Design and Analysis of Gear Pinion

(For Spur, Helical and Bevel pinions)

E. Shiva Shanker Kumar
Automobile Engineering Department.
Maturi Venkata Subba Rao (MVSR) Engineering College.
Hyderabad, Telangana, India.

Abstract—**A Pinion is a ger usually meshed with a driven gear is used for power transmission. The power from the source is directly transmitted to pinion by means of shafts, belts or chains etc.. A pinion is the live gear in the drive train. It is therefore very Important to design a pinion in such a way that it withstands all the designed loads on the transmission system. There are several parameters which influence the design of a pinion gear. In this paper we deal with design and analysis of all the gear pinions like spur, helical and bevel pinions.**

Keywords—Pinion, spur, bevel, helical and transmission.

I. INTRODUCTION

The pinion gear is the driving force for the entire transmission system. In this paper we discuss the parameters that affect the design of a gear pinion and the analysis of the gear. We take an example of a gear train and calculate all the parameters of the gear. We check the designed for maximum load conditions.

II. TERMS USED IN GEARS.

S.No.	Terms used in Gears.	
	Terms.	***Definition.***
1.	Pitch circle.	Imaginary circle which would give same motion as actual gears.
2.	Pitch circle diameter.	Diameter of pitch circle.
3.	Pitch point.	Point of contact between two pitch circles.
4.	Pitch surface.	Surface of two rolling discs which the gears have replaced.
5.	Pressure angle.	Angle between normal and tangent at the point of contact (φ).
6.	Addendeum.	Distance between pitch circle and top of gear.
7.	Dedendum.	Distance between pitch circle and bottom of gear tooth.
8.	Circular pitch.	Distance between two corresponding points on gear tooth when measured wrt circumference.
9.	Diametral pitch.	Ratio of no.of teeth to pitch circle diameter.
10.	Module.	Ratio of pitch circle diameter to no of teeth.

III. FACTORS AFFECTING THE DIAMETER OF PINION.

- A common question arises in designing a gear or a drive train is "what should be the diameter of the pinion?".
- The diameter of pinion links all the parameters required for designing a drive train.
- The diameter of pinion depends on the availability of space for the drive train and the selection of material.
- As we all know diameter of driven gear is directly proportional to dia. Of pinion.
- In case of high gear ratio applications, the size of gearbox is huge, in such cases multiple reduction geartrain is used.
- Selection of material plays a very important role in compatibility of geartrain.

Properties of gear materials			
Material	***Condition***	***B.H.N.***	***Minimum tensile strength(N/mm^2)***
Malleable cast iron (a)White heart castings, Grade B (b)Black heart castings, Grade B	- -	217 max 149 max	280 320
Cast iron (a) Grade 20 (b) Grade 25 (c) Grade 35 (d) Grade 35	As cast As cast As cast Heat treated	179 min 197 min 207 min 300 min	200 250 250 350
Cast steel	-	145	550
Carbon steel (a)0.3%carbon (b)0.3%carbon	Normalised Hardened and tempered	143 152	500 600
(c)0.4%carbon (d)0.4%carbon (e)0.35%carbon (f)0.55%carbon	Normalised Hardened and tempered Normalised Hardened and tempered	152 179 201 223	580 600 720 700
Carbon manganese steel (a)0.27%carbon (b)0.37%carbon	Hardened and tempered "	170 201	600 700
Manganese molybdenum steel (a)35 Mn 2 Mo 28 (b)35 Mn 2 Mo 45	Hardened and tempered	201 229	700 800

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 11 Issue 02, February-2022

Properties of gear materials

Material	***Condition***	***B.H.N.***	***Minimum tensile strength(N/ mm²)***
Chromium molybdenum steel (a)40 Cr 1 Mo 28 (b)40 Cr 1 Mo 60	Hardened and tempered	201 248	700 900
Nickel steel 40 Ni 3	Hardened and tempered	229	800
Nickel chromium steel 30 Ni 4 Cr 1	Hardened and tempered	444	1540
Nickel chromium molybdenum steel 40 Ni 2 Cr 1 Mo 28	Hardened and tempered	255	900
Surface hardened steel			
(a)0.4% carbon steel	-	145(core) 460(case)	551
(b)0.55% carbon steel	-	200(core) 520(case)	708
(c)0.55% carbon chromium steel	-	250(core) 500(case)	866
(d)1% chromium steel	-	500(case)	708
(e)3% nickel steel	-	200(core) 300(case)	708
Case hardened steel			
(a)0.12 to 0.22% carbon	-	650(case)	504
(b)3% nickel	-	200(core) 600(case)	708
(c)5% nickel steel	-	250(core) 600(case)	866
Phosphorus bronze castings	Sand casting Chill cast Centrifugal cast	60min 70min 90 min	160 240 260

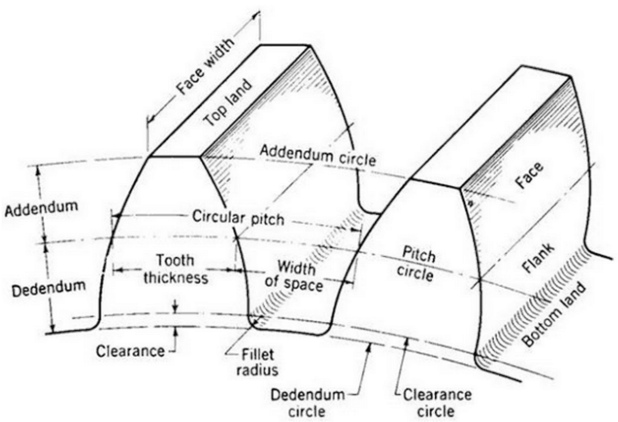


Fig.1. Spur gear terminology.

Design considerations for a gear.

In designing and analyzing a gear the following data is required:

- The power to be transmitted.
- The maximum torque on the system.
- The speed of pinion (or driving gear) usually given in RPM.
- The speed of driven gear.
- The Centre distance between gears. (The Centre distance depends on the orientation, availability of space and mounting feasibility of the gearbox).

A. The following requirements must be met in the design of gear:

a) The gear teeth should have sufficient strength so that they will not fail under static or dynamic loading during normal running conditions.

b) The gear teeth should have wear characteristics so that their life is satisfactory.

c) The use of space and material should be economical.

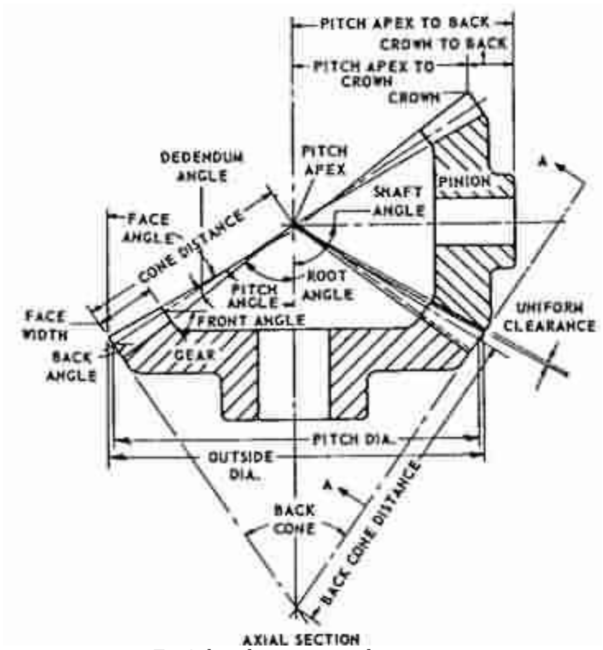


Fig.2. bevel gear nomenclature

V. DESIGN PROCEDURE OF GEAR.

S.No.	***Input parameters***	***values***
1.	Power	10 hp
2.	Torque	150 n-m
3.	Pinion RPM	3400
4.	Driven gear RPM	1500
5.	Gear ratio	2.27:1
6.	Center distance	50 mm
7.	Material	Alloy steel

1) Calculating the no. of teeth:

The minimum no. of teeth required to avoid interference of gears:

$$T_p = \frac{2A_w}{G[(\sqrt{1+1/G\{1/G+2\}\sin^2\varphi})-1]}$$

T_p = teeth on pinion
G = gear ratio.
φ = pressure angle

$$T_p = \frac{2(1)}{2.26[(\sqrt{1+1/2.26\{1/2.26+2\}\sin^2 20^0})-1]}$$

$T_p = 14.4$ (let's say 15)
$T_g = 34$

2) Calculating module:

We know that

$$L = D_P/2 + D_G/2 = 50mm$$

$$2.26\ D_G/2 + D_G/2 = 50$$

$$D_G = 30.67mm\ ;\ D_P = 19.32mm$$

$$\text{Module 'm'} = \frac{D_P}{T_P} = \frac{19.32}{15} = 1.28$$

The nearest standard module is '1.5'

Now,

$$T_P = \frac{19.32}{1.5} = 13 \text{ teeth}$$

$$T_P = \frac{30.67}{1.5} = 20 \text{ teeth}$$

3) Beam strength of gear:

$$W_T = \sigma_w \times b \times \pi \times m \times y$$

a) permissible working stress for gear teeth:

$$\sigma_w = \sigma_o \times C_V$$

$$\sigma_w = 450 \times C_V$$

$$C_V = \frac{3}{3+V} = \frac{3}{3+4} = 0.42$$

$$\therefore \sigma_w = 450 \times 0.42 = 192.85\ N/mm^2$$

b) Lewis form factor (y):

$$y = 0.154 - \frac{0.912}{T}$$

$$y = 0.083$$

Tangential tooth load:

$$W_T = 192.85 \times 15 \times \pi \times 1.5 \times 0.083$$

$$W_T = 1142.97\ N$$

Therefore, the gear can transmit **1147.97 N**

Standard proportions of gear systems

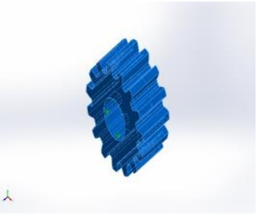
S.No.	***Particulars***	***14 ½ composite or full depth involute system***	***20˚ full depth involute system***	***Values (mm)***
1.	Addendum	1m	1m	1.5
2.	Dedendum	1.25m	1.25m	1.875
3.	Working depth	2m	2m	3
4.	Minimum total depth	2.25m	2.25m	3.375
5.	Tooth thickness	1.5708m	1.5708m	2.35
6.	Minimum clearance	0.25m	0.25m	0.375
7.	Fillet radius at root	0.4m	0.4m	0.6

Abbreviations:

P	Power
T	Torque
T_P	Teeth on pinion
T_G	Teeth on gear
G	Gear ratio
N	Rpm
V	Pitch line velocity
σ_W	Permissible working stress
σ_o	Allowable working stress
E_V	Velocity factor
W_T	Tangential load
m	Module
b	Width of gear
y	Lewis form factor
Q	Pressure angle
D_P	Diameter of pinion
D_G	Diameter of gear
L	Centre distance

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 11 Issue 02, February-2022

Simulation of spur pinion.

Model Reference	Properties	
	Name:	Alloy Steel (SS)
	Model type:	**Linear Elastic Isotropic**
	Default failure criterion:	**Unknown**
	Yield strength:	**620.422 N/mm^2**
	Tensile strength:	**723.826 N/mm^2**
	Elastic modulus:	**210,000 N/mm^2**
	Poisson's ratio:	**0.28**
	Mass density:	**7.7 g/cm^3**
	Shear modulus:	**79,000 N/mm^2**
	Thermal expansion coefficient:	**1.3e-05 /Kelvin**

STUDY RESULTS

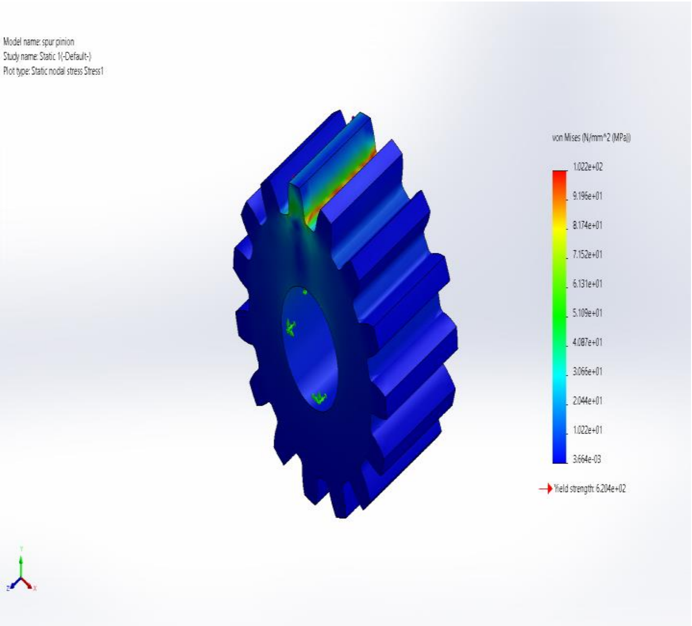


Fig.3. von mises stress result.

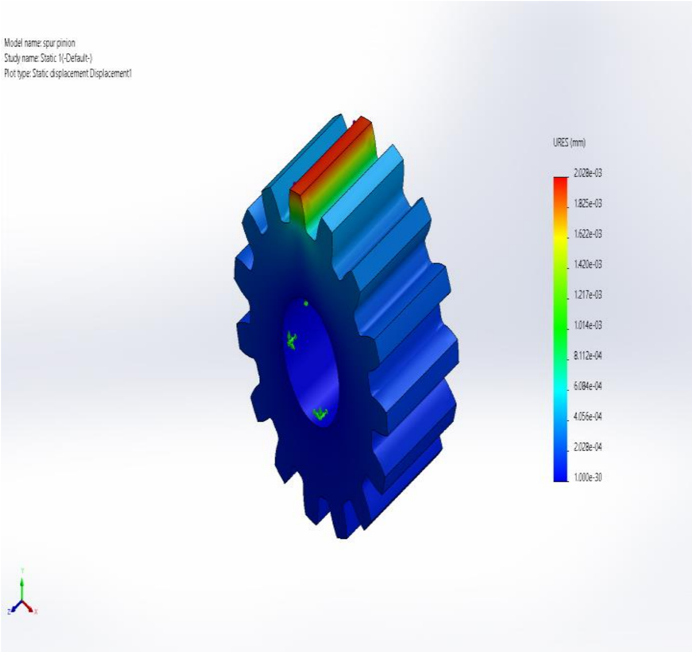


Fig.4. Resultant displacement result.

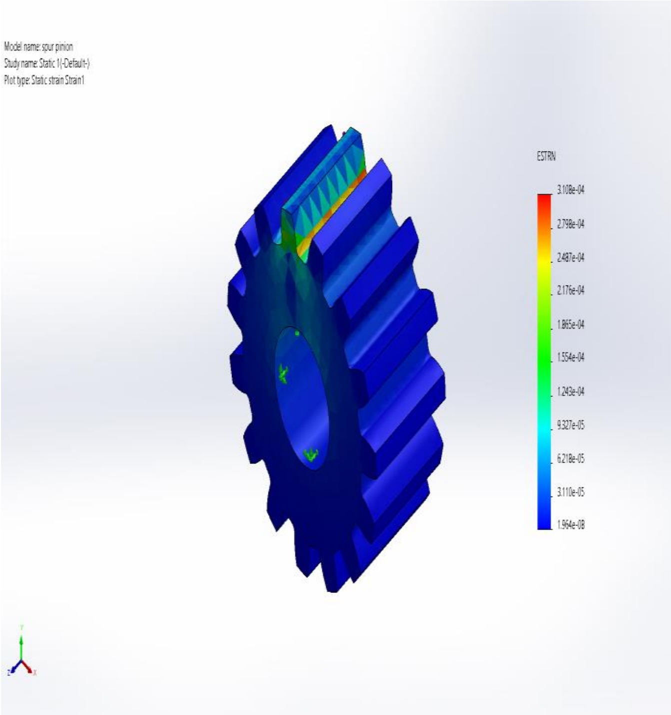


Fig.5. equivalent strain result.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 11 Issue 02, February-2022

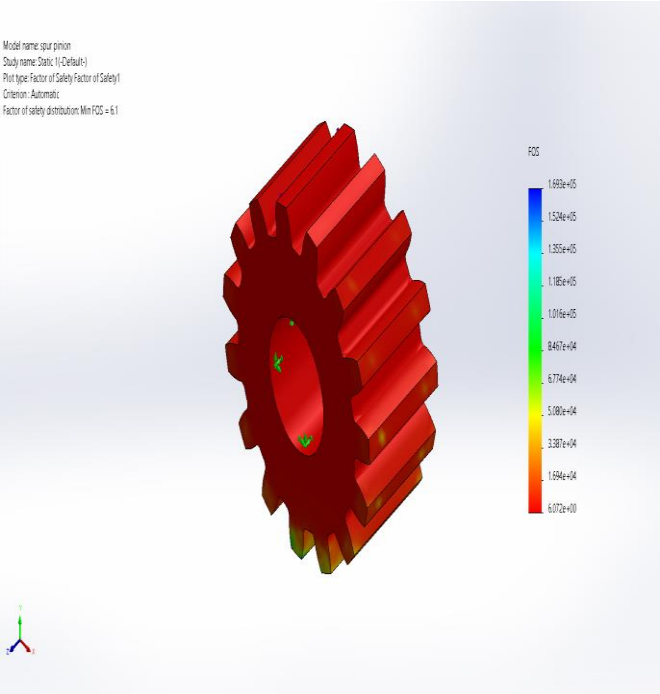


Fig.6. FOS result.

CONCLUSION.

The gear is designed and simulated the maximum displacement was found **2.028e-03mm**. The above calculations are applicable for helical and Bevel gears as well.

REFERENCES.

[1] Budynas-Nisbett "Shigley's Mechanical Engineering Design", Eighth Edition, 2008; Pg. 746-47
[2] Gitin M. Maitra:" Handbook of gear design", 1994 Stephen, P. Radzevich; "Dudley's Handbook of Practical Gear Design and Manufacture",Second Edition, 2012.
[3] Kapelevich, A. and McNamara, T., "Direct Gear Design for Automotive Applications", 2013
[4] Milosav Ognjanovicl Miroslav Milutinovic2," Design for Reliability Based
Methodology For Automotive Gearbox Load Capacity Identification", 2012
[5] R.S. Kurmi, "Theory of Machines", 14th Revised Edition, 2004.
[6] R.S. Kurmi, J.K.Gupta "Machine Design",Eurasia Publication House, 2005.