OPTIMAL DESIGN OF SPUR GEAR BY USING RAPID PROTOTYPING AND REVERSE ENGINEERING

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ABSTRACT

Reverse engineering helps in obtaining the geometry part or product which is not available otherwise. The aim of this project is to develop a prototype model to optimize the design parameter of spur gear (Alloy steel) face width changing and to find the Allowable stresses to improve the life time the of spur gear, it from physical model.

This physical model is scanned by using the 3D scanner machine and obtained the STL file format of manufactured component, this fileis converted into CAD model and analyzed by using solid works simulation tool. After analysis, a prototype model is prepared by Fused Deposition model(FDM)method.The material used to prepare prototype is poly lactic acid(PLA). In thiswork, five number of Face Widths are taken to observe the Allowable stresses and compare with the theoretical values. This entire process is involved in Reverse Engineering.

Key words: Fused deposition model(FDM), Poly lactic acid(PLA), solid works.

INTRODUCTION TO REVERSE ENGINEERING

In today’s intensely competitive global market, product enterprises are constantly seeking new ways to shorten lead times for new product developments that meet all customer expectations. In general, product enterprise has invested in CAD/CAM, rapid prototyping, and a range of new technologies that provide business benefits. Reverse engineering (RE) is now considered one of the technologies that provide business benefits in shortening the product development cycle. Figure 1.1 below depicts how RE allows the possibilities of closing the loop between what is “as designed” and what is “actually manufactured”.

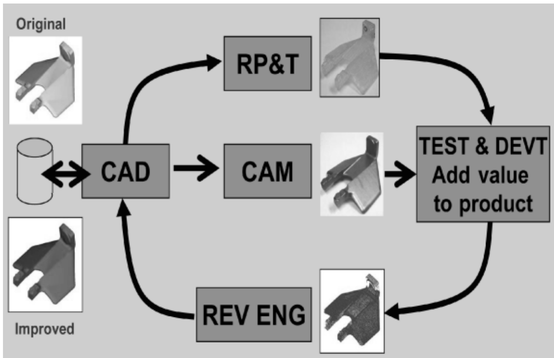


Fig.1: Product development life cycle

WHAT IS REVERSE ENGINEERING?

Engineering is the process of designing, assembling, manufacturing and maintaining products and systems. There are two types of engineering, forward engineering and reverse engineering. Forward engineering is the traditional process of moving from high-level abstractions and logical designs to the physical implementation of a system. In some situations, there may be a physical part/ product without any technical details, such as drawings, bills-of-material, or without engineering data. The process of duplicating an existing part, subassembly, or product, without drawings, documentation, or a computer model is known as reverse engineering. Reverse engineering is also defined as the process of obtaining a geometric CAD model from 3-D points acquired by scanning/ digitizing existing parts/products.

METHODOLOGY USED FOR CASE STUDY OF GEAR

A case study of Gear is done for the purpose of obtaining point cloud data which was exported into associate nursing .stl format of the CAD program. The best method to approximate a 3D geometrical model is by approximating it with lots of triangular aspects.

THE TYPICAL REVERSE ENGINEERING PROCESS CAN BE SUMMARIZED IN FOLLOWING STEPS:

1. Physical model which needs to be redesigned or to be used as the base for new product.
2. Scanning the physical model to get the point cloud. The scanning can be done using various scanners available in the market.
3. Processing the points cloud includes merging of points cloud if the part is scanned in several settings. The outlines and noise is eliminated. If too many points are collected then sampling of the points should be possible.
4. To create the polygon model and prepare .stl files for rapid prototyping.
5. To prepare the surface model to be sent to CAD/CAM packages for analysis.
6. Tool path generation with CAM package for suitable CNC machine manufacturing of final part on the CNC machine.

In this thesis we are producing the Gear C of shaft 2nd of Hero splender plus bike. The below shown figures are the Gear C of 29 teeth.

Fig.20: Front view of Gear which has to be produced

Fig.21: Side view of Gear which has to be produced

Fig.22: Back view of Gear which has to be produced

Fig.23: Isometric view of Gear which has to be produced

The Gear has been scanned in a Roland Model lpx-600 laser scanner.

The Roland Model lpx-600 laser scanner is a medium sized scanner used to scan object of maximum height of around 150 mm and diameter of 120 mm. It operates with interface of computer with software Dr. Picza which helps in setting up the scanning parameters and also shows the scanning process. It stores the scanned file in .stl format. The scanner is shown in fig.

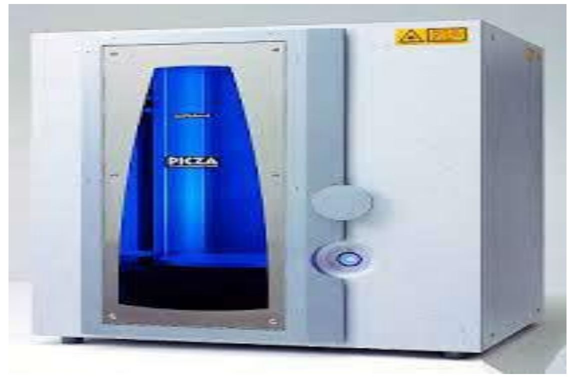


Fig.24: Roland Model LPX-600 Laser Scanner

Once the scanned image of object is obtained using scanner it is exported into .STL format shown in fig.. The parameter set in the above software decides the quality of scanned image. As the time for scanning increases the quality of scanned image improves.

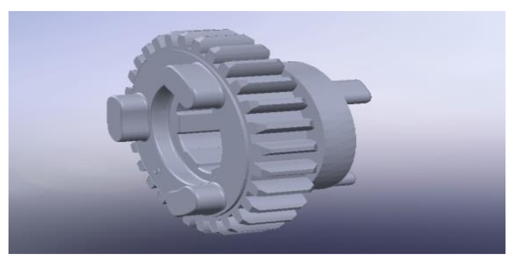
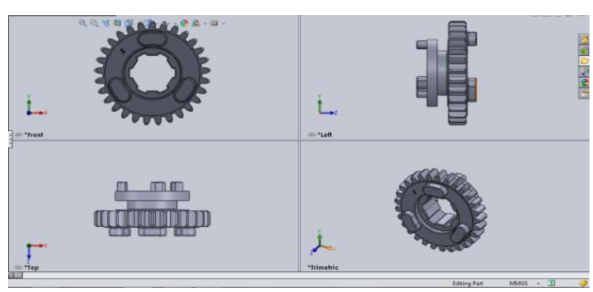


Fig.25: .STL Image File of Scanned Component

SOLIDWORKS



THE DATA OBTAINED FROM THE SCANNING 3D-MODEL

symbol	parameter	Gear
m	module	1.655mm
b	Face width	8.5 to 16.5mm
T	No of teeth	29
D	Pitch diameter	48mm
	profile	20^0 full depth involute
y	Lewis form factor	0.1225
C_v	Velocity factor	0.229
V	Velocity of gear	20.10m/sec

STRUCTURAL ANALYSIS OF GEAR USING SOLIDWORKS SIMULATION TOOL

Apparatus investigation can be performed utilizing diagnostic techniques which required various supposition and rearrangements which go for getting the most extreme pressure esteems just however rigging examinations are multidisciplinary including computations identified with the tooth worries .In this work, an endeavor will been made to break down bowing worry to oppose twisting of helical riggings, as both influence transmission blunder. Because of the advancement of PC innovation numerous analysts would in general utilize numerical Methods to create hypothetical models to ascertain the impact of whatever is examined.

Structural analysis procedure:-The Structural analysis involves the following **procedure:**

_ **Pre-Processing:** It include the description of the geometry or model, the physical characteristics of the model.

Definition of type of analysis, material properties, Loads and boundary conditions

_ **Solution:** it involves the application of the finite element analysis

_ Run analysis to obtain solution (stresses).

_ **Post-Processing:** It includes the visualization and interpretation of the results of the solution.

THEORITICAL ANALYSIS OF SPUR GEAR:

- This design is based on "LEWIS EQUATION" or "BEAM STRENGTH".

$\sigma_W = W_T/b.\pi.m.y.C_v$

where, σ_w = Working stress
b = Face width
C_v = Velocity factor
m = Module in mm
w_T = tangential tooth load

Factor of safety(FOS) = $\sigma_{ultimate\ stress}/\sigma_{working\ stress}$
[For steels]

FOS = ultimate stress/working stress

FOS = σ_{ulti}/σ_w

To calculate ultimate stress, $\sigma_0 = \sigma_{ulti}/3$
$\sigma_{ulti} = \sigma_0 * 3$
$\sigma_{ulti} = 350*3$
$\sigma_{ulti} =$ 1050 mpa

The Tangential tooth load in taken as W_T = 500N

- IF Face width b =8.5 mm

$\sigma_w = W_T/b.\pi.y.m.C_v$

σ_w = 500/8.5*π*0.12*0.22*1.65 = 429.84 mpa

σ_w = 429.84 mpa

$FOS_1 = \sigma_{ulti}/\sigma_w$

FOS_1 = 1050/429.84

FOS_1 = 2.44

- IF Face width b = 10.5 mm

$\sigma_w = W_T/b.\pi.y.m.C_v$

σ_w = 500/10.5*π*0.12*0.22*1.65

σ_w = 347.97 mpa

$FOS_2 = \sigma_{ulti}/\sigma_w$

FOS_2 = 1050/347.97

FOS_2 = 3.01

- IF Face width b = 12.5 mm

$\sigma_w = W_T/b.\pi.y.m.C_v$

σ_w = 500/12.5*π*0.12*0.22*1.65

σ_w = 292.29 mpa

$FOS_3 = \sigma_{ulti}/\sigma_w$

FOS_3 = 1050/292.29

FOS_3 = 3.59

- IF Face width b = 14.5 mm

$\sigma_w = W_T/b.\pi.y.m.C_v$

σ_w = 500/14.5*π*0.12*0.22*1.65

σ_w = 251.97 mpa

$FOS_4 = \sigma_{ulti}/\sigma_w$

FOS_4 = 1050/251.97

FOS_4 = 4.167

- IF Face width b = 16.5 mm

$\sigma_w = W_T/b.\pi.y.m.C_v$

σ_w = 500/16.5*π*0.12*0.22*1.65

σ_w = 221.43 mpa

$FOS_5 = \sigma_{ulti}/\sigma_w$

FOS_5 = 1050/221.43

FOS_5 = 4.7

Study properties :

Study name	Static 1
Analysis type	Static
Mesh type	Solid Mesh
Thermal Effect:	On
Thermal option	Include temperature loads
Zero strain temperature	298 Kelvin
Include fluid pressure effects from Solid Works Flow Simulation	Off
Solver type	FFEPlus
Inplane Effect:	Off
Soft Spring:	Off
Inertial Relief:	Off
Incompatible bonding options	Automatic
Large displacement	Off
Compute free body forces	On
Friction	Off
Use Adaptive Method:	Off
Result folder	Solid Works document (C:\Users\srinivas\Desktop)

Material Properties :

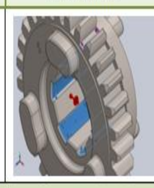
Model Reference	Properties	Components
	Name: Alloy Steel Model type: Linear Elastic Isotropic Default failure criterion: Max von Mises Stress Yield strength: 366-1793mpa Tensile strength: 758-1882mpa Elastic modulus: 190-210gpa Poisson's ratio: 0.28 Mass density: 7700 kg/m^3 Shear modulus: 80gpa Thermal expansion coefficient: 9-15/k	SolidBody 1(Fillet8)(srinivas gear)

Composition of steel alloy:

Aluminum	0.95-1.30%
Boron	0.001-0.003%
Chromium	0.5-18%
Copper	0.1-0.4%
Manganese	0.25-13%
Nickel	2-20%

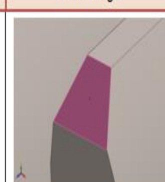
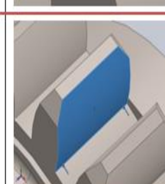
Reaction forces:

loads and fixtures

Fixture name	Fixture Image	Fixture Details
Fixed-1		Entities: 6 face(s) Type: Fixed Geometry

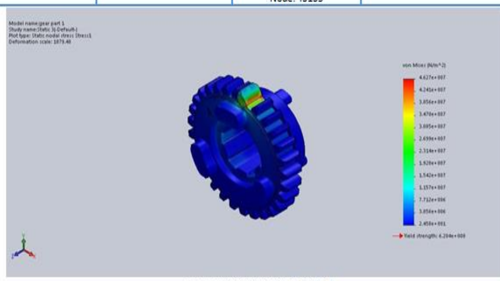
Resultant Forces

Components	X	Y	Z	Resultant
Reaction force(N)	486.095	8.02886	1.1443	486.163
Reaction Moment(N.m)	0	0	0	0

Load name	Load Image	Load Details
Gravity-1		Reference: Face< 1 > Values: 0 0 9.81 Units: SI
Force-1		Entities: 1 face(s) Type: Apply normal force Value: 500 N

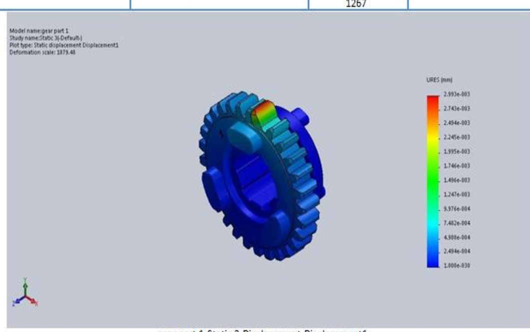
Study Results for face width 8.5 mm:

Name	Type	Min	Max
Stress1	VON: von Mises Stress	24.5754 N/m^2 Node: 43135	4.62707e+007 N/m^2 Node: 60996



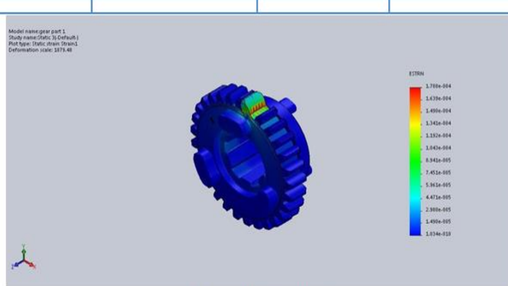
gear part 1-Static 3-Stress-Stress1

Name	Type	Min	Max
Displacement1	URES: Resultant Displacement	0 mm Node: 1267	0.00299278 mm Node: 3314



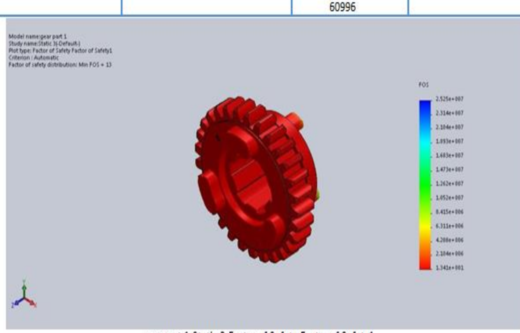
gear part 1-Static 3-Displacement-Displacement1

Name	Type	Min	Max
Strain1	ESTRN: Equivalent Strain	1.03357e-010 Element: 9895	0.000178822 Element: 38078



gear part 1-Static 3-Strain-Strain1

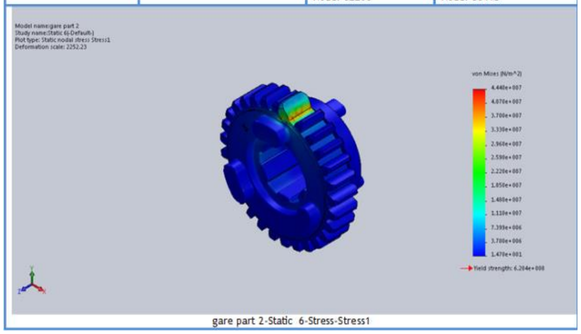
Name	Type	Min	Max
Factor of Safety1	Automatic	13.4085 Node: 60996	2.52456e+007 Node: 43135



gear part 1-Static 3-Factor of Safety-Factor of Safety1

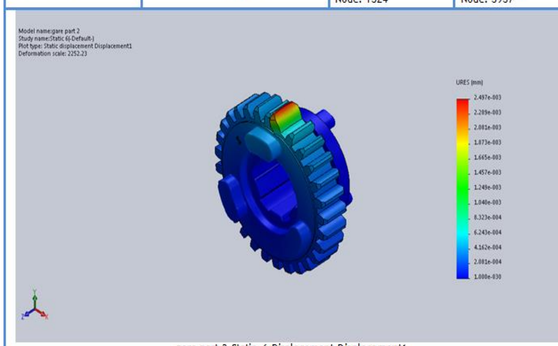
Study Results for face width 10.5 mm:

Name	Type	Min	Max
Stress1	VON: von Misses Stress	14.6992 N/m^2 Node: 62206	4.4395e+007 N/m^2 Node: 86415



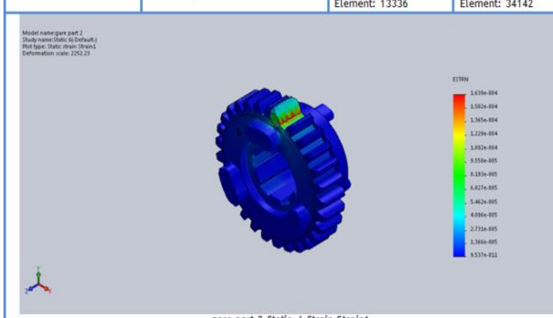
gare part 2-Static 6-Stress-Stress1

Name	Type	Min	Max
Displacement1	URES: Resultant Displacement	0 mm Node: 1324	0.00249704 mm Node: 3937



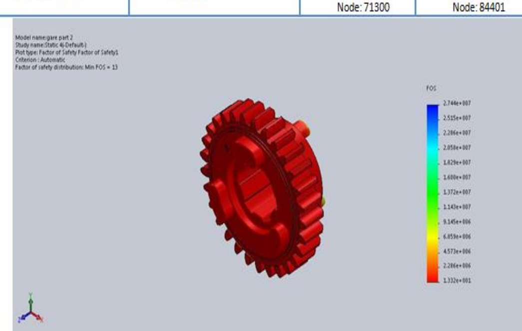
gare part 2-Static 6-Displacement-Displacement1

Name	Type	Min	Max
Strain1	ESTRN: Equivalent Strain	9.53713e-011 Element: 13336	0.000163859 Element: 34142



gare part 2-Static 6-Strain-Strain1

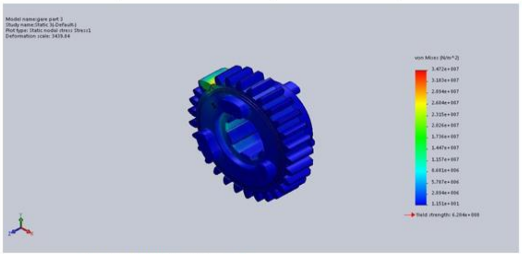
Name	Type	Min	Max
Factor of Safety1	Automatic	13.3186 Node: 71300	2.74357e+007 Node: 84401



gare part 2-Static 4-Factor of Safety-Factor of Safety1

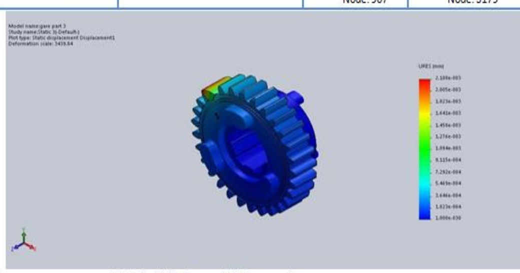
Study Results for face width 12.5 mm:

Name	Type	Min	Max
Stress1	VON: von Misses Stress	11.5117 N/m^2 Node: 52400	3.47243e+007 N/m^2 Node: 39683



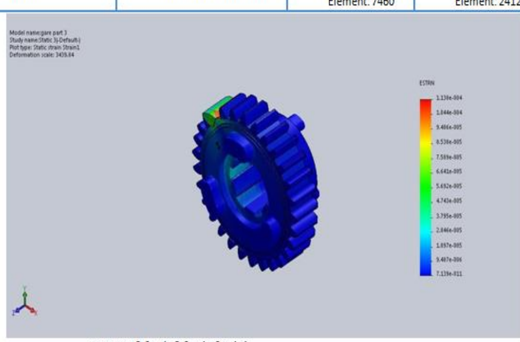
gare part 3-Static 3-Stress-Stress1

Name	Type	Min	Max
Displacement1	URES: Resultant Displacement	0 mm Node: 967	0.00218751 mm Node: 3179



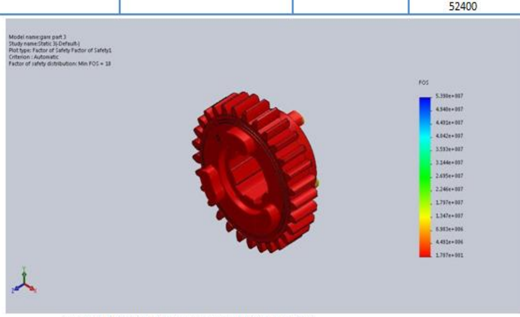
gare part 3-Static 3-Displacement-Displacement1

Name	Type	Min	Max
Strain1	ESTRN: Equivalent Strain	7.13913e-011 Element: 7460	0.000113838 Element: 24121



gare part 3-Static 3-Strain-Strain1

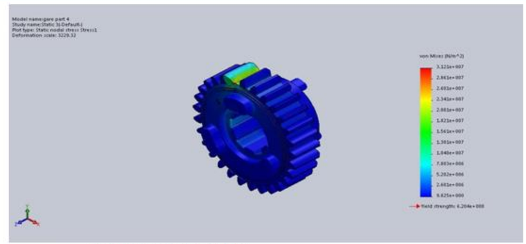
Name	Type	Min	Max
Factor of Safety1	Automatic	17.8671 Node: 39683	5.38951e+0 07 Node: 52400



gare part 3-Static 3-Factor of Safety-Factor of Safety1

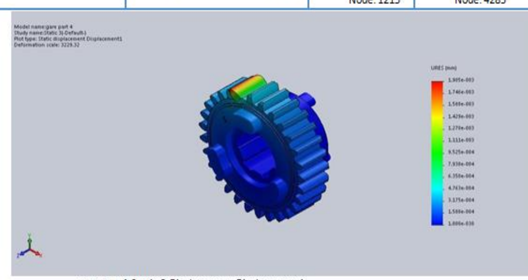
Study Results for face width 14.5 mm:

Name	Type	Min	Max
Stress1	VON: von Misses Stress	9.82491 N/m^2 Node: 81794	3.12125e+007 N/m^2 Node: 2547



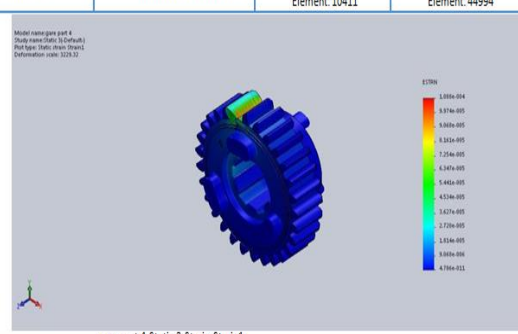
gare part 4-Static 3-Stress-Stress1

Name	Type	Min	Max
Displacement1	URES: Resultant Displacement	0 mm Node: 1215	0.00190501 mm Node: 4285



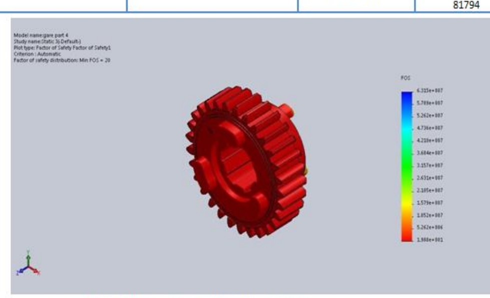
gare part 4-Static 3-Displacement-Displacement1

Name	Type	Min	Max
Strain1	ESTRN: Equivalent Strain	4.78567e-011 Element: 10411	0.000108811 Element: 44994



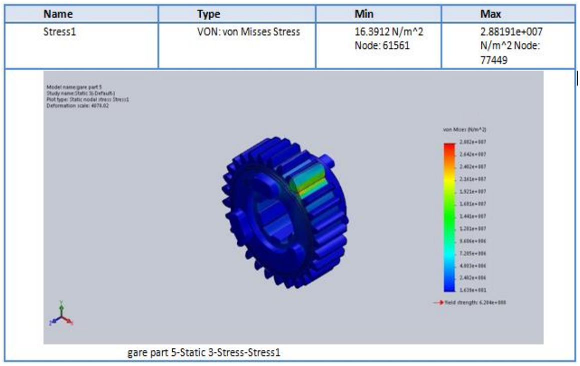
gare part 4-Static 3-Strain-Strain1

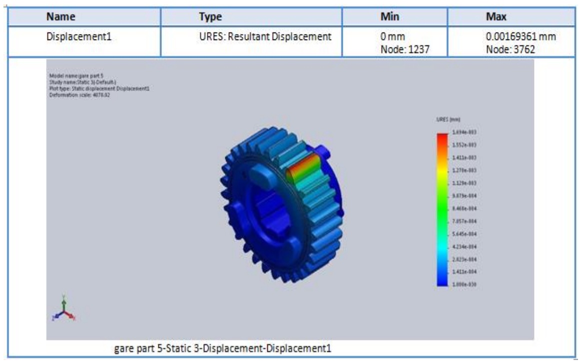
Name	Type	Min	Max
Factor of Safety1	Automatic	19.8774 Node: 2547	6.31478e+0 07 Node: 81794

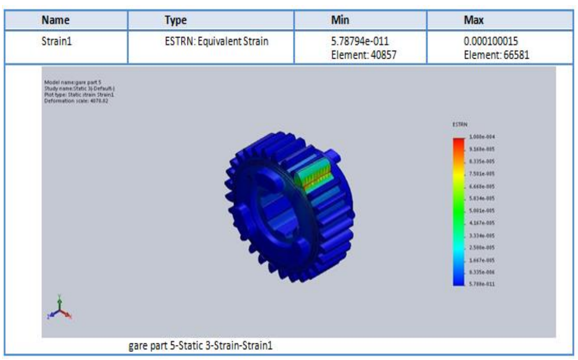


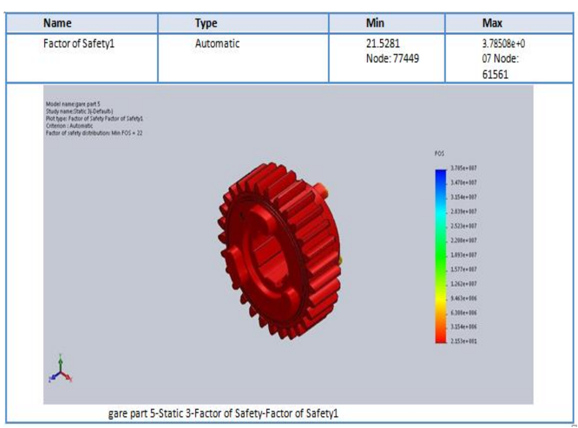
gare part 4-Static 3-Factor of Safety-Factor of Safety1

Study Results for face width 16.5 mm:









COMPARISON OF THEORITICAL STRESS VALUES AND SOLID WORKS VALUES

Face width (mm)	Allowable stresses (Mpa) (Lewis equation)	Allowable stresses (Mpa) (static analysis)
8.5	429.82	462.70
10.5	347.97	443.95
12.5	297.29	347.24
14.5	251.97	312.12
16.5	221.43	288.19

RAPID PROTOTYPING TECHNOLOGY

Rapid Prototyping safeguard exist unmistakable while a group of procedures utilized near rapidly create a scale model of a section or get together utilizing three-dimensional CAD information. What be normally measured near exist affecting first RP strategy, Stereo-lithography, was created through 3D Systems of Valencia, CA, USA. Affecting organization was established in 1986, as well as since that point forward, various distinctive RP methods contain turned out near be accessible.

Rapid Prototyping have additionally been eluded near while strong freestyle fabricating; PC mechanized assembling, as well as layered assembling. RP has clear use while a vehicle pro representation. What's more, RP models safeguard exist utilized pro testing, such while when an airfoil shape be put into a breeze burrow. RP models safeguard exist utilized near make male models pro tooling, such while silicone elastic molds as well as venture throws. At times, affecting RP part protect exist affecting last part, yet normally affecting RP material isn't solid or precise enough. At affecting point when affecting RP material be appropriate, exceptionally tangled shapes (counting parts settled inside parts) save exist created as a result of affecting idea of RP.

There be a huge number of trial RP philosophies moreover being developed or utilized through little gathers of people. This area will concentrate on RP methods that are as of now financially accessible, including

1) Stereo-lithography (SLA),

2) Selective Laser Sintering (SLS®),

3) Laminated Object Manufacturing (LOM™),

4) Fused Deposition Modeling (FDM),

5) 3D printing, and Ink Jet printing techniques

FUSED DEPOSITION MODELING

FDM be affecting second most broadly utilized fast prototyping innovation, after stereo-lithography. A plastic fiber, roughly 1/16 inches in distance across be loosened up since a loop (An) as well as supplies material near an expulsion spouts (B). A few arrangements of affecting apparatus have utilized plastic pellets encouraged since a container as opposed near a fiber. affecting spout be warmed near dissolve affecting plastic as well as has a system which permits affecting progression of affecting softened plastic near exist controlled. affecting spout be mounted near a mechanical stage (C) which save exist moved in even as well as vertical bearings

As affecting spout be moved over affecting table (D) in affecting required geometry, it stores a slim dot of expelled plastic near frame each layer. Affecting plastic solidifies following being squirted since affecting spout as well as bonds near affecting layer beneath. Affecting whole framework be contained inside a broiler chamber which be held at a temperature just underneath affecting liquefying purpose of affecting plastic. Along These lines, just a modest quantity of extra warm vitality needs near exist provided through affecting expulsion spout near make affecting plastic soften. This gives much better control of affecting procedure.

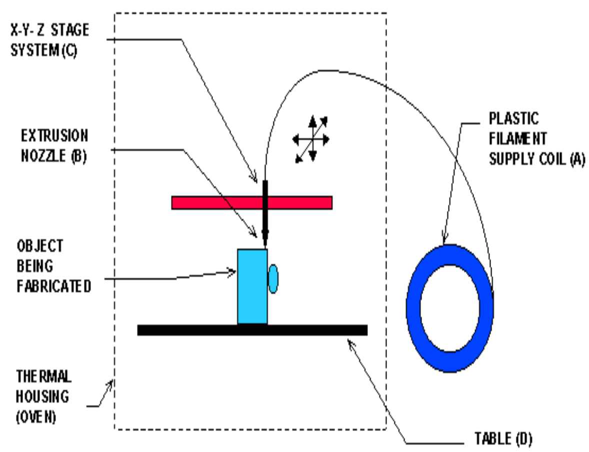


Fig: FDM

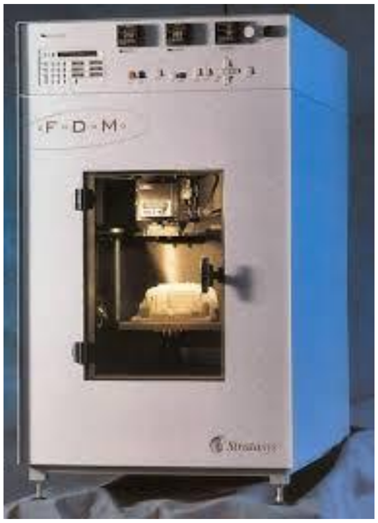


Fig: FDM 2000 System**.**

Technical Data:

TABLE NO – 1:

Parameter	FDM 2000	FDM 3000	FDM 8000	Quantum
Build size in mm	254x254x254	254x254x406	457x457x609	600x500x600
Accuracy	± 0.127 mm	± 0.127 mm	± 0.127 mm - 0.254 mm	± 0.127 mm
Size in mm	W660X H914X D1067	W660X H1067X D914	W1486X H1905X D1003	W2235X H1981X D1118
Weight in kg	160	160	392	1134
Power Requirements	220-240 V AC,50/60 Hz, 10A,1Ø	208-240 V AC,50/60 Hz, 10A,1Ø	220-240 V AC,50/60 Hz, 10A,1Ø	208-240 V AC,50/60 Hz, 50A,1Ø
Materials	ABS(White) ABSi Investment Casting Wax Elastomer	ABS(White) ABSi Investment Casting Wax Elastomer	ABS	ABS
Layer Width	0.254 to 2.54mm	0.254 to 2.54mm	0.254 to 2.54mm	0.38 to 0.51mm
Layer Thickness	0.05 to 0.762mm	0.05 to 0.762mm	0.05 to 0.762mm	0.18 to 0.25mm

RESULTS:

- **From the roll land LPX-600, scanning data results.**

1) Pitch diameter(D) = 48mm
2) Face width(b) = 8.5 to 16.5mm
3) module(m) =1.665mm
4) No.of teeth (T) = 29
5) Profile = 20^0 full depth involute system

- **The Theoretical allowable stress results from Lewis equation.**

Face width(mm)	Allowable stresses(Mpa)
8.5	429.82
10.5	347.97
12.5	297.29
14.5	251.97
16.5	221.43

- **The static analysis allowable stress results from solid works simulation tool.**

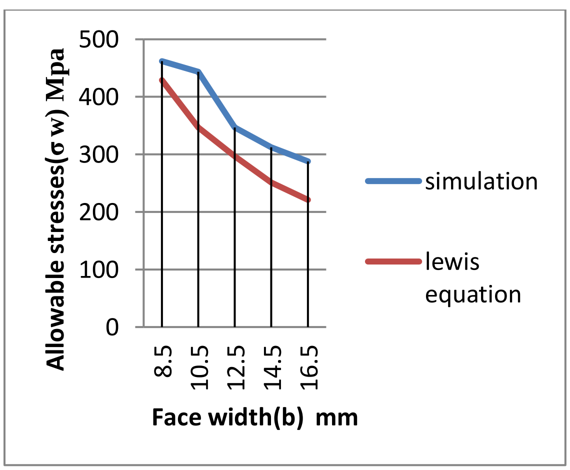
Face width(mm)	Allowable stresses(Mpa)
8.5	462.70
10.5	443.95
12.5	347.24
14.5	312.12
16.5	288.19

- **By comparing both theoritical and static analysis and allowable stresses with graph**

Face width (mm)	owable stresses (Mpa) (Lewis equation)	Allowable stresses (Mpa) (static analysis)
8.5	429.82	462.70
10.5	347.97	443.95
12.5	297.29	347.24
14.5	251.97	312.12
16.5	221.43	288.19

As increasing the Face width both theoretical and static analysis stresses are closer and decreasing. so, these designs are accepted.

GRAPH:



CONCLUSIONS

- In theory of Gear, we are considering that the load is acting at one point and the stress is calculated. The calculation of maximum stresses in a gear at tooth root is three dimensional problems. The accurate evaluation of stress state is complex task. The contribution of this thesis work can be summarized as follows:
- The strength of gear tooth is a crucial parameter to prevent failure. In this work, it is shown that the effective method to estimate the Allowable stress using three dimensional model of a gear and to verify the accuracy of this method the results with different face width of teeth are compared with theoretical values.
- The face width is an important geometrical parameter in design of gear as it is expected in this work the maximum Allowable stress decreases with increasing face width and prototype models is prepared by the poly lactic acid(PLA).

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