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TRANSMISSION WEIGHT & EFFICIENCY OPTIMIZATION IN OFF ROAD VEHICLE (TRACTOR GEARBOX)

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ABSTRACT: *Present Transmission in off road vehicle such as Tractor consist of Following measure parts Spur or helical gears, Shafts, Housing to Support gear box and to store Lubricants, bearing, oil seal, lubricants. In today's scenario fuel efficiency is prime importance; Transmission plays a vital role in fuel consumption. Fuel efficiency of vehicle can be improved by, optimizing weight and efficiency of Transmission.Various techniques can be used in optimization of Housing weight and finding optimized gear pair design.*

KEYWORDS: Transmission; Tractor; Efficiency; Optimization.

INTRODUCTION

Transmission weight and efficiency optimization is vast field of research with many facets of scope of work. Following major focus area is discussed as scope of work.

Weight optimization of gear box by selecting appropriate cross section of gear box casing.(Using Ansys)

Redesign of Gear Box by using planetary Gear arrangement, instead of Spur Gear arrangement.

Effect of Helix Angle and Tip Relief on Power Loss.

Oil churning loss optimization

Literature review on the efficiency improvement in offline vehicle is provided as follows:

Optimum Design and Research on the Involute Gear Tooth Profile: Paper explain design and analysis of involute circular arc gear , which is better than helical gear

Transmission efficiency study on planetary gear mechanism: Explains about the formulas for calculating efficiency of planet gear system.

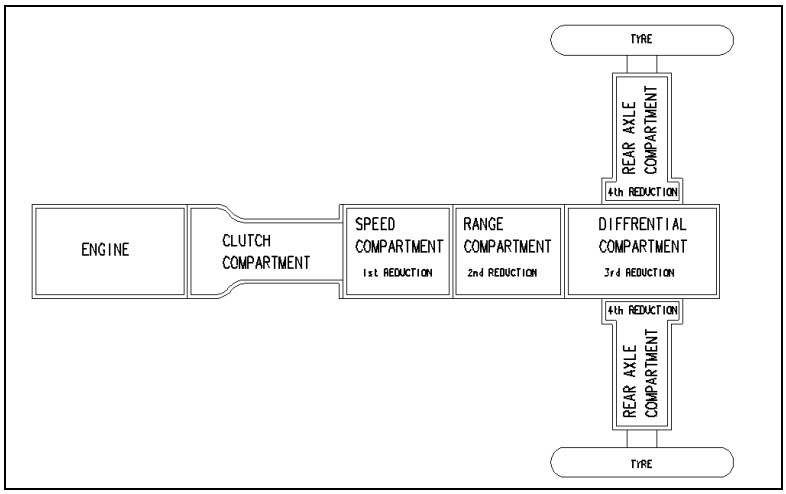
Load Sharing Analysis of High-Contact-Ratio Spur Gears in Military Tracked Vehicle Applications: Deals with comparison between HCR & LCR gears, load caring capacity, analysis for bending and pitting strength.

Design of Optimization of Gear Train Weigh Based on Reliability Simulated Annealing :

INTRODUCTION TO TRACTOR TRANSMISSION LAYOUT

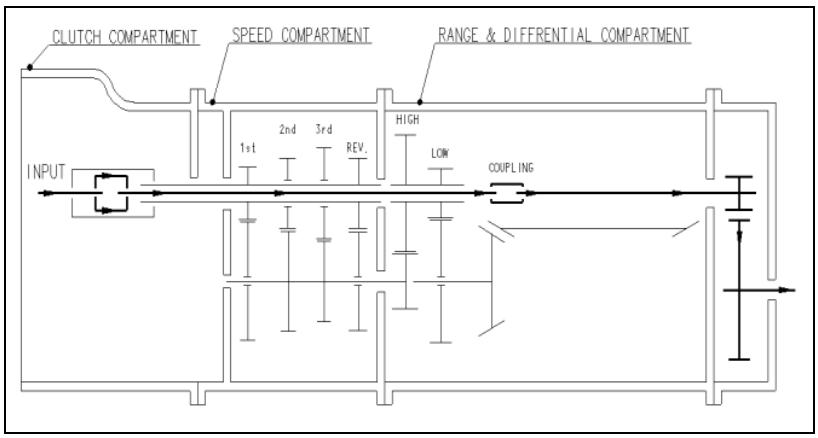
Fig. 1 below shows the schematic of Tractor Transmission, which consist of various compartments as shown. For example speed compartment has speed Gear, Shaft, and Housing/ Casing.

Figure 1. Transmission Gear Box.



Transmission gear box can be further detailed as below, showing schematic of gear and shaft.

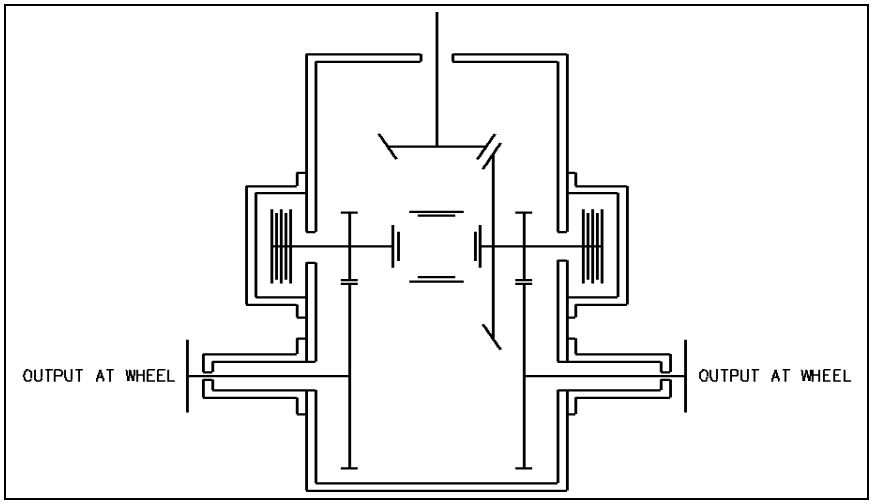
Figure 2. Schematic front section power flow Transmission.



There are various gear pairs, design as per the speed required for various application. These gears need to work in heavy load condition in field.

Rear section of transmission consisting of differential and rear axle as shown below

Figure 3. Line diagram of power flow in differential & axle of the tractor transmission

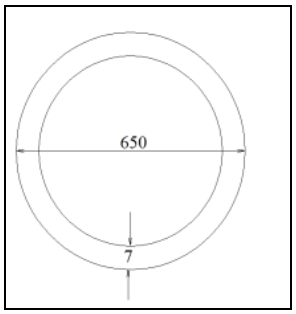


WEIGHT OPTIMIZATON OF TRANSMISSION BY SELECTING APPROPIATE CROSS SECTION OF GEAR BOX CASING

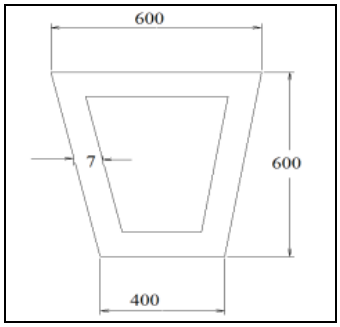
Function of Transmission casing is to envelop gears and shafts, store the lubricant & also to act like chassis member for Tractor.

Transmission casing contribute for 70% of total weight of Transmission.

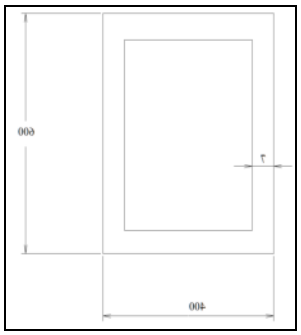
Following cross sections are selected for comparison.



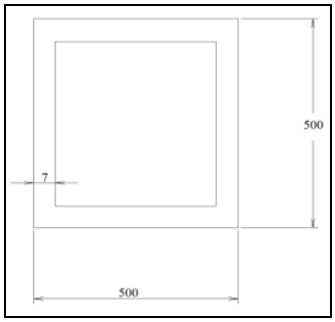
Circular



Trapezium



Rectangular



Square

Length and Cross Section dimension of sections are decided in such a way that weight of each section should be 50 Kg.

Each section is then loaded with 1000Kg.

Material of each section is considered as FG-260.

Stress analysis done in Ansys and comparison are as follows.

Figure 4. Stress & Deflection of Various Sections

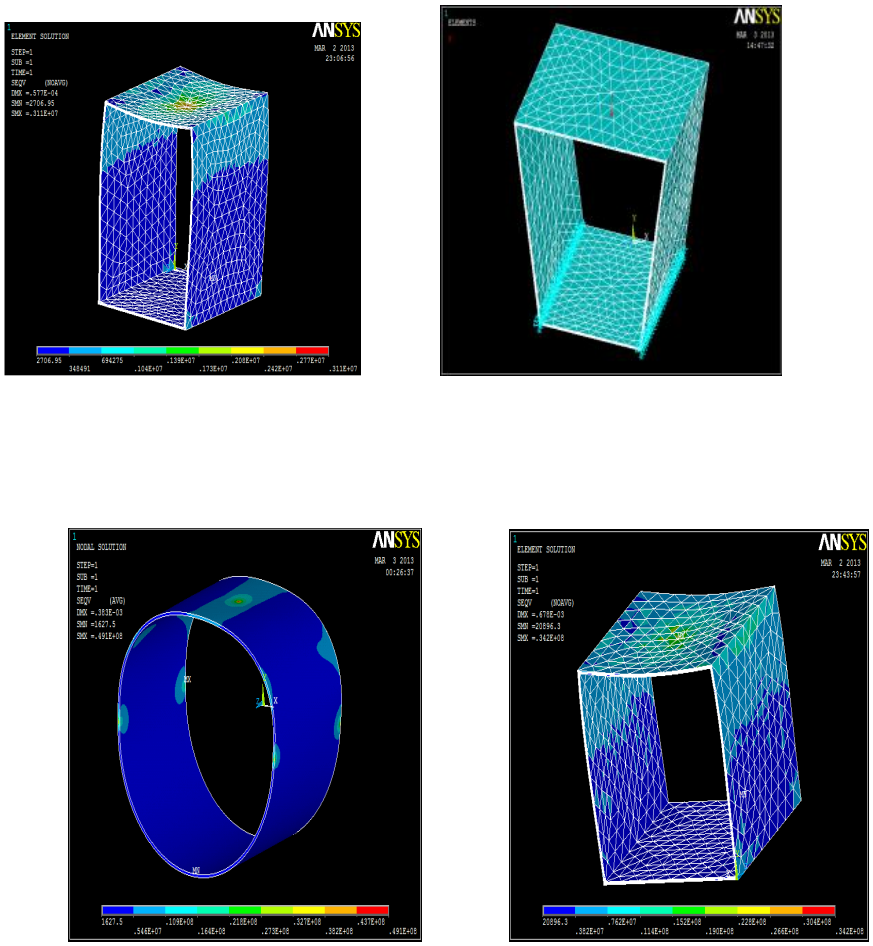


TABLE I: RESULT OF VARIOUS SECTION

	CROSS SECTION			
PARAMETER	RECTANGLE	SQUARE	CIRCULAR	TRAPEZIUM
Weight of Section(kg.)	50	50	50	50
Applied Load(kg)	1000	1000	1000	1000
Allowable Stress(N/m2)	3.0+07	3.0+07	3.0+07	3.0+07
Actual Stress(N/m2)	2.79E+06	2.21E+07	4.86E+07	2.72E+07
Actual Displacement (m)	5.77E-05	6.78E-04	3.84E-04	1.42E-04

Figure 5. Stress Plot For Various Section

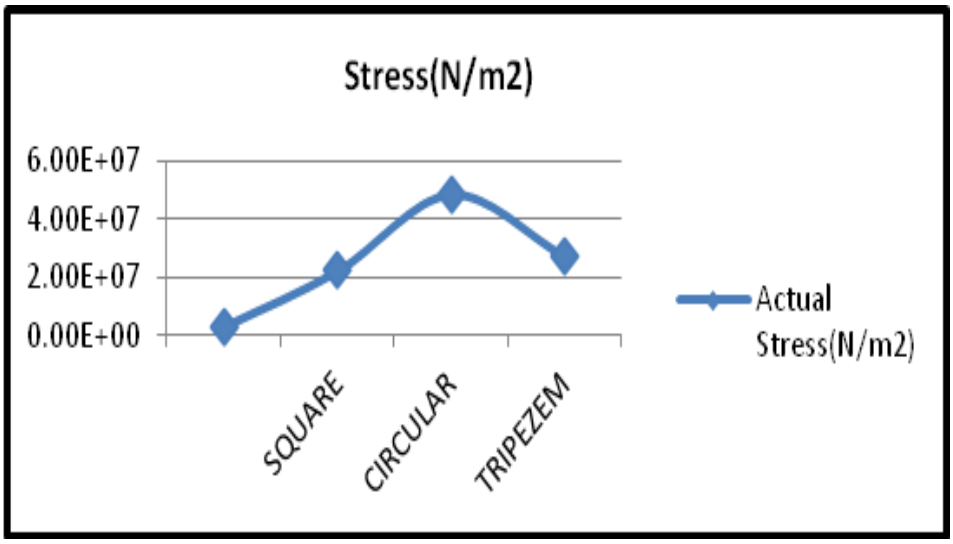
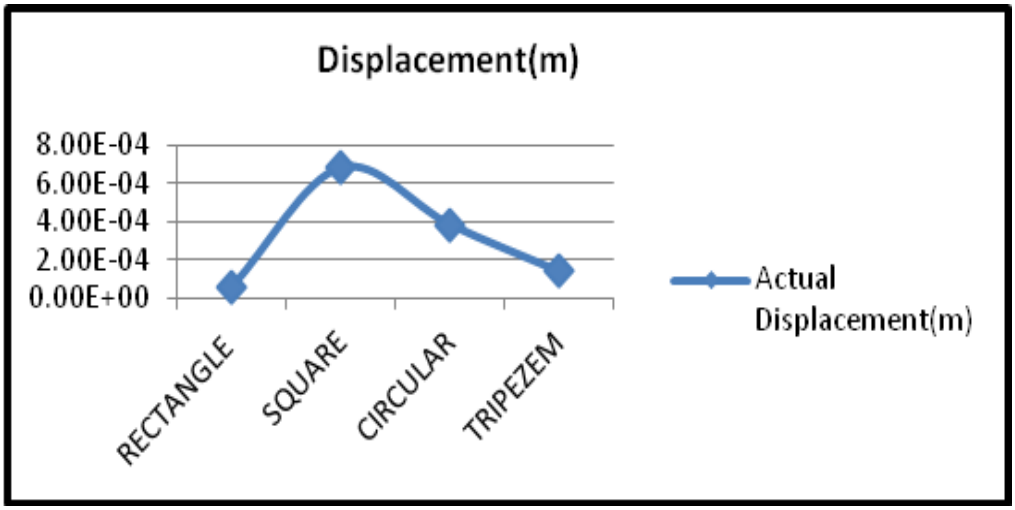


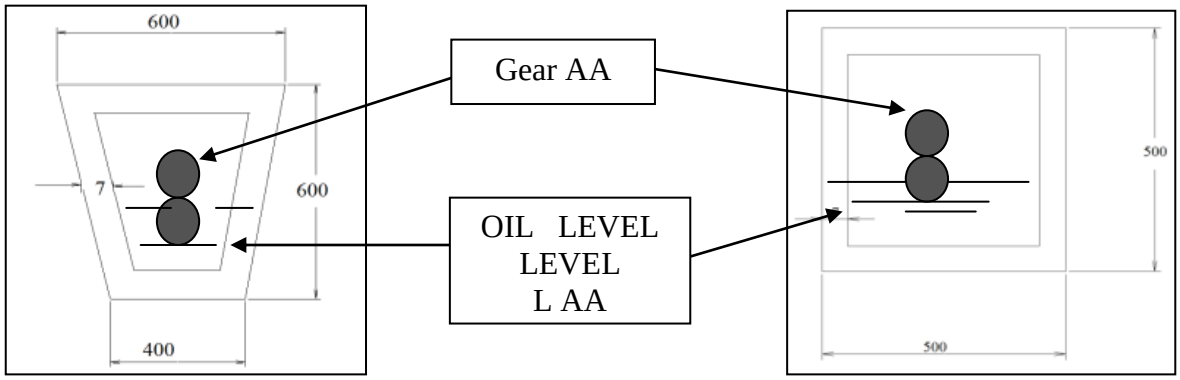
Figure 6. Displacement Plot For Various Section



CONCLUSION

Trapezium is best section of Housing because of Following Reasons.

Figure 7. Oil level comparison in two sections.



Optimum stress than other cross section.

Low oil level quantity than other section.

REDISIGN OF GEAR BOX BY USING PLANETARY GEAR ARRANGMGNT, INSTED OF SPUR GEAR ARRANGMENT

Figure 8. Spur Gear Reduction

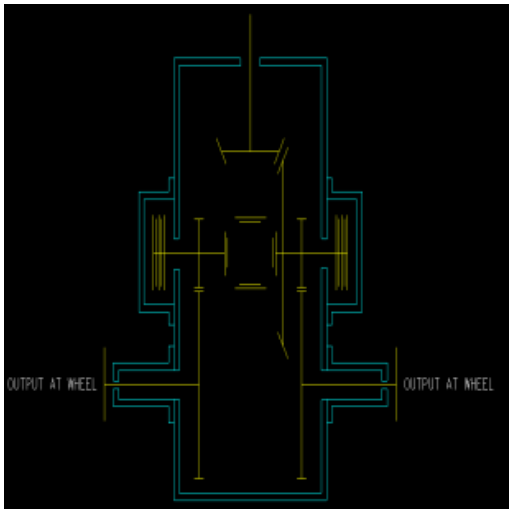
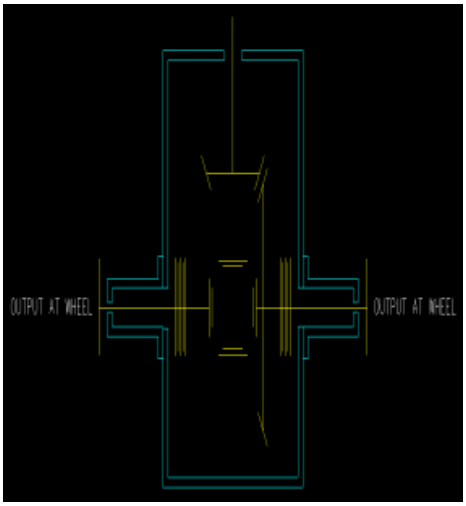


Figure 9. Planetary Gear Reduction



Final reduction in Tractor Transmission can be achieved by Spur gear or by planetary gear reduction. Planetary gear reduction gives compact design than spur gear for same reduction ratio.

We will now compare two design for Weight reduction.

Both systems will be design for 15Kw power & for reduction ratio 6.2.

Table II : shows detail comparison of various parameters of both designs.

Both designs are optimally design to have almost same contact and bending stress.

It is clear from data that planetary arrangement will be lighter than spur arrangement by 13.5 Kg

TABLE II Weight Comparison Spur Gear & Planetary Design

Parameter	Spur Gear		Planetary		
Input Power(KW)	15		15		
Torque (Nm)	1073		1073		
RPM	136		136		
Gear Ratio	6.2		6.2		
No. of Teeth	Pinion	Gear	Sun Gear	Planet	Ring Gear
	10	62	14	29	73
Centre Distance	252		69		
Module	6.5		3.17		
Face Width	50		50		
Bending Stress(N/mm2)	579		578		
Contact Stress (N/mm2)	1300		1302		
Weight (Kg.)	Pinion	Gear	Sun Gear	Planet (3)	Ring Gear +Carrier
	7.7	30.2	3.1	5.4	15.9
Total Weight (kg)	37.9		24.4		
Weight Difference (kg)	13.5				

EFFECT OF HELIX ANGLE AND TIP RELIEF ON POWER LOSS.

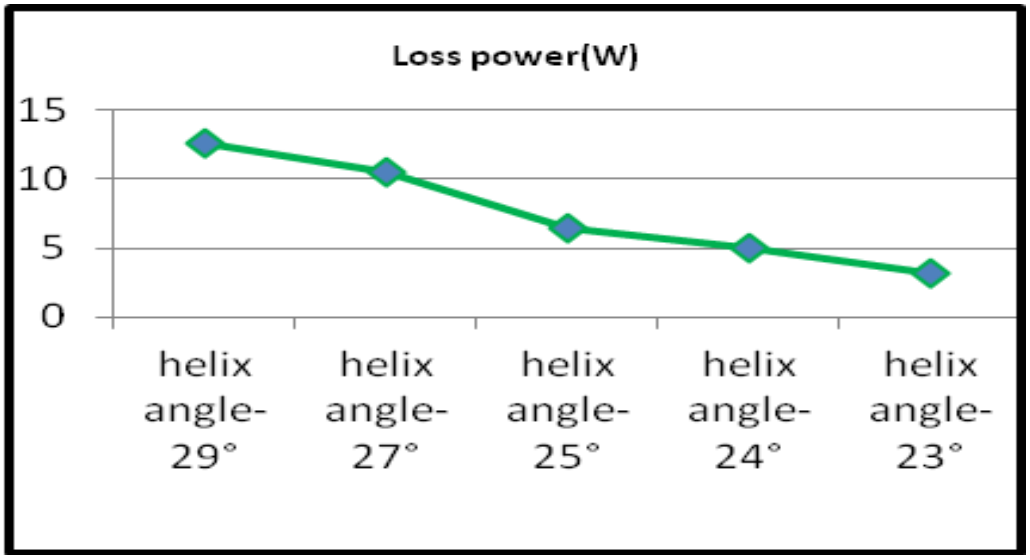
Gear loss is affected by various parameters such as speed of rotation, torque to be transmitted, helix angle, pressure angle, tip relief, etc.

Tables below show a effect of helix angle and tip relief on power loss.

TABLE III EFFECT OF HELIX ANGLE ON POWER LOSS

			HELIX ANGLE		
	29°	27°	25°	24°	23°
Module	3	3	3	3	3
Pressure Angle	20	20	20	20	20
Gear Ratio 2.2 (18/41)	2.2	2.2	2.2	2.2	2.2
Input Power(KW)	36	36	36	36	36
Torque(N-m)	172	172	172	172	172
Rpm	2000	2000	2000	2000	2000
Loss power(W)	12.653	10.558	6.487	4.952	3.139
Contact Stress(N/mm2)	621.4	644.4	654.1	659.1	675.5

Figure 10. Power Loss at various Helix Angles



It is concluded from above result that,

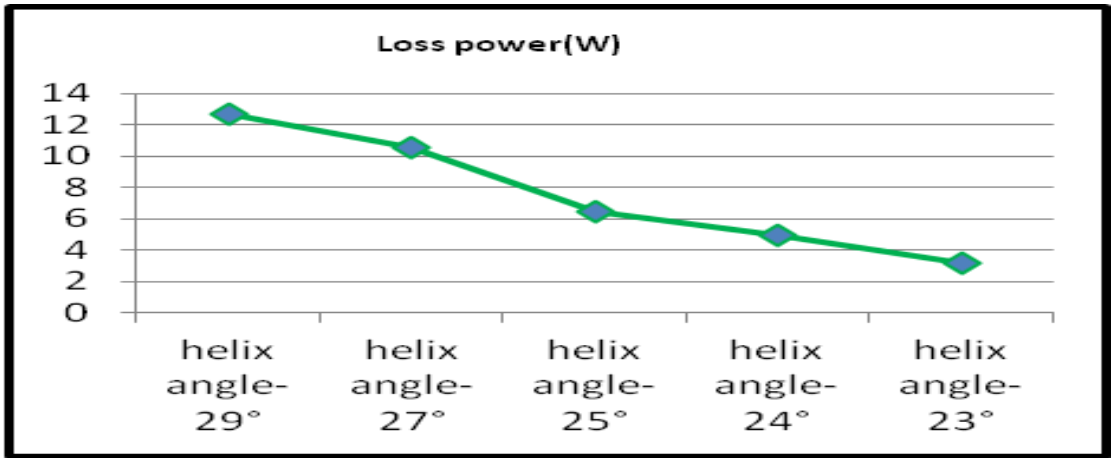
25 Deg. Helix angle will give optimum power loss.

Below this power loss is low but the contact stress is above the required limit.

TABLE III Effect of Tip Relief on Power Loss

	TIP RELIEF					
	15µm	12µm	10µm	8µm	6µm	4µm
Module	3	3	3	3	3	3
Pressure Angle	20	20	20	20	20	20
Gear Ratio 2.2 (18/41)	2.2	2.2	2.2	2.2	2.2	2.2
Input Power(KW)	36	36	36	36	36	36
Torque(N-m)	172	172	172	172	172	172
Rpm	2000	2000	2000	2000	2000	2000
Loss power(W)	11.905	10.432	9.585	8.716	7.73	6.504
Contact Stress(N/mm2)	980	845.5	742.187	605.581	570.21	522.67

Figure 11. Power Loss at various at various Tip Relief



It is concluded form above result that:

8 µm tip relief is optimum for power loss.

Below which power loss is less, but picking may happen on teeth.

OIL CHURNING LOSS OPTIMIZATION

TABLE IV Churning Loss at Variuos Oil Level

OIL QUANTITY	GEAR USED TO MEASURE POWER LOSS	POWER LOSS MEASURED
40 Lit	H3	11 Hp
35 Lit	H3	9.3 HP
30 Lit	H3	8.4 Hp
25 Lit	H3	9.1 Hp
20 lit	H3	10.2 Hp

Above reading taken after practical trails on transmission

We can conclude that 30 Lit is optimum qty. of oil for this transmission, above and below losses will increases.

CONCLUSION

Following conclusion can be made after all experiment.

1) Planetary design will save weight as compared to spur gear design.

2) Trapezium cross section is optimum for Gear box casing; it will also reduce the oil requirement for transmission.

3) 25 Deg. Helix angle & 8 um Tip relief is optimum for power loss for given condition.

4) After practical trials, 30 lit oil is optimum for given Transmission

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