Speed Reduction Gearbox

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SPEED REDUCTION GEARBOX

Content

SPEED REDUCTION

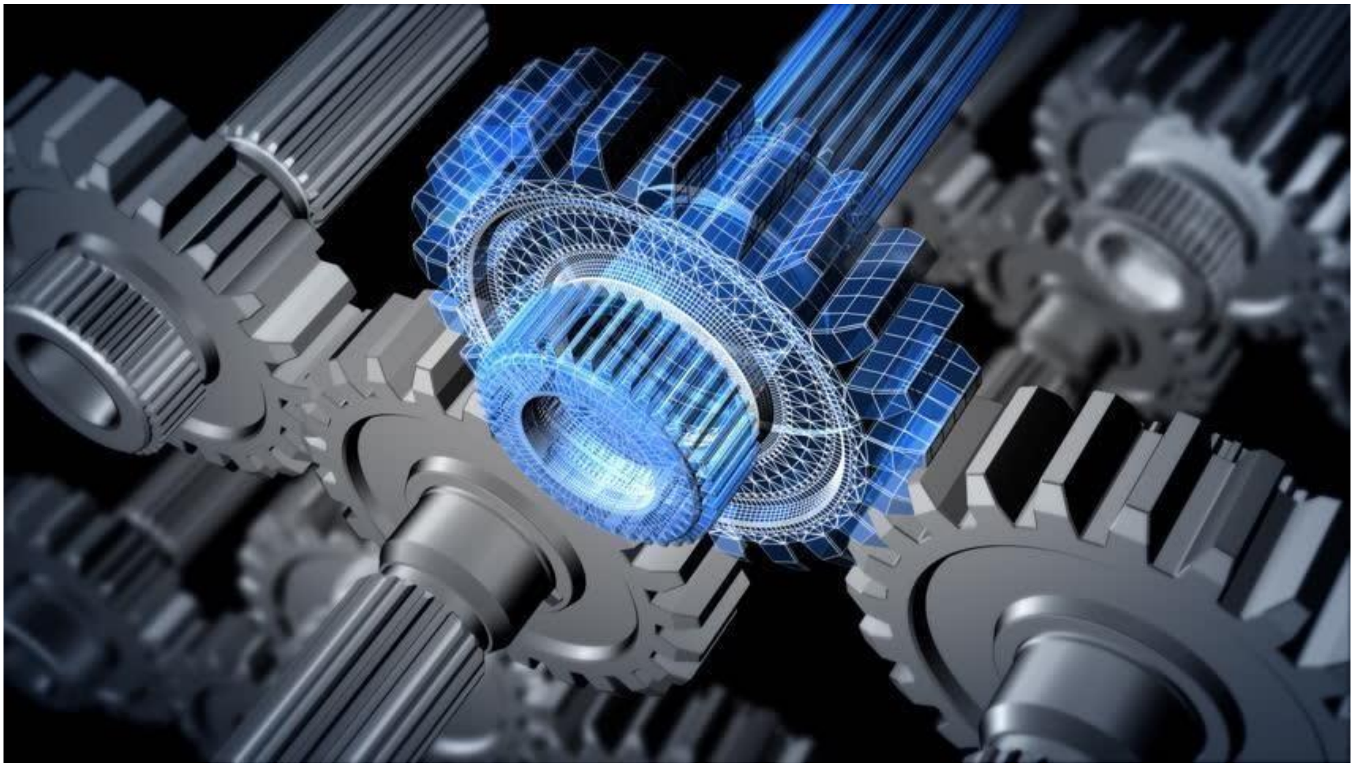
Abstract

The aim of this project is to set out the basic design for an industrial gearbox with its calculation to avoid any fatigue in the gears and to let the gearbox to achieve its desired work properly.

In this project we are going to design the gearbox using the cad software Solidworks, we are planning first to make calculations then draw gears using Solidworks, and after that making some analysis to the gears. Finally, we are going to assembly the parts and simulate the gearbox to be able to work properly.

Introduction

Gear reduction boxes are used in many factories and industries, their goal is to reduce speed and increase torque. You will find gear boxes in many machines around us such as (i.e.: electric motor, diesel or steam, cars and engines, etc.) and the driven equipment: conveyors, mills, paper machines, elevators, screws, agitators, etc.).



An industrial gearbox is defined as a machine for most drives requiring a reliable life and factor of safety, which used for specific duties demands high power and torque, or for applications where speed is more required such as automobile and aerospace applications. And Gear Reducers are a system of gears used in different ways of power and motion transmission.

Reducers are a system of gears used in different power and motion transmission applications. Gears Reducers are generally classified according to the type of teeth they have such as:

1. Spur gear reducers
2. Helical gear reducers
3. Worm gear reducers
4. Bevel gear reducers
5. Planetary gear reducers
6. Parallel gear reducers

Some reduction gearboxes are as simple as a gear train between the motor and the machinery, but regardless of complexity the decrease is possible because the output gear has more teeth than the input gear allowing the output gear to rotate more slowly, reducing the speed, and increasing torque. The speed of the input can be controlled with a speed reducer so that the output is the correct speed and torque.

Finding the right speed reducer for your application is essential to ensure performance. We offer a free checklist, the Speed Reducer Buying Checklist, that will guide you through the process of matching your application requirements with the information needed to allow your supplier to turn it into real it

Calculations

Selected engine is Mazda Renesas rotary (Wankel engine
) Input Power: P input 177 kW or 238hp
Input shaft speed: ng = up to 4500 rev / min (we choose 2100 rpm
) for example

Output shaft speed: (700rpm,950rpm,1750rpm) it is varying depends on the desired speed, but we are going to design different gear ratio for different speeds

Number of stages: 1 for each speed

Gear type: Spur gear wheel

Gear type Selected information:

Gear material: 16MnCr5 (Cementation Steel

) Efficiency of spur gears: $\eta 12 = 0.97$

Efficiency of rolling bearings: $\eta y = 0,97$ Since

this is informed.

Total yield: total = $\eta 12.\ y = (0.97).\ (0.97) = 0.941$

Calculation of gear numbers:

Because we want to design a gearbox for a vehicle for a different speed, we are going to design up to 7 gears, where each two mesh gears are going to produce the desired-out speed depends on its calculated gear ratio. But we can suppose different speeds to design different gear ratios gear ratio I Sum: It is calculated by dividing the input shaft revolution by the output shaft revolution.

It was calculated as Isum = nin / nout = 2100/700 = 3

Isum = nin / nout = 2100 /950 = 2.

22 Isum = nin / nout = 2100/1750 =

1.2

Since it is a single stage reducer, Isum = (3, 2.22, 1.2

) For gears the tooth count is 10-40 turning.

For the first output speed which is 700

rpm z1 = 12 tooth is selected

z2 = 36 tooth is selected (z2=z1*Isum)

For the first output speed which is 950

rpm z3 = 18tooth is selected

z4 = 40 tooth is selected (z4=z3*Isum)

For the first output speed which is 1750 rpm

z5 = 25 tooth is selected

z6 = 30 tooth is selected(z6=z5*Isum)

Power calculation

The input power, P, not as = 177kW = 177000 W.

P Output, which is the output power; It is found by the collision of the input power and the total efficiency (total).

Pout = Pinput* total efficiency = 177000* 0.941 = 166557W.

Total reducer power loss is found as PInput - POut = 177000-166557W= 10443 W.

Calculation of rotation moment

To calculate the turning moments, we first need to find the rotation of the shafts.

For first desired speed 700 rpm

nin = n1 =2100 rpm

nout = n2 = 700 rpm (n2 = n1 / İ12)

The input moment Md1; It is found by dividing the input power by its speed. In input power kW, rotation speed / minute, formulas are as follows.

For the first desired output speed 700 rpm:

Md1 = 9550*P input / n1 = 9550* 1/2100 = 4.548Nm = 4548Nmm.

Md2 = 9550* P input* ηtotal / n2 = 9550*1*0.941 / 700 = 12.838 Nm = 12838 Nmm

For second desired speed 950 rpm

Nin = n1 =2100 rpm

Nout = n2 = 900 rpm (n2 = n1 / İ12)

Md1 = 9550*P input / n1 = 9550* 1/2100 = 4.548Nm = 4548Nmm.

Md2 = 9550* P input* ηtotal / n2 = 9550*1*0.941 / 950 = 9.4595 Nm = 94595.2 Nmm

For third desired speed 1750 rpm

Md1 = 9550*P input / n1 = 9550* 1/2100 = 4.548Nm = 4548Nmm.

Md2 = 9550* P input* ηtotal / n2 = 9550*1*0.941 / 1750 = 5.1352 Nm = 5135.2 Nm

In the dimensioning of shafts and gears, these moments are multiplied by the S coefficient to find the maximum possible moments.

Safety impact factor S = 1.25 was chosen.

Calculation of the module

When we know the m and z values of a gear wheel, all other dimensions are calculated. Selections should be made in certain value ranges to find m (module).

1. Number of widths

The width number should be chosen according to the module (m), diameter (d). In this calculation, the selection was made according to the module. For precision machined gears bearing on both sides, Ψm = 18 -20.

Ψm = 20 was chosen.

2. Form factor (Kf)

According to DIN 867, if z = 15 for a = 20 °, the Kf value is found by looking at the table.
Kf = 3.23 was found.

3.Grip ratio (ε)

The grip ratio should be chosen between 1.1 - 1.4. If the system is to work more safely, it should be chosen small.
ε = 1,2 was chosen

16MnCr5 was chosen as gear material. The values of this material are:
σk = 880 N / mm² (tensile strength)
HB = 1800 N / mm² (Brinel hardness value)
E = 2.1. 10^5 N / mm² (Elasticity coefficient)
σd = 484 N / mm² (Fully variable strength value)
Kç = 1.6 (Notch factor at the root of the tooth)
σem = σd / Kç = 302,5 N / mm²
ρem = (0.2 - 0.4). Hb = 0.35. 1800 = 630 N / mm²
Thus, all the values required to calculate the modules according to tooth root strength and tooth surface crush were obtained.

For first speed 700 rpm
Module according to tooth root strength
m = 3√((2*𝑆*Md1*Kf) /(**z1*****Ψm***Ɛ***σem**)) =
3√((2*1.25*4548 *3.23)/(12* 20*1.2*302.5))= 0.7498mm

Module according to tooth surface crush

m = 3√(2*𝑆*Md1*E*(İ**12**+1/İ**12**)) /(**z1**² ***Ψm***Ɛ*ρem²) =
3√(2*1,25*4548*2,1*10^5(3+1/3))/(122*20*1,2*630²) = 1.797mm

for second speed 950rpm
Module according to tooth root strength
m = 3√((2*𝑆*Md1*Kf) /(**z**3***Ψm***Ɛ***σem**)) =
3√((2*1.25*4548*3.23)/(18* 20*1.2*302.5))= 0.655

Module according to tooth surface crush

m = 3√(2*𝑆*Md1*E*(İ**12**+1/İ**12**)) /(**z**3² ***Ψm***Ɛ*ρem²) =
3√(2*1,25*4548*2,1*10^5(2.22+1/2.22))/(182*20*1,2*630²) = 1.273

for third speed 1750rpm

Module according to tooth root strength

m = 3√((2*S*Md1*Kf) /(**z**5***Ψm***ε***σem**)) =

3√((2*1.25*4548*3.23)/(25* 20*1.2*302.5))= 0.587

Module according to tooth surface crush

m = 3√(2*S*Md1*E*(İ**12**+1/İ**12**)) /(**z**5² ***Ψm***ε*ρem²) =

3√(2*1,25*4548*2,1*10^5(1.0344+1/1.0344))/(252*20*1,2*630²) = 0.9293

For more suitable design option we choose module 11 for all gears.

Control for root fracture due to bending

for first speed 700 rpm

The environmental force is found by the relation

Fout = 2.S.Md1 / d1. Here d1 is the diameter of the rolling circle and is found by the relation d1 = m*z1.

Fout = 2* 1.25* 4548 / (11*12) = 86.14 N

It should be σemax = Kf * Fout /(m*ε*b) ≤ σem.

Kf = 3.23 b = Ψm *m = 20* 11 = 220.

Σemax = 3.23 * 86.14/(11*1.2*220) = 0.0958 N/mm2

Since σemax = 0.0958 = 0.0958 ≤ 302.5 N / mm², **it IS SAFE**

for second speed 950 rpm

The environmental force is found by the relation

Fout = 2.S.Md1 / d1. Here d1 is the diameter of the rolling circle and is found by the relation d1 = m*z1.

Fout = 2* 1.25* 4548 / (11*18) = 57.42 N

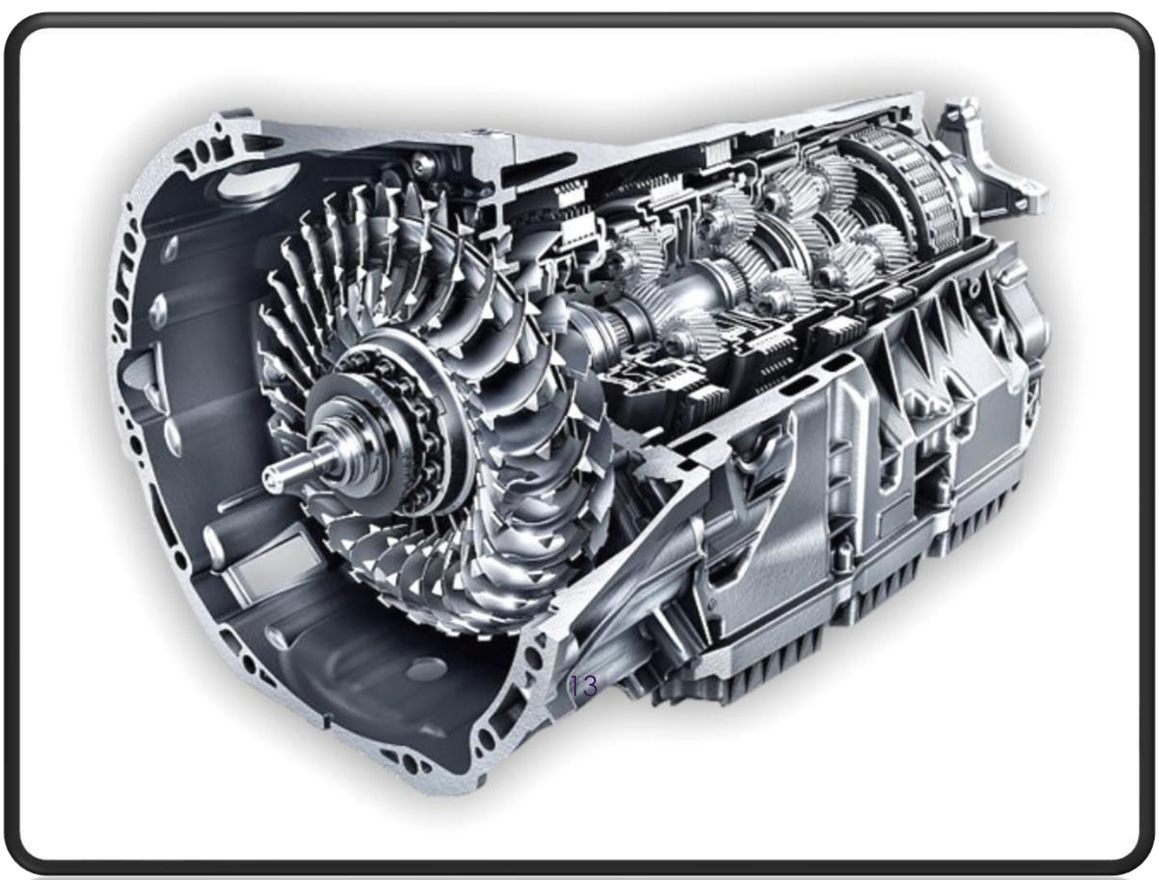
It should be σemax = Kf * Fout /(m*ε*b) ≤ σem.
Kf = 3.23 b = Ψm *m = 20* 11 = 220.
Σemax = 3.23 * 57.42 /(11*1.2*220) = 0.0639 N/mm2
Since σemax = 0.0639 = 0.0639 ≤ 302.5 N / mm^2, **it IS SAFE**

for third speed 1750 rpm
The environmental force is found by the relation
Fout = 2.S.Md1 / d1. Here d1 is the diameter of the rolling circle and is found by the relation d1 = m*z1.
Fout = 2* 1.25* 4548 / (11*25) = 41.34 N

It should be σemax = Kf * Fout /(m*ε*b) ≤ σem.
Kf = 3.23 b = Ψm *m = 20* 11 = 220.
Σemax = 3.23 * 41.34 /(11*1.2*220) = 0.046 N/mm2
Since σemax = 0.046 = 0.046 ≤ 302.5 N / mm^2, **it IS SAFE**

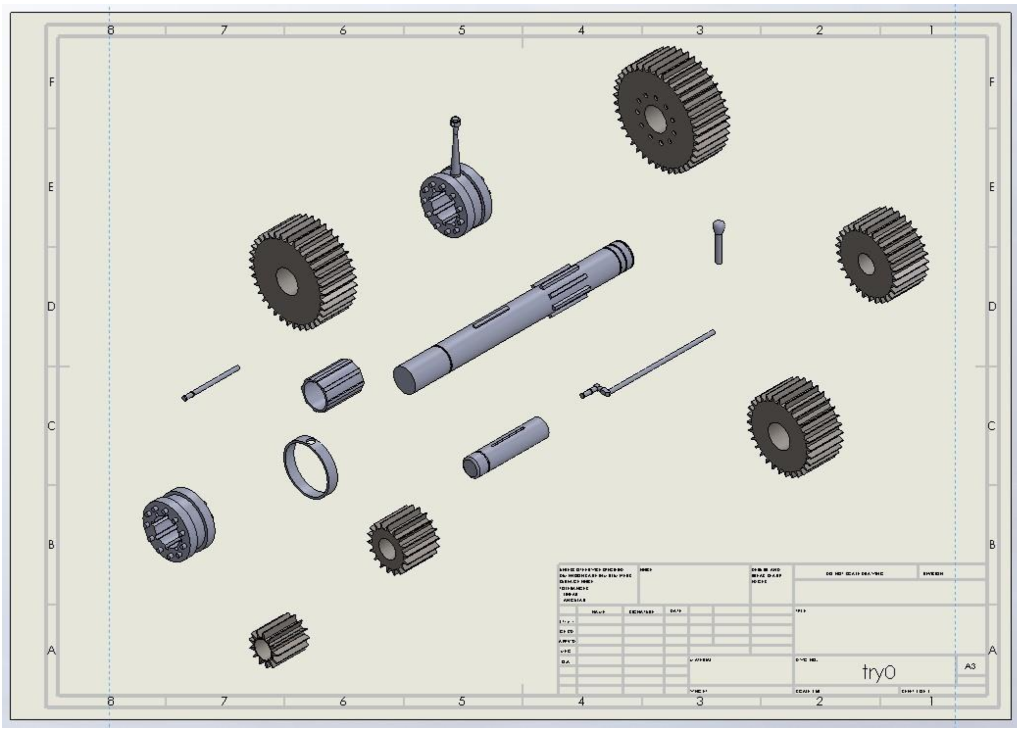
Control for surface crush:

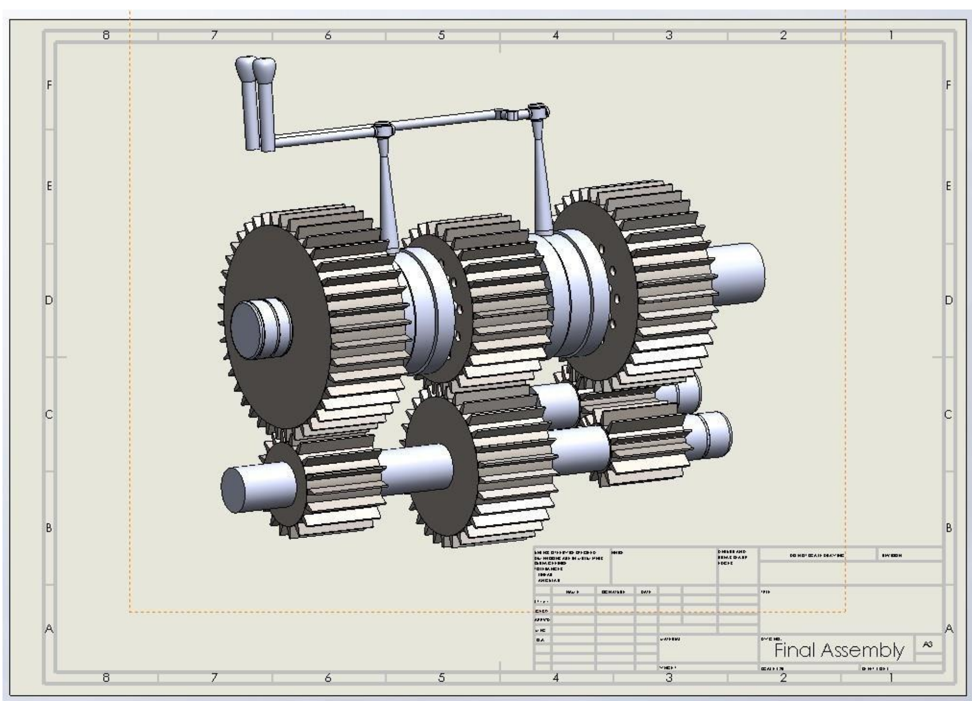
Hertz relation is used to control for surface crush.
ρmax = Km* Ka* Kε*√Fout*(i_{12} + 1/i_{12})l(b*d1) ≤ ρem.
Here, the material coefficient is found from the relation
Km = √35.
The rolling point coefficient is found from the relation
Ka = √1/(sina.cosa. a) and a =20 ° is chosen.
The thread length coefficient is found from Kε = 1/√ε. Where ε= 1,2 has been chosen.
As a result of these equations;
Km = 270
Ka = 1.76
Ka = 1,76
Kε = 0,91 alınır.
ρmax = 270 *1,76 * 0,91 *√86.14* ((3+1)/3)/220*132= 27.195 ≤ 630 N/mm² This value is for safety



Technical Drawing

We are going to show you some of our Solidworks drawing parts

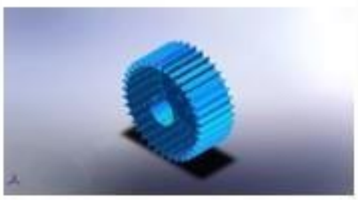




14

Analysis by Solidworks

Material Properties

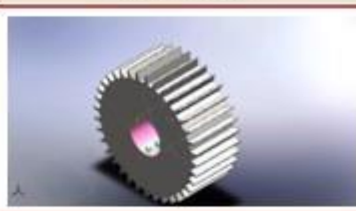
Model Reference	Properties	Components
	Name: 1.7131 (16MnCr5) Model type: Linear Elastic Isotropic Default failure criterion: Max von Mises Stress Yield strength: 5.90594e+008 N/m^2 Tensile strength: 8e+008 N/m^2 Elastic modulus: 2.1e+011 N/m^2 Poisson's ratio: 0.28 Mass density: 7800 kg/m^3 Shear modulus: 7.9e+010 N/m^2 Thermal expansion coefficient: 1.1e-005 /Kelvin	SolidBody 1(Cut-Extrude3)(Gear 6)
Curve Data:N/A		

Loads and Fixtures

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

Resultant Forces

Components	X	Y	Z	Resultant
Reaction force(N)	-0.943675	-1.08597	0.016778	1.4388
Reaction Moment(N.m)	0	0	0	0

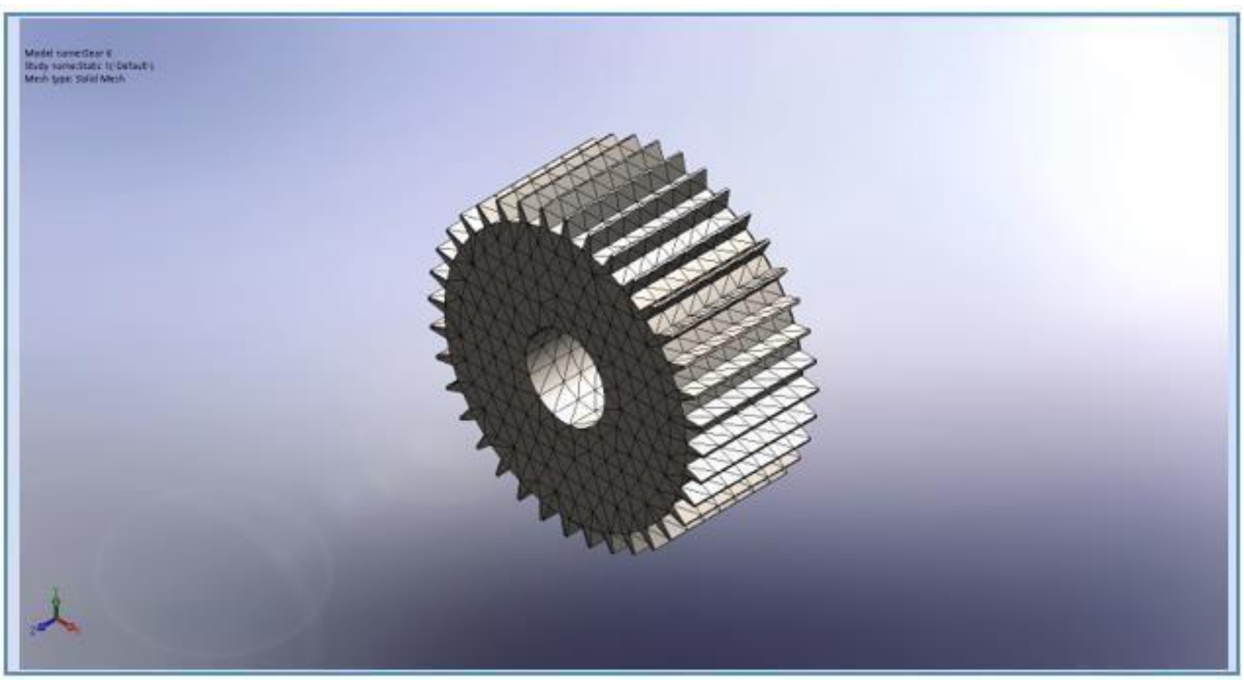
Load name	Load Image	Load Details
Torque-1		Entities: 1 face(s) Reference: Face< 1 > Type: Apply torque Value: 2000 N.m

Mesh information

Mesh type	Solid Mesh
Mesher Used:	Standard mesh
Automatic Transition:	Off
Include Mesh Auto Loops:	Off
Jacobian points	4 Points
Element Size	28.3855 mm
Tolerance	1.41928 mm
Mesh Quality Plot	High

Mesh information - Details

Total Nodes	24586
Total Elements	15612
Maximum Aspect Ratio	14.653
% of elements with Aspect Ratio < 3	82.9
% of elements with Aspect Ratio > 10	0.711
% of distorted elements(Jacobian)	0
Time to complete mesh(hh;mm;ss):	00:00:03
Computer name:	



Resultant Forces

Reaction forces

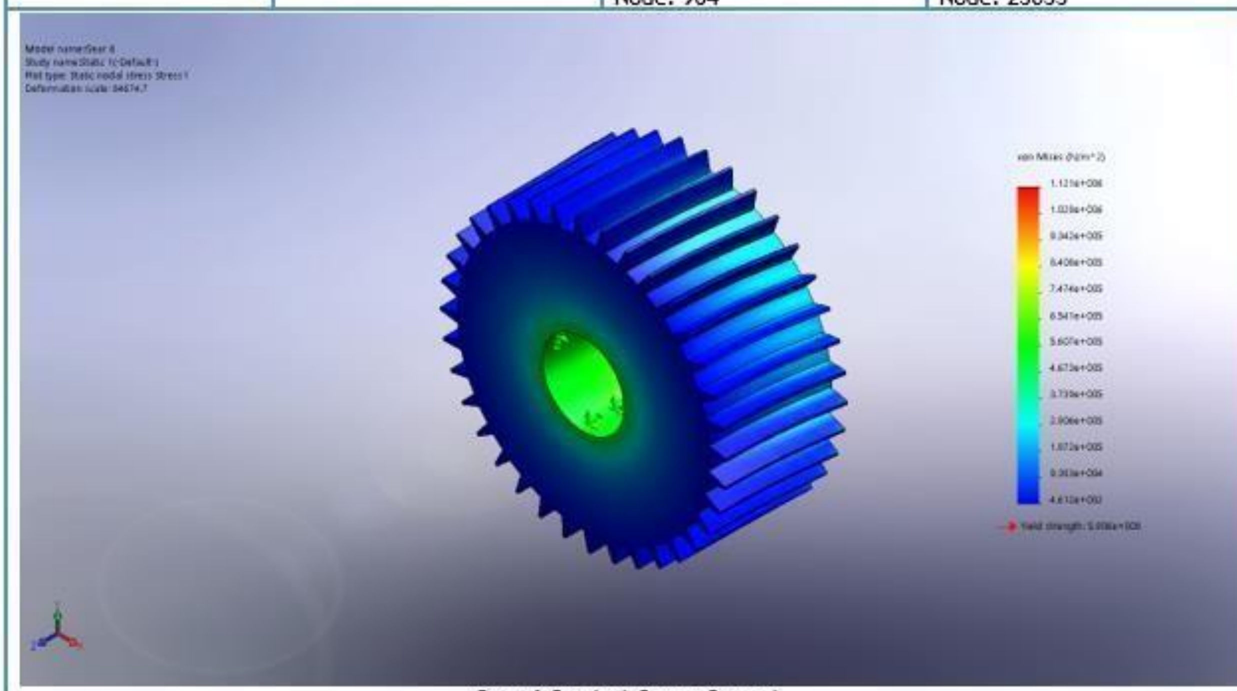
Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N	-0.943675	-1.08597	0.016778	1.4388

Reaction Moments

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N.m	0	0	0	0

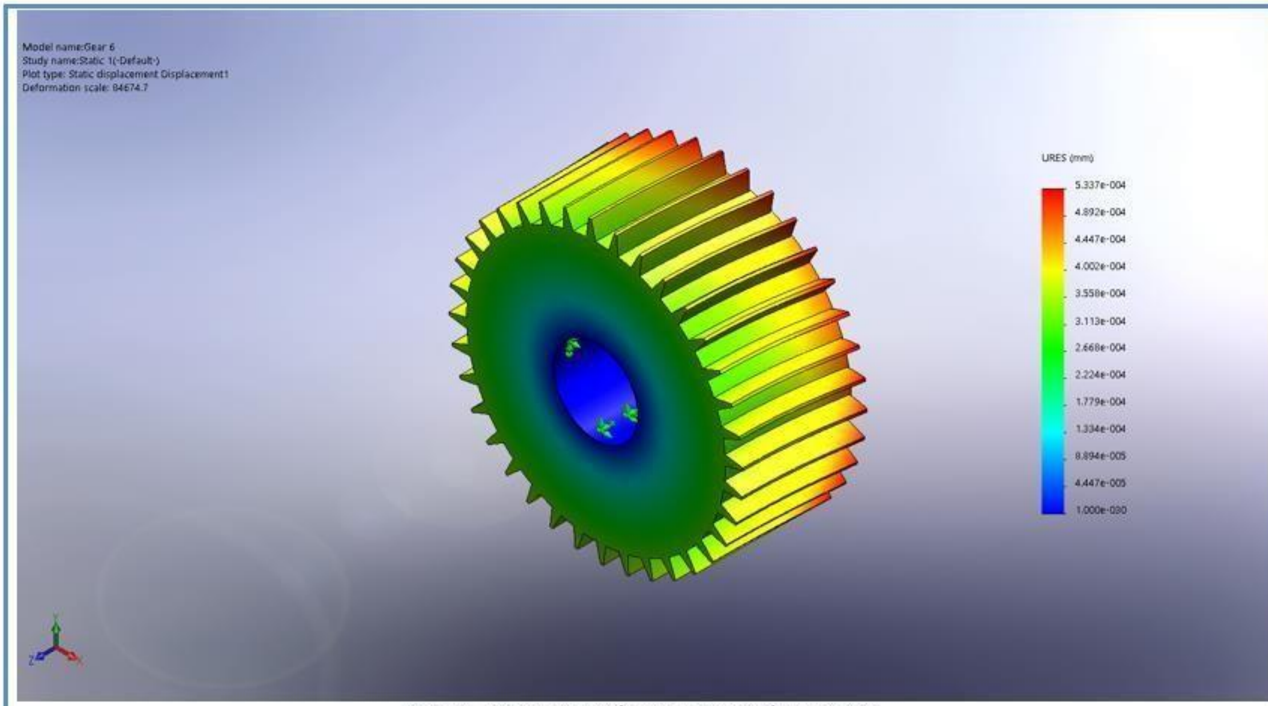
Study Results

Name	Type	Min	Max
Stress1	VON: von Mises Stress	4.612e+002N/m^2 Node: 964	1.121e+006N/m^2 Node: 23033



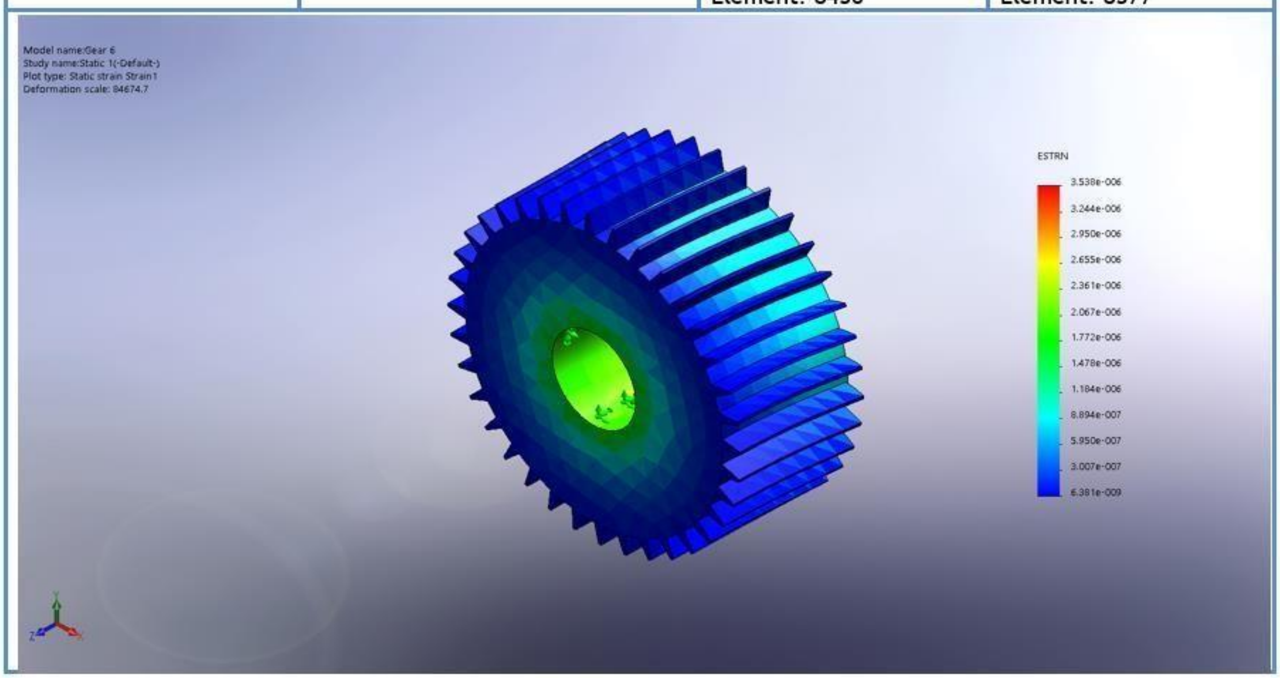
Gear 6-Static 1-Stress-Stress1

Name	Type	Min	Max
Displacement1	URES: Resultant Displacement	0.000e+000mm Node: 155	5.337e-004mm Node: 1567



Gear 6-Static 1-Displacement-Displacement1

Name	Type	Min	Max
Strain1	ESTRN: Equivalent Strain	6.381e-009 Element: 8456	3.538e-006 Element: 8577



Material Properties

Model Reference	Properties	Components
	Name: 1.7131 (16MnCr5) Model type: Linear Elastic Isotropic Default failure criterion: Max von Mises Stress Yield strength: 5.90594e+008 N/m^2 Tensile strength: 8e+008 N/m^2 Elastic modulus: 2.1e+011 N/m^2 Poisson's ratio: 0.28 Mass density: 7800 kg/m^3 Shear modulus: 7.9e+010 N/m^2 Thermal expansion coefficient: 1.1e-005 /Kelvin	SolidBody 1(Cut-Extrude3)(Gear 3-2), SolidBody 1(Cut-Extrude3)(Gear 6-3)
Curve Data:N/A		

Loads and Fixtures

Fixture name	Fixture Image	Fixture Details
Fixed-1		Entities: 2 face(s) Type: Fixed Geometry

Resultant Forces

Components	X	Y	Z	Resultant
Reaction force(N)	-8.03771	-4843.9	-0.0557809	4843.91
Reaction Moment(N.m)	0	0	0	0

Load name	Load Image	Load Details
Torque-1		Entities: 2 face(s) Reference: Face< 1 > Type: Apply torque Value: 2000 N.m

Resultant Forces

Reaction forces

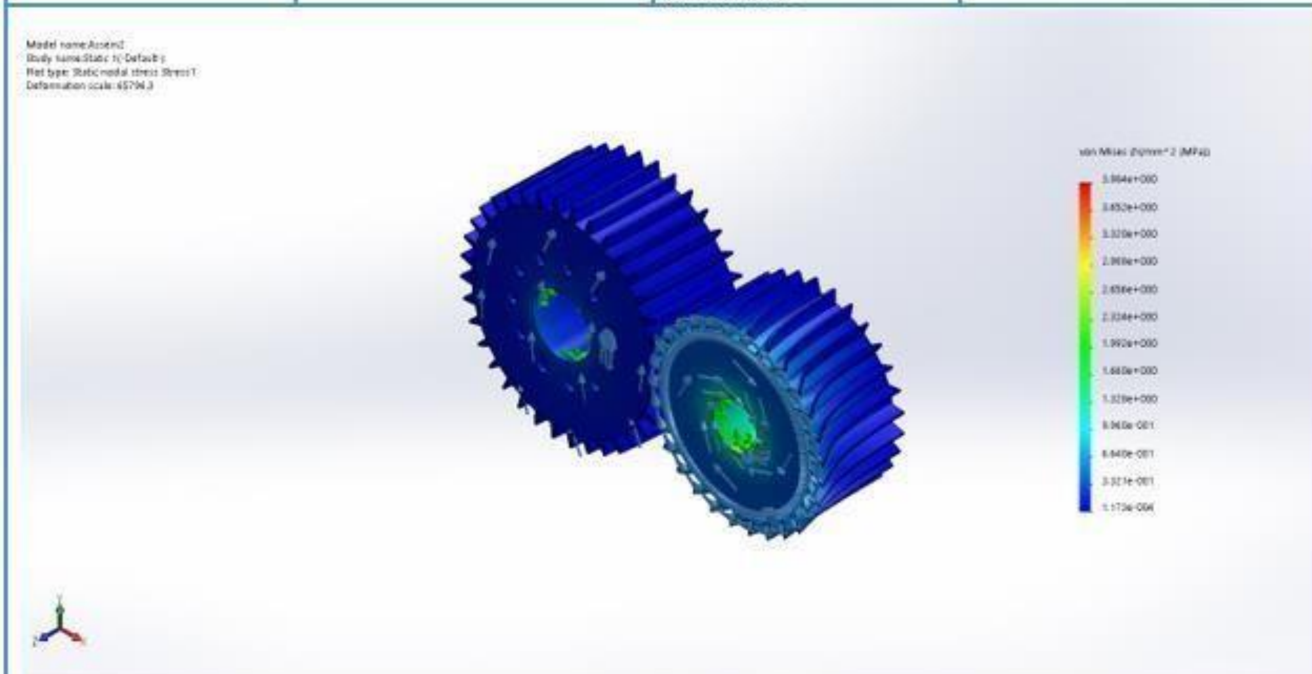
Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N	-8.03771	-4843.9	-0.0557809	4843.91

Reaction Moments

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N.m	0	0	0	0

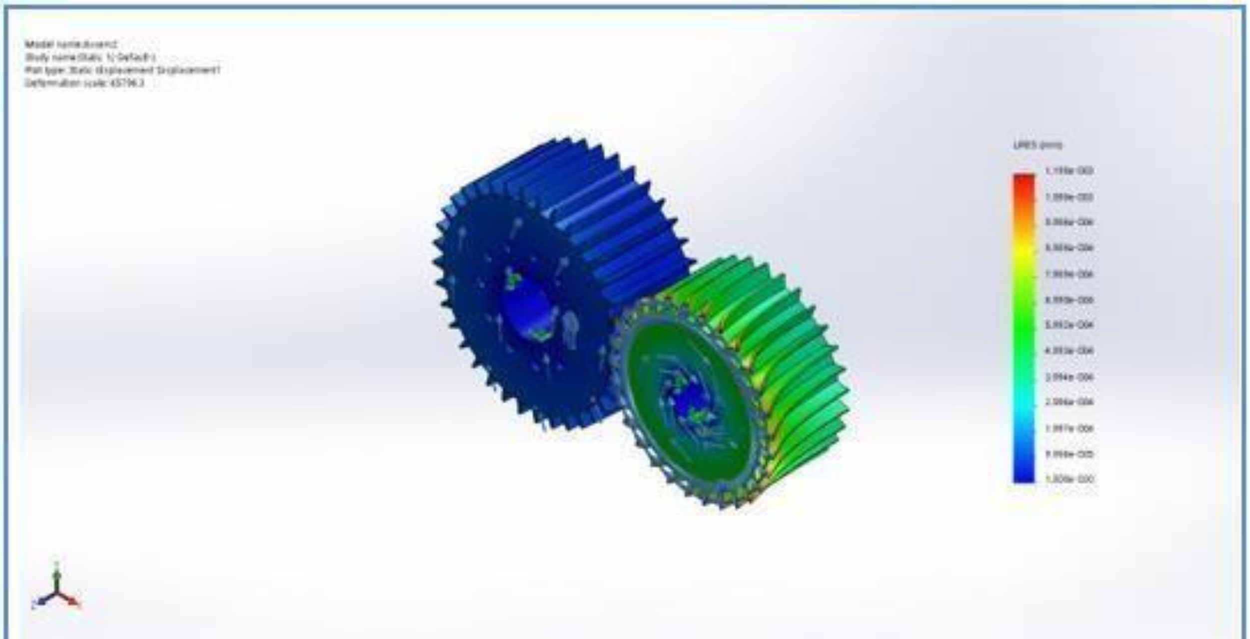
Study Results

Name	Type	Min	Max
Stress1	VON: von Mises Stress	1.173e-004N/mm^2 (MPa) Node: 24300	3.984e+000N/mm^2 (MPa) Node: 8522



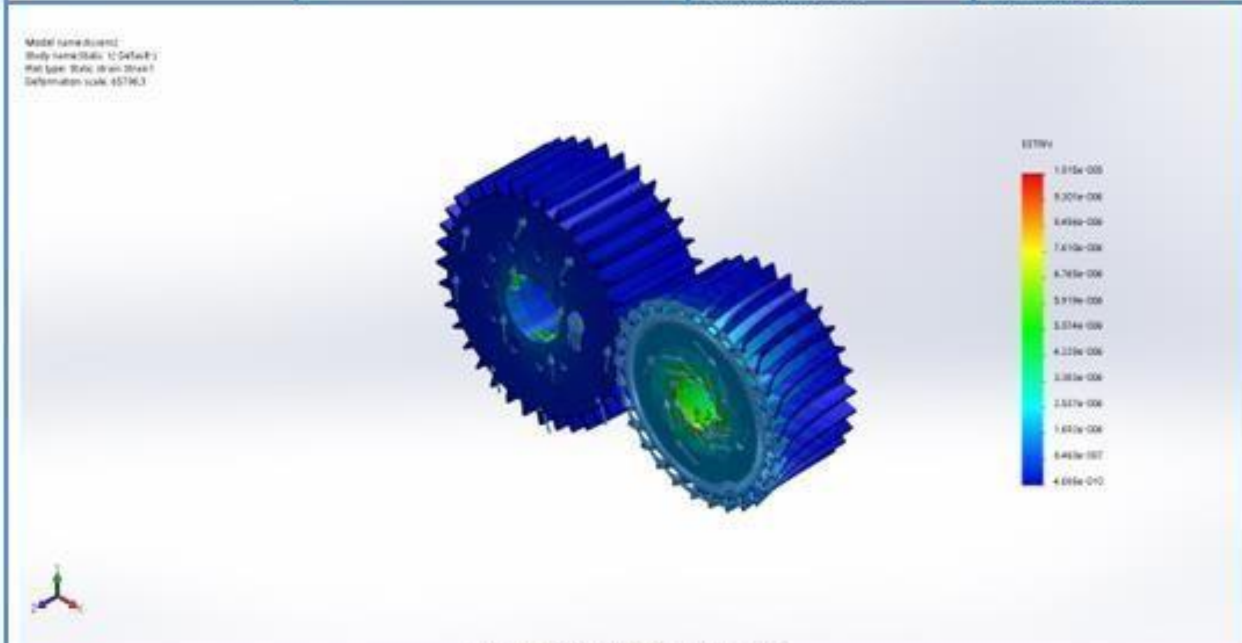
Assem2-Static 1-Stress-Stress1

Name	Type	Min	Max
Displacement1	URES: Resultant Displacement	0.000e+000mm Node: 335	1.198e-003mm Node: 443



Assem2-Static 1-Displacement-Displacement1

Name	Type	Min	Max
Strain1	ESTRN: Equivalent Strain	4.686e-010 Element: 12558	1.015e-005 Element: 2016



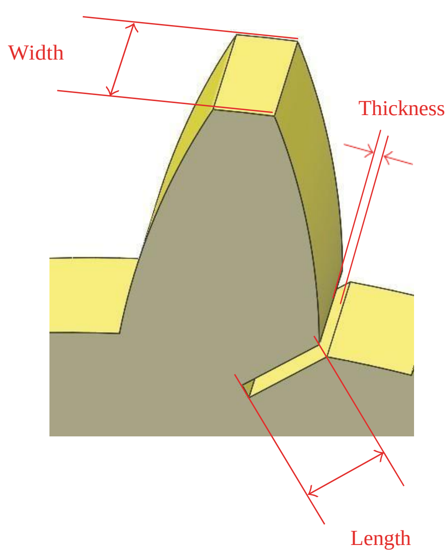
Assem2-Static 1-Strain-Strain1

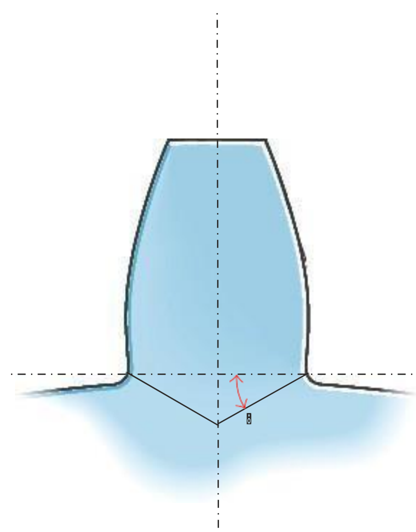
Mesh information

Mesh type	Solid Mesh
Mesher Used:	Standard mesh
Automatic Transition:	Off
Include Mesh Auto Loops:	Off
Jacobian points	4 Points
Element Size	33.3264 mm
Tolerance	1.66632 mm
Mesh Quality Plot	High

Analysis by Ansys

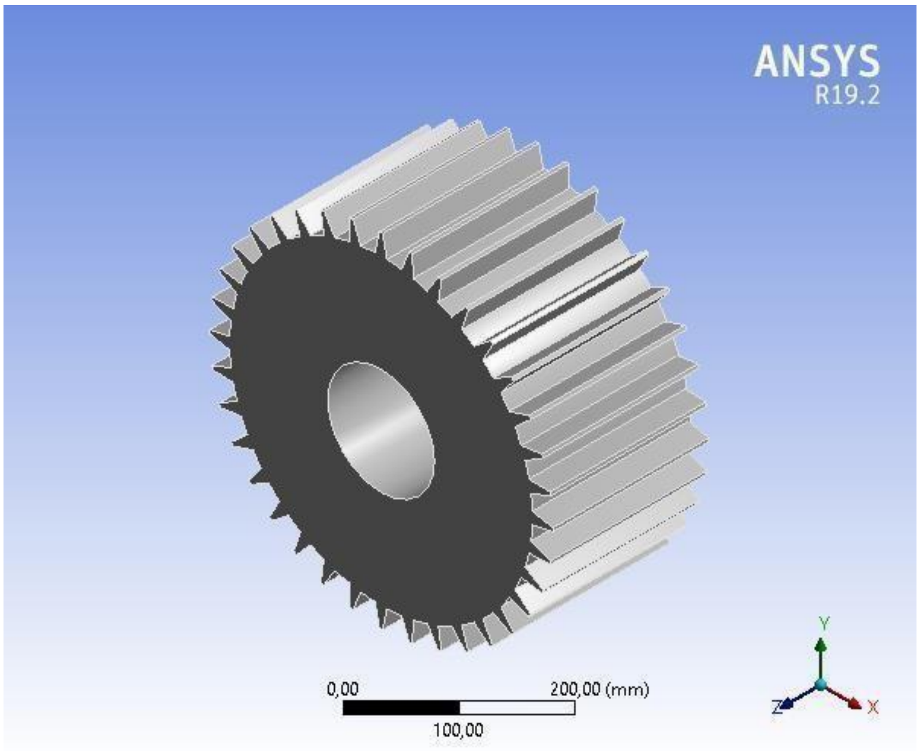
Gears are toothed mechanical components that are widely used in numerous industrial applications from heavy machinery to precision instruments to transmit power or motion. In a gear set, regardless of which one is driving the other, the smaller gear is called the pinion, and the larger gear is called the gear or wheel. Gear failure is an alarming and undesirable event that may happen because of an excessive applied load, invade quate lubrication, inaccurate manufacturing, or a bad install- lotion procedure. Gear failure may induce higher unaccepted able levels of sound and vibration. It may also decrease the efficiency of transmission, alter the normal operating conditions, and seriously disturb the production rate. In more severe cases, it can also provoke costly consequences that jeopardize machines' safety and even threaten human lives. Because of more competitive industry conditions, ma- chines are required to work under increasingly extreme operating environments for longer cycles and higher loads. Consequent, the gear teeth become more susceptible to surface.





Project

First Saved	Saturday, January 23, 2021
Last Saved	Saturday, January 23, 2021
Product Version	19.2 Release
Save Project Before Solution	No
Save Project After Solution	No



Contents

Report Not Finalized

Not all objects described below are in a finalized state. As a result, data may be incomplete, obsolete or in error. View first state problem. To finalize this report, edit objects as needed and solve the analyses.

Units

TABLE 1

Unit System	Metric (mm, kg, N, s, mV, mA) Degrees rad/s Celsius
Angle	Degrees
Rotational Velocity	rad/s
Temperature	Celsius

Model (A4)

Geometry

TABLE 2
Model (A4) > Geometry

Object Name	*Geometry*
State	Fully Defined
Definition	
Source	C:\Users\LENOVO\Desktop\Gear 6.x_t
Type	Parasolid
Length Unit	Meters
Element Control	Program Controlled
Display Style	Body Color
Bounding Box	
Length X	418, mm

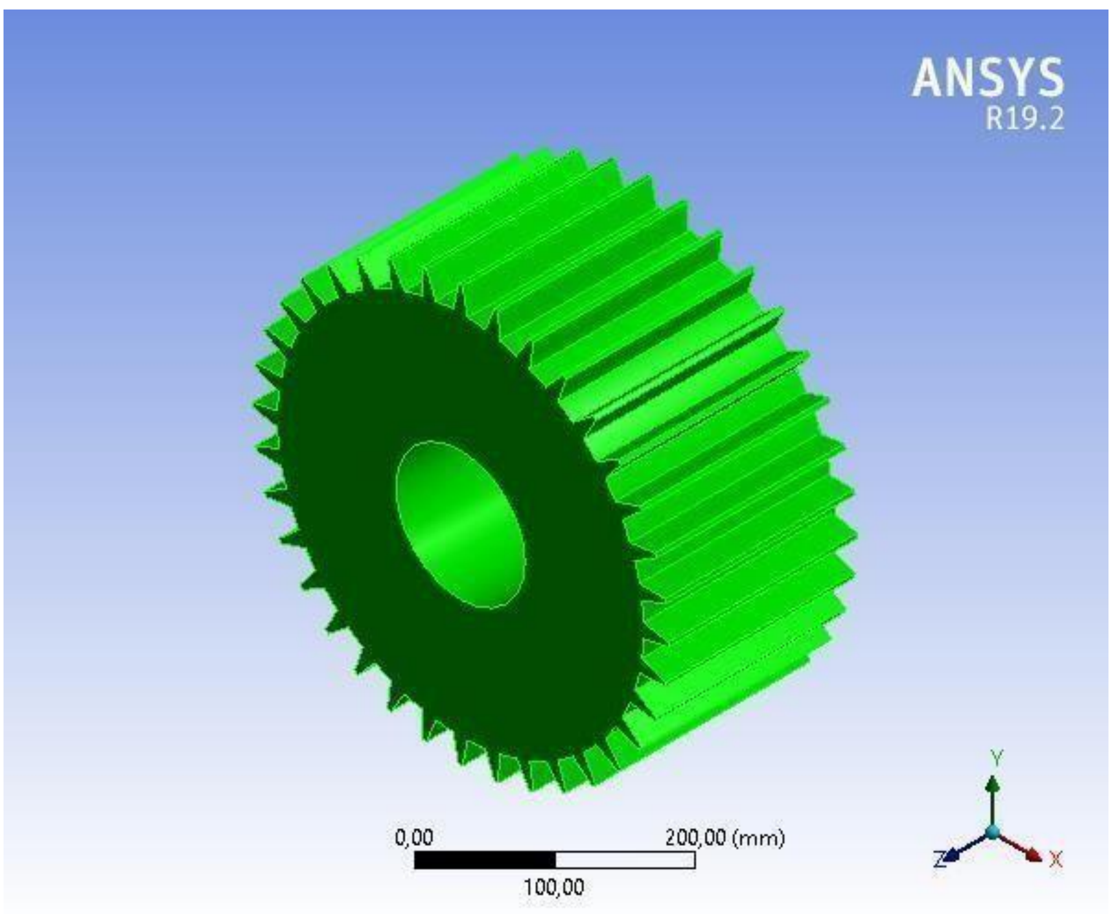
TABLE 3
Model (A4) > Geometry > Parts

Object Name	*Part 1*
State	Meshed
Graphics Properties	
Visible	Yes
Transparency	1
Definition	
Suppressed	No
Stiffness Behavior	Flexible
Coordinate System	Default Coordinate System
Reference Temperature	By Environment
Behavior	None
Material	
Assignment	16mncr5

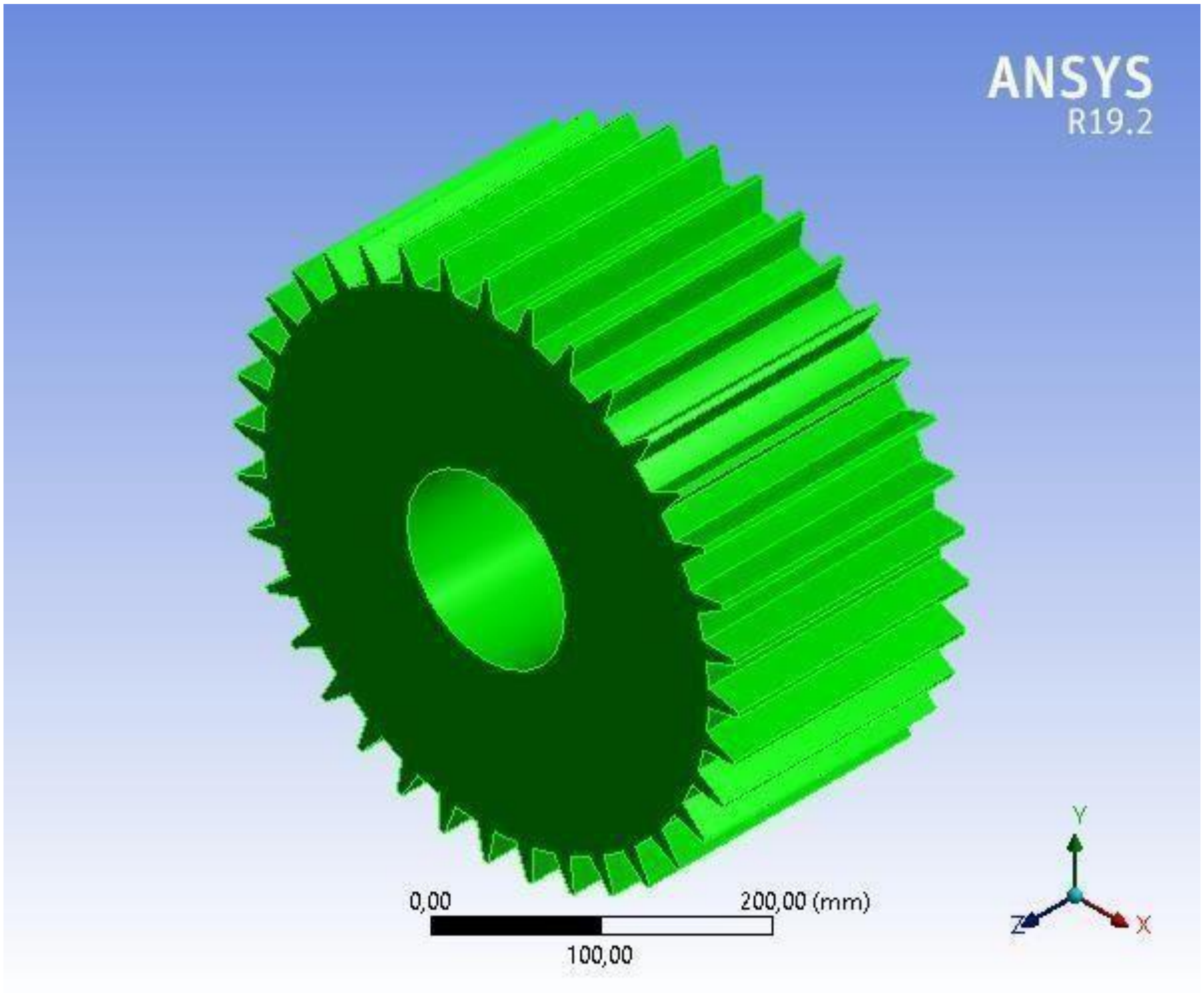
Length Y	418, mm
Length Z	192, mm
Properties	
Volume	1,944e+007 mm³
Mass	151,63 kg
Scale Factor Value	1,
Statistics	
Bodies	1
Active Bodies	1
Nodes	213003
Elements	133662
Mesh Metric	None
Update Options	
Assign Default Material	No
Basic Geometry Options	
Solid Bodies	Yes
Surface Bodies	Yes
Line Bodies	No
Parameters	Independent
Parameter Key	ANS;DS
Attributes	No
Named Selections	No
Material Properties	No
Advanced Geometry Options	
Use Associativity	Yes
Coordinate Systems	No
Reader Mode Saves Updated File	No
Use Instances	Yes
Smart CAD Update	Yes
Compare Parts On Update	No
Analysis Type	3-D
Mixed Import Resolution	None
Clean Bodies On Import	No
Stitch Surfaces On Import	No
Decompose Disjoint Geometry	Yes
Enclosure and Symmetry Processing	Yes

Nonlinear Effects	Yes
Thermal Strain Effects	Yes
Bounding Box	
Length X	418, mm
Length Y	418, mm
Length Z	192, mm
Properties	
Volume	1,944e+007 mm³
Mass	151,63 kg
Centroid X	-2,0208e-004 mm
Centroid Y	2,2038e-005 mm
Centroid Z	96,279 mm
Moment of Inertia Ip1	2,0238e+006 kg·mm²
Moment of Inertia Ip2	2,0238e+006 kg·mm²
Moment of Inertia Ip3	3,1203e+006 kg·mm²
Statistics	
Nodes	213003
Elements	133662
Mesh Metric	None

FIGURE 1
Model (A4) > Geometry > Part 1 > Figure



Model (A4) > Materials > 16mncr5 > Figure



Coordinate Systems

TABLE 4
Model (A4) > Coordinate Systems > Coordinate System

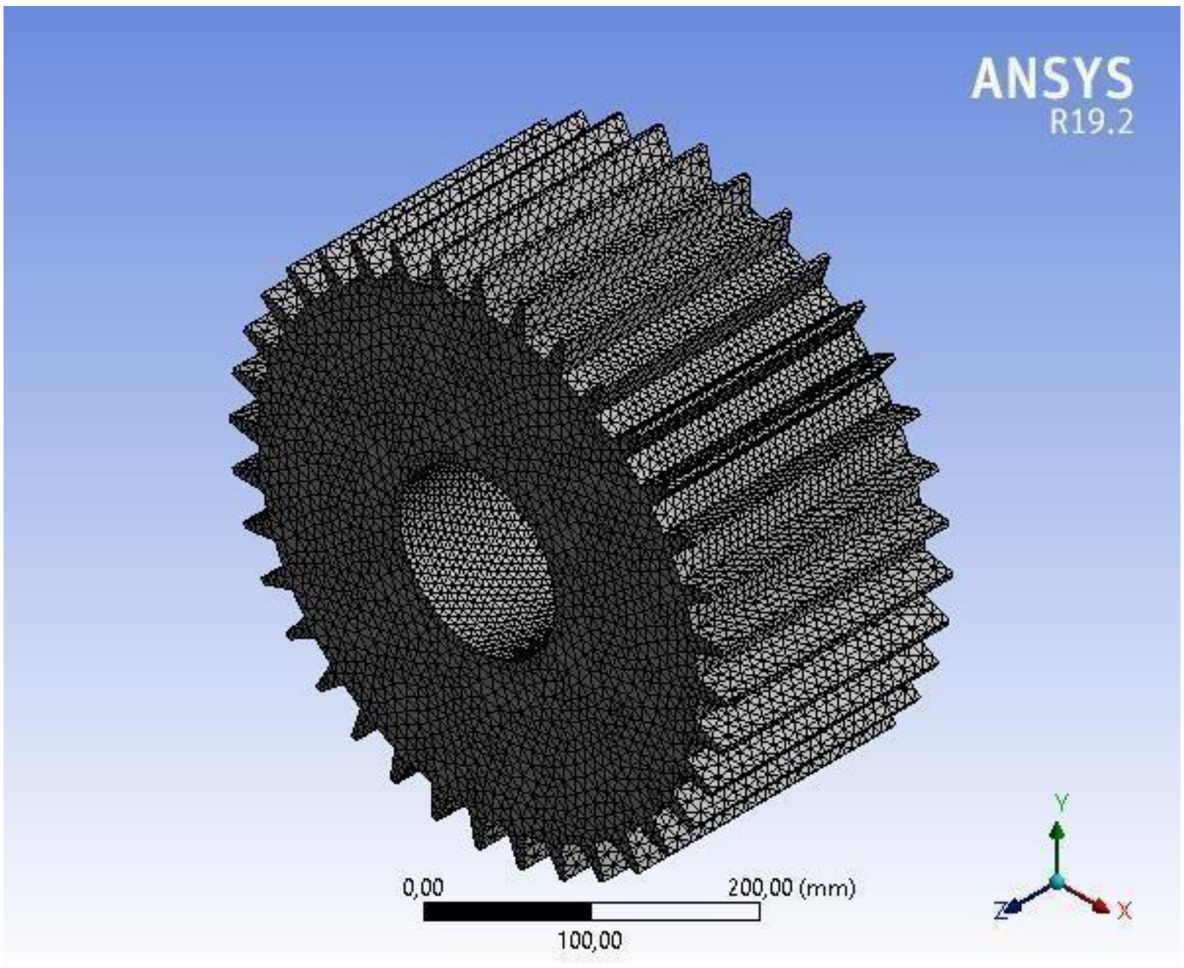
Object Name	*Global Coordinate System*
State	Fully Defined
Definition	
Type	Cartesian
Coordinate System ID	0,
Origin	
Origin X	0, mm
Origin Y	0, mm
Origin Z	0, mm
Directional Vectors	

X Axis Data	[1, 0, 0,]
Y Axis Data	[0, 1, 0,]
Z Axis Data	[0, 0, 1,]

TABLE 5
Model (A4) > Mesh

Object Name	*Mesh*
State	Solved
Display	
Display Style	Use Geometry Setting
Defaults	
Physics Preference	Mechanical
Element Order	Program Controlled
Element Size	Default
Sizing	
Use Adaptive Sizing	Yes
Resolution	7
Mesh Defeaturing	Yes
Defeature Size	Default
Transition	Fast
Span Angle Center	Coarse
Initial Size Seed	Assembly
Bounding Box Diagonal	621,54 mm
Average Surface Area	4632,1 mm²
Minimum Edge Length	4, mm
Quality	
Check Mesh Quality	Yes, Errors
Error Limits	Standard Mechanical
Target Quality	Default (0.050000)
Smoothing	High
Mesh Metric	None
Inflation	
Use Automatic Inflation	None
Inflation Option	Smooth Transition
Transition Ratio	0,272
Maximum Layers	5
Growth Rate	1,2
Inflation Algorithm	Pre
View Advanced Options	No
Advanced	
Number of CPUs for Parallel Part Meshing	Program Controlled
Straight Sided Elements	No
Number of Retries	Default (4)

Rigid Body Behavior	Dimensionally Reduced
Triangle Surface Mesher	Program Controlled
Topology Checking	Yes
Pinch Tolerance	Please Define
Generate Pinch on Refresh	No
Statistics	
Nodes	213003
Elements	133662



Static Structural (A5)

TABLE 6
Model (A4) > Analysis

Object Name	*Static Structural (A5)*
State	Solved
Definition	
Physics Type	Structural
Analysis Type	Static Structural
Solver Target	Mechanical APDL
Options	
Environment Temperature	22, °C
Generate Input Only	No

TABLE 7
Model (A4) > Static Structural (A5) > Analysis Settings

Object Name	*Analysis Settings*
State	Fully Defined
Step Controls	
Number Of Steps	1,
Current Step Number	1,

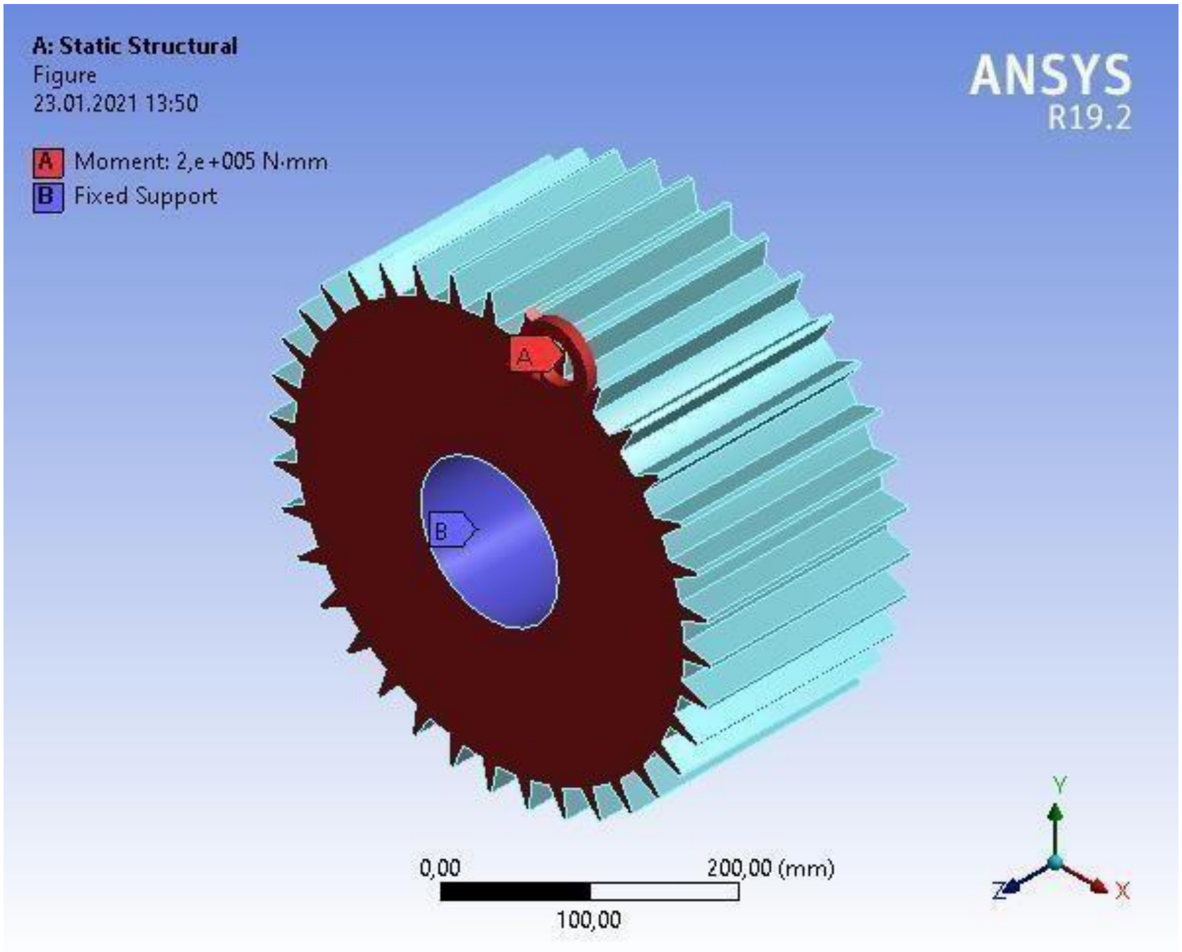


FIGURE 4
Model (A4) > Static Structural (A5) > Figure

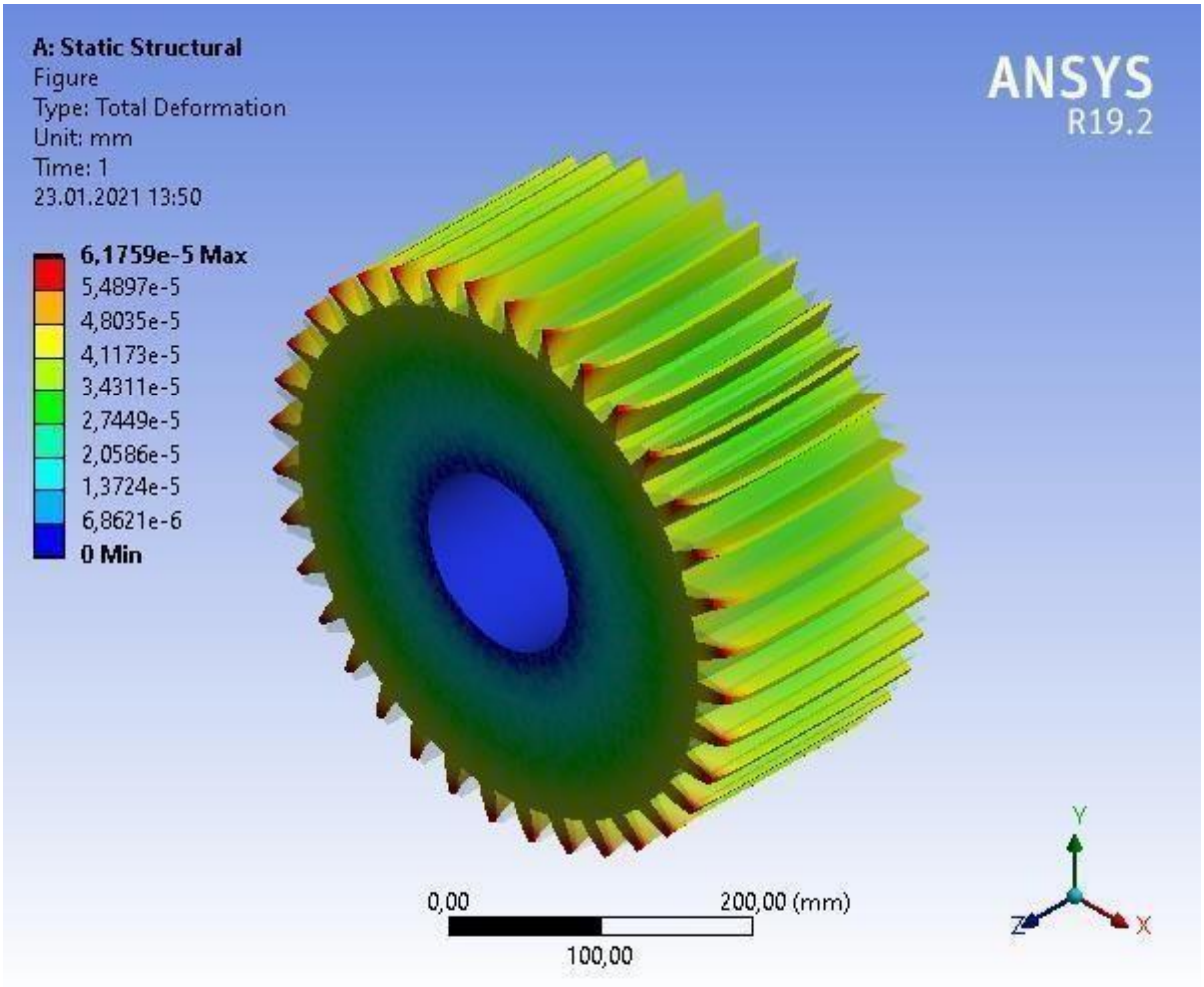


FIGURE 8
Model (A4) > Static Structural (A5) > Solution (A6) > Equivalent Stress

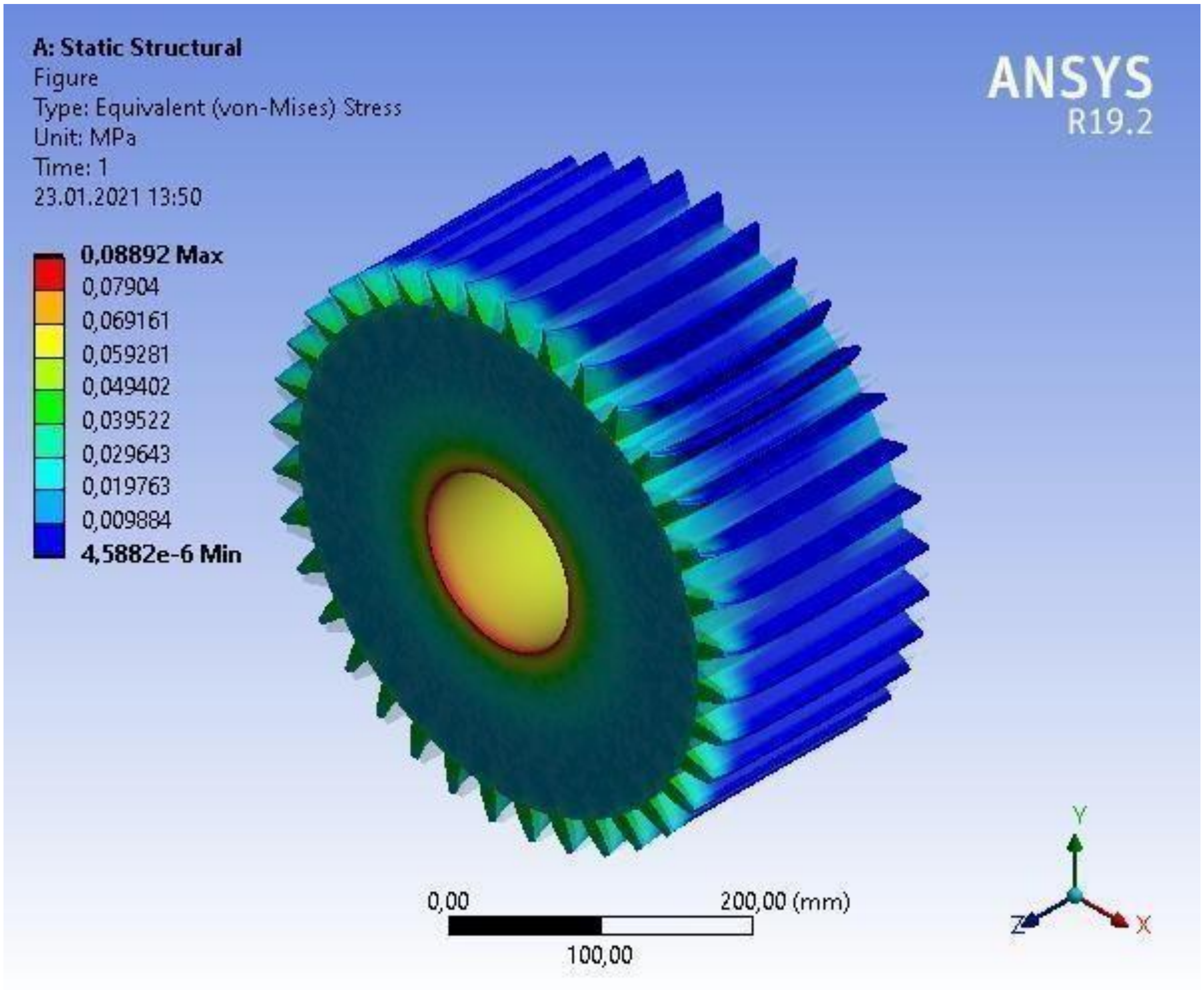


FIGURE 10
Model (A4) > Static Structural (A5) > Solution (A6) > Equivalent Elastic Strain

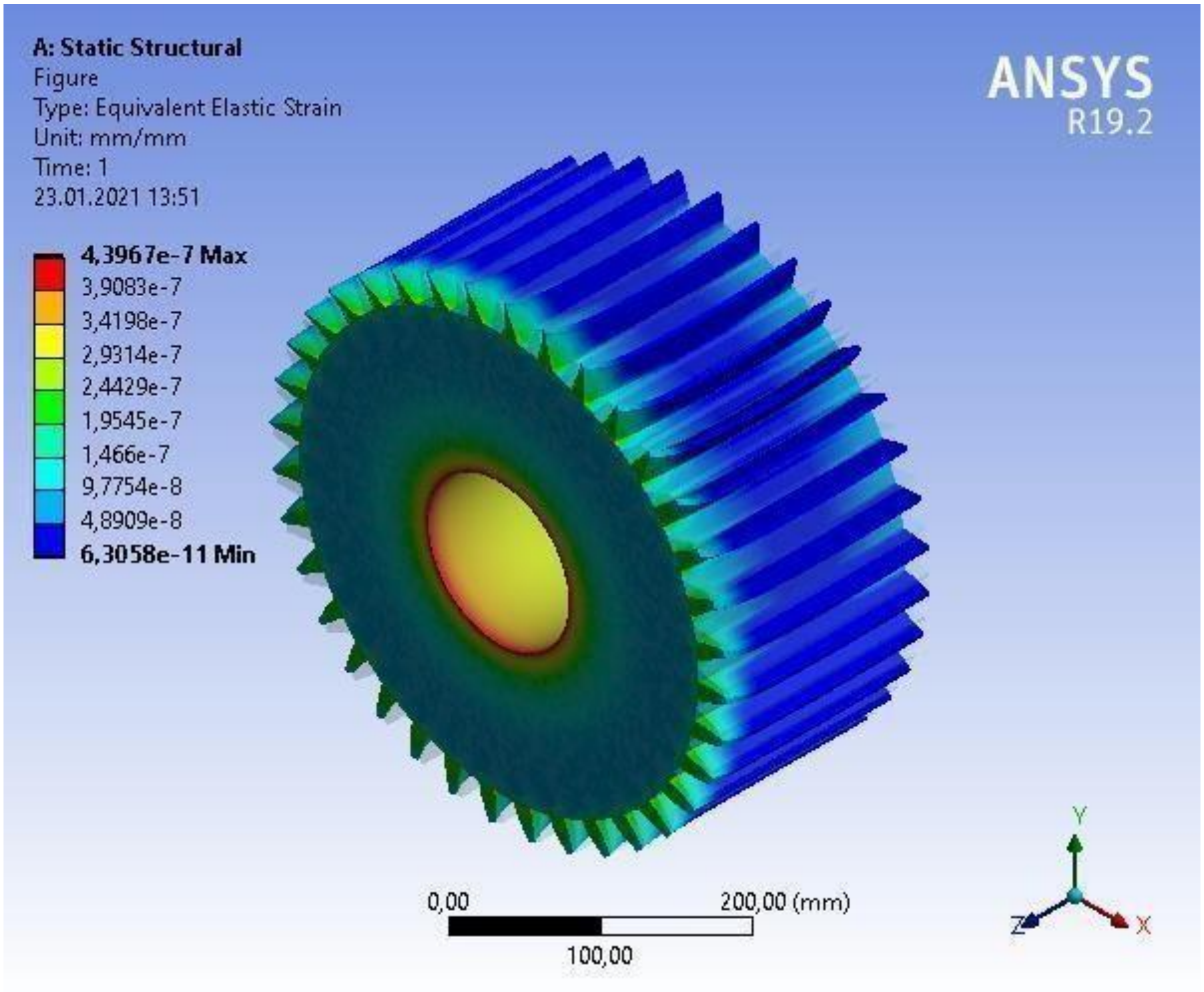
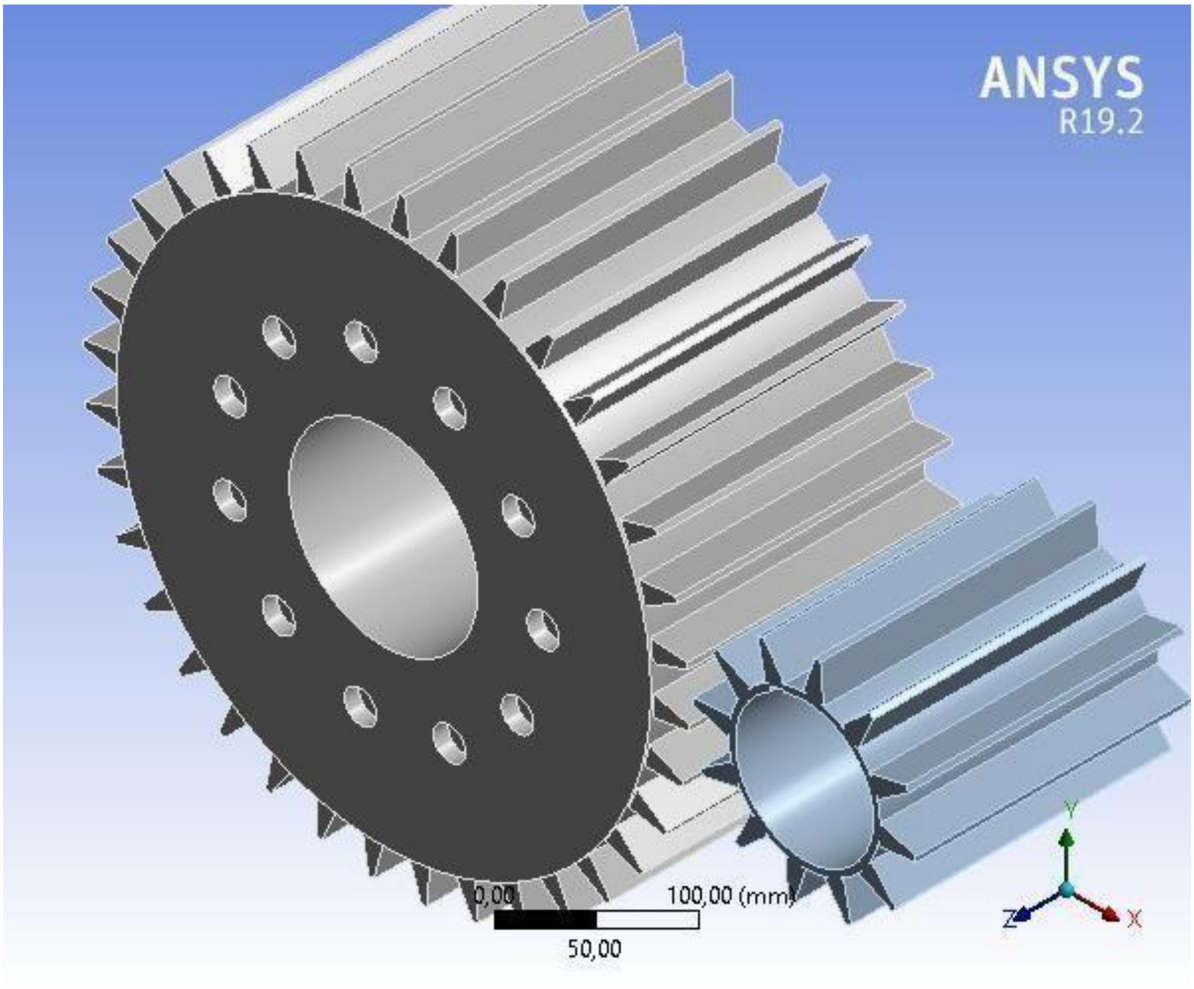


FIGURE 11
Model (A4) > Static Structural (A5) > Solution (A6) > Equivalent Elastic Strain

Project

First Saved	Saturday, January 23, 2021
Last Saved	Saturday, January 23, 2021
Product Version	19.2 Release
Save Project Before Solution	No
Save Project After Solution	No



Contents

Units

TABLE 1

Unit System	Metric (mm, kg, N, s, mV, mA) Degrees rad/s Celsius
Angle	Degrees
Rotational Velocity	rad/s
Temperature	Celsius

Model (B4)

Geometry

TABLE 2
Model (B4) > Geometry

Object Name	*Geometry*
State	Fully Defined
Definition	
Source	C:\Users\LENOVO\AppData\Local\Temp\WB_LAPTOP-4VADGGHN_LENOVO_13136_2\unsaved_project_files\dp0\SYS-1\DM\SYS-1.agdb
Type	DesignModeler
Length Unit	Meters
Element Control	Program Controlled
Display Style	Body Color
Bounding Box	
Length X	680,09 mm
Length Y	577,99 mm
Length Z	192, mm
Properties	
Volume	2,0243e+007 mm³

Mass	157,89 kg
Scale Factor Value	1,
Statistics	
Bodies	2
Active Bodies	2
Nodes	127272
Elements	74282
Mesh Metric	None
Update Options	
Assign Default Material	No
Basic Geometry Options	
Parameters	Independent
Parameter Key	
Attributes	Yes
Attribute Key	
Named Selections	Yes
Named Selection Key	
Material Properties	Yes
Advanced Geometry Options	
Use Associativity	Yes
Coordinate Systems	Yes
Coordinate System Key	
Reader Mode Saves Updated File	No
Use Instances	Yes
Smart CAD Update	Yes
Compare Parts On Update	No
Analysis Type	3-D
Clean Bodies On Import	No
Stitch Surfaces On Import	No
Decompose Disjoint Geometry	Yes
Enclosure and Symmetry Processing	Yes

TABLE 3
Model (B4) > Geometry > Parts

Object Name	*Gear 6\Gear 6*	*Gear 5,7\Gear 5,7*
State	Meshed	
Graphics Properties		
Visible	Yes	

Transparency	1	
Definition		
Suppressed	No	
Stiffness Behavior	Flexible	
Coordinate System	Default Coordinate System	
Reference Temperature	By Environment	
Behavior	None	
Material		
Assignment	16mncr5	
Nonlinear Effects	Yes	
Thermal Strain Effects	Yes	
Bounding Box		
Length X	577,99 mm	202,19 mm
Length Y	577,99 mm	202,19 mm
Length Z	192, mm	
Properties		
Volume	1,944e+007 mm³	8,024e+005 mm³
Mass	151,63 kg	6,2587 kg
Centroid X	-344,52 mm	-54,42 mm
Centroid Y	-147,99 mm	-148,21 mm
Centroid Z	-96,279 mm	-95,339 mm
Moment of Inertia Ip1	2,0246e+006 kg·mm²	29690 kg·mm²
Moment of Inertia Ip2	2,0246e+006 kg·mm²	29765 kg·mm²
Moment of Inertia Ip3	3,1224e+006 kg·mm²	21451 kg·mm²
Statistics		
Nodes	86209	41063
Elements	52384	21898
Mesh Metric	None	
CAD Attributes		
Color:175.159.143		

FIGURE 1
Model (B4) > Geometry > Figure

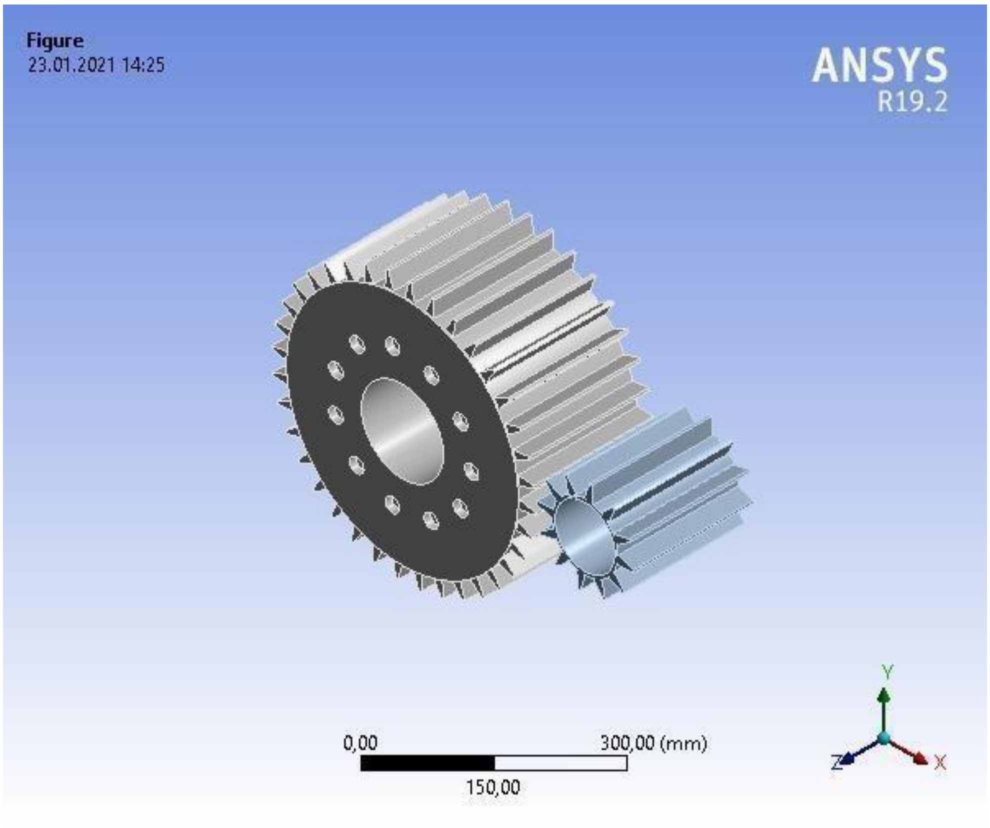
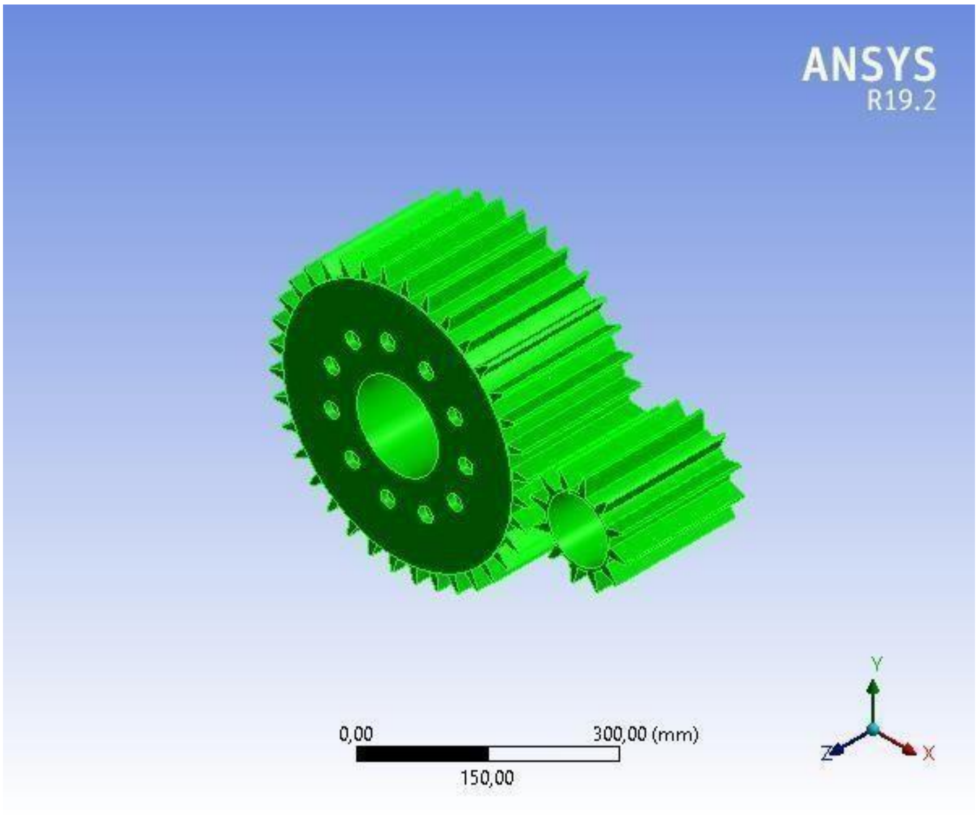


FIGURE 2
Model (B4) > Materials > 16mncr5 > Figure



Coordinate Systems

TABLE 4
Model (B4) > Coordinate Systems > Coordinate System

Object Name	*Global Coordinate System*
State	Fully Defined
Definition	
Type	Cartesian
Coordinate System ID	0,
Origin	
Origin X	0, mm
Origin Y	0, mm
Origin Z	0, mm
Directional Vectors	
X Axis Data	[1, 0, 0,]
Y Axis Data	[0, 1, 0,]
Z Axis Data	[0, 0, 1,]

Connections

TABLE 5
Model (B4) > Connections

Object Name	*Connections*
State	Fully Defined
Auto Detection	
Generate Automatic Connection On Refresh	Yes
Transparency	
Enabled	Yes

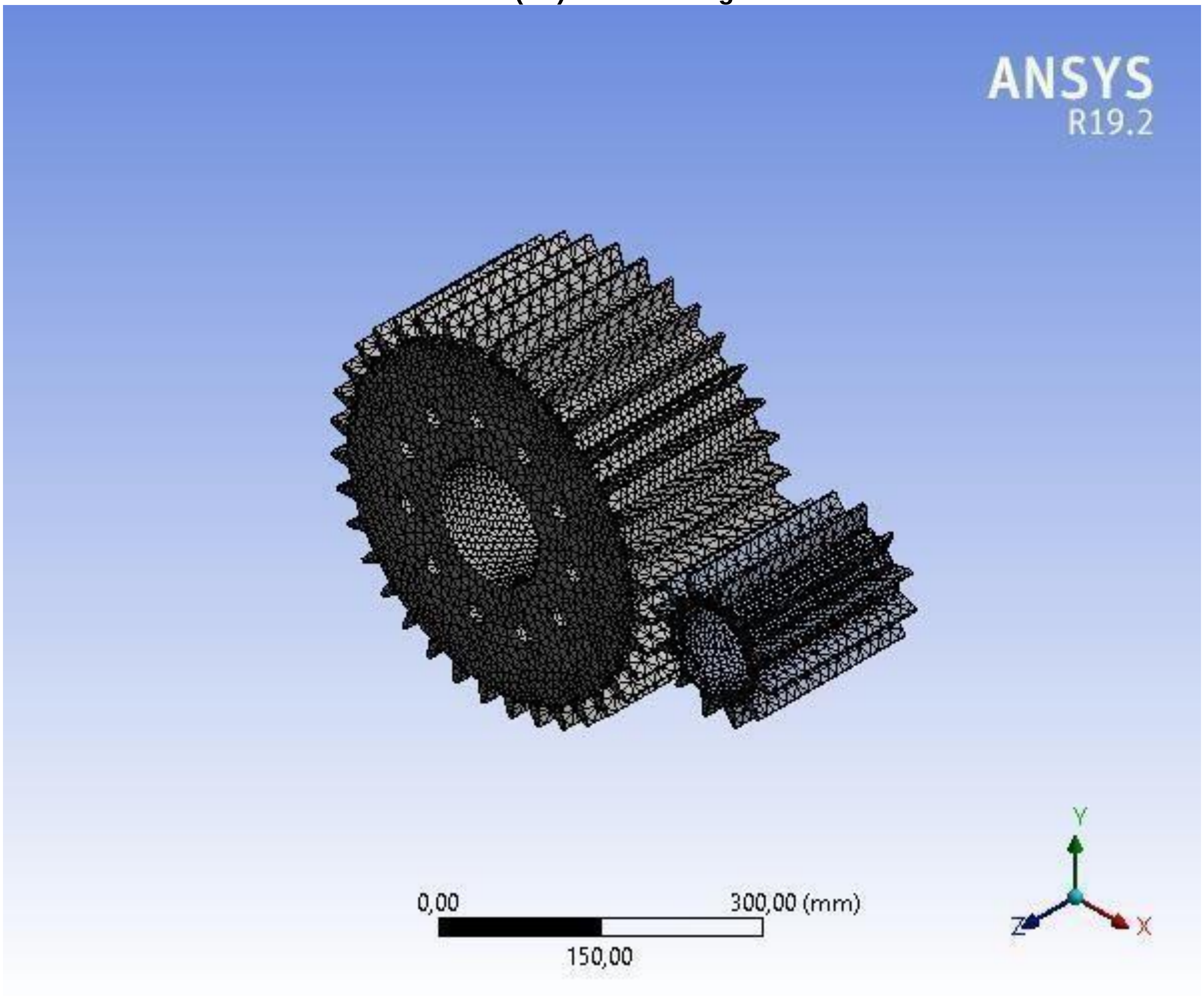
Mesh

TABLE 6
Model (B4) > Mesh

Object Name	*Mesh*
State	Solved
Display	
Display Style	Use Geometry Setting
Defaults	
Physics Preference	Mechanical
Element Order	Program Controlled
Element Size	Default
Sizing	
Use Adaptive Sizing	Yes
Resolution	7
Mesh Defeaturing	Yes
Defeature Size	Default
Transition	Fast
Span Angle Center	Coarse
Initial Size Seed	Assembly
Bounding Box Diagonal	912,94 mm
Average Surface Area	4134,9 mm²
Minimum Edge Length	2,0858 mm
Quality	
Check Mesh Quality	Yes, Errors
Error Limits	Standard Mechanical
Target Quality	Default (0.050000)
Smoothing	Medium
Mesh Metric	None
Inflation	
Use Automatic Inflation	None
Inflation Option	Smooth Transition
Transition Ratio	0,272
Maximum Layers	5
Growth Rate	1,2
Inflation Algorithm	Pre
View Advanced Options	No
Advanced	
Number of CPUs for Parallel Part Meshing	Program Controlled
Straight Sided Elements	No
Number of Retries	Default (4)
Rigid Body Behavior	Dimensionally Reduced
Triangle Surface Mesher	Program Controlled
Topology Checking	Yes
Pinch Tolerance	Please Define
Generate Pinch on Refresh	No

Statistics	
Nodes	127272
Elements	74282

FIGURE 3
Model (B4) > Mesh > Figure



Static Structural (B5)

TABLE 7
Model (B4) > Analysis

Object Name	*Static Structural (B5)*
State	Solved
Definition	
Physics Type	Structural
Analysis Type	Static Structural
Solver Target	Mechanical APDL
Options	
Environment Temperature	22, °C
Generate Input Only	No

TABLE 8
Model (B4) > Static Structural (B5) > Analysis Settings

Object Name	*Analysis Settings*

State	Fully Defined
Step Controls	
Number Of Steps	1,
Current Step Number	1,
Step End Time	1, s
Auto Time Stepping	Program Controlled
Solver Controls	
Solver Type	Program Controlled
Weak Springs	Off
Solver Pivot Checking	Program Controlled
Large Deflection	Off
Inertia Relief	Off
Rotordynamics Controls	
Coriolis Effect	Off
Restart Controls	
Generate Restart Points	Program Controlled
Retain Files After Full Solve	No
Combine Restart Files	Program Controlled
Nonlinear Controls	
Newton-Raphson Option	Program Controlled
Force Convergence	Program Controlled
Moment Convergence	Program Controlled
Displacement Convergence	Program Controlled
Rotation Convergence	Program Controlled
Line Search	Program Controlled
Stabilization	Off
Output Controls	
Stress	Yes
Strain	Yes
Nodal Forces	No
Contact Miscellaneous	No
General Miscellaneous	No
Store Results At	All Time Points
Analysis Data Management	
Solver Files Directory	C:\Users\LENOVO\AppData\Local\Temp\WB_LAPTOP-4VADGGHN_LENOVO_13136_2\unsaved_project_files\dp0\SYS-1\MECH\
Future Analysis	None
Scratch Solver Files Directory	
Save MAPDL db	No

Contact Summary	Program Controlled
Delete Unneeded Files	Yes
Nonlinear Solution	No
Solver Units	Active System
Solver Unit System	nmm

TABLE 9
Model (B4) > Static Structural (B5) > Loads

Object Name	*Moment*	*Moment 2*	*Fixed Support*
State	Fully Defined		
Scope			
Scoping Method	Geometry Selection		
Geometry	2 Faces	14 Faces	1 Face
Definition			
Type	Moment		Fixed Support
Define By	Vector		
Magnitude	2,e+005 N·mm (ramped)		
Direction	Defined		
Suppressed	No		
Behavior	Deformable		
Advanced			
Pinball Region	All		

FIGURE 4
Model (B4) > Static Structural (B5) > Moment

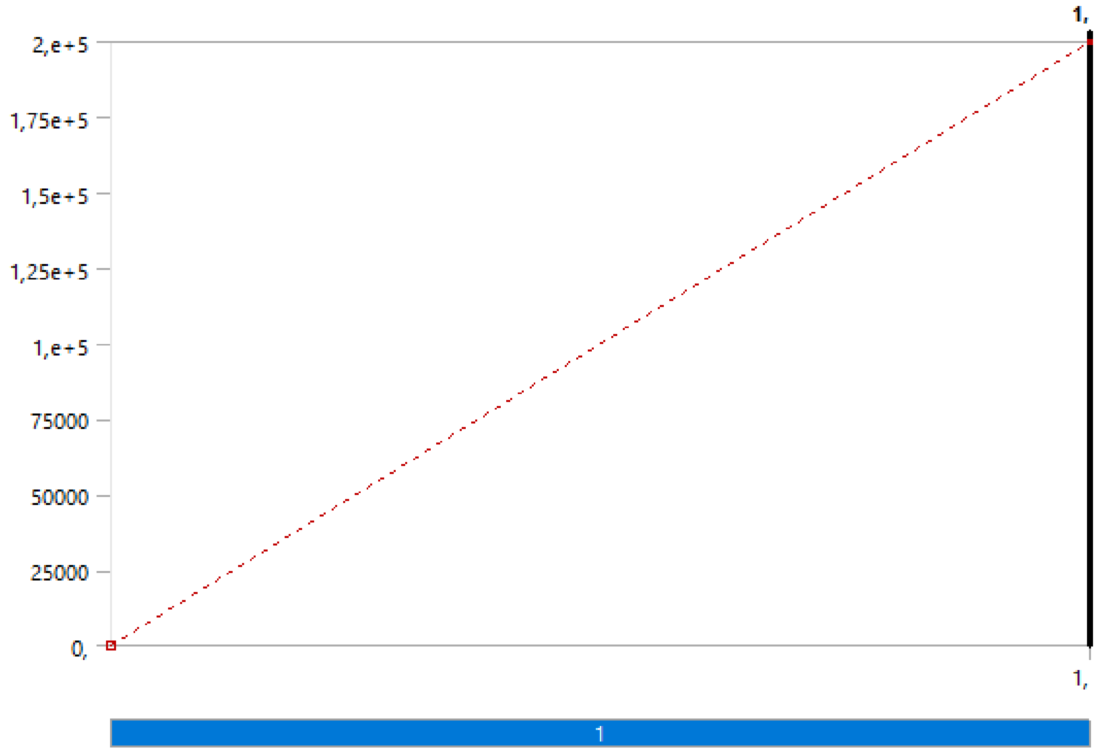


FIGURE 5
Model (B4) > Static Structural (B5) > Moment 2

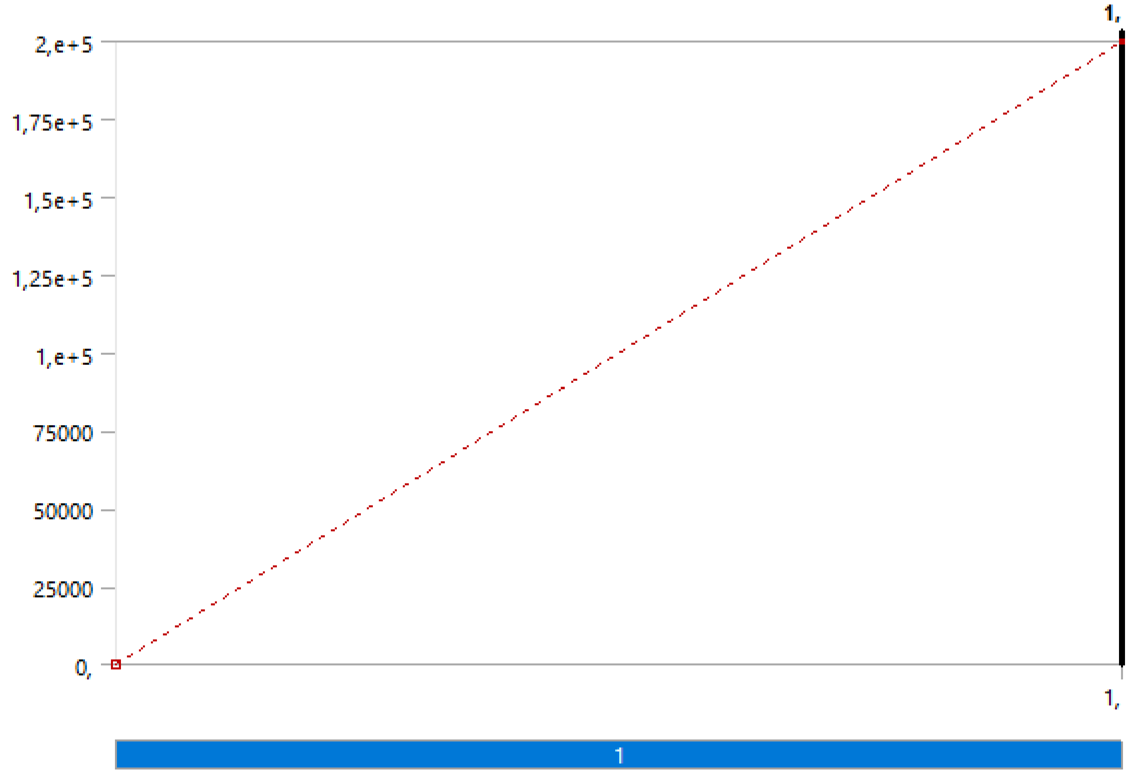


FIGURE 6
Model (B4) > Static Structural (B5) > Figure

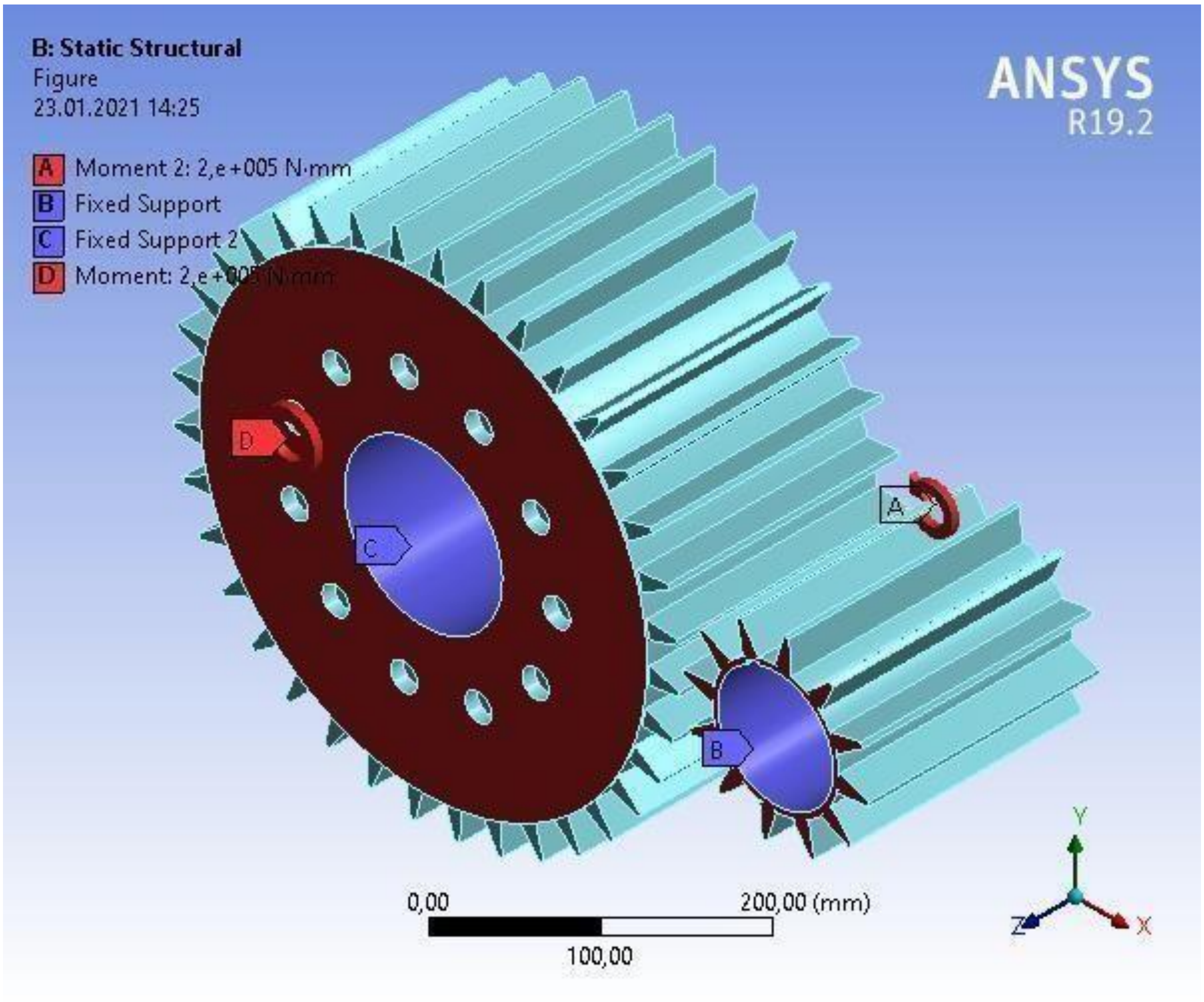


TABLE 10
Model (B4) > Static Structural (B5) > Loads

Object Name	*Fixed Support 2*
State	Fully Defined
Scope	
Scoping Method	Geometry Selection
Geometry	1 Face
Definition	
Type	Fixed Support
Suppressed	No

Solution (B6)

TABLE 11
Model (B4) > Static Structural (B5) > Solution

Object Name	*Solution (B6)*
State	Solved
Adaptive Mesh Refinement	
Max Refinement Loops	1,
Refinement Depth	2,
Information	
Status	Done
MAPDL Elapsed Time	30, s
MAPDL Memory Used	2,8408 GB
MAPDL Result File Size	62,063 MB
Post Processing	
Beam Section Results	No
On Demand Stress/Strain	No

TABLE 12
Model (B4) > Static Structural (B5) > Solution (B6) > Solution Information

Object Name	*Solution Information*
State	Solved
Solution Information	
Solution Output	Solver Output
Newton-Raphson Residuals	0
Identify Element Violations	0
Update Interval	2,5 s
Display Points	All
FE Connection Visibility	
Activate Visibility	Yes
Display	All FE Connectors
Draw Connections Attached To	All Nodes
Line Color	Connection Type
Visible on Results	No
Line Thickness	Single
Display Type	Lines

TABLE 13
Model (B4) > Static Structural (B5) > Solution (B6) > Results

Object Name	*Total Deformation*	*Equivalent Elastic Strain*	*Equivalent Stress*
State	Solved		
Scope			
Scoping Method	Geometry Selection		
Geometry	All Bodies		
Definition			
Type	Total Deformation	Equivalent Elastic Strain	Equivalent (von-Mises) Stress
By	Time		
Display Time	Last		
Calculate Time History	Yes		
Identifier			
Suppressed	No		
Results			
Minimum	0, mm	8,3854e-011 mm/mm	1,9593e-006 MPa
Maximum	8,5994e-004 mm	2,3792e-005 mm/mm	4,0336 MPa
Average	2,8203e-005 mm	7,7489e-007 mm/mm	0,12629 MPa
Minimum Occurs On	Gear 6\Gear 6		
Maximum Occurs On	Gear 5,7\Gear 5,7		
Information			
Time	1, s		
Load Step	1		
Substep	1		
Iteration Number	1		
Integration Point Results			
Display Option		Averaged	
Average Across Bodies		No	

FIGURE 7
Model (B4) > Static Structural (B5) > Solution (B6) > Total Deformation

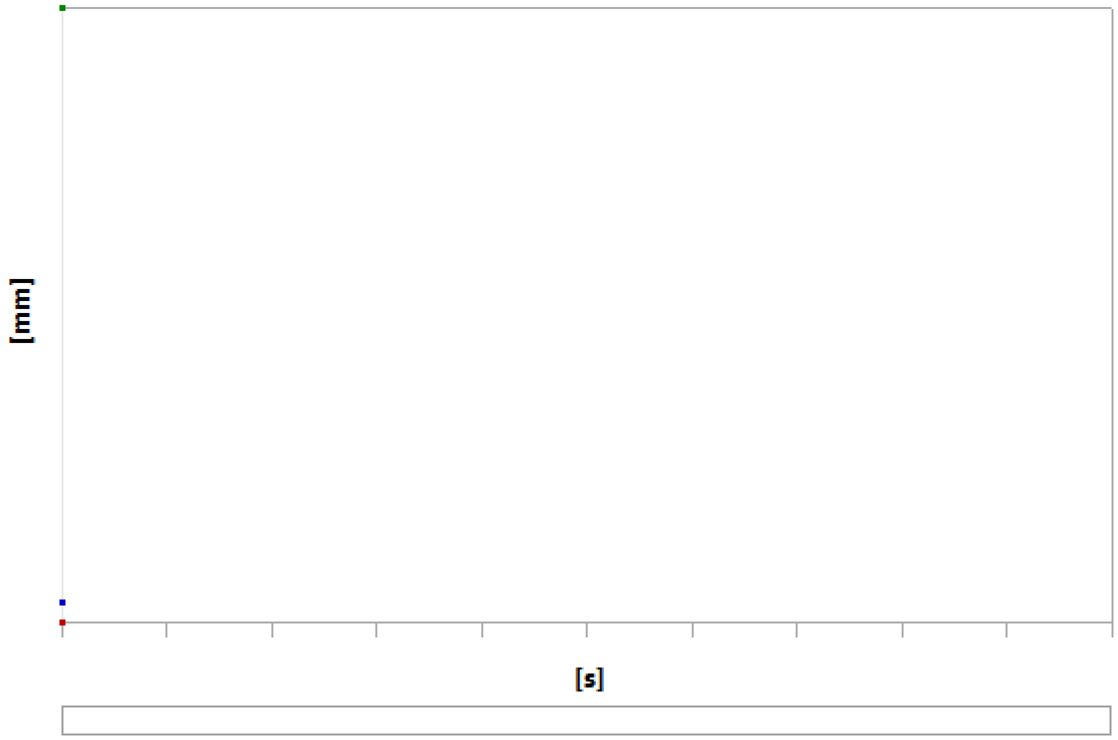


TABLE 14
Model (B4) > Static Structural (B5) > Solution (B6) > Total Deformation

Time [s]	Minimum [mm]	Maximum [mm]	Average [mm]
1,	0,	8,5994e-004	2,8203e-005

FIGURE 8
Model (B4) > Static Structural (B5) > Solution (B6) > Total Deformation > Figure

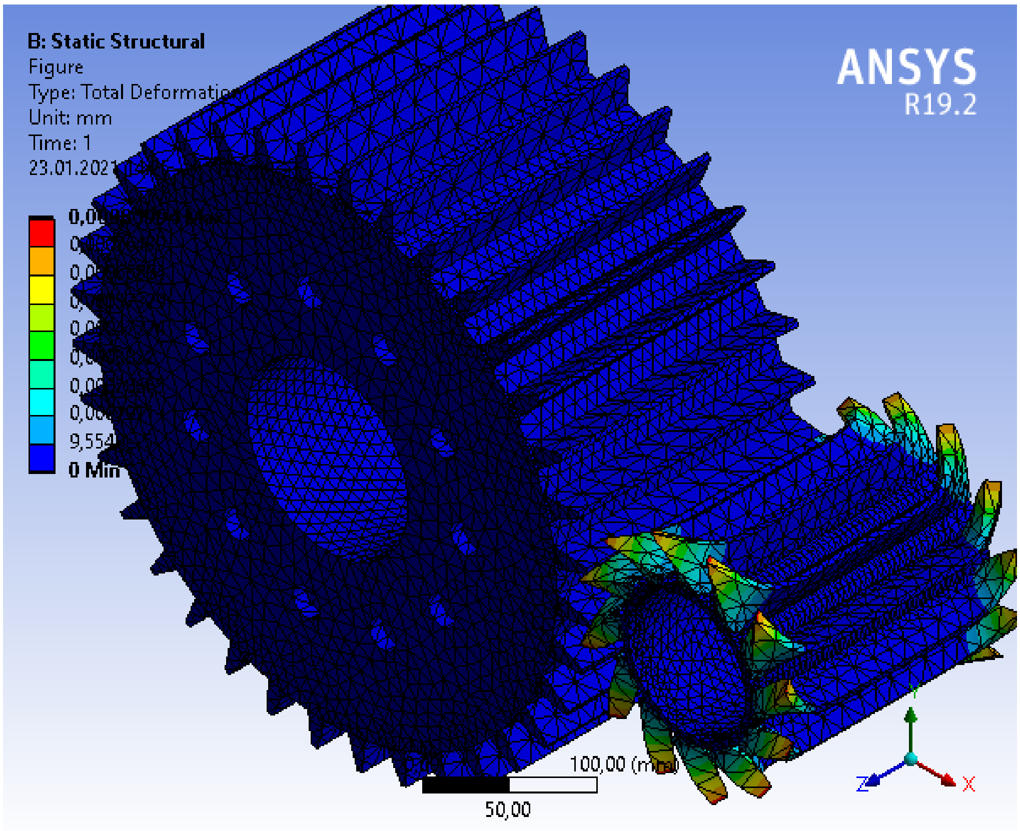


FIGURE 9
Model (B4) > Static Structural (B5) > Solution (B6) > Equivalent Elast

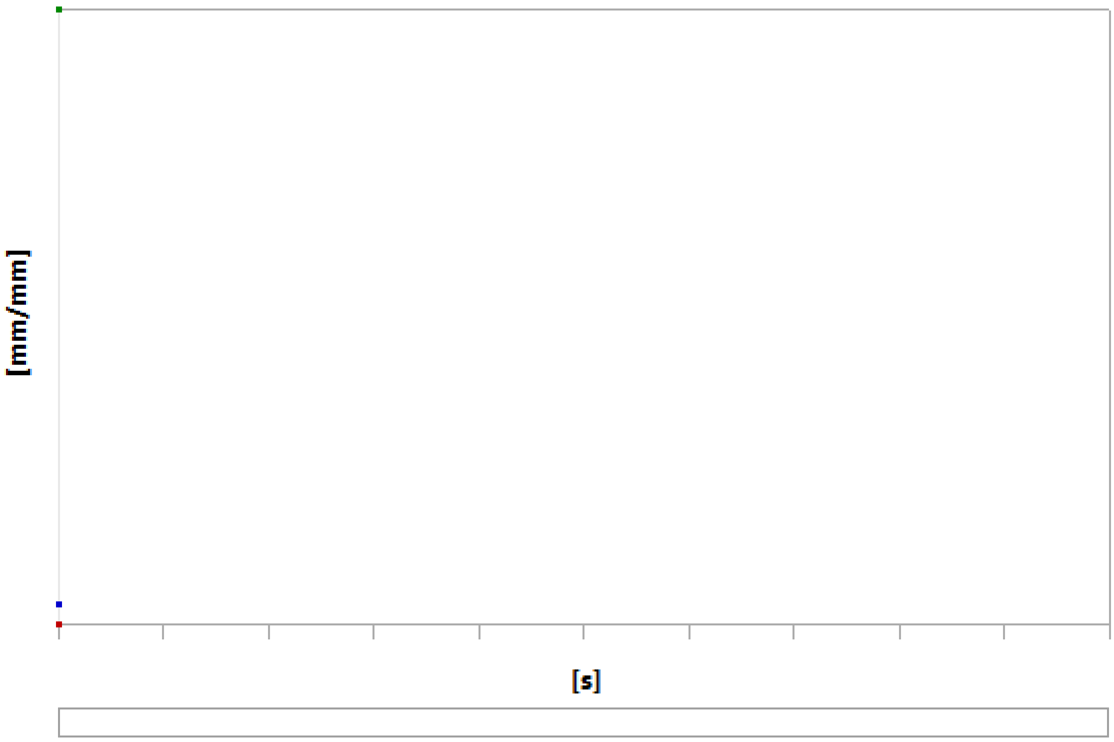


TABLE 15
Model (B4) > Static Structural (B5) > Solution (B6) > Equivalent Elastic Strain

Time [s]	Minimum [mm/mm]	Maximum [mm/mm]	Average [mm/mm]
1,	8,3854e-011	2,3792e-005	7,7489e-007

FIGURE 10
Model (B4) > Static Structural (B5) > Solution (B6) > Equivalent Elastic Strain > Figure

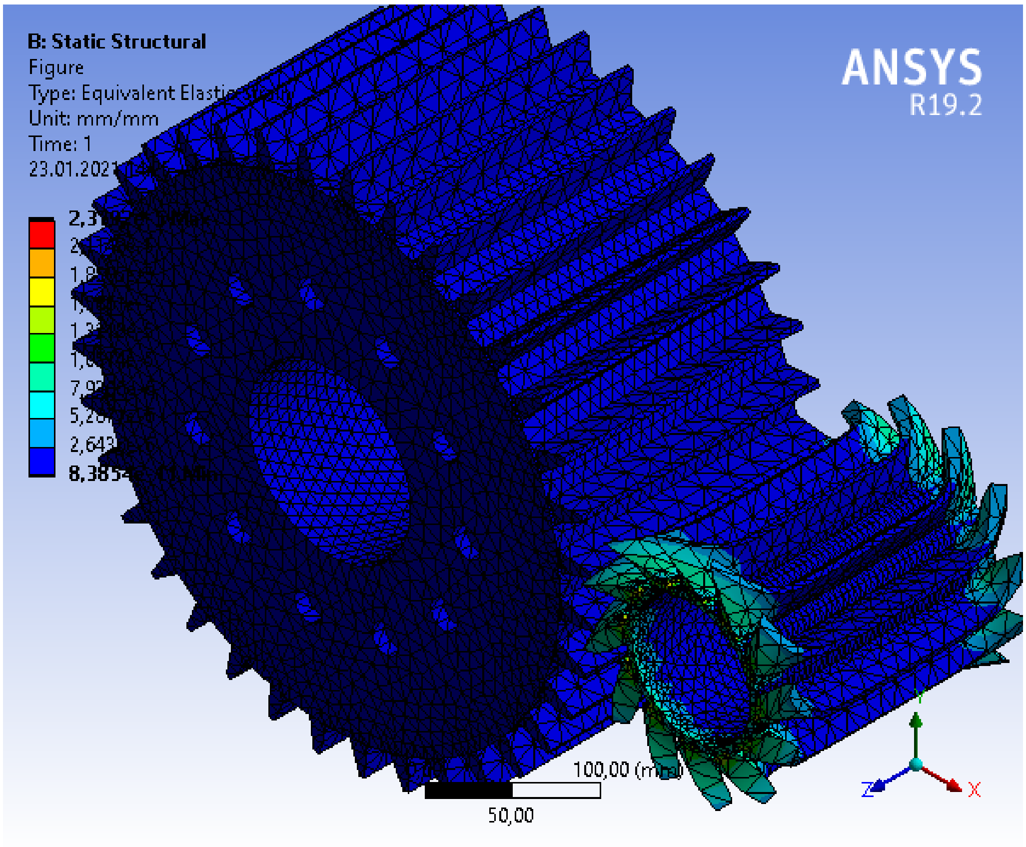


FIGURE 11
Model (B4) > Static Structural (B5) > Solution (B6) > Equivalent Stress

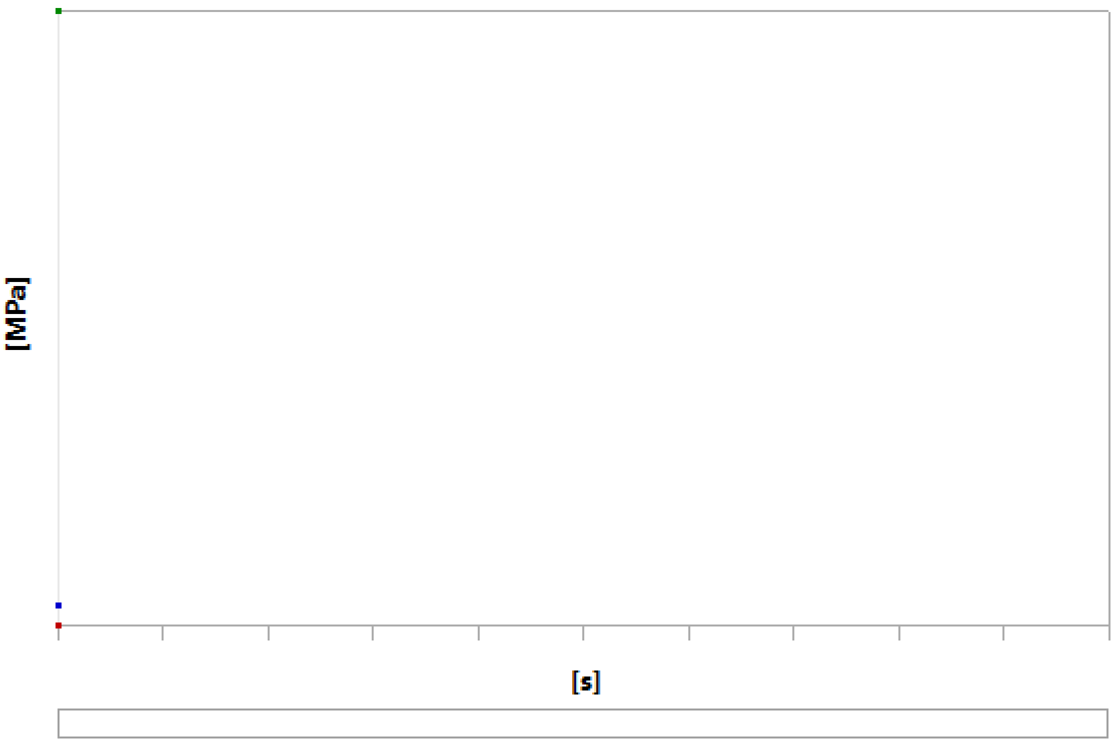
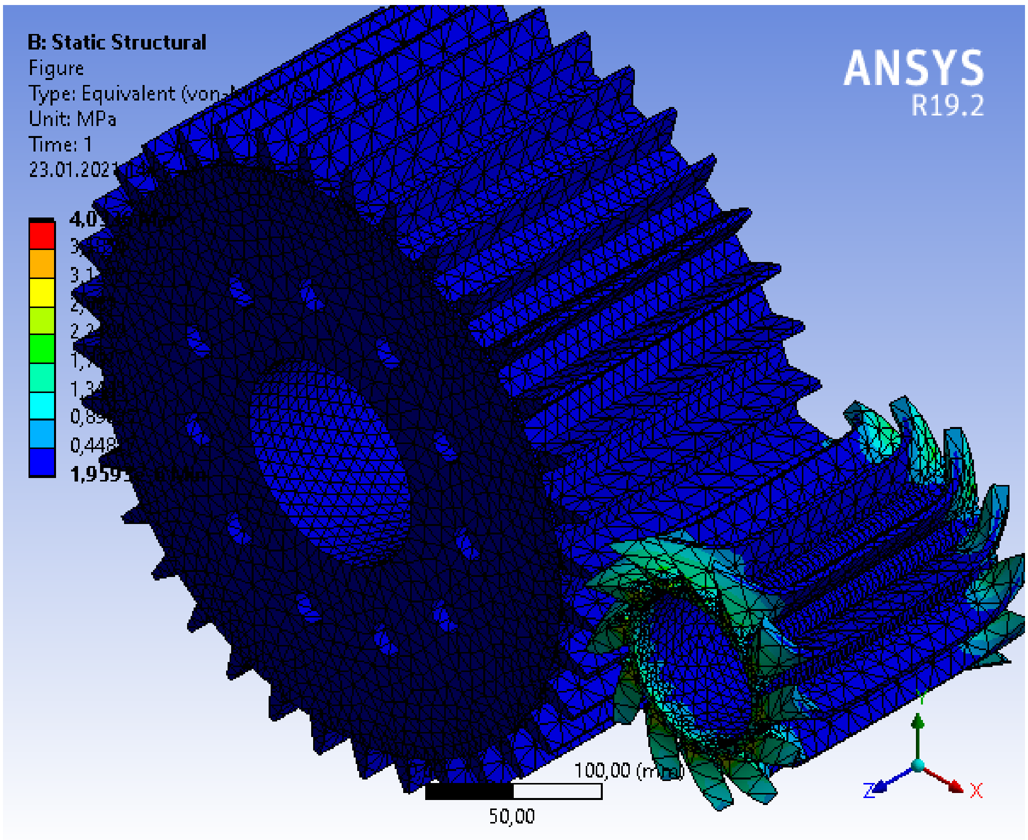


TABLE 16
Model (B4) > Static Structural (B5) > Solution (B6) > Equivalent Stress

Time [s]	Minimum [MPa]	Maximum [MPa]	Average [MPa]
1,	1,9593e-006	4,0336	0,12629

FIGURE 12
Model (B4) > Static Structural (B5) > Solution (B6) > Equivalent Stress > Figure



Material Data

16mncr5

TABLE 17
16mncr5 > Constants

Density	7,8e-006 kg mm^-3
Coefficient of Thermal Expansion	1,1e-005 C^-1

TABLE 18
16mncr5 > Color

Red	Green	Blue
155,	244,	255,

TABLE 19
16mncr5 > Tensile Yield Strength

Tensile Yield Strength MPa
590,59

TABLE 20
16mncr5 > Tensile Ultimate Strength

Tensile Ultimate Strength MPa
800,

TABLE 21
16mncr5 > Isotropic Elasticity

Young's Modulus MPa	Poisson's Ratio	Bulk Modulus MPa	Shear Modulus MPa	Temperature C
2,0224e+005	0,28	1,5321e+005	79000	

Manufacturing Process

After we have finished the required calculations for the gear box , We have designed each part of the gear box and made the required analysis and required assembly Using Solidworks and Ansys to ensure that our design will endure the stress and work properly .Now we have reached the final step which is manufacturing those parts of the gear box, and to do that each part of that gearbox (gears ,pinions, rods and shafts) had gone in same Steps of Manufacturing using Milling Machine process.

Manufacturing Steps Using Mastercam program:

1-Import the desired design from Solidworks or another 3D drawing program.

2- Choose Milling Machine as the Manufacturing Machine

3- Define the suitable Stock size

4- Choose the most appropriate toolpath to shape that stock

5- Simulate the Manufacturing process in the program

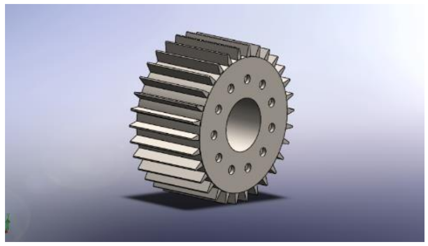
6- Generate the NC files and the G code of that manufacturing process

7- Using the generated G code in the Milling Machine CNC to Manufacture the desired part.

Note: In this thesis we only show the manufacturing information related to ONE GEAR among many parts in the Gearbox and all related drawings and manufacturing files are collected in one specific file for this project .

Manufacturing Process

The Selected part to manufacture:



The Toolpaths that Used to manufacture that Gear:

1- Face Milling

The tool info.: type = Endmill3Bull diameter = 62mm Corner diameter: 1.2mm flutes = 7

Cutting speed (Cs)=150 Feed per teeth(fpt) = 0.16 Feed rate= 1272.32 plunge rate =424.0667

2- Contour

The tool info: type = end mill diameter =1.5mm flutes= 4

Cutting speed = 150 fpt=0.09 plunge rate = 3819.6 Feed rate = 11458.8

3- Drill (center drill)

The tool info. : type = Ctr Drill diameter = 3.15mm flutes = 2

Cs = 14.8 fpt = 0.0502 feed rate = 150

4- Drill

The tool info.: type= Drill diameter = 22 mm flute =2

Cs= 14.8 fpt =0.3505 feed rate = 150

5- Pocket

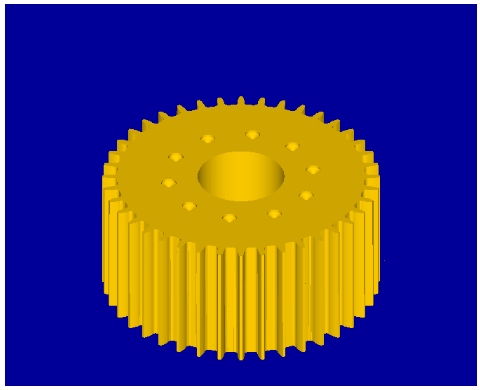
The tool info.: type= endmill diameter = 14mm flutes = 7

Cutting Speed (Cs)=120 Feed per teeth (fpt) = 0.08 Feed rate = 1527.68

Plunge rate = 509.23 Spindle rate = 2728

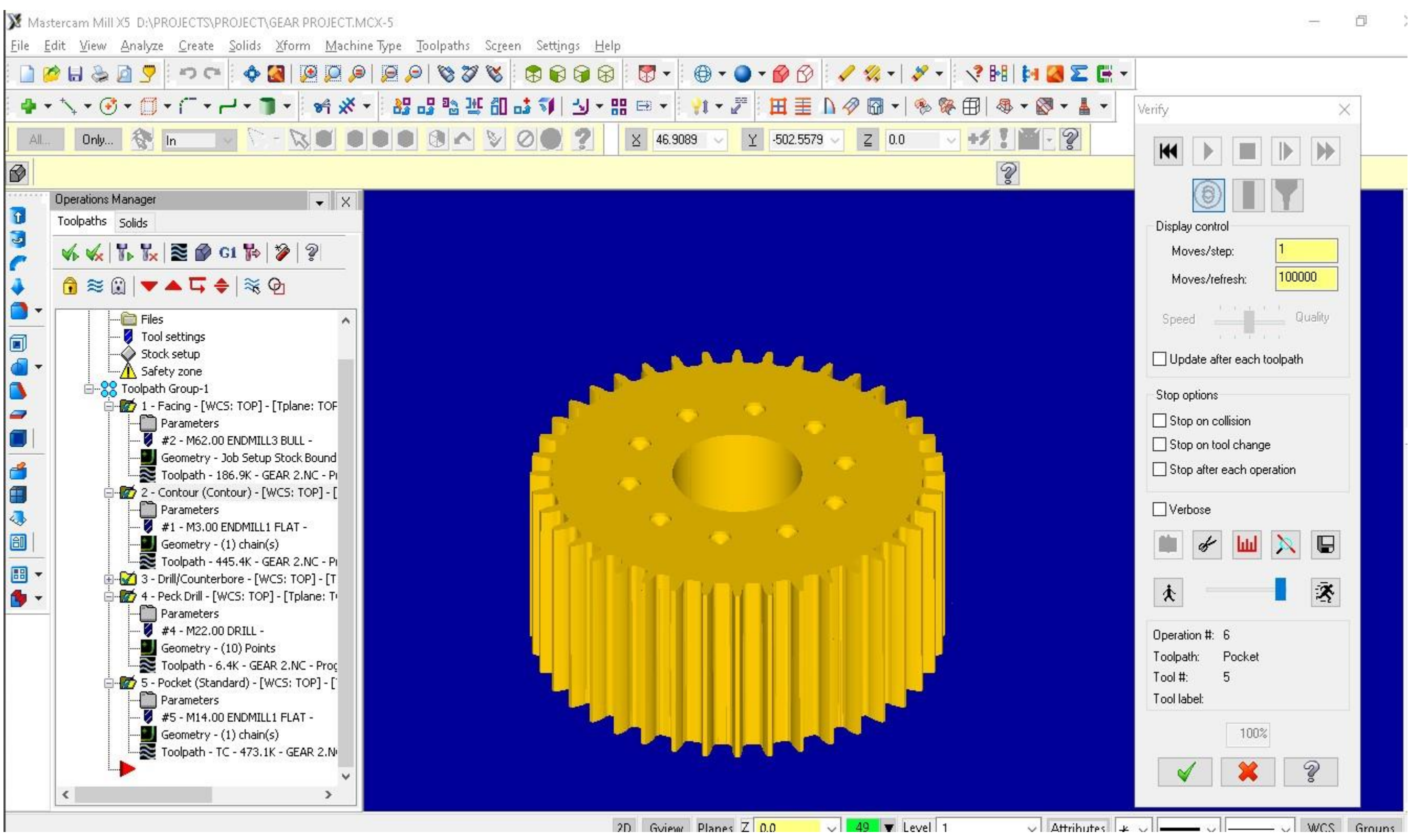
Manufacturing process

The selected part showing in simulation after applying the Manufacturing steps:



`

The Selected part as in Mastercam program:



Manufacturing process

After we simulated the Manufacturing process, we are going to generate the G codes (NC files) to Manufacture that part using Milling Machine CNC.

Note: the code below is just apart from the original Code file.

The G code for that Gear:

```
N100 G21

N102 G0 G17 G40 G49 G80 G90

N104 T2 M6

N106 G0 G90 G54 X273.672 Y29.142 A0. S1136 M3

N108 G43 H2 Z25.

N110 Z6.

N112 G1 Z1. F424.1

N114 X256.139 Y-.055 F1272.3

N116 G3 X256.121 Y-.094 I.06 J-.052

N118 G1 X255.604 Y-4.927

N120 X255.012 Y-9.653

N122 X254.658 Y-12.165

N124 X254.266 Y-14.742

N126 X253.836 Y-17.37

N128 X253.368 Y-20.038

N130 X252.862 Y-22.738

N132 X252.318 Y-25.464

N134 X251.736 Y-28.211

N136 X251.115 Y-30.976

N138 X250.457 Y-33.754

N140 X249.76 Y-36.543
```

Continue with the G code:

```
N142 X249.025 Y-39.341
N144 X248.251 Y-42.144
N146 X247.439 Y-44.952
N148 X246.589 Y-47.762
N150 X245.701 Y-50.573
N152 X244.774 Y-53.383
N154 X243.809 Y-56.191
N156 X242.806 Y-58.996
N158 X241.765 Y-61.796
N160 X240.686 Y-64.59
N162 X239.57 Y-67.377
N164 X238.415 Y-70.156
N166 X237.223 Y-72.927
N168 X235.994 Y-75.687
N170 X234.727 Y-78.437
N172 X233.423 Y-81.175
N174 X232.082 Y-83.901
N176 X230.704 Y-86.614
N178 X229.29 Y-89.312
N180 X227.84 Y-91.996
N182 X226.353 Y-94.664
N184 X224.83 Y-97.315
N186 X223.272 Y-99.95
N188 X221.678 Y-102.567
N190 X220.049 Y-105.166
N192 X218.384 Y-107.745
N194 X216.685 Y-110.305
N196 X214.952 Y-112.845
N198 X213.185 Y-115.363
```

```
N200 X211.383 Y-117.86
N202 X209.548 Y-120.335
N204 X207.68 Y-122.787
N206 X205.779 Y-125.216
N208 X203.845 Y-127.621
N210 X201.879 Y-130.002
N212 X199.88 Y-132.357
N214 X197.85 Y-134.687
N216 X195.789 Y-136.991
N218 X193.697 Y-139.268
N220 X191.575 Y-141.518
N222 X189.422 Y-143.741
N224 X187.239 Y-145.935
N226 X185.027 Y-148.101
N228 X182.786 Y-150.238
N230 X180.516 Y-152.345
N232 X178.218 Y-154.422
N234 X175.892 Y-156.469
N236 X173.538 Y-158.484
N238 X171.158 Y-160.469
N240 X168.751 Y-162.422
N242 X166.319 Y-164.343
N244 X163.86 Y-166.232
N246 X161.377 Y-168.088
N248 X158.868 Y-169.911
N250 X156.336 Y-171.7
N252 X153.78 Y-173.455
N254 X151.2 Y-175.176
N256 X148.598 Y-176.863
```

Conclusion

reduction gear box with all its components like spur gears, pinions, integral shaft, and radial ball bearings are modeled in a 3D cad tool called SOLIDWORKS. And analysis is done in solid works simulation. The strength of the gear is an important parameter while designing a gear. In this project to compare the theoretical and simulation values of helical gear by varying the face width of the gear. Finally, the design is safe. The product design requires the dimensions and their characteristics of different size. Market requirements stipulated that the product needed to be with different size that can fit the circumstances and conditions where it will be used, therefore.

required product to be with different size that can meet the market demand. Therefore, it is essential to create members of family of same products but with different dimensions and characteristics. Usage of computer in the design of these members as well as, usage of computer in creation of construction of a member of family has considerable effect in shortening the time of product and cost and in increase efficiency and quality of product.

References

1. Ogura, I.; Kotake, M.; Ata, S. Quantitative evaluation of carbon nanomaterial releases during electric heating
wire cutting and sawing machine cutting of expanded polystyrene-based composites using thermal carbon
analysis. *J. Occup. Environ. Hyg.* **2018**. [CrossRef]

2. Aryafar, A.; Mikaeil, R.; Haghshenas, S.S.; Haghshenas, S.S. Application of metaheuristic algori1thms to
optimal clustering of sawing machine vibration. *Measurement* **2018**, *124*, 20–31. [CrossRef]
strategies for parallel robot instruction. *IEEE Trans. Educ.* **2013**, *56*, 268–273. [CrossRef]

3. Li, C.; Ji, S.M.; Tan, D.P. Softness abrasive flow method oriented to tiny scale mold structural surface. *Int. J.
Adv. Manuf. Technol.* **2012**, *61*, 975–987. [CrossRef]

4. Han, D.; Zhao, N.; Shi, P. Gear fault feature extraction and diagnosis method under different load excitation
based on EMD, PSO-SVM and fractal box dimension. *J. Mech. Sci. Technol.* **2019**, *33*, 487–494. [CrossRef]

5. Zhang, L.B.; Lv, H.P.; Tan, D.P.; Xu, F.; Chen, J.L.; Bao, G.J.; Cai, S.B. An adaptive quantum genetic algorithm
for task sequence planning of complex assembly systems. *Electron. Lett.* **2018**, *54*, 870–871. [CrossRef]

6. Tan, D.P.; Chen, S.T.; Bao, G.J.; Zhang, L.B. An embedded lightweight GUI component library and the
ergonomics optimization method for industry process monitoring. *Front. Inf. Technol. Electron. Eng.* **2018**, *19*,
604–625. [CrossRef]

7. He, C.R.; Qin, W.B.B.; Ozay, N.; Orosz, G. Optimal gear shift schedule design for automated vehicles: Hybrid
system based analytical approach. *IEEE Trans. Control Syst. Technol.* **2018**, *26*, 2078–2090. [CrossRef]

8. Ge, J.Q.; Tan, D.P.; Ji, S.M. A gas-liquid-solid three-phase abrasive flow processing method based on bubble
collapsing. *Int. J. Adv. Manuf. Technol.* **2018**, *95*, 1069–1085. [CrossRef]

9. Zhang, L.; Yuan, Z.; Tan, D.; Huang, Y. An Improved abrasive flow processing method for complex geometric
surfaces of titanium alloy artificial joints. *Appl. Sci.* **2018**, *28*, 1037. [CrossRef]
10. Tan, D.P.; Zhang, L.B. A WP-based nonlinear vibration sensing method for invisible liquid steel slag detection.
Sens. Actuators B Chem. **2014**, *202*, 1257–1269. [CrossRef]
11. Zeng, X.; Ji, S.M.; Jin, M.S.; Tan, D.P.; Ge, J.Q. Research on dynamic characteristic of softness consolidation
abrasives in machining process. *Int. J. Adv. Manuf. Technol.* **2016**, *82*, 1115–1125. [CrossRef]
12. Tan, D.P.; Ji, S.M.; Fu, Y.Z. An improved soft abrasive flow finishing method based onfluid collision theory.
Int. J. Adv. Manuf. Technol. **2016**, *85*, 1261–1274. [CrossRef]
13. Xu, Z.F.; Shao, R.P. Forecast of sound pressure level of gear systems and fault diagnosis based on acoustics.
Comput. Meas. Control **2009**, *17*, 1688–1691.
14. Ji, S.M.; Weng, X.X.; Tan, D.P. Analytical method of softness abrasive two-phase flow field based on 2D
model of LSM. *Acta Phys. Sin.* **2012**, *61*, 188–198.
15. Zeng, X.; Ji, S.M.; Jin, M.S.; Tan, D.P.; Li, J.H.; Zeng, W.T. Investigation on machining characteristic of
pneumatic wheel based on softness consolidation abrasives. *Int. J. Precis. Eng. Manuf.* **2014**, *15*, 2031–2039.
[CrossRef]
16. Tan, D.P.; Ji, S.M.; Li, P.Y.; Pan, X.H. Development of vibration style ladle slag detection method and the key
technologies. *Sci. China Technol. Sci.* **2010**, *53*, 2378–2387. [CrossRef]
17. Gu, Y.Z.; Zuo, D.W.; Xu, W.M. A modal analysis and optimization of physiotherapy appliance bed structure.
Mach. Build. Autom. **2009**, *1*, 36–39.
18. Jiang, L.; Xiang, D.; Mou, P.; Shen, Y.H. Study of gearbox's robust optimization design. *Mach. Des. Manuf.*
2018, *1*, 14–16.