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Methodology for Designing a Gearbox and its Analysis

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***Abstract*—Robust and Axiomatic design, a property based approach in design, is applied and integrated into a new methodology for developing Functional Requirements (FR) or Design Parameters (DP).The reliability of the design structure and design components are used as a functional requirements of the gearbox, in relation to the service and driving conditions, and also as a design constraints in analytical relationships. The different operating conditions of gearbox are used as case study in this paper. The same design structures have to operate under different operating conditions. In these circumstances, the carrying capacity as a functional requirement is related to driving conditions [5]. This paper unveils the more sophisticated methodology of the gearbox designing using the modern designing software's.**

Keywords—KISSsoft, Load spectrum, Gears, Shafts, Bearings

INTRODUCTION

Gears and gear drives have been known and used for millennia as critical components of mechanisms and machines. Over the last several decades the development of gearing has mostly focused in the following fields: the improving of material, manufacturing technology and tooling, thermal treatment, tooth surface engineering and coatings, tribology and lubricants, testing technology and diagnostics [4]. Gear design is a highly complicated art. The constant pressure to build less expensive, quieter running, lighter, and more powerful machinery has resulted in a steady change in gear designs [3]. At present much is known about gear load-carrying capacity, and many complicated processes for making gears are available. Gear design also included material selection, which should provide the required strength and durability of every component in the gear drive. The vast majority of gears are designed with the standard 20^0 pressure angle tooth proportions [4]. In this paper, two stage reduction helical gearbox has been designed. The gears and shaft design calculations are done with the help of KISSsoft. KISSsoft is a program for machine design calculations. KISSsoft have been incorporated with various calculation methods for the gear and shaft design separately. Here AGMA 2101-D04 (Metric Edition) has been selected as the calculation method. When the gear design completes, the next stage of gear drive development is fabrication of parts and assembly; this stage included technological process selection and tool design [4].

I. DESIGN PROCESS:

A. *MATERIAL SELECTION*

The first step in the gearbox design process is to select the material. A material is to be selected by doing intensive research on the properties of the various materials. A material is to be selected keeping in mind the various parameters like strength, weight, durability, cost and other parameters. KISSsoft provide the user, list of the various materials which can be selected for the designing of gears.

TABLE.I MATERIAL SPECIFICATION

PROPERTIES	VALUE
Surface hardness	HRC 61
Allowable bending stress number (N/mm^2)	430
Allowable contact stress number (N/mm^2)	1500
Tensile strength (N/mm^2)	1200
Yield point (N/mm^2)	850
Young's modulus (N/mm^2)	206000
Poisson's ratio	0.3

Also there is a provision for the user to enter his own material properties and thus one can define his own material in the program. In this paper for the sake of designing gearbox, **case-carburized steel** is selected due to its better mechanical properties. Also the material selected for gears and shaft is to be same because of the fact, same material can be manufactured as a single unit.

B. *INPUT PARAMETERS*

- *FOR 1ST REDUCTION*

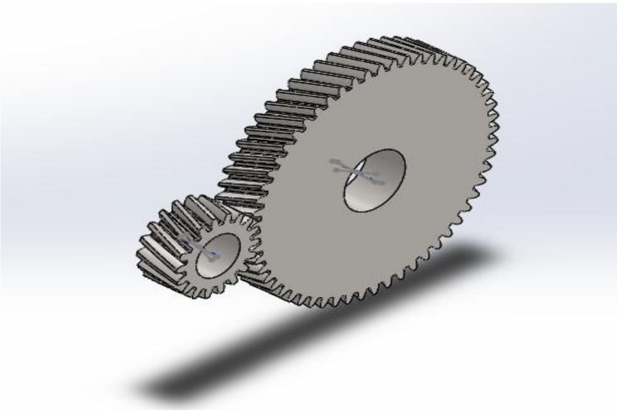

Fig.1 Gear Pair 1

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TABLE.II INPUT PARAMETERS

PARAMETERS	GEAR 1	GEAR 2
Transmitted power (KW)	7.5	7.5
Speed (1/min)	1278.9	403.9
Torque(Nm)	56	177.3
Overload factor	2.0	2.0
Required service life(h)	2000	2000

- *FOR 2ND REDUCTION*

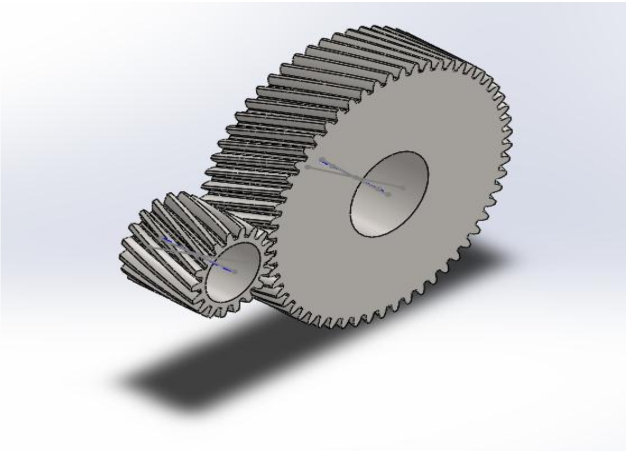

Fig.2 Gear Pair 2

TABLE.III INPUT PARAMETERS

PARAMETERS	GEAR 1	GEAR 2
Transmitted power (KW)	7.5	7.5
Speed (1/min)	400.1	126.4
Torque(Nm)	179	566.8
Overload factor	2.0	2.0
Required service life(h)	2000	2000

TABLE.IV INPUT SHAFT PARAMETERS

PARAMETERS	VALUE
Initial position	0.0
Length (mm)	142
Speed (1/min)	1279
Sense of rotation	Counter clockwise

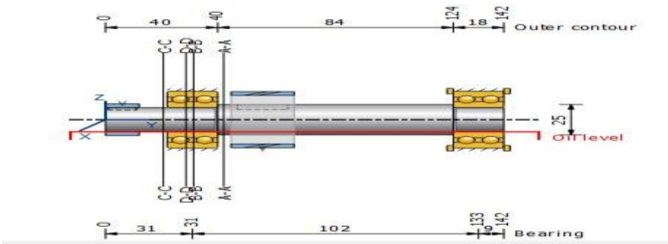

Fig.3 Input shaft

TABLE.V INTERMADIATE SHAFT PARAMETERS

PARAMETERS	VALUE
Initial position	0.0
Length (mm)	142.350
Speed (1/min)	400
Sense of rotation	Clockwise

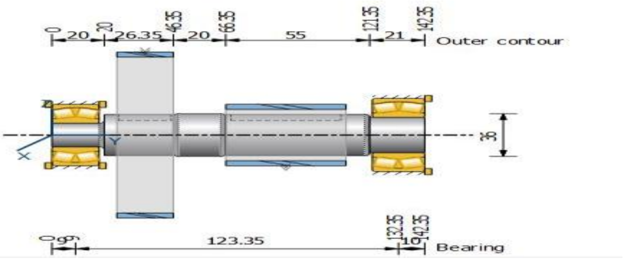

Fig.4 Intermediate Shaft

TABLE.VI OUTPUT SHAFT PARAMETERS

PARAMETERS	VALUE
Initial position	0.0
Length (mm)	183.2
Speed (1/min)	125
Sense of rotation	Counter clockwise

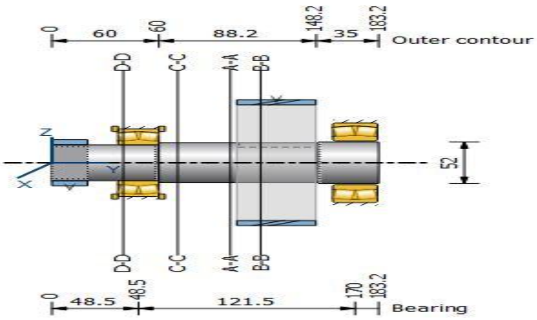

Fig.5 Output Shaft

C. ROUGH SIZING OF GEARS

TABLE.VII 1ST REDUCTION PARAMETERS

PARAMETERS	GEAR 1	GEAR 2
Centre distance (mm)	89	89
Centre distance tolerance	ISO 286:2010 Measure js7	ISO 286:2010 Measure js7
Normal diametral pitch (1/in)	11.28889	11.28889
Transverse diametral pitch (1/in)	10.60809	10.60809
Normal module (mm)	2.25	2.25
Pressure angle (^{0})	20	20
Helix angle (^{0})	20	20
Number of teeth	18	57
Facewidth (mm)	22.49	21.55
Hand of gear	right	Left
Accuracy grade	A8	A8
Inner diameter	0.0	0.0
Roughness average value, Flank (µm)	0.6	0.6
Roughness average value, Root (µm)	3.0	3.0
Mean roughness height, Flank (µm)	4.8	4.8
Mean roughness height, Root (µm)	20	20

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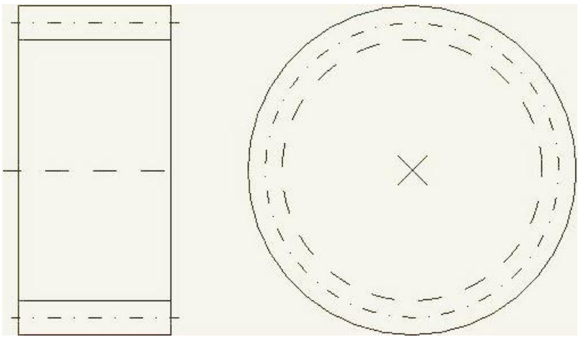

Fig.6 Drawing Gear 1

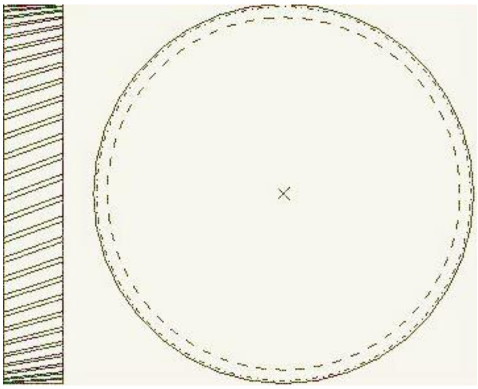

Fig.7 Drawing Gear 2

TABLE.VIII 2ND REDUCTION PARAMETERS

PARAMETERS	GEAR 3	GEAR 4
Centre distance(mm)	100	100
Centre distance tolerance	ISO 286:2010 Measure js7	ISO 286:2010 Measure js7
Normal diametral pitch(1/in)	10.160	10.160
Transverse diametral pitch(1/in)	9.54728	9.54728
Normal module(mm)	2.5	2.5
Pressure angle(^{0})	20	20
Helix angle(^{0})	20	20
Number of teeth	18	57
Facewidth(mm)	45.88	44.38
Hand of gear	Right	left
Accuracy grade	A8	A8
Inner diameter	0.0	0.0
Roughness average value, Flank (µm)	0.6	0.6
Roughness average value, Root (µm)	3.0	3.0
Mean roughness height, Flank (µm)	4.8	4.8
Mean roughness height Root(µm)	20	20

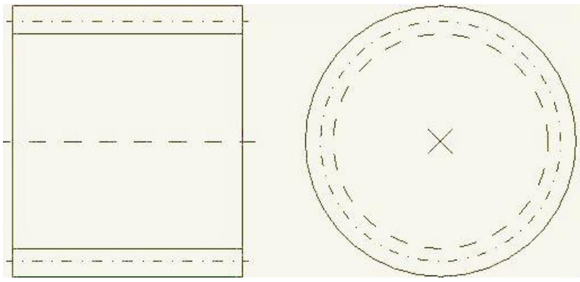

Fig.8 Drawing Gear 3

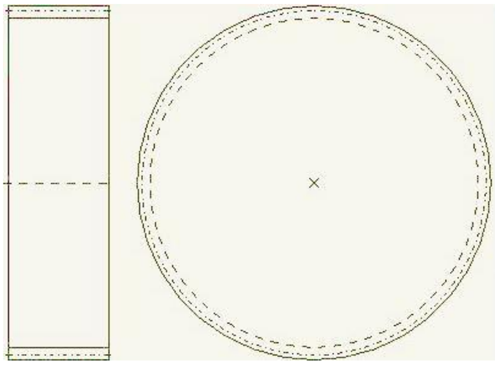

Fig.9 Drawing Gear 4

D. FINE SIZING OF GEARS

- *FOR 1ST REDUCTION*

TABLE.IX PROFILE PARAMETERS

PARAMETERS	GEAR 1	GEAR 2
Reference profile	1.25 / 0.38 / 1.0 ISO 53.2:1997 Profile A	1.25 / 0.38 / 1.0 ISO 53.2:1997 Profile A
Dedendum coefficient	1.25	1.25
Root radius factor	0.380	0.380
Addendum	1.0	1.0
Tip radius factor	0.0	0.0
Protuberance height factor	0.0	0.0
Protuberance angle	0.0	0.0
Tip form height coefficient	0.0	0.0
Ramp angle	0.0	0.0

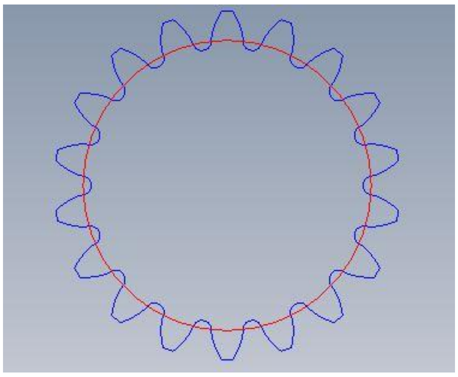

Fig.10 Tooth Form Gear 1

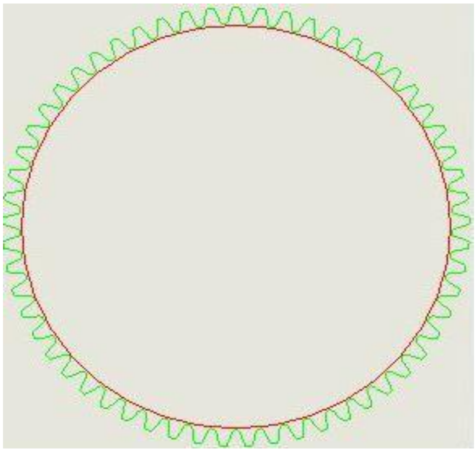

Fig.11 Tooth Form Gear 2

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TABLE.X RECTIFIED PARAMETERS

PARAMETERS	GEAR 1	GEAR 2
Overall transmission ratio	-3.167	-3.167
Gear ratio	3.167	3.167
Transverse module(mm)	2.394	2.394
Pressure angle at pitch circle (^{0})	21.173	21.173
Working transverse pressure angle (^{0})	19.818	19.818
Working pressure angle at normal section (°)	19.850	19.787
Helix angle at operating pitch circle (°)	18.727	18.727
Base helix angle (°)	18.747	18.747
Reference centre distance (mm)	89.790	89.790
Sum of profile shift coefficients	-0.3405	-0.3405
Profile shift coefficient	0.1605	-0.5010
Tooth thickness (Arc) (module)	1.6876	1.2061
Tip alteration (mm)	-0.024	-0.024
Reference diameter (mm)	43.099	136.481
Base diameter (mm)	40.190	127.268
Tip diameter (mm)	48.273	138.678
Tip diameter allowances (mm)	0.0	0.0
Tip form diameter (mm)	48.273	138.678
Active tip diameter (mm)	48.273	138.678
Operating pitch diameter (mm)	42.720	135.280
Root diameter (mm)	38.196	128.601
Generating Profile shift coefficient	0.1275	-0.5590
Manufactured root diameter with xE (mm)	38.048	128.340
Theoretical tip clearance (mm)	0.563	0.563
Effective tip clearance (mm)	0.748	0.701
Active root diameter (mm)	40.533	131.630
Root form diameter (mm)	40.513	130.893
Reserve (dNf-dFf)/2 (mm)	0.056	0.511
Addendum (mm)	2.587	1.099
Dedendum (mm)	2.451	3.940
Roll angle at dFa (°)	38.123	24.800
Roll angle at dNa (°)	38.123	24.800
Roll angle to dNf (°)	7.684	15.185
Roll angle at dFf (°)	6.696	13.448
Tooth height (mm)	5.038	5.038
Virtual gear no. of teeth	21.362	67.646
Normal-tooth thickness at tip circle (mm)	1.434	1.807
Normal-tooth thickness on tip form circle (mm)	1.488	1.900
Normal space width at root circle (mm)	0.0	2.089
Max. sliding velocity at tip (m/s)	1.080	0.813
Specific sliding at the tip	0.378	0.284
Specific sliding at the root	-0.284	-0.378
Mean specific sliding	0.644	0.644
Sliding factor on tip	0.378	0.284
Sliding factor on root	-0.284	-0.378
Pitch on reference circle (mm)	7.522	7.522
Base pitch (mm)	7.014	7.014
Transverse pitch on contact-path (mm)	7.014	7.014
Lead height(mm)	372.009	1178.03
Axial pitch (mm)	20.667	20.667
Length of path of contact (mm)	10.740	10.740
Length T1-A, T2-A (mm)	2.631	27.554
Length T1-B (mm)	6.356	23.818
Length T1-C (mm)	7.242	22.933
Length T1-D (mm)	9.645	20.529
Length T1-E (mm)	13.371	16.804
Length T1-T2 (mm)	30.174	30.174
Diameter of single contact point B (mm)	42.152	135.891
Diameter of single contact point D (mm)	44.580	133.727
Addendum contact ratio	0.874	0.657
Minimal length of contact line (mm)	34.348	34.348
Transverse contact ratio	1.531	1.531
Transverse contact ratio with allowances	1.538	1.538
Overlap ratio	1.043	1.043
Total contact ratio	2.574	2.574
Total contact ratio with allowances	2.581	2.581

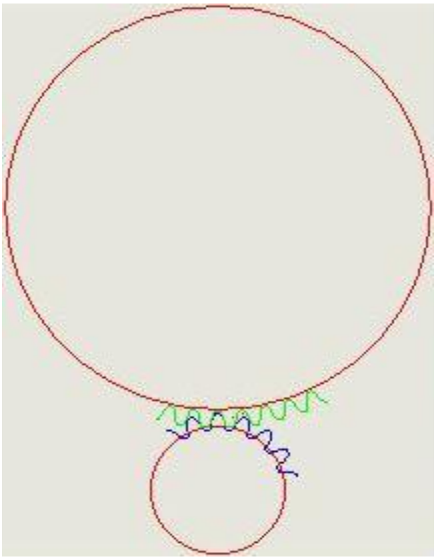

Fig.12 Meshing of Gear 1 and 2

- *FOR 2ND REDUCTION*

TABLE.XI PROFILE PARAMETERS

PARAMETERS	GEAR 1	GEAR 2
Reference profile	1.25 / 0.38 / 1.0 ISO 53.2:1997 Profile A	1.25 / 0.38 / 1.0 ISO 53.2:1997 Profile A
Dedendum coefficient	1.25	1.25
Root radius factor	0.380	0.380
Addendum	1.0	1.0
Tip radius factor	0.0	0.0
Protuberance height factor	0.0	0.0
Protuberance angle	0.0	0.0
Tip form height coefficient	0.0	0.0
Ramp angle	0.0	0.0

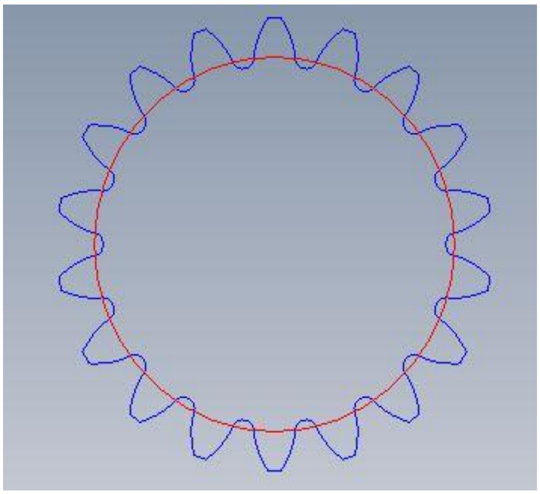

Fig.13 Tooth Form Gear 3

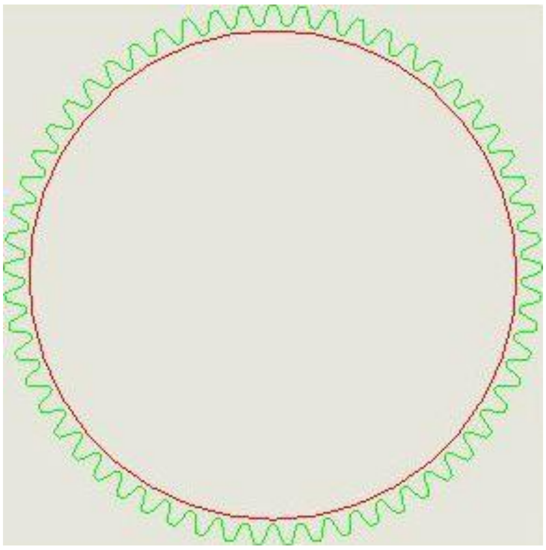

Fig.14 Tooth Form Gear 4

TABLE.XII RECTIFIED PARAMETERS

PARAMETERS	GEAR 1	GEAR 2
Overall transmission ratio	-3.167	-3.167
Gear ratio	3.167	3.167
Transverse module(mm)	2.660	2.660
Pressure angle at pitch circle(^{0})	21.173	21.173
Working transverse pressure angle(^{0})	21.515	21.515
Working pressure angle at normal section (°)	20.322	20.322
Helix angle (^{0})	20.043	20.043
Base helix angle (°)	18.747	18.747
Reference centre distance (mm)	99.767	99.767
Sum of profile shift coefficients	0.2238	-0.1298
Profile shift coefficient	1.7337	1.4763
Tooth thickness (Arc) (module)	1.7337	1.4763
Tip alteration (mm)	-0.002	-0.002
Reference diameter (mm)	47.888	47.888
Base diameter (mm)	44.655	141.409
Tip diameter (mm)	54.003	155.993
Tip form diameter (mm)	54.003	155.993
Active tip diameter (mm)	54.003	155.993
Operating pitch diameter (mm)	48.0	152.0
Root diameter (mm)	42.757	144.747
Generating Profile shift coefficient	0.1941	-0.1820
Manufactured root diameter with xE (mm)	42.609	144.486
Theoretical tip clearance (mm)	0.625	0.625
Effective tip clearance (mm)	0.847	0.763
Active root diameter (mm)	45.279	147.797
Root form diameter (mm)	45.133	146.723
Reserve (dNf-dFf)/2 (mm)	0.127	0.698
Addendum (mm)	3.058	2.174
Dedendum (mm)	2.565	3.449
Roll angle at dFa (°)	38.965	26.684
Roll angle at dNa (°)	38.965	24.684
Roll angle to dNf (°)	9.765	17.461
Roll angle at dFf (°)	7.879	15.563
Tooth height (mm)	5.623	5.623
Virtual gear no. of teeth	21.362	67.646
Normal-tooth thickness at tip circle (mm)	1.562	2.019
Normal-tooth thickness on tip form circle (mm)	1.562	2.019
Normal space width at root circle (mm)	0.0	2.024
Max. sliding velocity at tip (m/s)	0.352	0.279
Specific sliding at the tip	0.378	0.640
Specific sliding at the root	-1.776	-1.237
Mean specific sliding	0.591	0.591
Sliding factor on tip	0.350	0.277
Sliding factor on root	-0.277	-0.350
Pitch on reference circle (mm)	8.358	8.358
Base pitch (mm)	7.794	7.794
Transverse pitch on contact-path (mm)	7.794	7.794
Lead height(mm)	413.343	1308.92
Axial pitch (mm)	22.964	22.964
Length of path of contact (mm)	11.438	11.438
Length T1-A, T2-A (mm)	3.746	32.929
Length T1-B (mm)	7.390	29.285
Length T1-C (mm)	8.802	27.873
Length T1-D (mm)	11.540	25.135
Length T1-E (mm)	15.184	21.491
Length T1-T2 (mm)	36.675	36.675
Diameter of single contact point B (mm)	47.038	153.058
Diameter of single contact point D (mm)	50.267	150.078
Addendum contact ratio	0.819	0.649
Minimal length of contact line (mm)	67.913	67.913
Transverse contact ratio	1.468	1.468
Transverse contact ratio with allowances	1.474	1.474
Overlap ratio	1.933	1.933
Total contact ratio	3.4	3.4
Total contact ratio with allowances	3.406	3.406

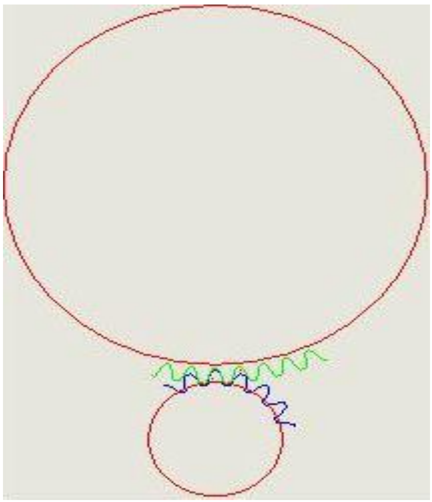

Fig.15 Meshing of Gear 3 and 4

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E. SHAFT AND BEARING DESIGN

TABLE.XIII INPUT SHAFT PARAMETERS

PARAMETERS	CYLINDER 1	CYLINDER 2	CYLINDER 3
Diameter (mm)	20	25	20
Length (mm)	40	84	18
Surface roughness(μm)	8	8	8
Keyway (mm)	10	18	-

TABLE.XIV INPUT SHAFT FORCES PARAMETERS

PARAMETERS	GEAR 1	COUPLING
Position on shaft (mm)	56.0000	6.0000
Position in global system (mm)	56.0000	6.0000
Operating pitch diameter (mm)	43.0990	0.0000
Helix angle (°)	19.8380	0.0000
Working pressure angle at normal section (°)	18.7270	0.0000
Position of contact (°)	0.0000	0.0000
Length of load application (mm)	22.5000	0.0000
Power (kW)	7.5000 driving (Output)	7.5000 driven (Input)
Torque (Nm)	55.9967	-55.9967
Axial force (N)	937.469	0.0000
Shearing force X (N)	-936.48	0.0000
Shearing force Z (N)	-2598.5	0.0000
Bending moment X (Nm)	-0.0000	0.0000
Bending moment Z (Nm)	20.2020	0.0000

TABLE.XV INPUT SHAFT BEARINGS PARAMETERS

PARAMETERS	BEARING 1	BEARING 2
Bearing type	SKF 4204 ATN9 Deep groove ball bearing (double row)	SKF 4204 ATN9 Deep groove ball bearing (double row)
Bearing position (mm)	31.000	133.000
Attachment of external ring	Free bearing	Fixed bearing
Inner diameter (mm)	20.000	20.000
External diameter (mm)	47.000	47.000
Width (mm)	18.000	18.000
Corner radius (mm)	1.000	1.000
Basic static load rating	12.500	12.500
Basic dynamic load rating	17.800	17.800
Fatigue load rating	0.530	0.530
Basic dynamic load rating (kN)	0.000	0.000
Basic static load rating (kN)	0.000	0.000

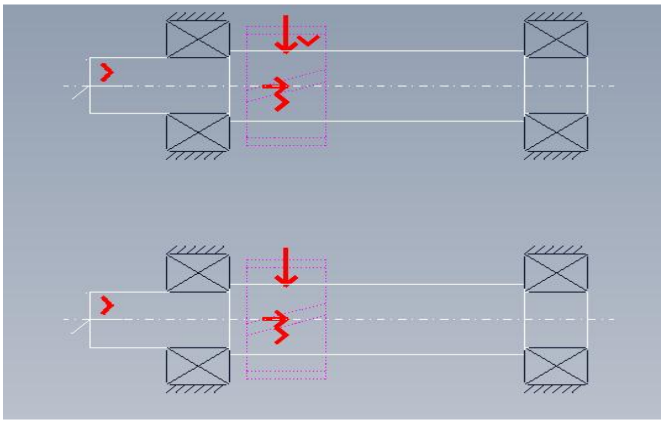

Fig.16 Load application

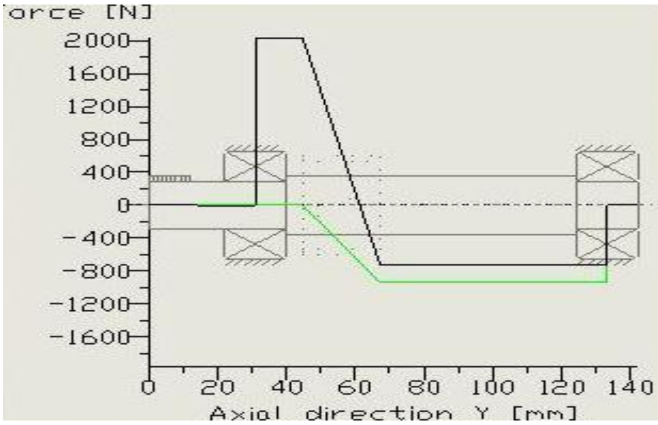

Fig.17 Force diagram

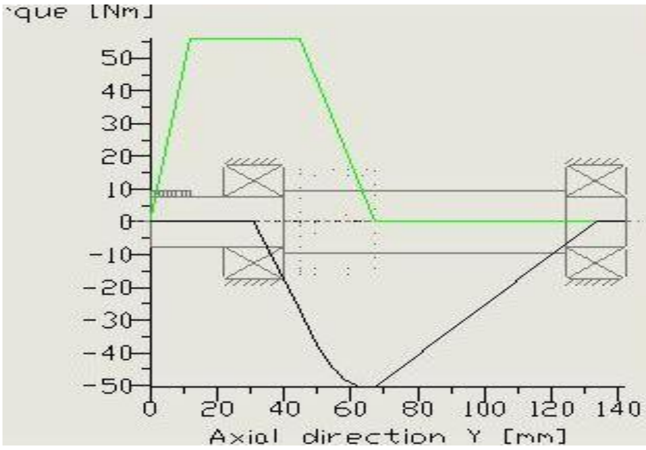

Fig.18 Torque diagram

TABLE.XVI INTERMEDIATE SHAFT PARAMETERS

PARAMETERS	CYLINDER 1	CYLINDER 2	CYLINDER 3	CYLINDER 4	CYLINDER 5
Diameter (mm)	20	35	36	35	30
Length (mm)	20	26.3	20	55	21
Surface roughness (μm)	8	8	8	8	8
Keyway (mm)	-	20	-	42	-

TABLE.XVII INTERMEDIATE SHAFT FORCES PARAMETERS

PARAMETERS	GEAR 2	GEAR 3
Position on shaft (mm)	35.5750	89.35
Position in global system (mm)	35.5750	89.35
Operating pitch diameter (mm)	136.5	47.888
Helix angle (°)	19.8380 right	20.0430 right
Working pressure angle at normal section (°)	18.7270	20.3320
Position of contact (°)	0.0000	0.0000
Length of load application (mm)	21.5500	45.900
Power (kW)	7.5000 driving (Input)	7.5000 driven (Output)
Torque (Nm)	179.049	-179.049
Axial force (N)	-946.460	2728.067
Shearing force X (N)	945.459	-2949.520
Shearing force Z (N)	-2623.43	7477.83
Bending moment X (Nm)	0.0000	-0.0000
Bending moment Z (Nm)	-64.5959	65.3205

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TABLE.XVIII INTERMEDIATE SHAFT BEARINGS

PARAMETERS	BEARING 1	BEARING 2
Bearing type	SKF *22205/20E Spherical roller bearings	SKF *22206E Spherical roller bearings
Bearing position (mm)	9.000	132.350
Attachment of external ring	Fixed bearing	Fixed bearing
Inner diameter (mm)	20.000	30.000
External diameter (mm)	52.000	62.000
Width (mm)	18.000	20.000
Corner radius (mm)	1.000	1.000
Basic static load rating	44.000	60.000
Basic dynamic load rating	49.000	64.000
Fatigue load rating	4.750	6.400
Basic dynamic load rating (kN)	0.000	0.000
Basic static load rating (kN)	0.000	0.000

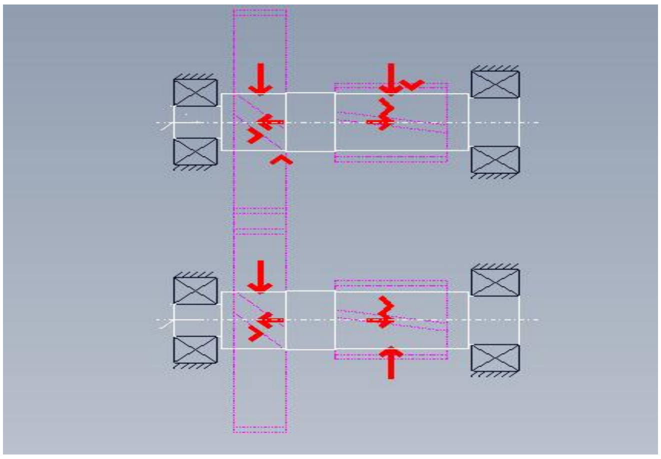

Fig.19 Load application

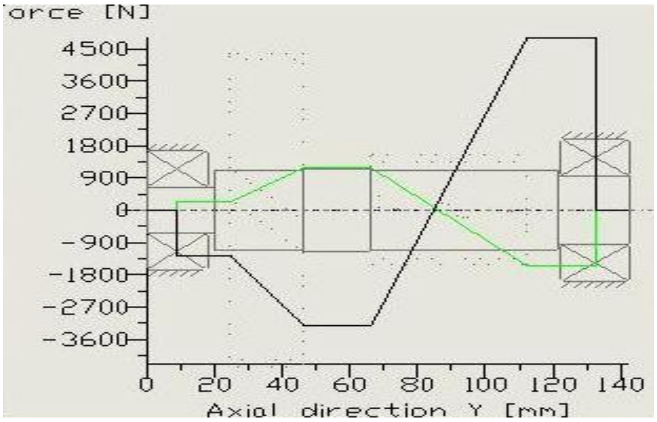

Fig. 20 Force Diagram

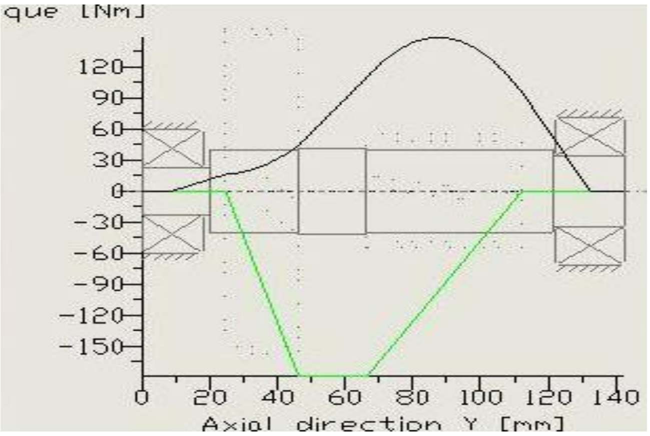

Fig.21 Torque Diagram

TABLE.XIX OUTPUT SHAFT PARAMETERS

PARAMETERS	GEAR 4	COUPLING
Position on shaft (mm)	125.8	10.0
Position in global system (mm)	125.8	10.0
Operating pitch diameter (mm)	151.645	0.0000
Helix angle (°)	20.0430	0.0000
Working pressure angle at normal section (°)	20.3220	0.0000
Position of contact (°)	180.000	0.0000
Length of load application (mm)	44.4000	0.0000
Power (kW)	7.5000 driving (Input)	7.5000 driven (Output)
Torque (Nm)	-572.95	572.95
Axial force (N)	-2756.8	0.0000
Shearing force X (N)	2978.98	0.0000
Shearing force Z (N)	-7556.5	0.0000
Bending moment X (Nm)	0.0000	0.0000
Bending moment Z (Nm)	209.026	0.0000

TABLE.XX OUTPUT SHAFT FORCES PARAMETERS

PARAMETERS	CYLINDER 1	CYLINDER 2	CYLINDER 3
Diameter (mm)	45	50	52
Length (mm)	60	88	35
Surface roughness (µm)	8	8	8
Keyway (mm)	-	43	-
Splines (mm)	44.60	-	-

TABLE.XXI OUTPUT SHAFT BEARINGS PARAMETERS

PARAMETERS	BEARING 1	BEARING 2
Bearing type	SKF *22209E Spherical roller bearings	SKF *22211E Spherical roller bearings
Bearing position (mm)	48.500	170.000
Attachment of external ring	Fixed bearing	Fixed bearing
Inner diameter (mm)	45.000	55.000
External diameter (mm)	85.000	100.00
Width (mm)	23.000	25.000
Corner radius (mm)	1.100	1.500
Basic static load rating	98.000	127.000
Basic dynamic load rating	102.000	125.000
Fatigue load rating	10.800	13.700
Basic dynamic load rating (kN)	0.000	0.000
Basic static load rating (kN)	0.000	0.000

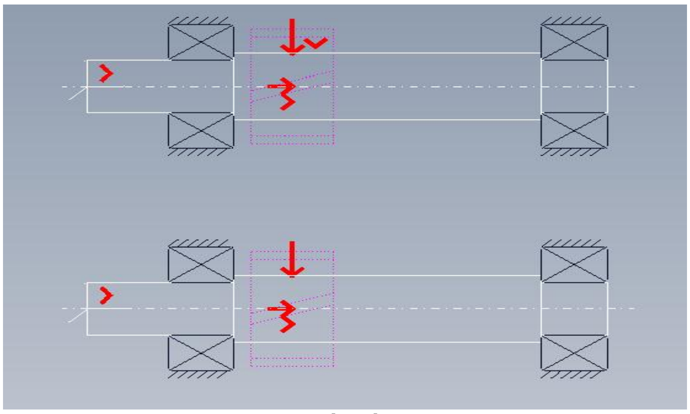

Fig.22 Load application

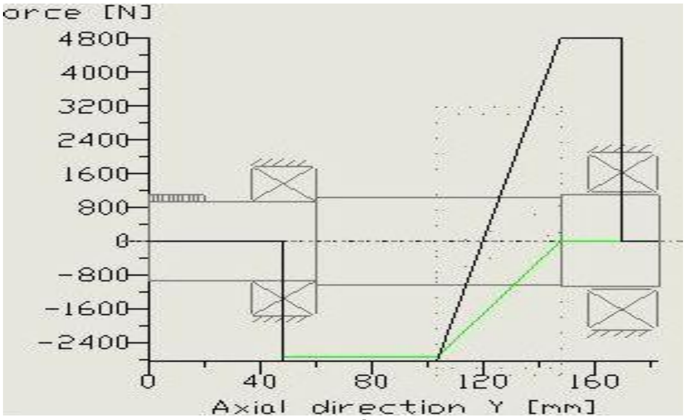

Fig.23 Force diagram

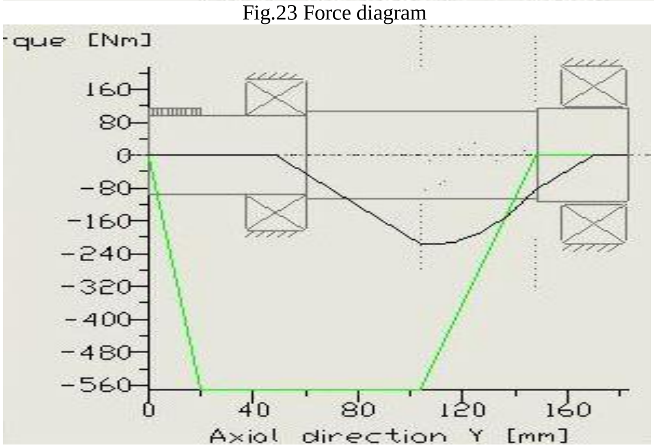

Fig.24 Torque diagram

F. FACTORS OF GENERAL INFLUENCE

TABLE.XXII 1ST REDUCTION PARAMETERS

PARAMETERS	GEAR 1	GEAR 2
Axial force (N)	945.8	945.8
Radial force (N)	944.8	944.8
Pitch line velocity (ft/min)	563.13	563.13
Mesh alignment factor	0.140	0.140
Mesh alignment correction factor	0.800	0.800
Lead correction factor	1.000	1.000
Pinion proportion factor	0.025	0.025
Face load distribution factor	1.138	1.138
Load distribution factor	1.138	1.138
Dynamic factor	1.250	1.250
Number of load cycles (in mio.)	153.471	48.464
Rim thickness factor	1.00	1.00
Size factor	1.00	1.00
Load angle (°)	30.33	21.45
Height of Lewis parabola(mm)	4.08	3.90
Tooth thickness at critical section(mm)	4.31	4.29
Helical factor	1.35	1.35
Tooth form factor Y	0.512	0.469
Stress correction factor	1.464	1.482
Load sharing ratio	0.63	0.63
Bending strength geometry factor J	0.557	0.505
Bending stress number(N/mm^2)	259.23	286.26
Stress cycle factor	0.969	0.989
Temperature factor	1.000	1.000
Reliability factor	1.000	1.000
Required safety factor	1.400	1.400
Size factor	1.000	1.000
Load sharing ratio	0.627	0.627
Geometry factor I	0.217	0.217
Contact stress number	168021	1158.26
Service factor for tooth root	3.22	2.97
Service factor for pitting	2.96	3.12
Service factor for gear set	2.96	2.96

TABLE.XXIII 2ND REDUCTION PARAMETERS

PARAMETERS	GEAR 3	GEAR 4
Axial force (N)	2721.0	2721.0
Radial force (N)	2940.2	2940.2
Pitch line velocity (ft/min)	197.95	197.95
Mesh alignment factor	0.154	0.154
Mesh alignment correction factor	0.800	0.800
Lead correction factor	1.000	1.000
Pinion proportion factor	0.077	0.077
Face load distribution factor	1.200	1.200
Load distribution factor	1.200	1.200
Dynamic factor	1.091	1.091
Number of load cycles (in mio.)	48.013	15.162
Rim thickness factor	1.00	1.00
Size factor	1.00	1.00
Load angle (°)	30.33	21.45
Height of Lewis parabola (mm)	4.60	4.52
Tooth thickness at critical section(mm)	4.89	5.12
Helical factor	1.35	1.35
Tooth form factor Y	0.527	0.524
Stress correction factor	1.475	1.525
Load sharing ratio	0.65	0.65
Bending strength geometry factor J	0.556	0.526
Bending stress number(N/mm^2)	302.83	314.68
Stress cycle factor	0.990	1.010
Temperature factor	1.000	1.000
Reliability factor	1.000	1.000
Required safety factor	1.400	1.400
Size factor	1.000	1.000
Load sharing ratio	0.627	0.627
Geometry factor I	0.217	0.217
Contact stress number	168021	1158.26
Service factor for tooth root	2.81	2.76
Service factor for pitting	2.76	2.90
Service factor for gear set	2.75	2.90

G. FORMULAE USED

- *Gear Wear Equations*

$$d_p = \frac{N_p}{P_d}$$

$$V = \frac{\pi dn}{12}$$

$$W^t = \frac{33000H}{V}$$

$$\sigma_c = C_p{}^2\sqrt{(W^t K_o K_v K_s \frac{K_m}{d_p}\frac{C_p}{IF})}$$

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- $S_H = \frac{S_C Z_N C_H/(K_T K_R)}{\sigma_c}$ [1]

- *Gear Bending Equations*

- $d_p = \frac{N_p}{P_d}$
- $V = \frac{\pi d n}{12}$
- $W^t = \frac{33000H}{V}$
- $\sigma = W^t K_o K_v K_s \frac{P_d}{F} \frac{K_m K_B}{J}$
- $S_F = \frac{\frac{S_t Y_N}{K_T K_R}}{\sigma}$ [1]

H. RESULTS AND DISCUSSIONS

TABLE.XXIV GEAR PARAMETERS

PARAMETERS	1st Reduction		2nd Reduction	
	Gear 1	*Gear 2*	*Gear 3*	*Gear 4*
Bending safety factor	1.61	1.49	1.41	1.38
Pitting safety factor	1.22	1.25	1.17	1.20
Probability of scuffing	<5%		<5%	
Meshing stiffness (N/mm/μm)	17.145		17.463	
Total weight (kg)	2.871		7.464	
Wear sliding coefficient by Niemann	0.986		0.868	
Gear power loss (kW)	0.113		0.126	
Meshing efficiency (%)	98.489		98.323	
Kinematic viscosity of oil (40°C)	220		220	
Kinematic viscosity of oil (100°C)	17.5		17.5	
Oil temperature (°C)	70		70	

- FOR 1ST REDUCTION

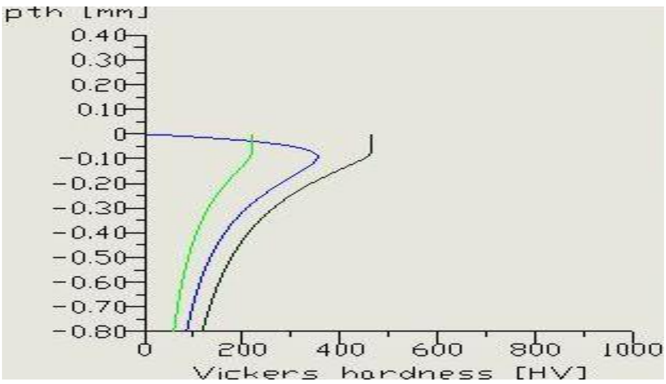

Fig.25 Hardening depth

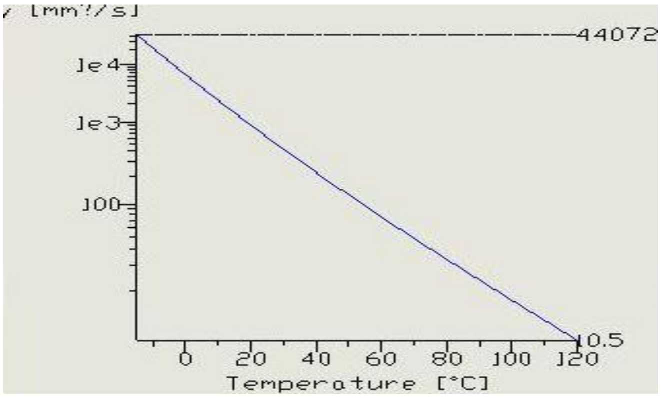

Fig.26 Oil viscosity

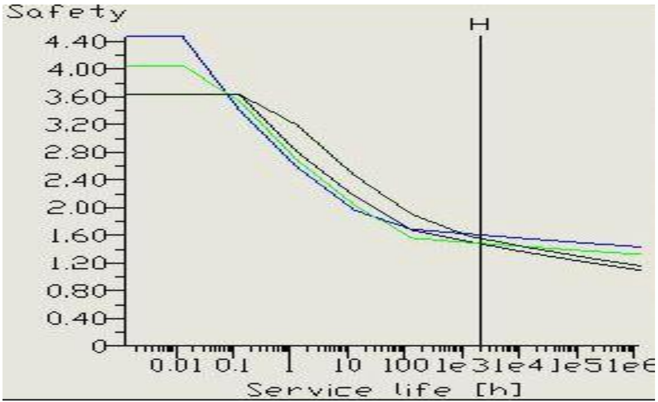

Fig.27 Factor of safety

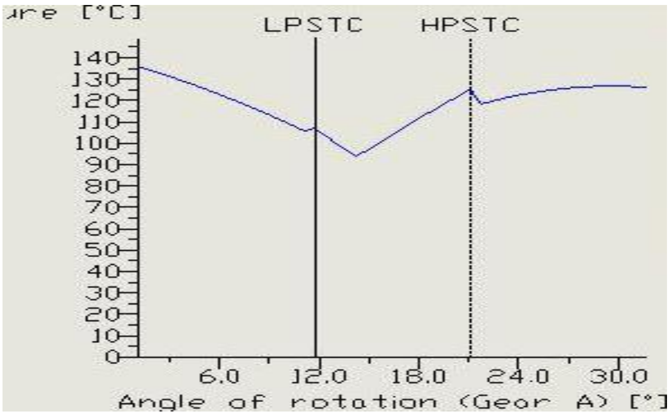

Fig.28 Contact temperature

- FOR 2ND REDUCTION

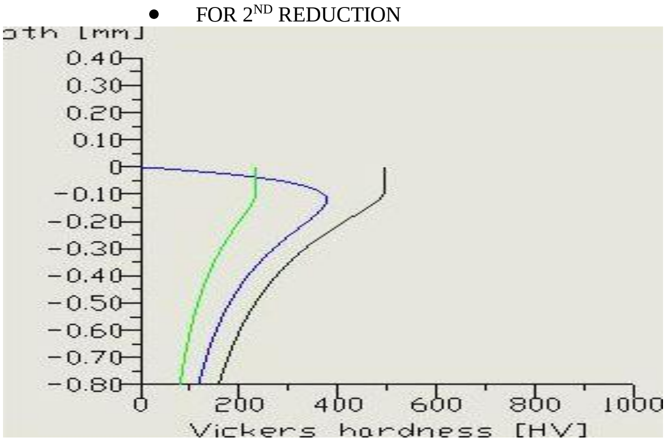

Fig.29 Hardening depth

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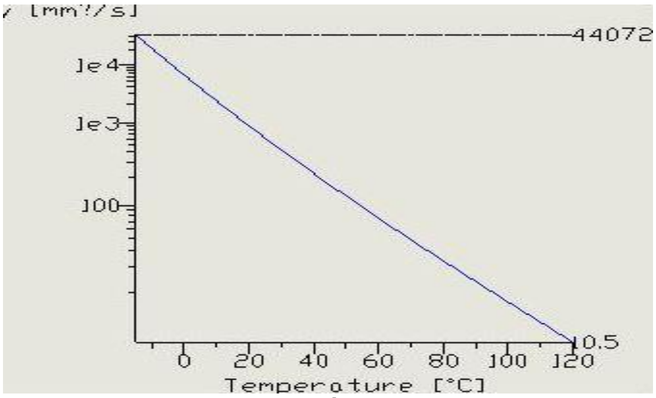

Fig.30 Oil viscosity

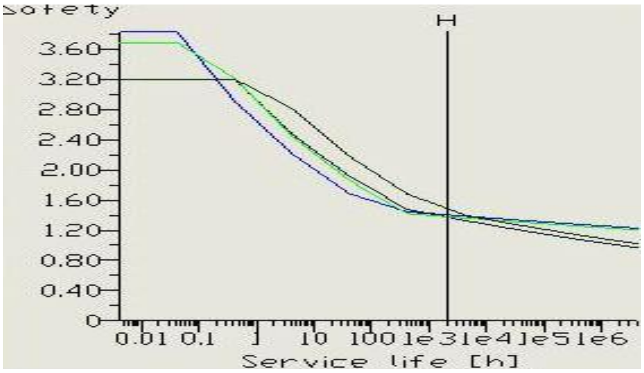

Fig.31 Factor of safety

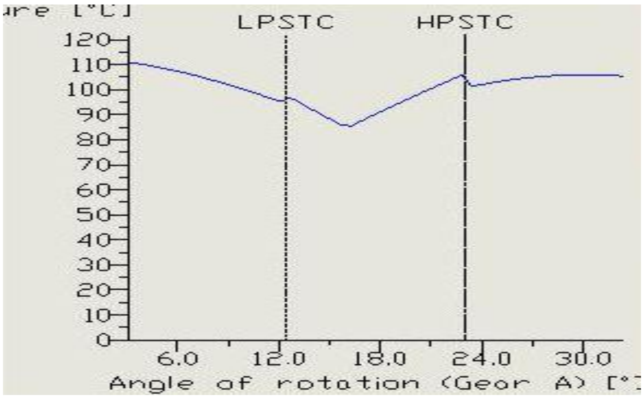

Fig.32 Contact temperature

TABLE.XXV SHAFT PARAMETERS

PARAMETER	INPUT SHAFT	INTERMEDIATE SHAFT	OUTPUT SHAFT
Maximum deflection	0.019	0.028	0.029
Mass centre of gravity (mm)	73.746	74.941	117.0
Total axial load (N)	937.47	1781.604	-2756.7
Torsion under torque(^{0})	0.105	-0.045	-0.096
Minimum factor of safety for endurance	3.49	2.56	3.77
Minimum factor of safety for yield point	4.92	6.45	3.69
Eigen frequency (Hz)	4195.66	4116.53	4816.68
Critical speed (1/min)	251739.33	246991.62	289000.64

- FOR INPUT SHAFT

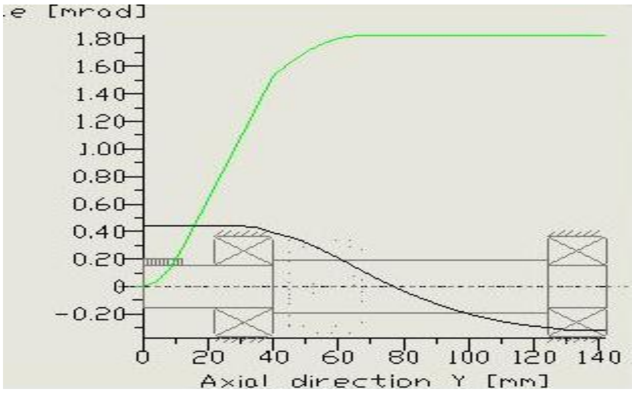

Fig.33 Bending and torsion angle

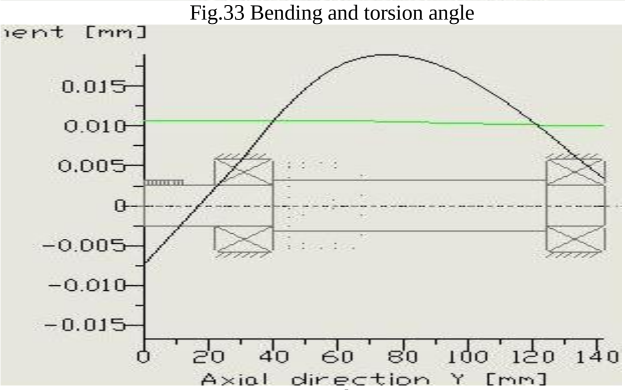

Fig.34 Displacement

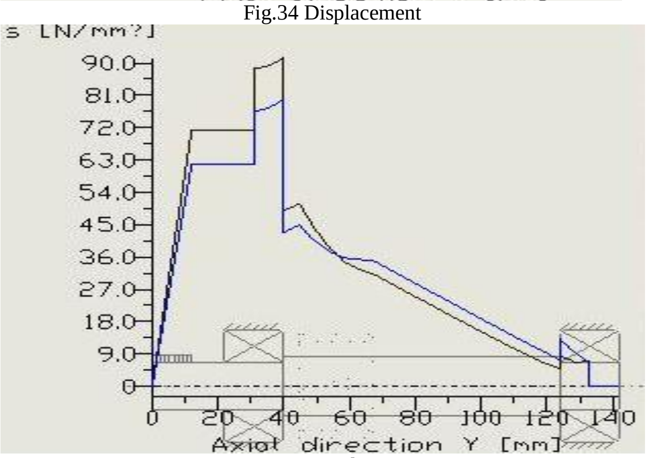

Fig.35 Equivalent stress

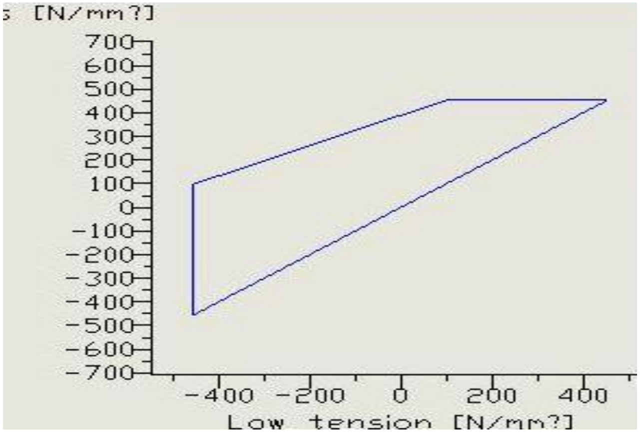

Fig.36 Goodman diagram

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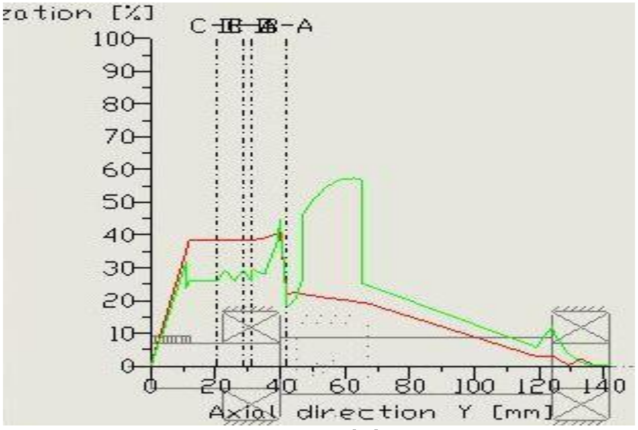

Fig.37 Strength diagram

- FOR INTERMEDIATE SHAFT

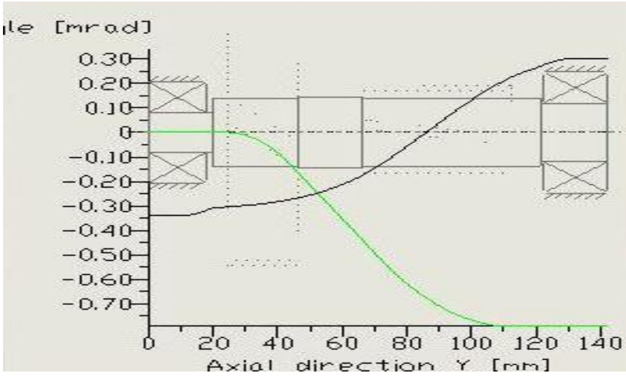

Fig.38 Bending and torsion angle

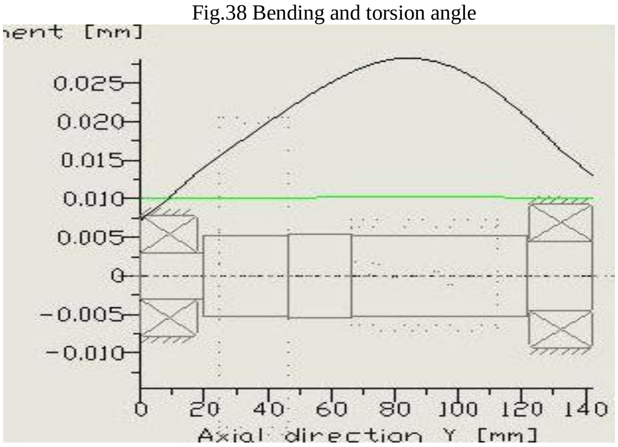

Fig.39 Displacement

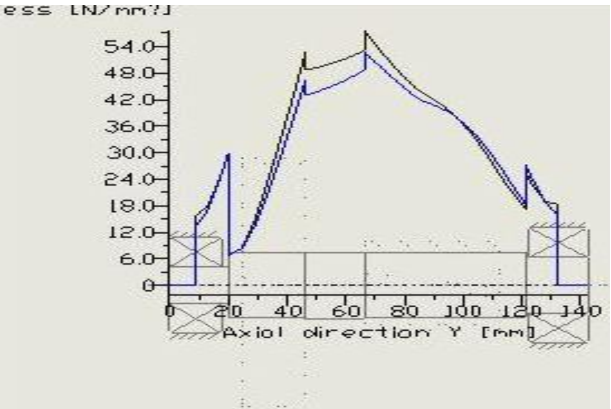

Fig.40 Equivalent stress

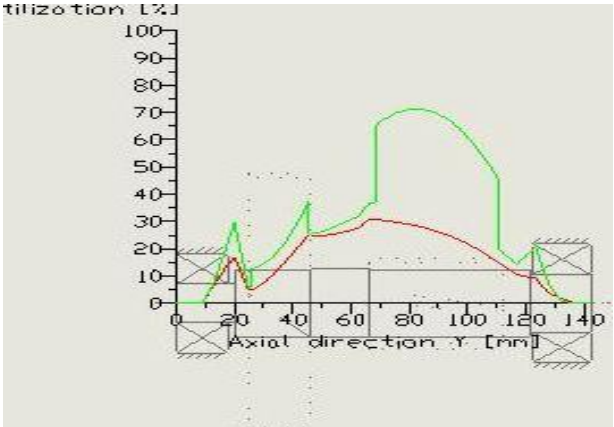

Fig.41 Strength

- FOR OUTPUT SHAFT

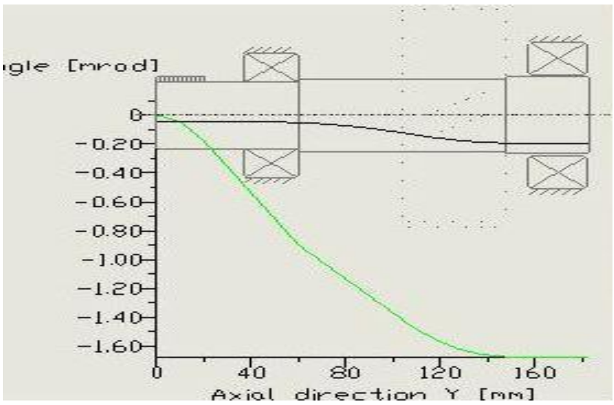

Fig.42 Bending and torsion angle

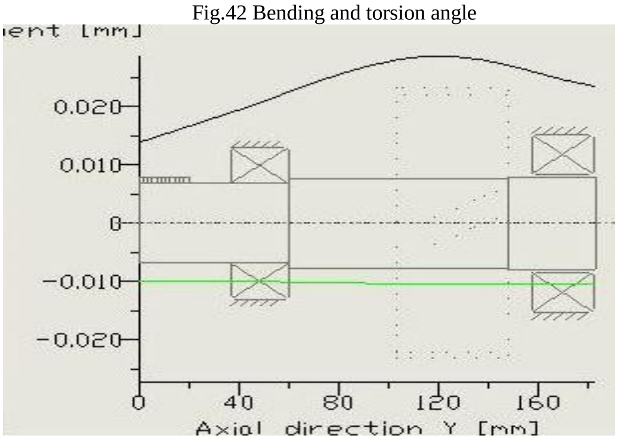

Fig.43 Displacement

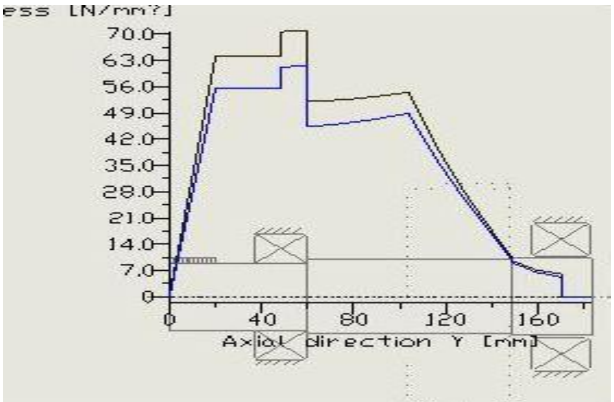

Fig.44 Equivalent stress

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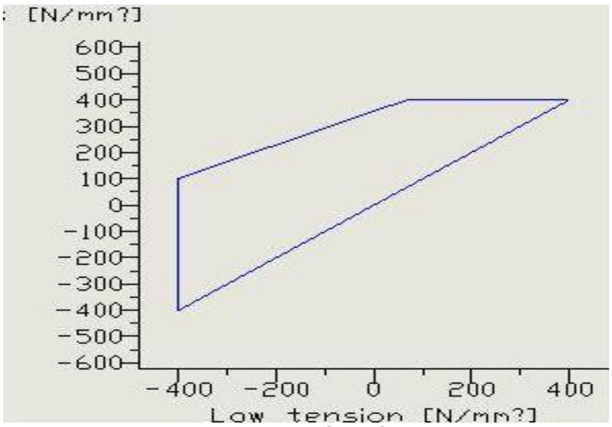

Fig.45 Goodman diagram

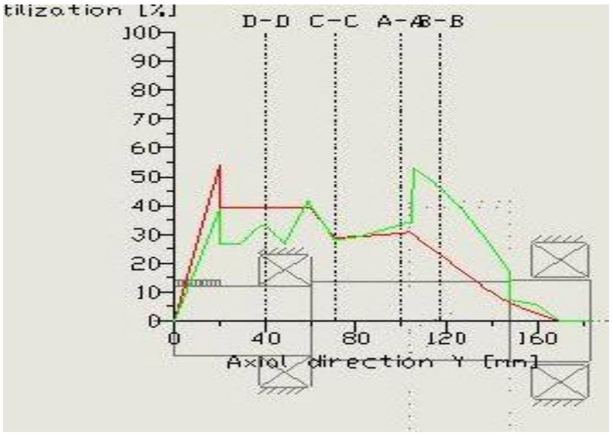

Fig.46 Strength

I. GEARBOX DESIGN

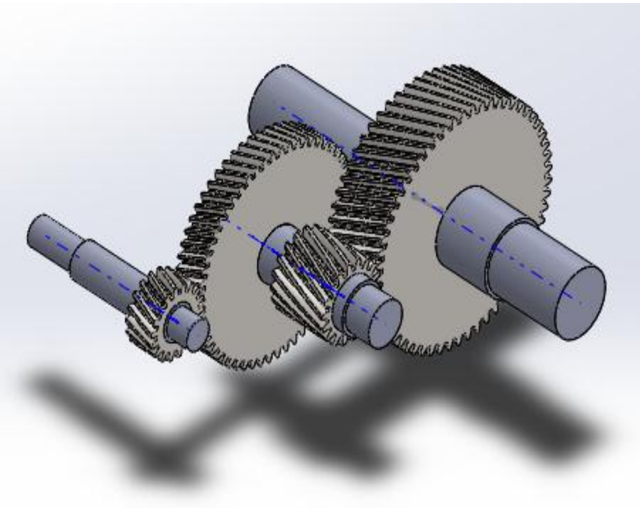

Fig.47 Without Casing

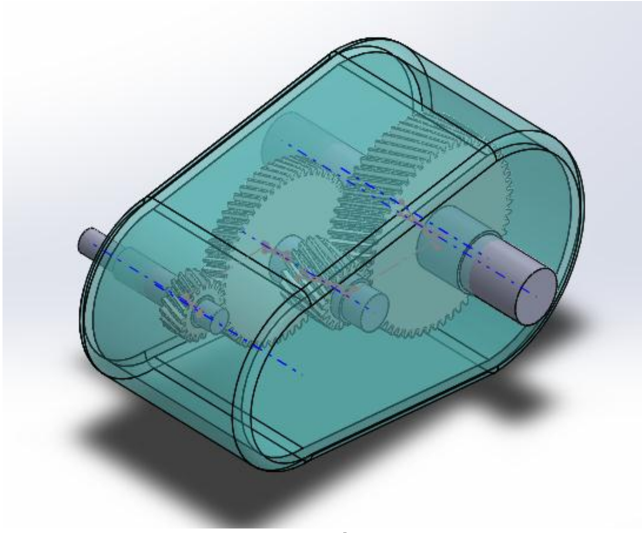

Fig.48 With Casing

J. GEAR PAIR ANALYSIS

TABLE.XXVI ANALYSIS PARAMETERS

PARAMETERS	VALUE
Equivalent stress	2.5924e-6
Maximum deformation	1.124e-10
Minimum factor of safety	4.5

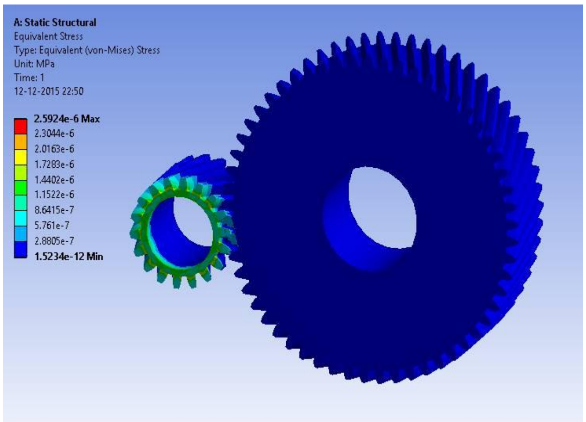

Fig.49 Equivalent stress

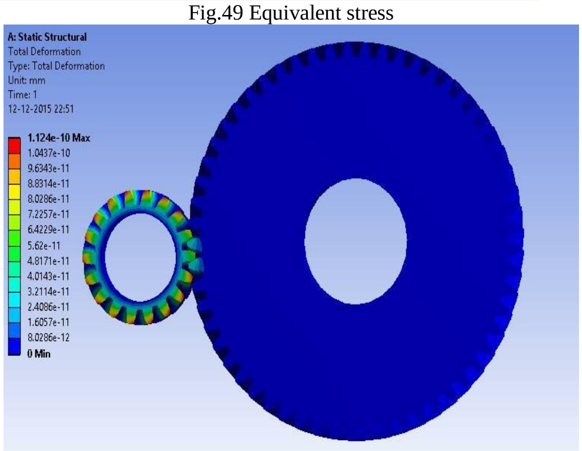

Fig.50 Total deformation

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K. TOOLS USED

SOLIDWORKS- It is used to create a complete 3D digital model of the component. The model consists of 2D and 3D solid model data which can also be used downstream in finite element analysis.

ANSYS- It is software which provides finite element analysis (FEA), in this methodology any component under consideration is discredited into small geometric shapes and the material properties are analyzed over these small elements.

KISSsoft- It is used for the design calculations involved in the designing of the various mechanical parts. KISSsoft have been incorporated with various calculation methods for the gear and shaft design separately.

II. CONCLUSION

This paper unveils the more sophisticated methodology of the gearbox designing using the modern designing software's. By defining the load spectrum in the program more realistic driving conditions have been entered as an input to the software. And as a result designer can achieve more accurate results of strength, equivalent stress, deformation, safety factors and other such parameters .

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