INCREASING LIFE OF SPUR GEARS WITH THE HELP OF FINITE ELEMENT ANALYSIS

Gagandeep Singh

School of electrical, mechanical and mechatronic system,
Faculty of Engineering and IT,
University of Technology,Sydney, Australia

Abstract

The Focus of this research is on mathematical analysis of life of gears and reducing noise frequency of gears due to change of material from C-45 to 19mncr5. Calculations for gears life was done with the help of Lewis equation and Buckingham formula. Basically life of a gear is depending upon the stress, more the stress on gear lesser life of gear will be. In this paper some major condition to perform a gear without failure is achieved i.e. tangential force should be less than tangential load to sustain static load, dynamic load should be less than endurance load to sustain dynamic load and wear load should be less than static load to sustain wear load. After calculation of 19mncr5 material we evaluate that endurance load acting on the gear which is greater than the dynamic load so our gear come out be safe. Also this study shows declination of noise level in 19mncr5 material compare to C-45 material.

Introduction

The requirement of component design is a specific life as well as specific function to be performed. As long as these criteria are satisfied, one can think of optimization of the components as regards size, shape and material. However, when there is deviation i.e. failure before expected life or unsatisfied performance then there is a need to look into various aspects such as material composition, hardness of material, manufacturing processes, heat treatments and operating conditions etc. If there is no variation in these, then there is a need to go into details such as type of failure, nature of fracture and analysis of induced stress and arrive at a conclusion whether some modifications can do the job or total redesign of the component is required [1].

From decades, Companies facing one huge problem i.e. damaging of gears before warranty period's ends and one of the major reason for that is vibration which generate noises and ultimately help to decrease down the efficiency of the transmission box [6]. This paper is lighting up the cluster gear 1st and 2nd gear of transmission system. If gear will experience maximum power during engagement then at the same time it will give minimum torque output as we all know that power and torque is inversely related to each other [8]. During engagement of the gears driven and driving gear ratio must match then only they can engaged properly. Now this is the area where problem sticks when these gears engaged they start making rattling noise which ultimately reduces down the life of gear.

Traditionally, transmission box contain number of gears which differentiate by forward gears and reverse gear. Maintaining such complex shifting system is not an easy task. This huge

DOI : 10.14810/ijmech.2014.3311

transmission box create problem in the field of vibration and noise also we have to balance this shifting system with engine. Recently many attempts have been made by numerous authors to set up models aimed at stimulating the dynamic behaviour of gears [5].Umpteen conclusion where draw out and those conclusion were judged practically for the betterment of transmission. This paper show that how vibration and noise reduction directly relates to life of gears and help to increase life of gears**.** According to literature, if the gears were perfectly rigid and no geometrical errors or modifications were present, the gears would transmit the rotational motion perfectly, which means that a constant speed at the input shaft would result in a constant speed at the output shaft. The assumption of no friction leads to that the gears that would transmit the torque perfectly, which means that a constant torque at the input shaft would result in a constant torque at the output shaft. No force variations would exist and hence no vibrations and no sound (noise) could be created. Of course, in reality, there are geometrical errors, deflections and friction present, and accordingly, gears sometimes create noise to such an extent that it becomes a problem [3]. Simulation of meshing of gear drives performed by application of tooth contact analysis (TCA) and test of gear drives have confirmed that transmission errors are the main source of vibrations of the gear box and such vibrations cause the noise of gear drive [4].

It is assumed that the tooth surfaces are at any instant in point tangency due to the localization of contact. Henceforth, we will consider two types of meshing: (i) surface-to-surface, and (ii) surface-to-curve. Surface-to-surface tangency is provided by the observation of equality of position vectors and surface unit normal. Surface-to-curve meshing is the result of existence of edge contact [7].Reduction of noise of a gear drive requires modification of one of the pair of contacting surfaces. The surface modification is illustrated for three types of gear drives: helical gears, spiral bevel gears, and worm gear drives [4].

Background

The gears in transmission box of 4 cylinder, 6 cylinder (in line or V), wind turbine, ships even the helicopters faces transmission noises like Rattling/clattering, Whining/Squealing, bearing noise and gear shifting noise which generates from vibration that led to damage the gears when they were transferring the power from input shaft to output shaft[8,9]. Basically Rattling noise is also caused due to lose part assemble and after examined idler gear, radial and axel float of driving and driven gears and sliding sleeves. According to data collected, Cluster gear failure take place before 1 year of 1000 hours whichever is less. After research several pragmatic aspects of gear I check one common error which I make that is for every attempt I am using same material for the gear. Generally industries use C-45 material for manufacture gear. But noticeable advantages were seen when we use 19mncr5 material. Specification of 19mncr5 is that it has 235 annealing hardness, 788 degree preheating temperature, and Quenching temperature in salt bath surface is 1191 degree and in controlled atmosphere furnace 1204 degree Celsius. This material generally used for flat bar, tube/pipe, profiled forging, steel plates.

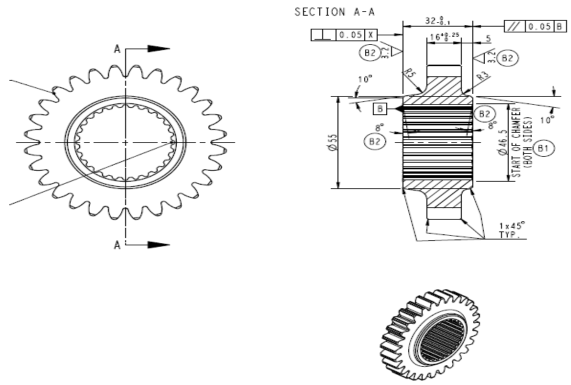


Figure 1.shows dimensional view of gear.

Mathematical Analysis

	Loads on gears				Pass or fail		
Gears	Gear teeth	WD	WS	WW	Static load	Dynamic load	Wear load
1 and 2 (C-45)	24	125155.74	2562.918	2395.98	Fail	Pass	Fail
	51	23836.88	37039.37	2771.05	Pass	Fail	Fail
1 and 2 (19mncr5)	24	15155.74	30068.64	23697.46	Pass	Pass	Pass
	51	28836.88	49360.8	20659.72	Pass	Pass	Pass

CHECKING OF THE GEAR FOR DYNAMIC AND WEARING LOAD

We have from Buckingham formula

WD= WT+ {21 v (b*c + WT) / 21v + (b*c + $WT^{1/2}$)
All the terms in the expression are known except "c" which depends upon the type of gear that is quality of the gear. It is known Dynamic factor.
For first class commercial gear dynamic factor c is 476 (refer 2).
Substitute all the value in the equation (5), we get

W_D = 15155.74 N

Substitute the value of module (m) in equation ($), above we get
y = .133
Now we calculate the endurance strength of the gear having module = 3

Ws = ∏e * b* 3.14*m*y

∏e = 1200 MPa for 19MnCr5
Put all the values in the above expression, we get

W_S = 30068.64 N

We know that ratio factor "Q" is
given, we get Q= 2* velocity ratio/ (velocity ratio+1) Q= 1.35

Wear load WW = Dp *b*Q*k

Where

K = load stress factor

$K = [\{(\sigma S)^2 * \sin^2 Q\}*\{(1/E_P) + (1/E_G)\}]/1.4$

Where

∏s = 1200 Mpa for 19MnCr5

Q = 20 degree

E_P and E_G are the young modulas of pinion and gear respectively. Since the material are made up of same material. Therefore we take it as $2*10^5$

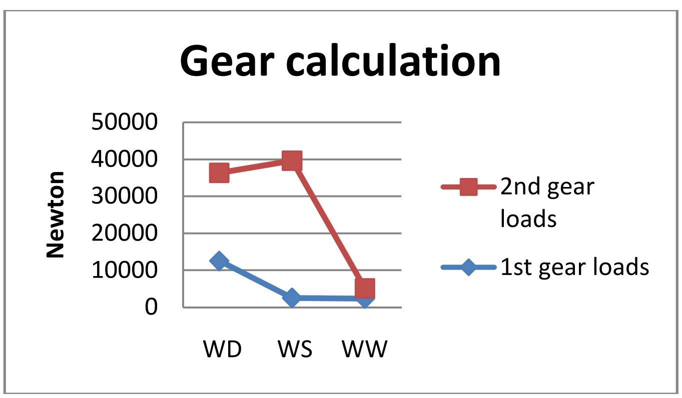
Substitute the value of the expression in the above equation.
We get K = .8799

Put the value of load stress factor equation (6), we get **W_W = 23697.46 N**

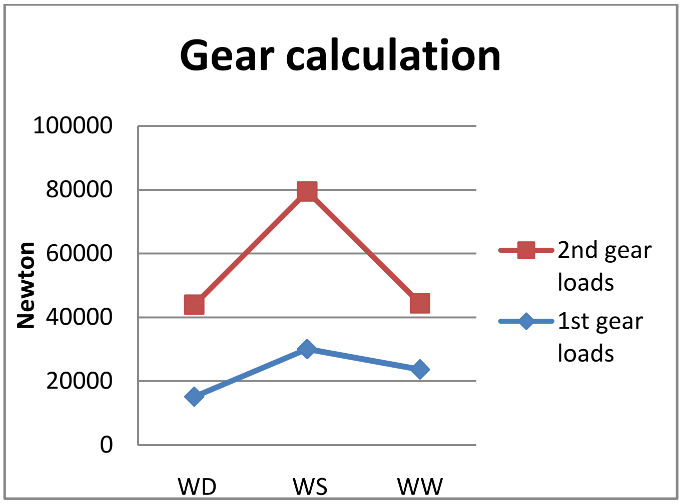
The conditions for a gear to function without failure under static, dynamic and wear load conditions.

- $F_T < W_T$ to sustain static load
- $W_D < W_s$ to sustain dynamic load
- $W_w < W_s$ to sustain wear load.

Data of Loaded Gear with material C-45



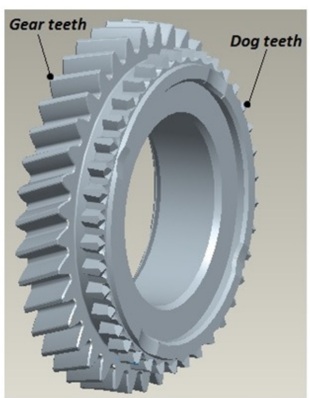
Data of Loaded Gear with Material 19Mncr5



For the gear to be safe Ws&Ww should be greater than Wd Since in our case Ws is greater than Wd. So our gear is safe in Dynamic loading. But Ww is come out be less than WD. Therefore our gear is failing in wear. This problem can be easily rectified by giving proper heat treatment to the gears.

To find the value of the hardness which must be kept on the gear to avoid their failure in the wear, we will work out the load stress factor. This is obtained by equating Ws= Ww

- Therefore corresponding to this value of K and gear quality 9, if we keep the HRC 58~63 then our gear is safe in wear.
- Since in our case WS is greater than WD. So our gear is safe in Dynamic loading.



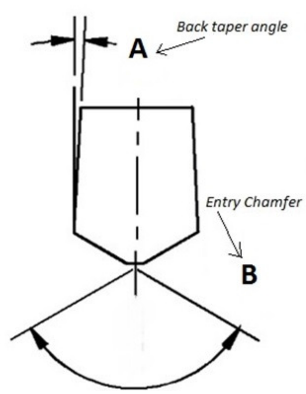
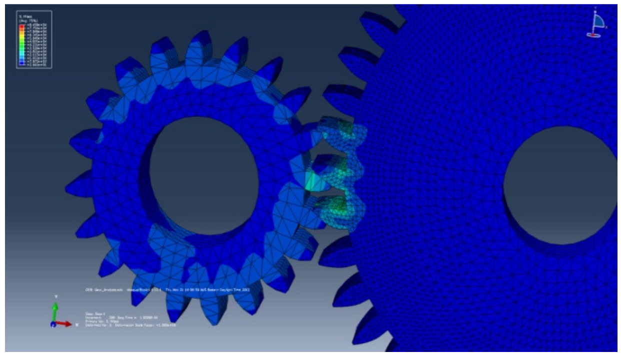
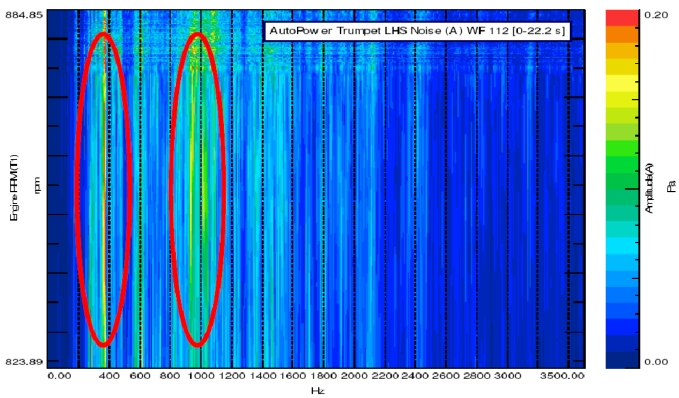


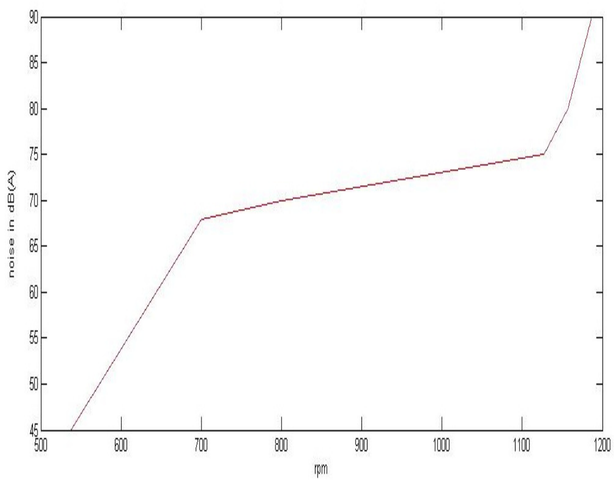
Figure showing gear and dog teeth (Left) and top view showing entry chamfer angle and back taper angle (Right)



Noise Experiment



Noise Level of Gear with material C-45



Noise Level with Material 19MNCR5

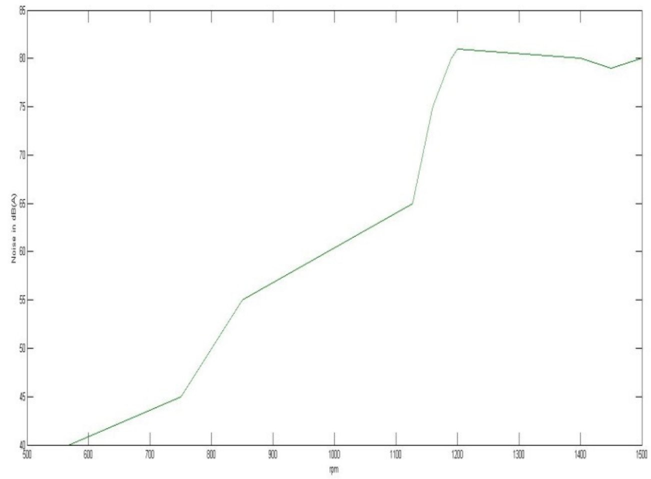


Figure 1 Show the inclination pattern in noise which keep on increase as RPM increase and Figure 2 show inclination pattern till 1100 rpm and noise at that point is 82 dB(A) and But after that it show constant pattern at 80 decibel which is a very good sign in Material 19Mncr5.

Conclusion

According to the results, the modified gears 1st and 2nd in driving gears are safe from strength and noise parameters.

- the reduction in noise is from ~90 to 80 dB
- Increasing endurance load and wear load from 2562 N, 2395 N to 30068.64 N, 23697.46 N (respectively)

Reducing noise and increasing load of gear is most efficient if tackled at its source, that is, on the gear, shaft and bearing level. Proper design of gears and shaft-bearing systems ensures that the excitation of the transmission housing is minimized. Need to work on numerical coordination of tooth surface by analysis 3d-Cad software.

References

[1] G.K. Nanawarea, M.J. Pableb, Feb 2003,Failures of rear axle shafts of 575 DI tractors, page 3-4

[2] J. Argyris, A. Fuentes, F.L. Litvin, 2002, Computerized integrated approach for design and stress analysis of spiral bevel gears, Comput. Methods Appl. Mech. Engrg. 1057–1095.

[3] Mats Akerbolm, 2005, Gear Noise and vibration a literarturesurvey , page 107-150

[4] Faydor L. Litvin a, Daniele Vecchiato a, Kenji Yukishima a, Alfonso Fuentes b,*, Ignacio Gonzalez-Perez b, Kenichi Hayasaka, 2005, Reduction of noise of loaded and unloaded misaligned gear drives, page 28-34

[5] P. Velex_, M. Ajmi, 2005, on the modeling of excitations in geared systems by transmission errors, page 96-110.

[6] New Holland Research Head ,RajdeepSingh, 2010

[7] kirkwalters , Richard J. socin,2004, Manual transmission synchronizers, page 78-88

[8] M. Barthod a, B. Hayne a, J.-L., Te´bec a, J.-C. Pin b, 2006, Experimental study of gear rattle excited by a multi-harmonic excitation, page 79-81

[9] F.L. Litvin et al., 2001, Helical and spur gear drive with double crowned pinion tooth surfaces and conjugated gear tooth surfaces, USA Patent 6,205,879,

[10] YumeiHua, YiminShaoa,n, ZaigangChen a, MingJ.Zuo , 2011 ,"Transient meshing performance of gears with different modification coefficients and helical angles using explicit dynamic FEA", page 12-54

[11] A.Palermo, D. Mundo, A.S. Lentini, R. Hadjit, P. Mas, W. Desmet, 2007 ,"Gear noise evaluation through multibody TE-based simulations",University of Calabria, Italy, page 4-8

[12] J.D. Smith, (2003), Gear noise and vibration, Marcel Dekker, Cambridge, page 121-180.

[13] F. L. Litvin, A. Fuentes, (2004),"Gear geometry and applied theory", Cambridge University Press, Cambridge, page 10-12

[14] Yu-Ren Wu, Jen-Wei Chi(2013), A numerical method for the evaluation of themeshing clearance for twin screw rotors with discrete tooth profile points,Pingtung County 91201, Taiwan, ROC

[15] Jiri Tuma, 2009, Gearbox Noise and Vibration Prediction and control, university of Ostrava, Czech Republic, page 153-190.