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Design and Optimization on Sprocket Wheel with Different Materials

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ABSTRACT

The sprocket is a very essential part in the transmission of power and motion in most motorcycles. Generally sprockets are made of mild steel. In this paper, existing sprocket motorcycle is compared with the sprocket of carbon Cast Iron, Stainless Steel and Steel materials. The drawing and drafting is done using CAD and Pro/E software. Further FEA software is used for analysis of sprocket wheel. With different properties of mild steel and other materials, stress and deformation of sprocket is compared. This work will be useful for further development of sprockets wheels.

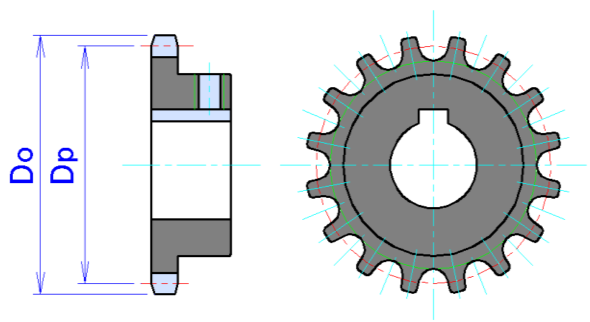
Keywords : CAD, Pro/E, FEA, Mild steel, Stainless Steel, Steel, Cast Iron, Sprocket, Stress and deformation.

I. INTRODUCTION

A **sprocket** or **sprocket-wheel** is a profiled wheel with teeth, or cogs, that mesh with a chain, track or other perforated or indented material. The name 'sprocket' applies generally to any wheel upon which radial projections engage a chain passing over it. It is distinguished from a gear in that sprockets are never meshed together directly, and differs from a pulley in that sprockets have teeth and pulleys are smooth.

Sprockets are used in bicycles, motorcycles, cars, tracked vehicles, and other machinery either to transmit rotary motion between two shafts where gears are unsuitable or to impart linear motion to a track, tape etc. Perhaps the most common form of sprocket may be found in the bicycle, in which the pedal shaft carries a large sprocket-wheel, which drives a chain, which, in turn, drives a small sprocket on the axle of the rear wheel. Early automobiles were also largely driven by sprocket and chain mechanism, a practice largely copied from bicycles.

Sprockets are of various designs, a maximum of efficiency being claimed for each by its originator. Sprockets typically do not have a flange. Some sprockets used with timing belts have flanges to keep the timing belt centered. Sprockets and chains are also used for power transmission from one shaft to another where slippage is not admissible, sprocket chains being used instead of belts or ropes and sprocket-wheels instead of pulleys. They can be run at high speed and some forms of chain are so constructed as to be noiseless even at high speed.



PROBLEM ARISES IN SPROCKET

The sliding motion between chain roller and sprocket tooth causes friction wear and wear occur in pin hole of chain rollers making the chain to elongate and so that chain becomes slack. Chain sprocket has problems like breaking of bushings and/or rollers, breaking of plates and pins (unusual cracks), quickly wear of sprockets, Worn rollers, etc. Possible causes of these problems are significant overload breakage, high impact pressure, combination of worn chain with new sprockets, excessive chain wear far beyond replacement level etc. Also there is a wear on sprocket tooth and outer surface becomes rough affecting the transmission of motion in motorcycle. According to survey after approx. 20000 km of motorcycle drive chain sprocket assembly needs to be replaced.

II. LETERATURE REVIEW

Based on Literature Review, different design optimization processes and techniques was used by different researchers. Some of them re-designed the chain sprocket, analysis using FEA and using the results from FEA they optimized the weight of sprocket. Mostly researchers have used different grades of steel as their base material and re-designed the sprocket by using different CAD software, few have used composite materials like Carbon Fiber or Nylon66GF30 also as an alternative to steel and compared to earlier research. Some has given heat treatment and other types of chemical treatment to the sprocket to enhance its mechanical properties. For this review, many international and national papers were helpful. Worldwide researchers have applied the efforts to design and tried to optimize the weight of chain sprocket as

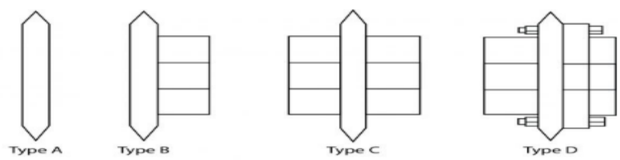
III. INTRODUCTION TO ROLLER CHAIN SPROCKETS

ROLLER CHAIN SPROCKETS

A sprocket is a wheel with teeth, cogs, or even sprockets that mesh with the holes in the links of chain, track, or other perforated material. A sprocket is different from a gear because a sprocket never meshes directly with another sprocket. Sprockets are designed to be used with a specific chain. Choosing the right sprocket optimizes sprocket/chain interaction, ensures drive performance, and decreases maintenance.

Sprockets are characterized by type, which indicates hub style

- **Type A** sprockets are flat and have no hub. They are usually mounted on flanges or hubs of the device they are driving through a series of holes that are plain or tapered.
- **Type B** sprockets have a hub on one side, allowing the sprocket to be fitted closely to the machinery on which it is mounted. This eliminates a large overhung load on the bearings of the equipment.
- **Type C** sprockets are extended on both sides of the plate and usually used on the driven sprocket where the pitch diameter is larger and where there is more weight to support on the shaft. Larger loads should have larger hubs.
- **Type D** sprockets use a type A sprocket mounted on a solid or split hub. The sprocket is split and bolted to the hub for easy removal. Speed ratio can be changed by without having to remove bearings and other equipment.



Types of sprockets

1) SPROCKET SELECTION TERMINOLOGY

Sprocket Caliper Diameter: The measurement from sprocket tooth valley to sprocket tooth valley on the opposite side. It measures the diameter of the sprocket plate without the teeth.

Sprocket Outside Diameter: The measurement from sprocket tooth peak to sprocket tooth peak on the opposite side.

Maximum Bore Diameter: Maximum bore size a sprocket can be machined without compromising structural integrity. Associated with B and C style sprockets.

Length Through Bore (LTB): The inside hub diameter and the length to which it was machined. The length must be able to accommodate the proper sized keyway to withstand shear and torque stress.

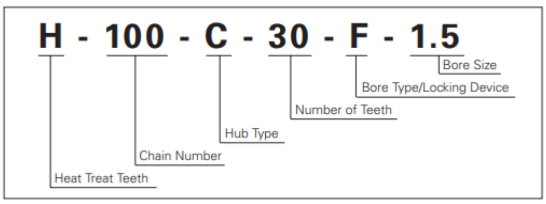
Plain Bore: Associated with B and C style where inside diameter of the hub is machined with a standard keyway and two set screws.

Sprocket Hub Style: A, B, and C style hub configurations are offered by many U.S. manufacturers.

2) TYPES OF SPROCKETS

Double Pitch Sprockets
Multiple Strand Sprockets
QD (Quick Disconnect) Sprockets
Taper-Lock Sprockets
Steel Split Sprockets
Double Single Sprockets
Idler Sprockets
Double Plus Sprockets

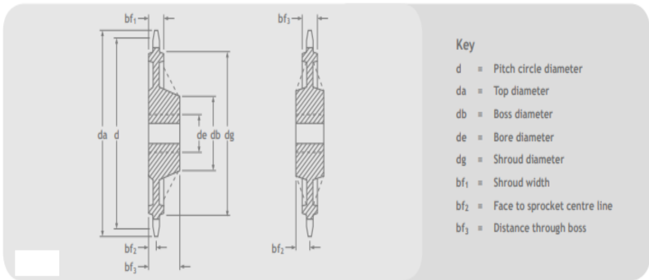
SPROCKET ORDER NUMBER



Sprocket Order Number

SPROCKET DIMENSIONS

Salient sprocket dimensions are shown in below Pitch circle diameter The pitch circle diameter is drawn through the bearing pin centres when a length of chain is wrapped around a sprocket [table 01] shows pitch circle diameter for sprockets to suit a chain of unit pitch. The pitch circle diameters for sprockets to suit a chain of any other pitch are directly proportional to the pitch of the chain, ie, unit PCD x Chain Pitch = Sprocket PCD.



Sprocket Dimensions

Chain Number indicates the type and size of chain that will run on the Sprocket. For ANSI roller chain, the right hand number refers to the chain proportions. For example, 0 (zero) is for normal proportions. The numbers to the left of the right-hand digit denote the number of 1/8 inches in the pitch. The letter "H" following the chain number denotes heavy series. British Standard roller chain does not have a designation for the proportions of the chain. Instead, the first two digits of the chain number denote the number of 1/16 inches in the pitch.

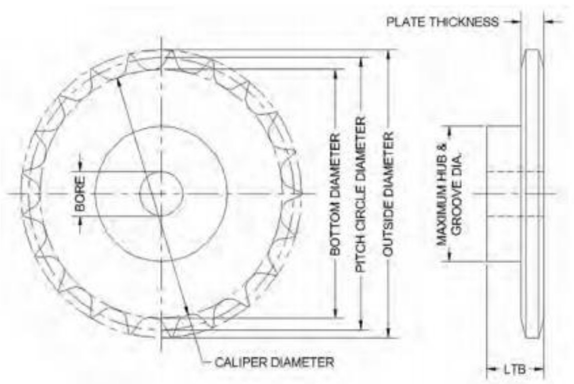
Chain Pitch is the distance between the pin centerlines in a link of chain. This distance is used to make the tooth profile of a sprocket, but cannot easily be measured on a finished sprocket. If the pitch of a sprocket is incorrect, the chain will not sit properly when wrapped around the teeth.

Pitch Diameter is the diameter of the theoretical circle that passes through the centers of the link pins when the chain is wrapped around the sprocket. This can't be measured on the sprocket itself, since it is a dimension used to design to tooth profile.

Bottom Diameter is the diameter of a circle tangent to the curve (called the seating curve) at the bottom of the tooth gaps. This dimension cannot be measured properly on odd-toothed sprockets, so the Caliper Diameter is used.

Caliper Diameter is the same as the bottom diameter for a sprocket with an even number of teeth. For a sprocket with an odd number of teeth, it is the distance from the bottom of one tooth gap to the bottom of the nearest opposite tooth gap.

Outside Diameter is the diameter over the tips of the sprocket teeth.



sprocket dimensions explanation

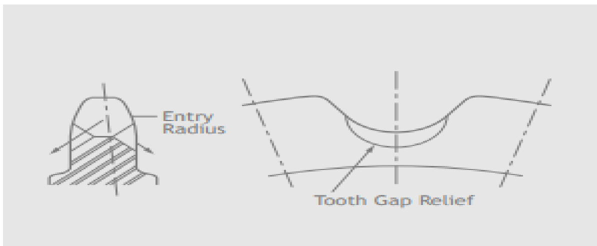
No.of teeth	Unit pitch circle diameter	No. of teeth	Unit pitch circle diameter	No. of teeth	Unit pitch circle diameter
6	2,000	21	6,709	36	11,474
7	2,305	22	7,027	37	11,792
8	2,613	23	7,344	38	12,110
9	2,924	24	7,661	39	12,428
10	3,236	25	7,979	40	12,746
11	3,549	26	8,296	41	13,063
12	3,864	27	8,614	42	13,382
13	4,179	28	8,931	43	13,700
14	4,494	29	9,249	44	14,018
15	4,810	30	9,567	45	14,336
16	5,126	31	9,885	46	14,654
17	5,442	32	10,202	47	14,972
18	5,759	33	10,520	48	15,290
19	6,076	34	10,838	49	15,608
20	6,392	35	11,156	50	15,926

Table 1: length of chain is wrapped around a sprocket

TOOTH FORM

For most applications sprocket teeth as cast and unmachined are satisfactory, but machine cut teeth may however be preferable as referred to later. In conjunction with the chain rollers, the shape of the teeth facilitates a smooth gearing action. The teeth shape, whether cast or cut, is based on chain roller diameter and pitch for each specific chain. To ensure easy entry and exit of the chain the teeth have a radius on their outside faces at the periphery. When an application calls for a size of sprocket and a number of teeth that are not contained within the stock sprocket range then fabricated steel sprockets are supplied with flame cut teeth.

The accuracy of flame cut tooth form is usually better than the cast tooth form and has generally replaced it for non-stock sprockets. If necessary, fabricated sprockets can be manufactured fro medium carbon steel and the teeth can then be flame hardened to give a very tough, hard-wearing surface. In some handling equipment such as elevators and scraper conveyors, both the chain and the sprockets have to operate in contact with bulk material. This is liable to enter the spaces between the chain rollers and sprocket teeth, where the roller pressure can cause it to pack. If this is allowed to occur, the chain then takes up a larger pitch circle diameter leading to excessive chain tension, and possibly breakage. This packing effect can be minimised by relieving the tooth gap as shown in below.



Tooth gap

Machine cut teeth with their closer tolerances are employed in the class of applications listed because of their greater accuracy.

High speed applications with chain speed in excess of about 0.9m/s.

Where synchronization of the chain to a predetermined stopping position is required.

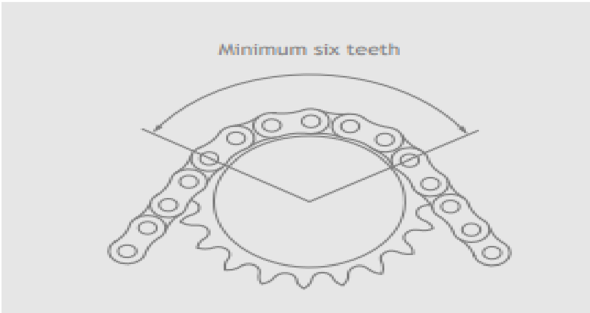
Where numerous sprockets are employed in a closed circuit and variations in tooth form and pitch circle diameter could result in a tendency to tighten or slacken the chain on straight sections. This applies particularly where the sprockets are closely spaced in either the horizontal or vertical planes or in close proximity in combined planes.

Where the linear chain speed variation has to be reduced to a minimum. Number of teeth For the majority of conveyor applications, experience shows that eight teeth represents a reasonable minimum size for sprockets. Below this the effect of polygonal speed variation is pronounced. [table 02] indicates the normal range of sprockets for conveyors and elevators. The maximum number of teeth in any driven sprocket (72) should not exceed 114. This limitation is due to the fact that for a given elongation of chain due to wear, the working pitch diameter of the chain on the sprocket increases in relation to the nominal pitch diameter. The allowable safe chain wear is considered to be in the order of 2% elongation over the nominal length.

Application	Normal range of sprockets *No. of teeth*		
Slat, bar, steel apron, wire mesh or similar conveyors	8-12		
Tray, soft fruit and similar elevators	8-12		
Cask, package and similar elevators	8-12		
Swing tray elevators	16-24		
Ore feed conveyors	6-8		
Scraper conveyors	8-12		
Box scraper conveyors	8-16		
	Normal minimum number of teeth in sprocket		
Bucket elevators	Head	Boot	Deflector
Spaced bucket			
High speed vertical (one or two chains)	14	11	
Medium speed inclined (one or two chains)	14	11	
Slow speed vertical (two chains)	12	11	9
Continuous bucket			
Medium speed; vertical or inclined (one or two chains)	8	8	
Slow speed; vertical or inclined (two chains)	8	8	
	Driver	Top corner	Follower
Gravity bucket conveyor/ Elevator	12	12	8

Table 2: normal range of sprockets for conveyors and elevators

A simple formula for determining how much chain elongation a sprocket can accommodate is 200 N expressed as a percentage where N is the number of teeth on the largest sprocket in the drive system. It is good practice to have the sum of the teeth not less than 50 where both the driver and driven sprockets are operated by the same chain, eg, on a 1:1 ratio drive, both sprockets should have 25 teeth each. Centre distance For optimum wear life, centre distance between two sprockets should normally be within the range 30 to 50 times the chain pitch. On drive proposals with centre distances below 30 pitches or greater than 2m, we would recommend that the drive details are discussed with our technical staff. The minimum distance is sometimes governed by the amount of chain lap on the driver sprocket, our normal recommendation in this circumstance being not less than 6 teeth in engagement with the chain shown below.



Teeth in engagement with the chain

The centre distance is also governed by the desirability of using a chain with an even number of pitches to avoid the use of a cranked link, a practice that is not recommended except in special circumstances. For a drive in the horizontal plane the shortest centre distance possible should be used consonant with recommended chain lap on the driver sprocket. Recommended centre distances for drives can be found in [table 03]. Lie of drive Drives may be arranged to run horizontally, inclined or vertically. In general, the loaded strand of the chain may be uppermost or lowermost as desired. Where the lie of the drive is vertical, or nearly so, it is preferable for the drive sprocket (Z1) to be above the driven sprocket (Z2); however, even with a drive of vertical lie it is quite feasible for the driver sprocket to be lowermost, provided care is taken that correct chain adjustment is maintained at all times.

Pitch	Inch mm	3/8 9.525	1/2 12.70	5/8 15.87	3/4 19.05	1 25.40	1 1/4 31.75	1 1/2 38.1	1 3/4 44.45	2 50.80	2 1/2 63.50	3 76.20
Centre distance	mm	450	600	750	900	1000	1200	1350	1500	1700	1800	2000

Table 3: Recommended centre distances for drives

SELECTION OF SPROCKET MATERIALS

Choice of material and heat treatment will depend upon shape, diameter and mass of the sprocket. [table 04] can be used as a simple guide to the correct selection of sprocket material.

Sprocket	Smooth running	Moderate shocks	Heavy shocks
Up to 29T	EN8 or EN9	EN8 or EN9 Hardened and tempered or case hardened Mild Steel	EN8 or EN9 Hardened and tempered or case hardened Mild Steel
30T and over	Cast iron	Mild Steel or Meehanite	EN8 or EN9 Hardened and tempered or case hardened Mild Steel

Table 4: Correct selection of sprocket material

SPROCKET AND CHAIN COMPATIBILITY

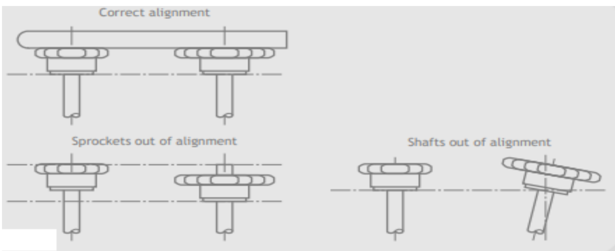
Most drives have an even number of pitches in the chain and by using a driver sprocket with an odd number of teeth, uniform wear distributes over both chain and sprocket teeth is ensured. Even numbers of teeth for both the driver and driven sprockets can be used, but wear distribution on both the sprocket teeth and chain is poor.

Preparation

Check equipment to ensure that general transmission requirements are correct (eg, flexible couplings, flywheel, means of drive adjustment). Check condition and rigidity of the shafts and bearings, particularly if there has been considerable previous service with an alternative method of transmission. Replace or rectify if necessary. Driver and driven shafts should be checked to ensure they are level and parallel to each other. This applies equally to the jockey shaft if present. Use a spirit level and adjustable comparator bar or micrometer between shafts at extreme points on each side of the drive. Rectify any parallelism error present and mark a permanent datum line for the adjustable shaft. Place sprockets or respective shafts in approximate alignment and fit the keys in accordance with correct engineering practice. Do not finally secure keys at this stage. Care must be taken with sprockets of split design to ensure perfect abutting of the faces of each half. Proceed with the key fitting after the halves are finally bolted together, otherwise the key can prevent correct assembly and subsequently result in malgearing. It should be verified that key heads will not project beyond the width of any chaincases.

Checking sprocket alignment

Accurate alignment of shafts and sprocket tooth faces [fig 30] provides a uniform distribution of load across the entire chain width and contributes substantially to maximum drive life. Use a straight edge across the machines faces of the sprockets [fig 31] in several different positions, if possible, as a check against wobble. A nylon or similar line is a good substitute for a straight edge particularly on longer centre distances. Should endwise "float" of shafts be present, make due allowance so that sprocket alignment is correct at the mid position of the "float". When alignment is correct within closest practical limits, drive the keys home and take a final check on sprocket alignment.



Alignment of shafts and sprocket tooth faces

Machines faces of the sprockets

IV. INTRODUCTION TO SOFTWARES USED

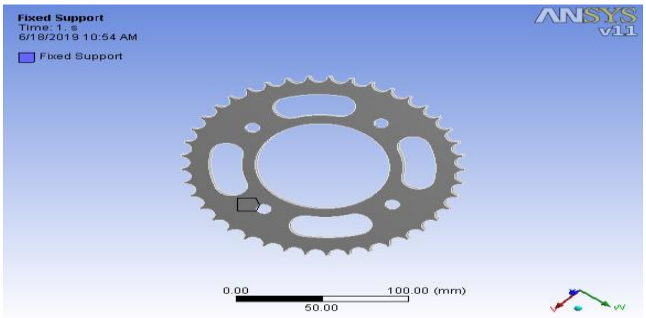
COMPUTER AIDED DESIGN (CAD)

Computer Aided Design (CAD) is the use of wide range of computer based tools that assist engineering, architects and other design professionals in their design activities. It is the main geometry authoring tool within the product life cycle management process and involves both software and sometimes special purpose hardware. Current packages range from 2D vector based drafting systems to 3D parametric surface and solid design modelles.

INTRODUCTION TO PRO/E

PRO/E is the industry's de facto standard 3D mechanical design suit. It is the world's leading **CAD/CAM /CAE** software, gives a broad range of integrated solutions to cover all aspects of product design and manufacturing. Much of its success can be attributed to its technology which spurs its customer's to more quickly and consistently innovate a new robust, parametric, feature based model. Because that ***PRO/E*** is unmatched in this field, in all processes, in all countries, in all kind of companies along the supply chains.***PRO/E*** is also the perfect solution for the manufacturing enterprise, with associative applications, robust responsiveness and web connectivity that make it the ideal flexible engineering solution to accelerate innovations. ***PRO/E*** provides easy to use solution tailored to the needs of small medium sized enterprises as well as large industrial corporations in all industries, consumer goods, fabrications and assembly. Electrical and electronics goods, automotive, aerospace, shipbuilding and plant design. It is user friendly solid and surface modeling can be done easily.

MODAL IS DRAWN:



V. INTRODUCTION TO ANSYS

Introduction

ANSYS is general-purpose finite element analysis (FEA) software package. Finite Element Analysis is a numerical method of deconstructing a complex system into very small pieces (of user-designated size) called elements. The software implements equations that govern the behaviour of these elements and solves them all; creating a comprehensive explanation of how the system acts as a whole. These results then can be presented in tabulated or graphical forms. This type of analysis is typically used for the design and optimization of a system far too complex to analyze by hand. Systems that may fit into this category are too complex due to their geometry, scale, or governing equations.

ANSYS is the standard FEA teaching tool within the Mechanical Engineering Department at many colleges. ANSYS is also used in Civil and Electrical Engineering, as well as the Physics and Chemistry departments.

ANSYS provides a cost-effective way to explore the performance of products or processes in a virtual environment. This type of product development is termed virtual prototyping.

Procedure for ANSYS solutions

Static analysis is used to determine the displacements stresses, stains and forces in structures or components due to loads that do not induce significant inertia and damping effects. Steady loading in response conditions are assumed. The kinds of loading that can be applied in a static analysis include externally applied forces and pressures, steady state inertial forces such as gravity or rotational velocity imposed (non-zero) displacements, temperatures (for thermal strain). A static analysis can be either linear or non linear. In our present work we consider linear static analysis. The procedure for static analysis consists of these main steps

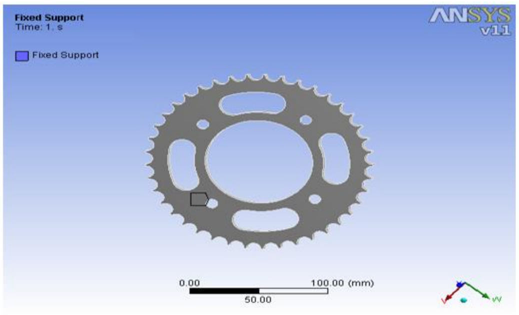
- Building the model
- Obtaining the solution
- Reviewing the results.
- Build the Model

In this step we specify the job name and analysis title use PREP7 to define the element types, element real constants, material properties and model geometry element type both linear and non- linear structural elements are allowed. The ANSYS elements library contains over 80 different element types. A unique number and prefix identify each element type. E.g. BEAM 94, PLANE 71, SOLID 96 and PIPE 16.

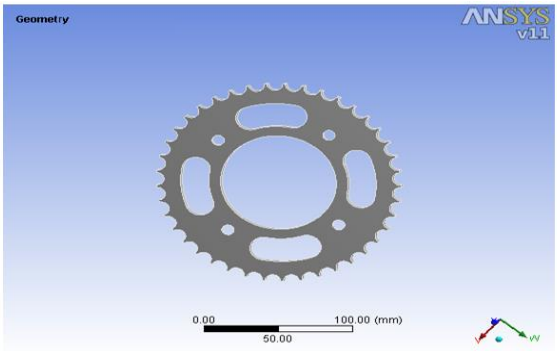
Definition of problem domain

Due to the application of brakes on the car disc brake rotor, heat generation takes place due to friction and this thermal flux has to be conducted and dispersed across the disc rotor cross section. The condition of braking is very much severe and thus the thermal analysis has to be carried out. The thermal loading as well as structure is axis- symmetric. Hence axis-symmetric analysis can be performed, but in this study we performed 3-D analysis, which is an exact representation for this thermal analysis. Thermal analysis is carried out and with the above load structural analysis is also performed for analyzing the stability of the structure.

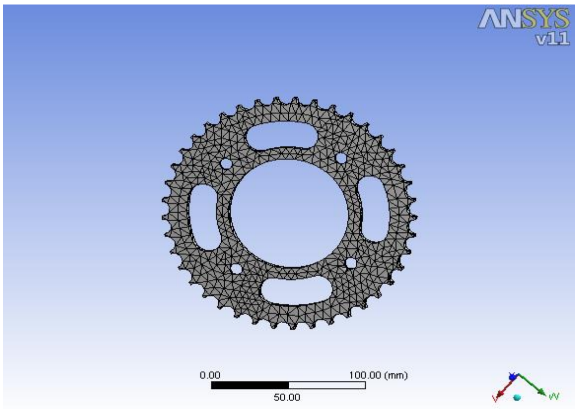
FIXED SUPPORT1



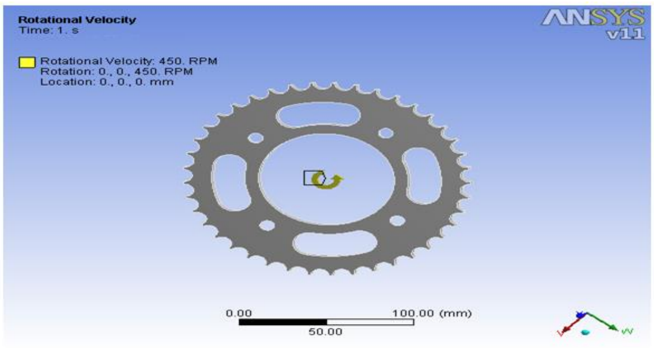
GEOMETRY



MESSING



ROTATIONAL VELOCITY

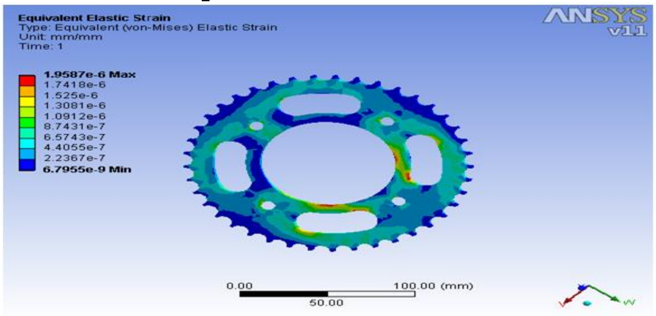


VI. RESULTS AND DISCUSSIONS

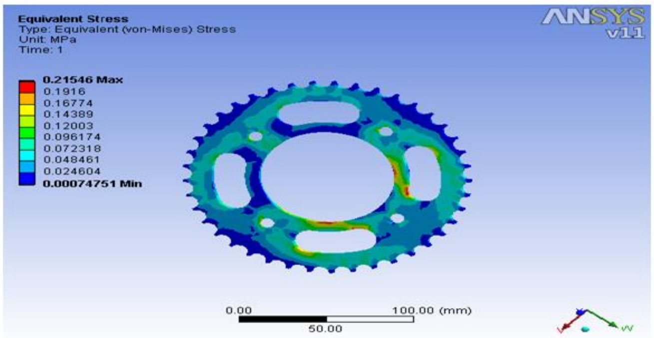
DISCUSSIONS ABOUT DIFFERENT MATERIALS

CAST IRON

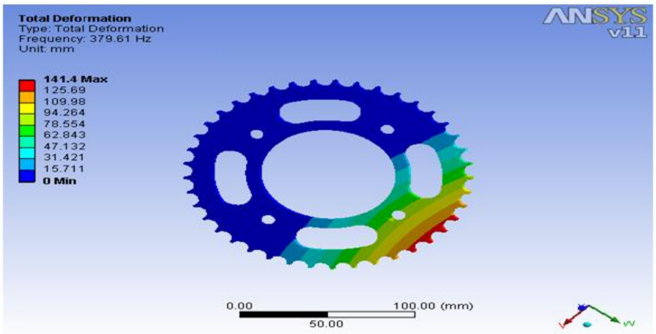
Equivalent Elastic Strain



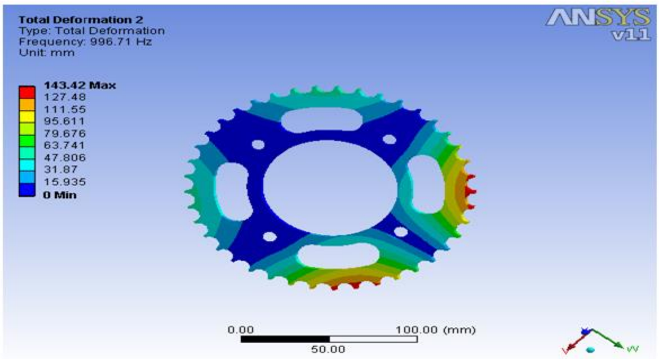
Equivalent stress



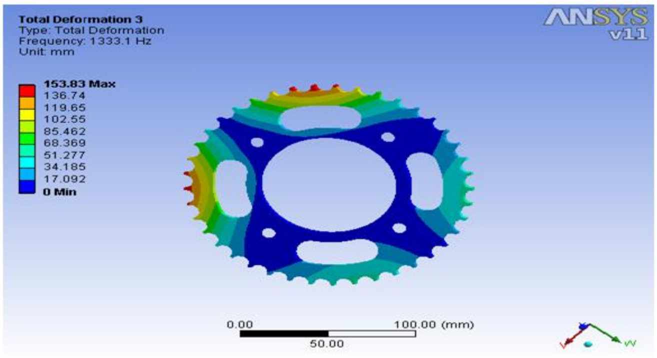
Total Deformation 1



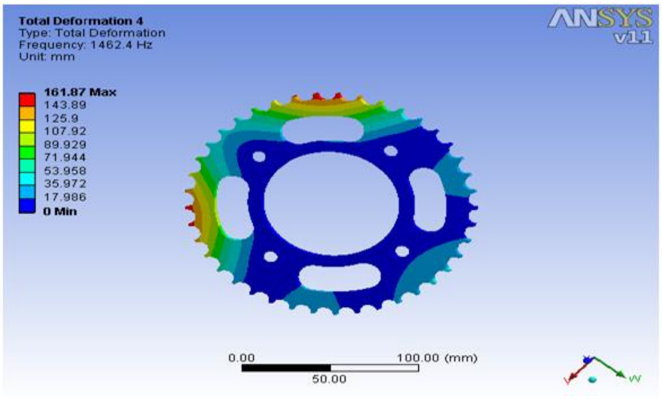
Total Deformation 2



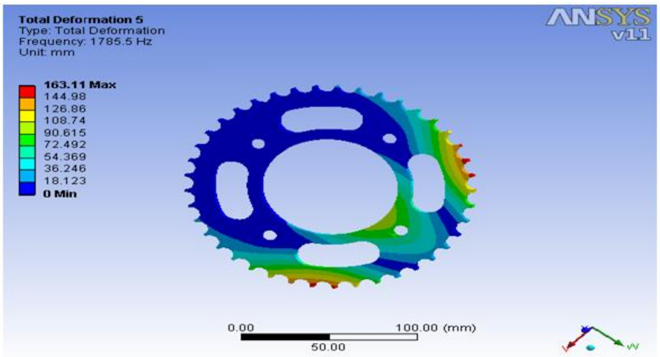
Total Deformation 3



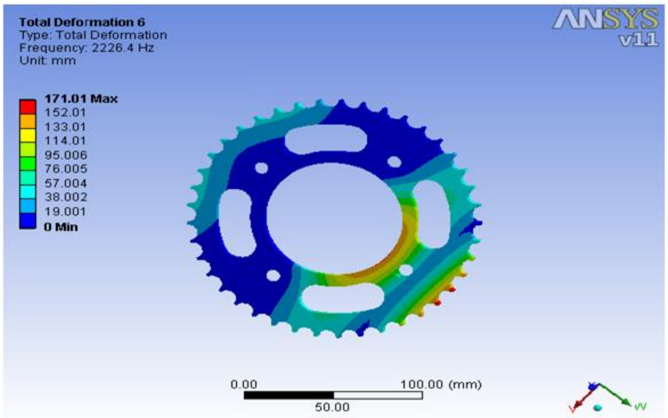
Total Deformation 4



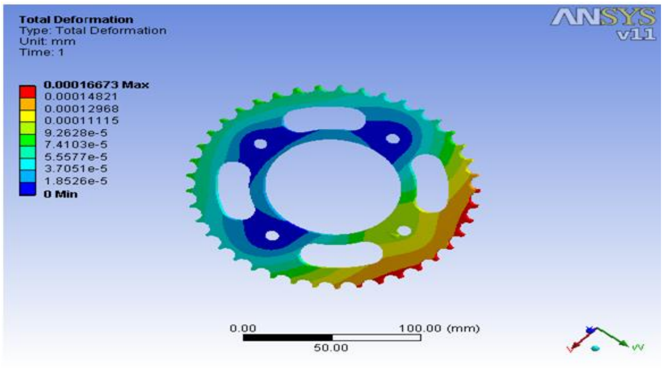
Total Deformation 5



Total Deformation 6

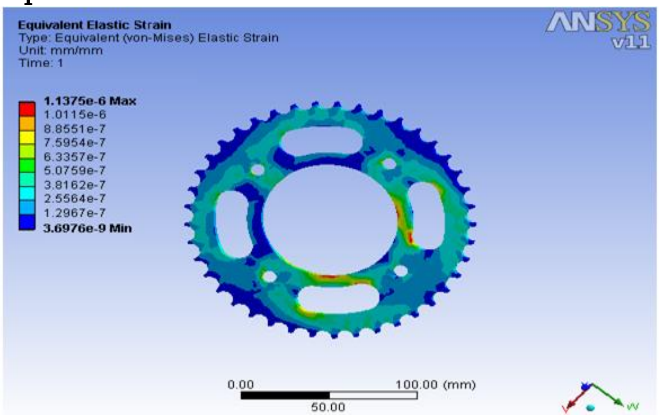


Total deformation

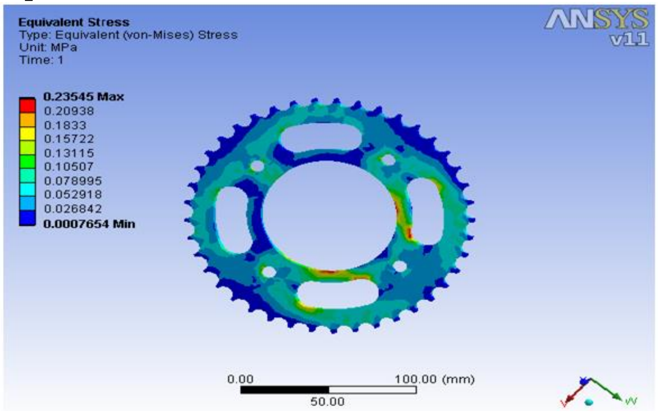


MILD STEEL

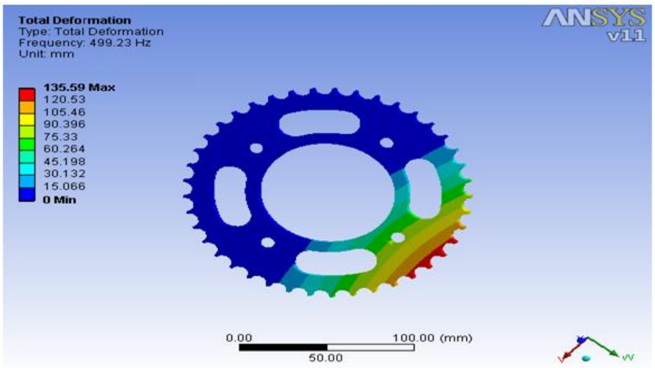
Equivalent elastic stress



Equivalent stress



Total Deformation 1



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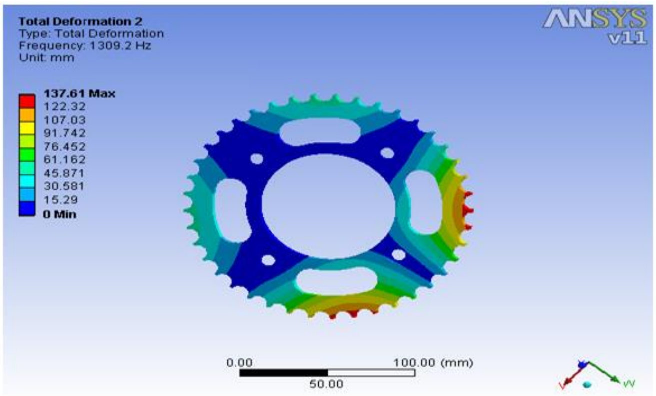

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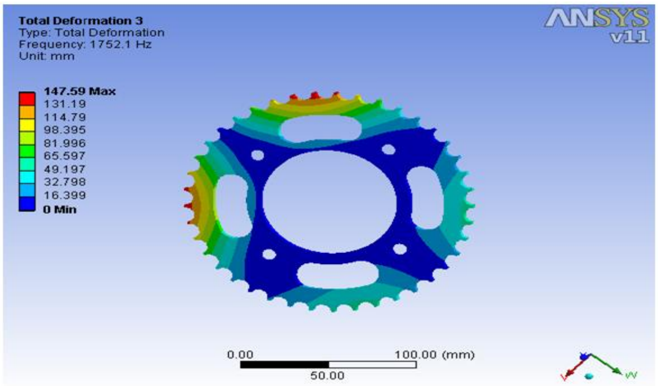

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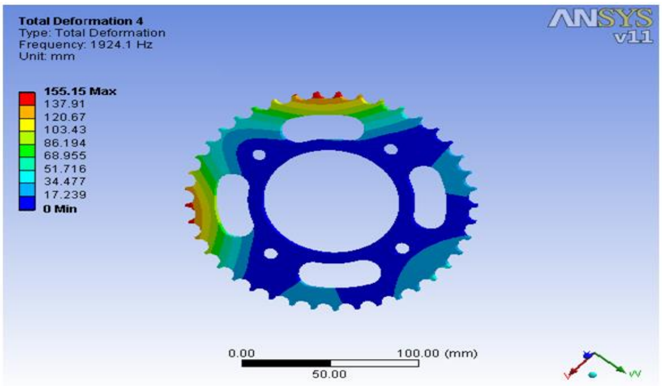

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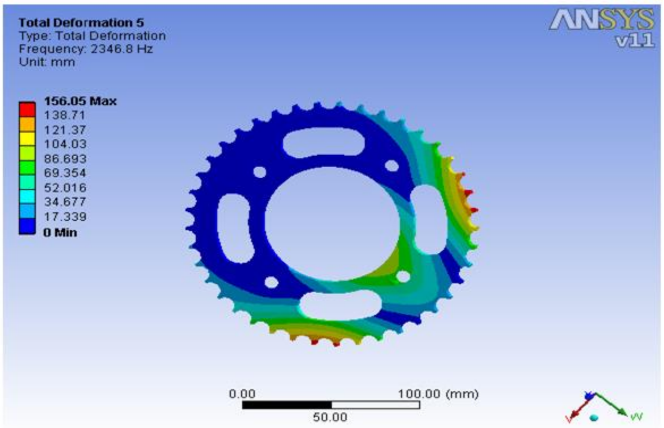
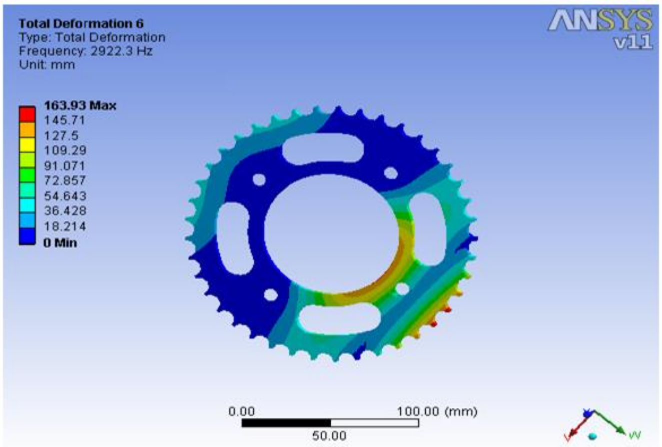
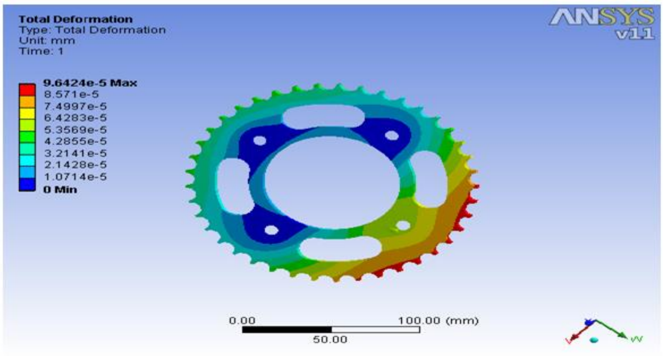


Total Deformation 6

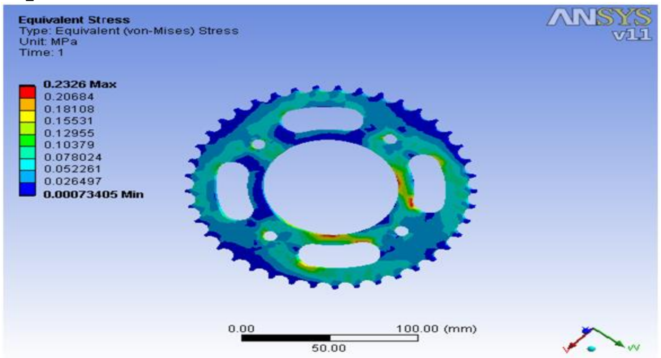


Total deformations

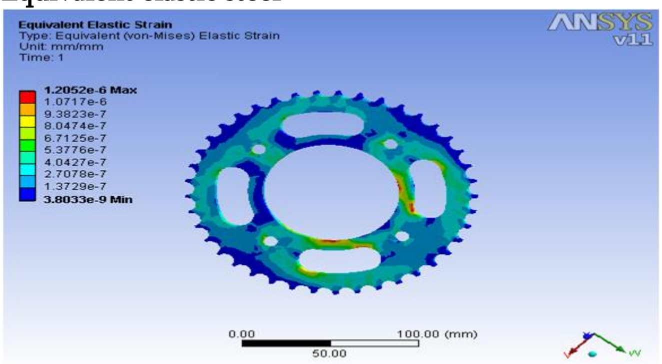


STAINLESS STEEL

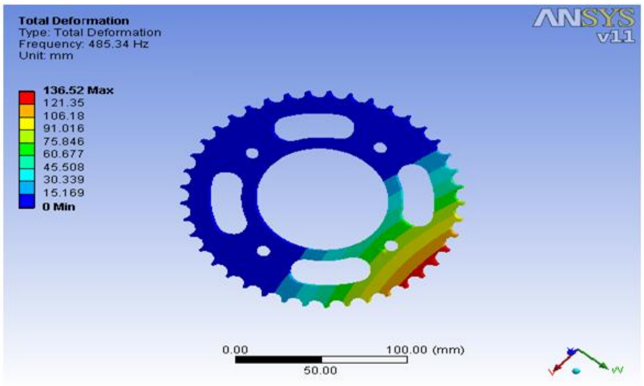
Equivalent elastic stress



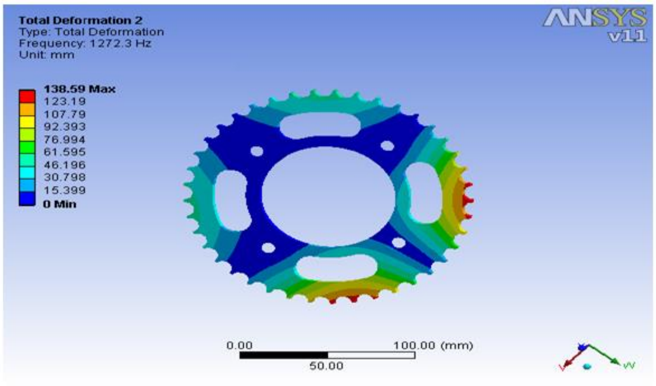
Equivalent elastic steel



Total Deformation 1



Total Deformation 2



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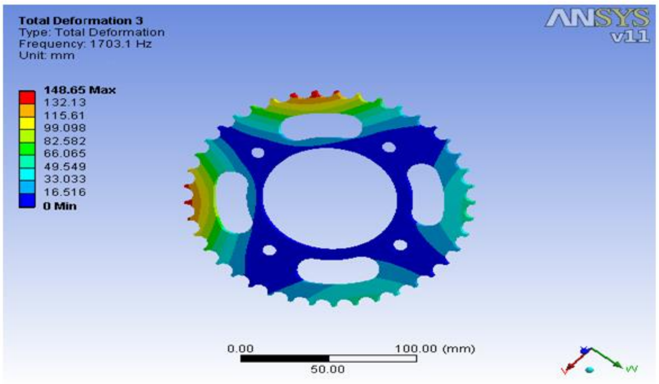
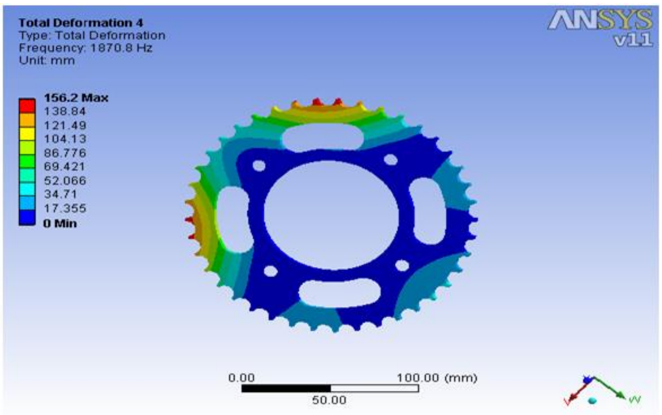


Total Deformation 4



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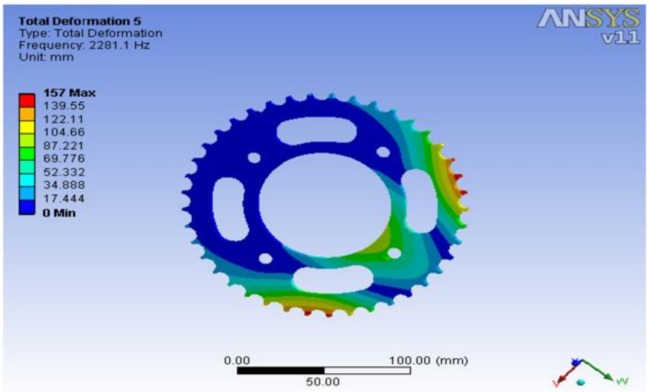

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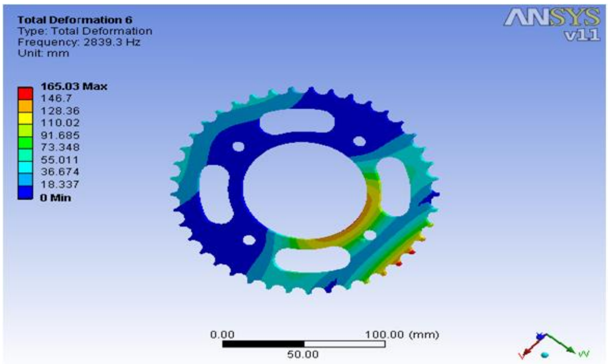
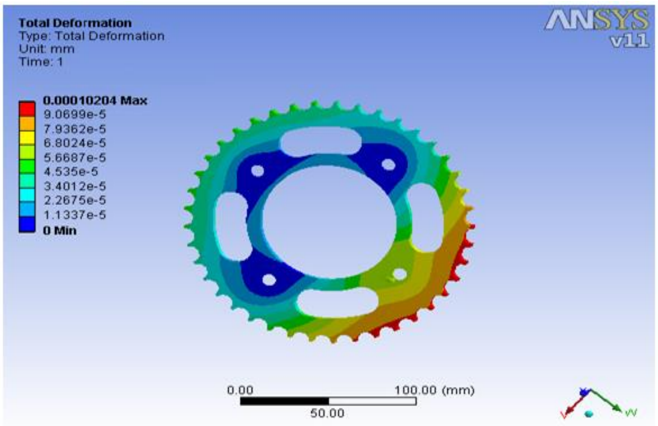
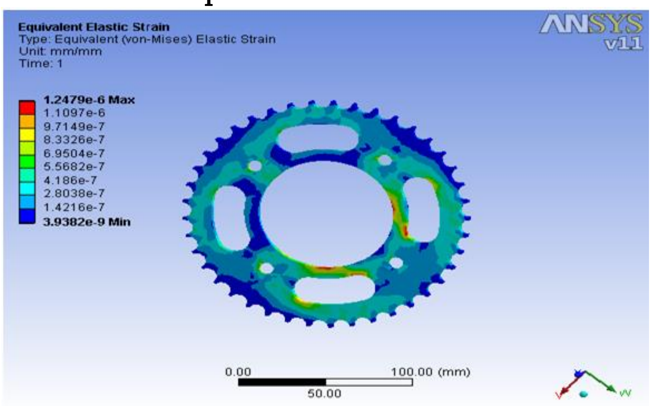


TOTAL DEFORMATION

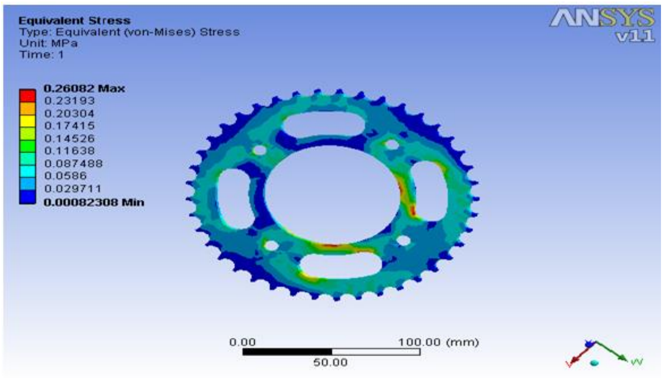


STEEL

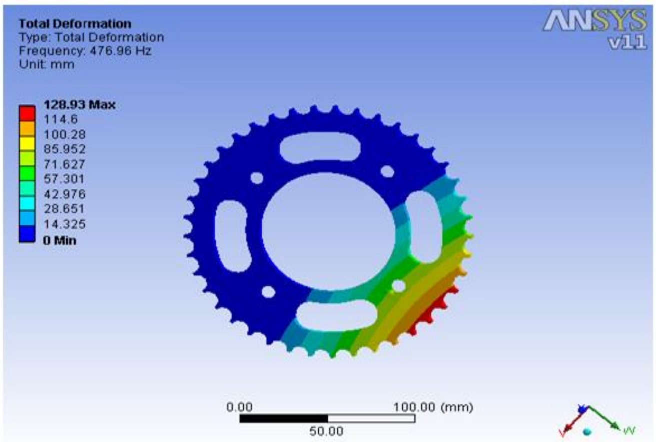
Equivalent elastic stress



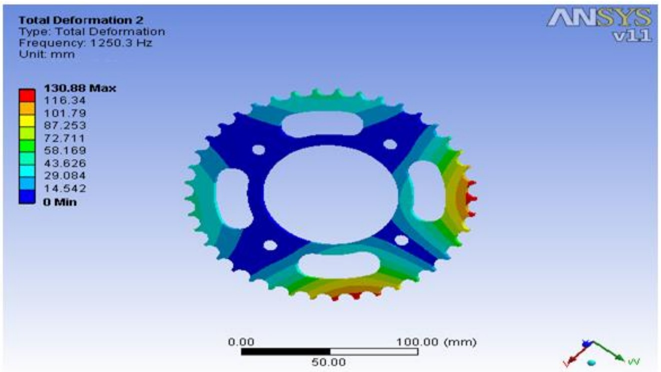
EQUIVALENT STRESS



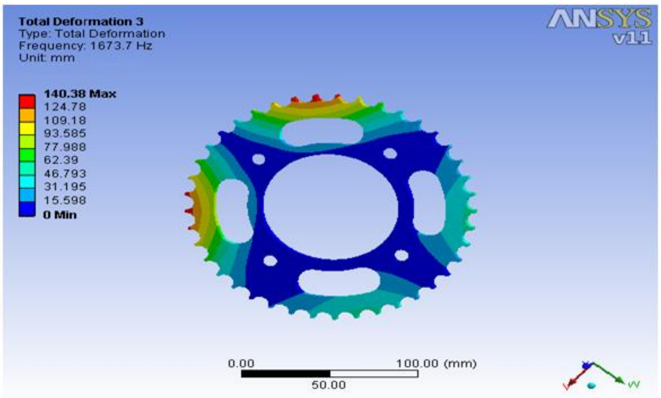
Total Deformation 1



Total Deformation 2



Total Deformation 3



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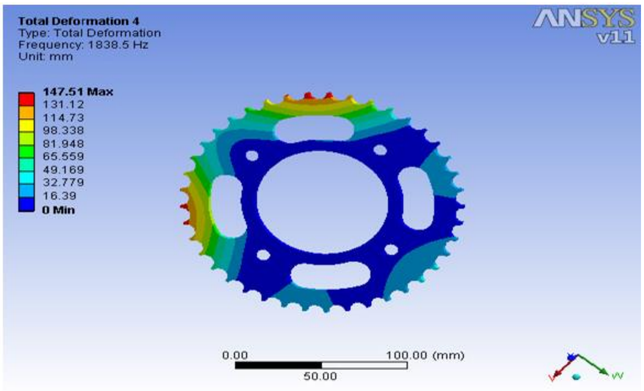
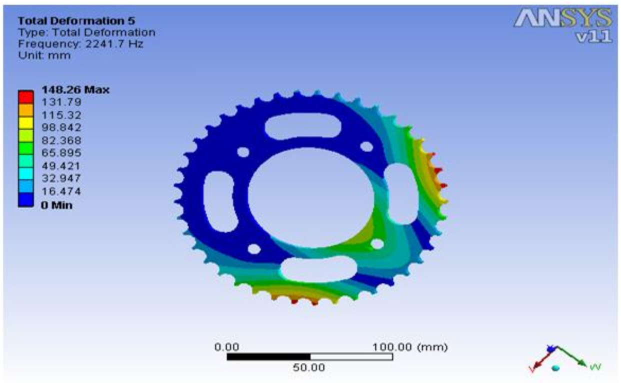
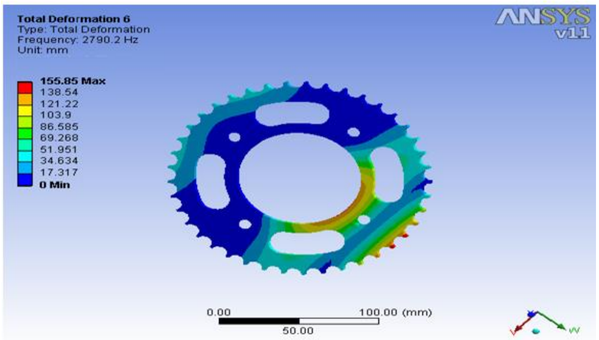


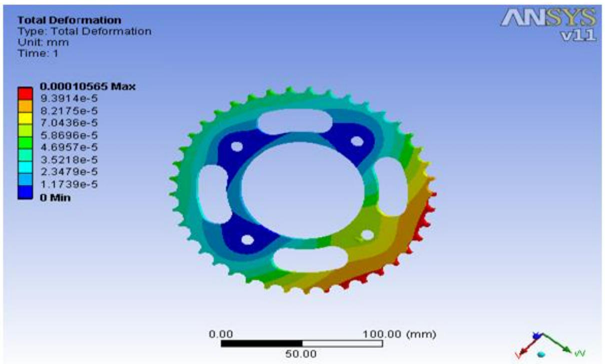
Total Deformation 5



Total Deformation 6



TOTAL DEFORMATION



RESULTS

S	Material	Equivalent Elastic Stress	Equivalent Stress in MPa	Total Deformation in mm
1	Cast Iron	1.958	0.1916	0.000148
2	Mild Steel	1.1376	0.2345	9.6424
3	Stainless Steel	0.2336	1.2052	0.0001020
4	Steel	1.2477	0.26082	0.00010565

VII. CONCLUSION

Different other composite materials can be used for analysis in Symmetric condition of the chain sprocket and can be analyzed for further investigation. In this project total deformation of chain sprocket, structural stress of chain sprocket, equivalent stress of the sprocket wheel were studied. The chain sprocket is subjected to various, thrust & dynamic loads, which simulated easily through CATIA & analysis because experimental calculation is complicated. In all the materials Stainless steel given a better results than the CI, MS, Steel. For further investigation, regression analysis is suggestive.

VIII. REFERENCES

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