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STRESS REDUCTION BY INTRODUCING STRESS RELIEVING FEATURES OF SPUR GEAR USED IN LATHE HEADSTOCK

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ABSTRACT

This paper deals with the reduction of contact stresses of the spur gear and pinion used in headstock of a lathe machine by introducing stress relieving feature of different shapes i.e. circular hole, elliptical hole and aero fin hole. In this paper the stress analysis of mating gears of the spur gear with three different materials is done to determine the contact stresses generated in the gear teeth. In the previous paper the results obtained from Finite Element Analysis (FEA) using Ansys are compared with the values obtained from theoretical Hertzian equation. The materials of spur gear used for analysis are grey cast iron, high carbon steel and medium carbon steel. In this paper the stresses which were calculated has been reduced by introducing stress relieving feature of different shapes. It was found that Stress relieving feature having the shape of aero- fin yielded better results when compared to elliptical and circular holes.

KEYWORDS:.

INTRODUCTION

Power transmission has always been of high importance. The efficiency of any machine depends on the amount of power loss in the process. One of the best methods of transmitting power between the shafts is gears. Gears are mostly used to transmit torque and angular velocity. There are also a wide variety of gear types to choose from. Gears have found very wide application in mechanical engineering field such as metal cutting tools, automobiles, hoists, rollng mills etc.

Parallel and co-planer shafts connected by gears are called spur gears. The arrangement is called spur gearing. Spur gears have straight teeth and are parallel to the axis of the wheel. Spur gears are the most common type of gears.
There are two kinds of stresses in gear teeth, root bending stresses and tooth contact stresses. These two stresses results in the failure of gear teeth, root bending stress results in fatigue fracture and contact stresses results in pitting failure at the contact surface. So both these stresses are to be considered when designing gears. Usually heavily loaded gears are made of ferrous materials that have infinite life for bending loads. But it is impossible to design gears with infinite life against surface failure. In this thesis both the principal failure modes are studied based on the calculation of bending and contact stresses.

In the previous paper[1] the contact stresses of spur gear and pinion has been calculated by Hertz equation and through Ansys 12.1 , now in this paper the stresses which were calculated has been reduced by introducing stress relieving feature of different shapes i.e. circular hole, elliptical hole and aero fin hole.

METHODOLOGY

In this research work, stress relieving feature of different shapes is tried. A finite element model of Spur gear and pinion of Lathe machine headstock is considered for analysis and the stress relieving feature of various types are introduced on gear teeth at the point of contact. The shape of stress relieving features are circular hole, elliptical hole and aero fin hole are used. The analysis has been done for the three materials i.e. grey cast iron, high carbon steel and medium carbon steel.

Significance of different Holes:

The different shapes of hole is used to modify the stress flow into a smoother way, i.e., circular hole, elliptical hole and aero fin hole help in achieving the stress reduction in the given spur gears because the curvy nature of this helps stress flow lines of stress to find a fluent path without any interruptions,. The different shapes of hole make the stress flow in the spurs gears smoother than the gears without the holes.

Finite Element Analysis:

After the assembly is imported in ANSYS Workbench 12.1, assembly is subjected to the boundary conditions. As both the teeth are already in contact, the main purpose is to study the contact stresses due to the applied torque. Following are steps followed for the Finite Element Analysis.

Three Dimensional Analysis of Spur Gear:

ANSYS has many type of analysis, so it is necessary to select the correct type of analysis from the menu bar. As the imported geometry is 3-Dimensional, select 3-D and Static Structural Analysis from menu and connect the geometry to the analysis tab. Then the next step is to enter the mechanical properties of the material. This can be done by selecting the Engineering Data from the analysis tab and inserting the corresponding values.

Defining Contact Region:

Once the geometry is attached with Static Structural analysis tab, next thing is to define the contact between the two involute teeth. ANSYS has an inbuilt option, which automatically reads the attached geometry for any predefined contacts or other boundary definitions. The contact between the two teeth is assumed to be frictionless; the figure below shows the contact being defined as frictionless. One of the most important things is to change the "Interface Treatment" to "Adjust to touch". This option defines the kind of contact between the selected bodies. The figure below shows the image from ANSYS showing the contact defined for the two spur gear teeth in mesh.

Scope	
Scoping Method	Geometry Selection
Contact	1 Face
Target	1 Face
Contact Bodies	SG23[39]
Target Bodies	SG23[46]
Definition	
Type	Frictionless
Scope Mode	Automatic
Behavior	Symmetric
Suppressed	No
Advanced	
Formulation	Augmented Lagrange
Interface Treatment	Adjust to Touch
Normal Stiffness	Program Controlled
Update Stiffness	Never
Pinball Region	Program Controlled
Time Step Controls	None

Figure 1: Defining contact

Mesh Generation:

The mesh with the default settings is not adequate to get the accurate results. In this analysis both the gear were finely meshed with "Sizing" option in menu. The element size was chosen to be 0.01 and the mesh type was tetrahedron. The image below shows the meshed assembly according to the size written above. The mesh looks fine enough for the analysis.

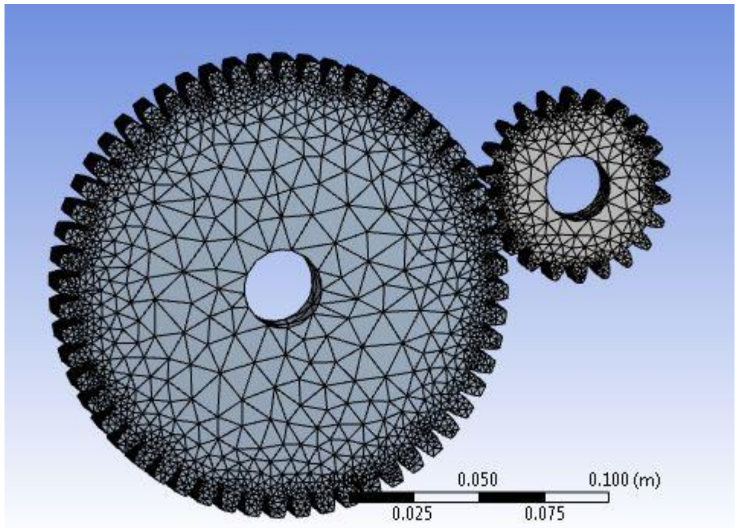

Figure 2: Gear after meshing

Supports and Loads:

Tangential load of 2315 N is applied at the point of contact during the mating of the two gears. Frictionless support and the moment of 194.46 N-m to the gear and moment of 76.395 N-m to the pinion in opposite direction is given. The image below shows how the supports and loads were applied to the spur gear and the pinion model.

Contact stresses of Spur gear :

Finite Element Method is the easy technique as compared to the theoretical methods to find out the stress developed in a pair of gears. Therefore FEM is widely used for the stress analysis of mating gears. In this research, finite element analysis is carried out in ANSYS Workbench 12.1 to determine the maximum contact stresses for grey cast iron, high carbon steel and medium carbon steel.The results obtained after finite element analysis of spur gear and pinion to find the contact stresses are given below:

For grey cast iron without hole:

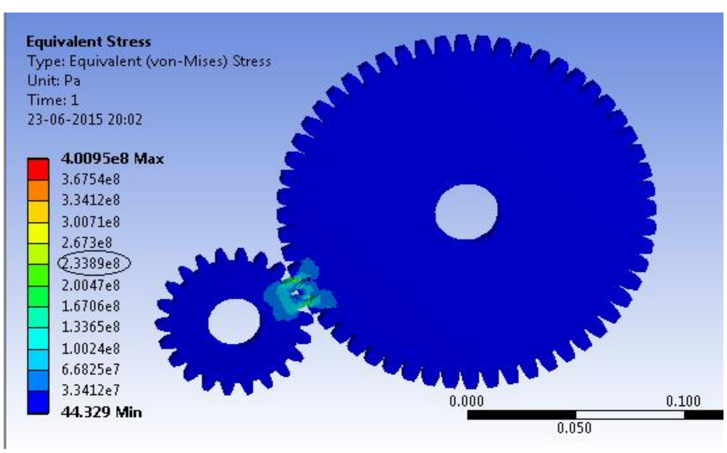

Figure 3: Stress distribution in grey cast iron

Grey cast iron with circular hole:

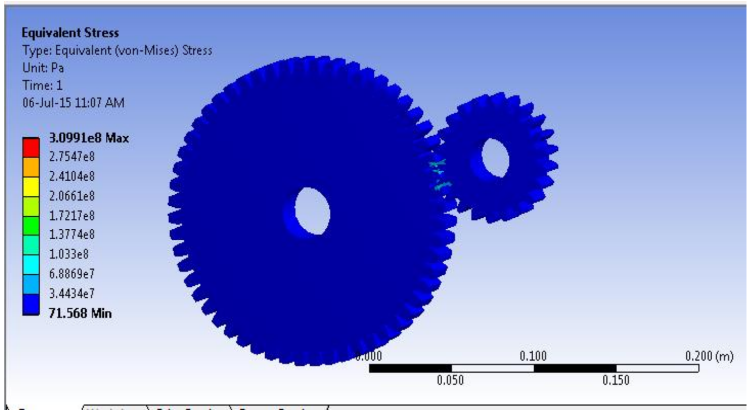

Figure 4: Stress distribution in grey cast iron with circular hole

Grey cast iron with elliptical hole:

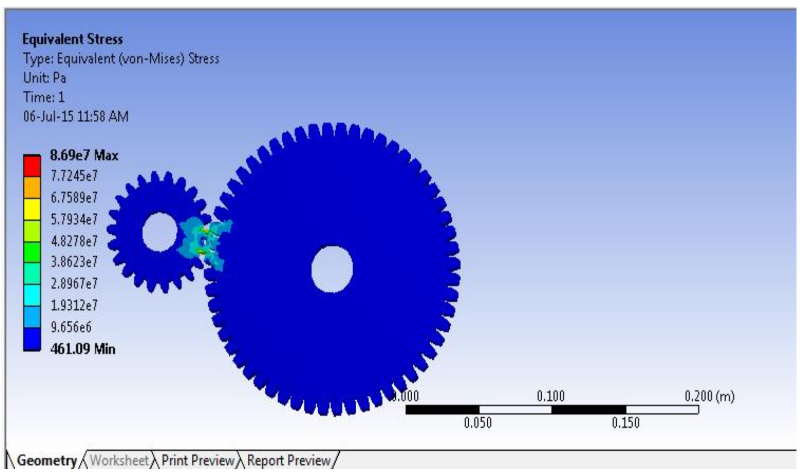

Figure 5.: Stress distribution in grey cast iron with elliptical hole

Grey cast iron with aierofoil hole:

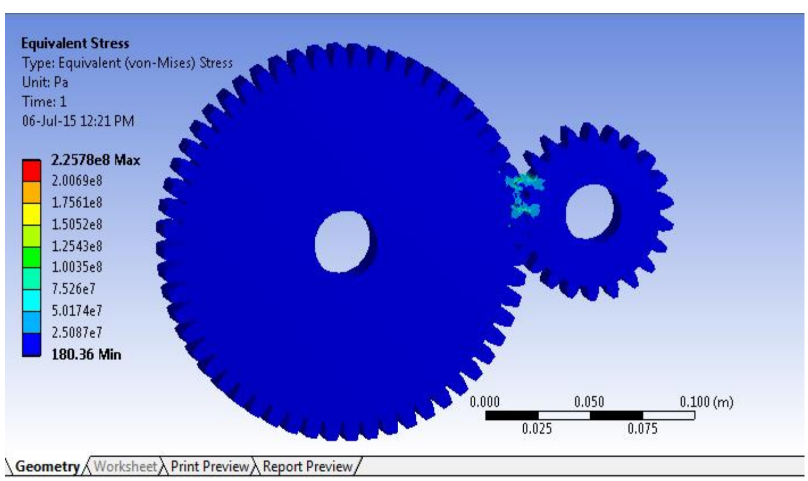

Figure 6: Stress distribution in grey cast iron with aero fin hole

For high carbon steel without hole :

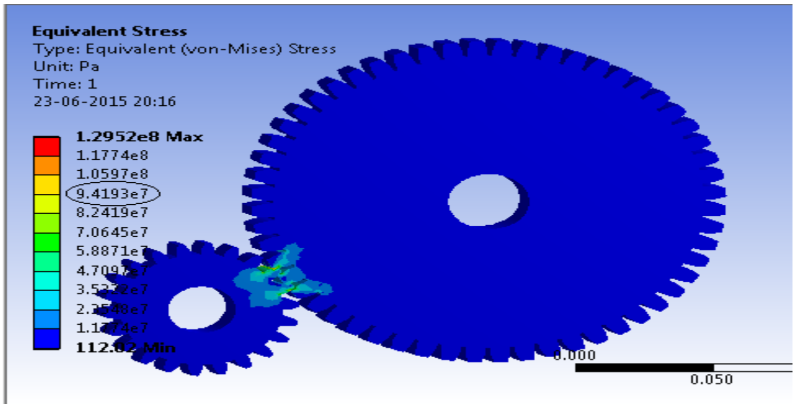

Figure 7: Stress distribution in high carbon steel

High Carbon Steel with circular hole

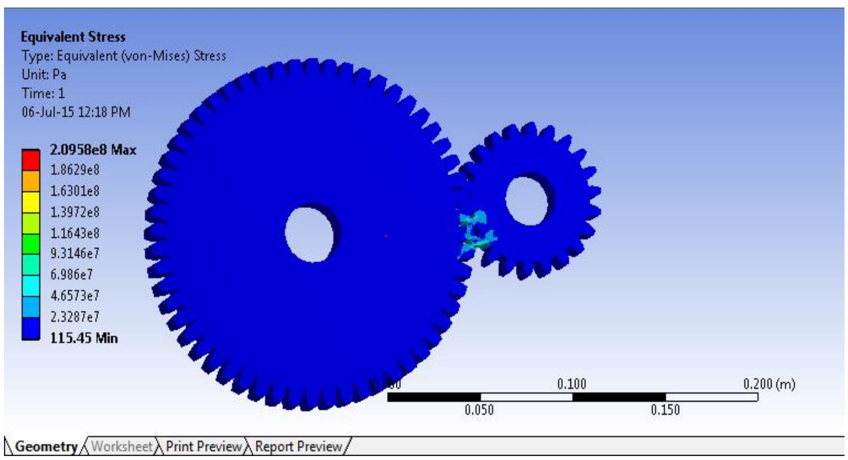

Figure 8: Stress distribution in high carbon steel with circular hole

High Carbon Steel with elliptical hole:

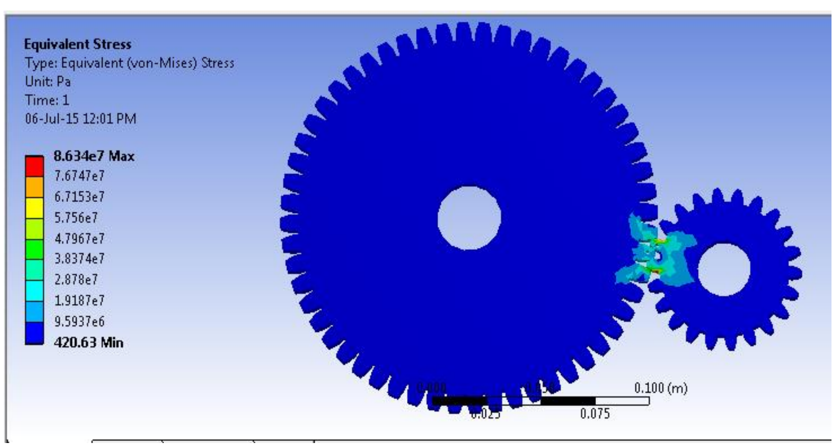

Figure 9: Stress distribution in high carbon steel with elliptical hole

High Carbon Steel with aero fin hole:

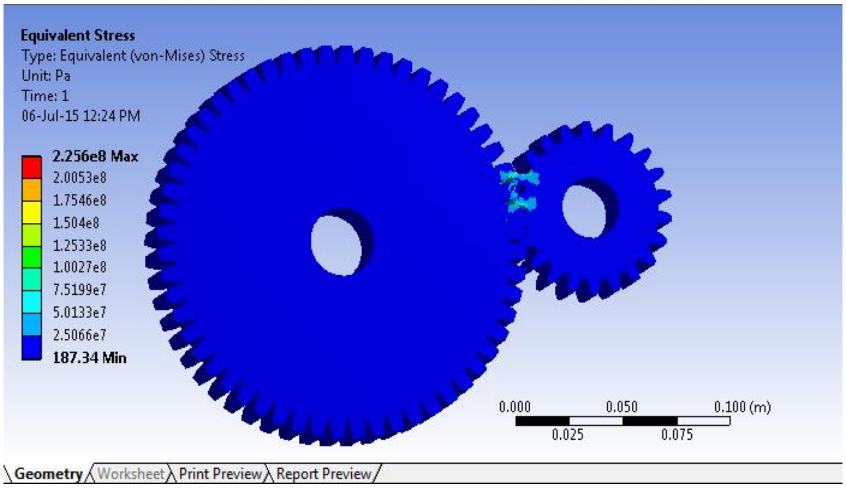

Figure 10: Stress distribution in high carbon steel with aero fin hole

For medium carbon steel without hole:

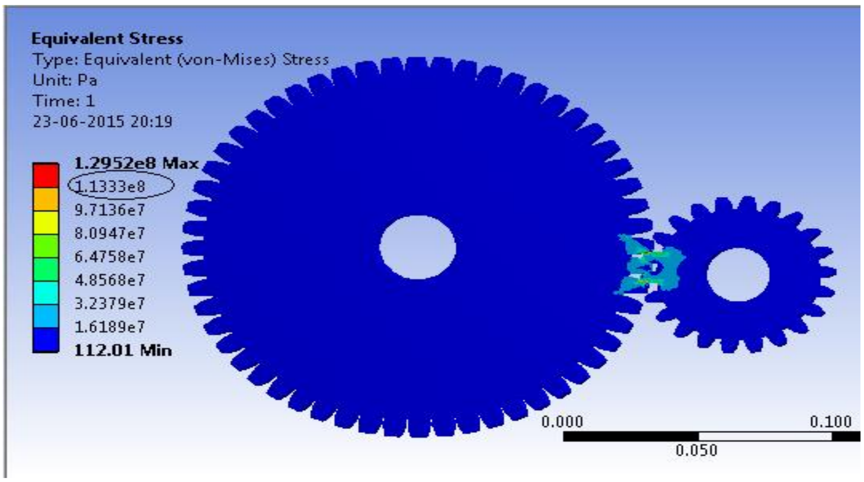

Figure 11: Stress distribution in medium carbon steel

Medium Carbon Steel with circular hole:

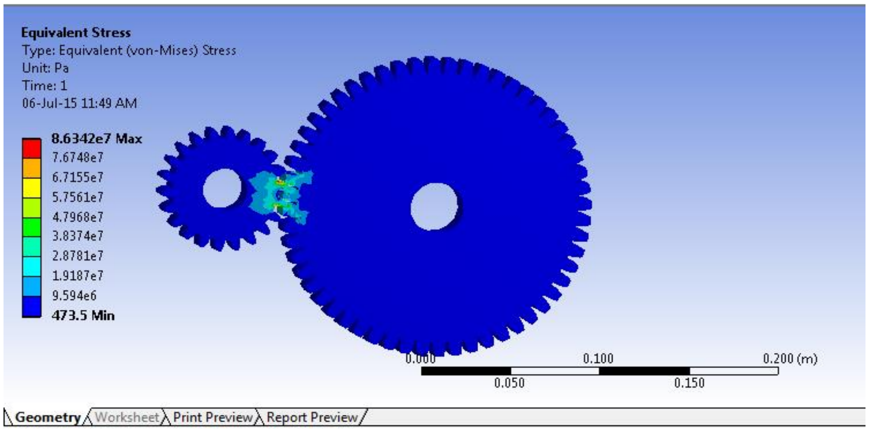

Figure 5.12: Stress distribution in medium carbon steel with circular hole

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Medium Carbon Steel with elliptical hole:

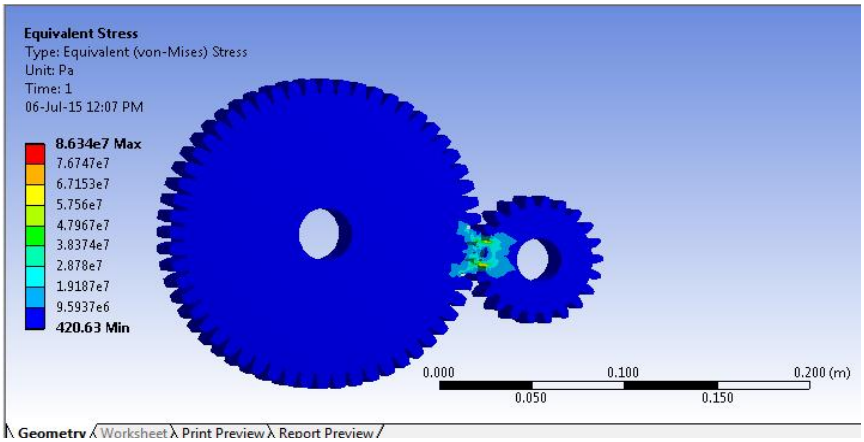

Figure 5.13: Stress distribution in medium carbon steel with elliptical hole

Medium Carbon Steel with aero fin hole:

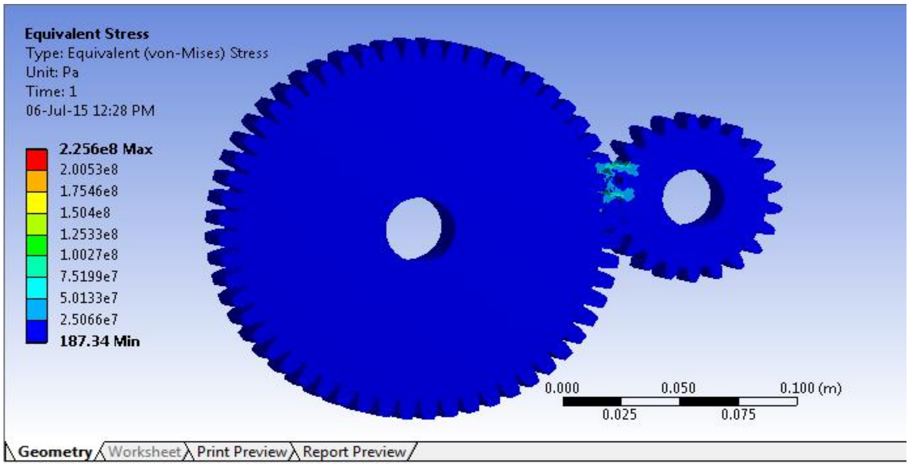

Figure 5.14: Stress distribution in medium carbon steel with aero fin hole

RESULTS AND DISCUSSION

Result obtained by introducing stress relieving features of different shapes to reduce the contact stresses:
CASE I : FOR GREY CAST IRON:

stress relieving features of different shapes	σ_a (MPa)	% of reduction in contact stresses
Spur gear and pinion without any hole	233.89	-
Spur gear and pinion with circular hole	172.17	26.323
Spur gear and pinion with elliptical hole	86	63.323
Spur gear and pinion with aero fin hole	75.26	67.822

Table 1: Percentage of reduction in contact stresses in grey cast iron

CASE I : FOR HIGH CARBON STEEL:

stress relieving features of different shapes	σ_a (MPa)	% of reduction in contact stresses
Spur gear and pinion without any hole	94.19	-
Spur gear and pinion with circular hole	93.146	1.1083
Spur gear and pinion with elliptical hole	86.34	8.334
Spur gear and pinion with aero fin hole	75.199	20.162

Table 2: Percentage of reduction in contact stresses in high carbon steel

CASE I : FOR MEDIUM CARBON STEEL:

stress relieving features of different shapes	σ_a (MPa)	% of reduction in contact stresses
Spur gear and pinion without any hole	113.33	-
Spur gear and pinion with circular hole	86.34	23.815
Spur gear and pinion with elliptical hole	76.74	32.286
Spur gear and pinion with aero fin hole	75.199	33.645

Table 3: Percentage of reduction in contact stresses in medium carbon steel

CONCLUSION

The main aim of this paper is to relieve stress from the maximum value to as minimum as possible. So the highest point of contact of teeth is selected as pressure application point which causes highest stress. Stress relieving feature having the shapes of circular, elliptical and aero- fin were used in the path of stress flow which helped to regulate stress flow by redistributing the lines of force. Stress relieving feature having the shape of aero- fin yielded better results when compared to elliptical and circular holes.

This study gives the better result when an aero-fin hole is introduced and the percentage of stress reduction in case of grey cast iron is 67.822. In case of high carbon steel is 20.162 and for medium carbon steel its 33.645.

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