maximum.

Table 2 General linear Model (ANOVA) for strength of spur gear

Source	DF	Seq SS	Adj SS	Adj MS	F	P	Contribution %
Module (mm)	2	26.4215	26.4215	13.2107	6137.02	0.000	66
No. of Teeth	2	3.3266	3.3266	1.6633	772.68	0.001	8.3
Speed (rpm)	2	10.2747	10.2747	5.1373	2386.54	0.000	25.6
Residual Error	2	0.0043	0.0043	0.0022			
Total	8	40.0270					

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Table 3: General linear Model (ANOVA) for strength of helical gear

Source	DF	Seq SS	Adj SS	Adj MS	F	P	Contribution %
Module (mm)	2	52.6602	52.6602	26.3301	4140.93	0.000	98.8
Helix Angle	2	0.2488	0.2488	0.1244	19.56	0.049	0.5
No. of teeth	2	0.3740	0.3740	0.1870	29.41	0.033	0.7
Residual Error	2	0.0127	0.0127	0.0064			
Total	8	53.2957					

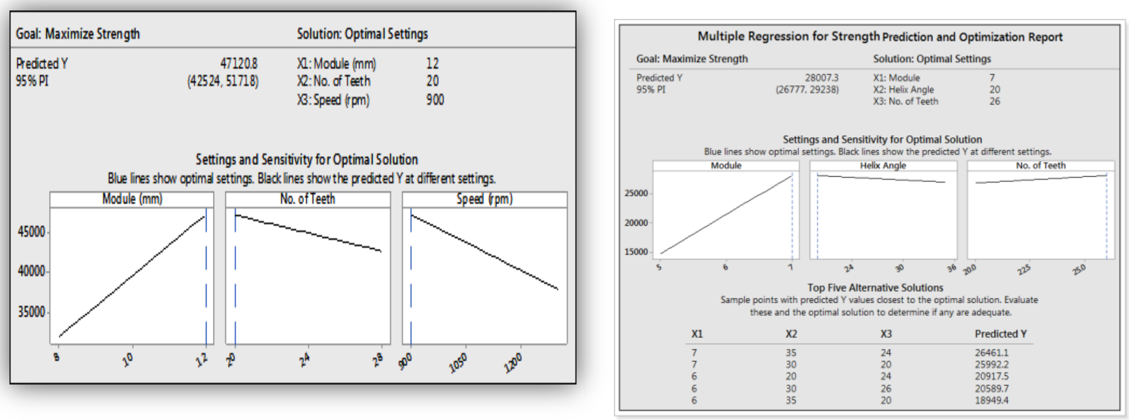

Figure 3: Multiple Regression for Strength Optimization

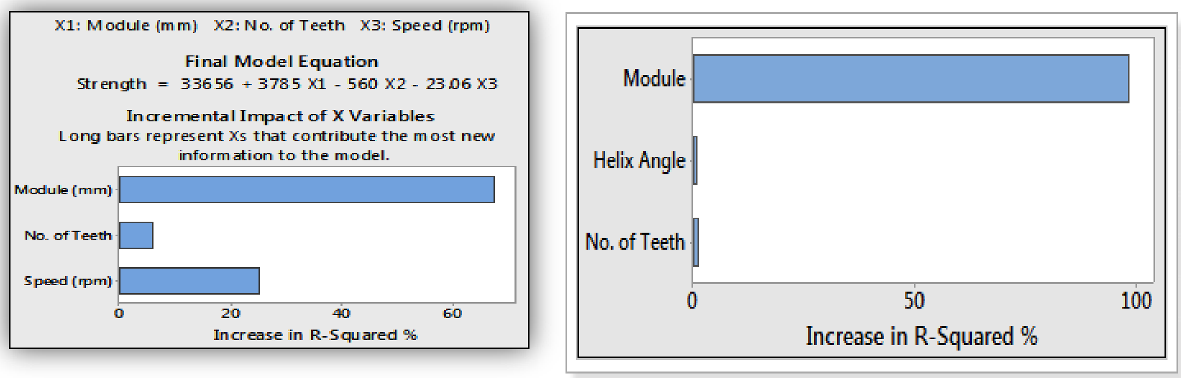

Figure 4: Percentage contribution of design parameters

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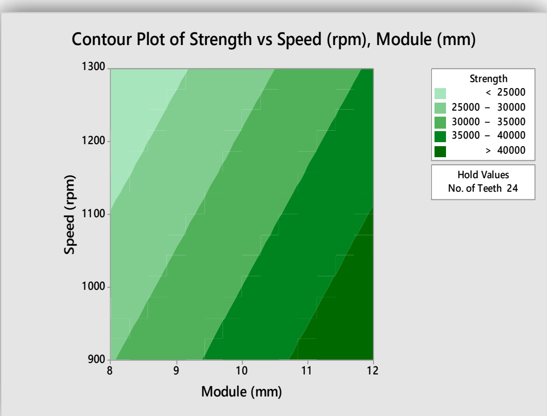
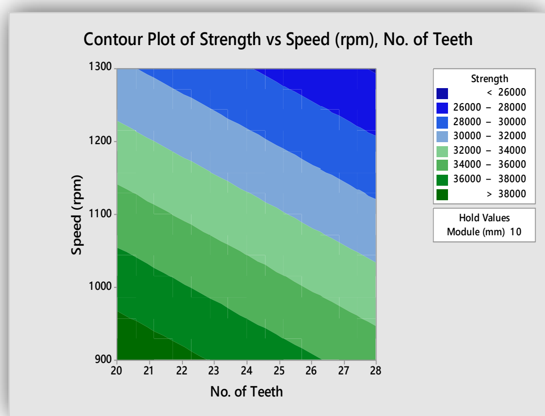
IV. CONTOUR PLOTS OF STRENGTH

A contour plot is a graphical technique for representing a 3-dimensional surface by plotting constant z slices, called contours, on a 2-dimensional format. That is, given a value for z, lines are drawn for connecting the (x,y) coordinates where that z value occurs.





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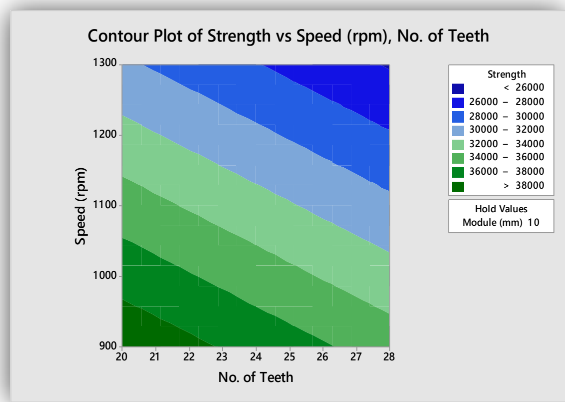

Figure 5: Contour plots for spur gear

V. CONCLUSION

The optimized value of strength of spur gear teeth comes out to be at 12 mm module,20 number of teeth and speed of 900 rpm as shown in Fig2 and the optimized value is 47120.8N at 95% confidence level. Further from Table2 it is evident that maximum contribution towards achieving the optimized output is of module which is 66%.. The optimized value of strength of helical gear teeth comes out to be at 7 mm module,26 number of teeth and helix angle 20° as shown in Fig2 and the optimized value is 28007.3 at 95% confidence level. Further from Table3 it is evident that maximum contribution towards achieving the optimized output is of module which is 98.8 %..The contribution of number of teeth and helix angle is insignificant as compared to module. The application of Taguchi L9 array provides the optimized result with 95 percent confidence level and by using only 9 input values rather than conducting 27 experiments. Hence this technique of optimizing is accurate, fast and reliable and can be carried out conveniently with less effort and resources.

VI. FUTURE SCOPE

The study presented in the paper is limited to spur gears with module, number of teeth and speed as design inputs. It can be extended to include face width as design variable. Further Taguchi technique can be used to optimize heat generation and dissipation in worm gears. The present study can be extended to improve the strength of bevel gears. For helical gears helix angle can be taken as one of design input and for bevel gears angle between the shafts can be included as the design input variable. The optimized parameter in future study can be wear strength of helical gear taking into account three set of input variables out of module,no of teeth ,face width and helix angle.

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