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Buckling Analysis of Connecting Rod with Ultra Fine Grained Material AA2618

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***Abstract*— Connecting rod is one of the very important and critical components employed in an internal combustion engine which transmits thrust force which is developed in the cylinder because of the combustion of the fuel during the power cycle, to the crankshaft for availing the rotational motion to drive a vehicle. The objective of the work is to find critical buckling stress for existing material used (C70S6) and new material (Ultrafine grained material AA2618) by numerical method and FEM method and to optimize the connecting rod. The new material used for connecting rod is ultrafine grained material aluminium alloy AA2618.Now a day ultrafine grained materials are widely using in different automobile sector. First the Model of connecting rod is prepared in solidworks software, which is analyzed for both the material C70S6 and AA2618 analytically (Using Rankine's formula) as well as using ANSYS software.Comparisions are made for both the material. Results are found that Critical Buckling stresses (using Rankine Formula) for AA2618 is 45.05% is less compared to C70S6 material and Critical Buckling stress (using ANSYS method) for AA2618 is 51.58% is less compared to C70S6 material.**

Keywords—I.C. Engine;ANSYS;Critical Buckling Stress;Rankine's formula; Ultrafine grained material

I. INTRODUCTION

Connecting rod is one of the very important and critical components employed in an internal combustion engine of any automobile vehicle. Every internal combustion engine requires at least one or more connecting rods depend on the number of cylinder used in I C Engine.[1] Connecting rod transmits thrust force which is developed in the cylinder because of the combustion of the fuel during the power cycle, to the crankshaft for availing the rotational motion to drive a vehicle. It acts as an intermediate link between piston and crankshaft which converts the reciprocating motion of piston into the rotary motion of the crankshaft. So it has both rotary as well as reciprocation motion. Since it is subjected to the various tensile and compressive loads so it should have enough strength to withstand against high tensile and compressive stresses, buckling and fatigue stresses. [2, 3, 4]

There are various factors and design parameter which affects the performance and life of connecting rod. These factors and parameters are engine type, maximum rpm that engine can produce, shank area types like I-section, H-section etc., design parameters like thickness of shank area, fillet radius etc., material selection criteria, type of manufacturing technique etc. By optimizing these parameters and factors one can enhance the performance of connecting rods. [5, 6]

A limited number of studies are performed on the buckling of connecting rods. Buckling analysis is an important criterion for the analysis of connecting rod. Consequently, when weight reduction of connection rod shank is attempted, buckling should be considered as an essential factor along with the other criteria such as yield and fatigue. [7]

Various materials like forged steel, aluminium alloy and titanium etc. are using to manufacture the connecting rods to achieve better performance, life and reduced cost of connecting rod. [1] After a long period of research the Ultra Grained Fine Materials are considered as an important category of material for the manufacturing of the connecting rod. Ultrafine-grained (UFG) metallic materials are great interest of research and development of modern materials science as these materials exhibit outstanding properties which make them very interesting for prospective structural or functional engineering applications. During the last decade there is enormous progress in severe plastic deformation techniques which is used to produce the Ultrafine-grained (UFG) metallic materials. Because of recent advancement in severe plastic deformation process ultrafine-grained microstructures are no longer only restricted to easy to deform single-phase materials, but can also be introduced in complex and hard to deform alloys of technological relevance. UFG materials have good hardening effect and high mechanical properties because of that it usage is various applications. [8]

One of the most interesting techniques for the production of the UFG material is severe plastic deformation (SPD).Various other techniques are available to produce high values of plastic deformation, such as Equal Channel Angular Extrusion (ECAE), High pressure torsion (HPT), Accumulative Roll Bonding (ARB), among others, severe plastic deformation (SPD) being a favorable method to conform and to control the mechanical behavior of the materials. [9]

In the present work buckling analysis is performed for existing materail C70S6 and new material ultrafine grained material AA2618 analytically (Using Rankine's formula) as well as using ANSYS software.

II. METHODOLOGY

For the Buckling analysis dimensions and sketch of connecting rod are taken from the reference paper. Buckling analysis is performed analytically and critical buckling stress is calculated using rankine's formula for the existing material C70S6 used to manufacture the connecting rod. Then the

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model of connecting rod is prepared using Solidworks software. Then model is exported to ANSYS Workbench software and critical buckling stress is calculated using ANSYS.In the second phase both the analysis (analytical and FEM) are performed for new material ultrafine grained material AA2618..

Finally results are compared for existing material C70S6 and new material AA2618 and graphs are plotted.

III. DESIGN PARAMETERS

The design of connecting rod is taken from the fig shown below. It shows various parts and dimensions of connecting rod.

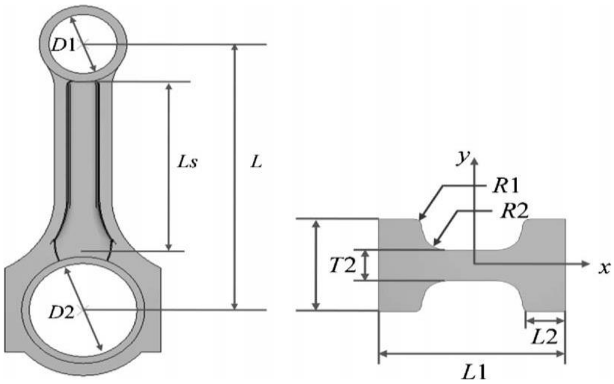

Fig. - 1 Design parameters and buckling axes of the cross-section in a connecting rod

Design Parameter	Values (mm)
Frontal profile	
Diameter of small bore(D1)	24
Diameter of Big bore(D1)	48
Effective length(L)	141
Shank length(Ls)	98
Shank Sections	
Fillet radius1(R1)	1
Fillet radius (R2)	3.5
Total width(L1)	18
Total thickness(T1)	16
Side width(L2)	2.5
Middle Thickness(T2)	1.5

Table No. -1 Design Parameters

IV. BUCKLING ANALYSIS

(A) ***Critical Buckling Stress*** - Connecting rod is use to convert reciprocating motion into rotary motion. The design of connecting rod is always based upon buckling load. Connecting rod is subjected to tensile load as well as compressive load. When compressive load acts on a connecting rod it may fracture if compressive load acts on a connecting rod is more than its resisting compressive strength. Also if the length of connecting rod is increased above its sectional dimension i.e. if slenderness ratio is more than 40, then the connecting rod gets buckle for the lower value of compressive load which is known as critical buckling load and the stress developed due to this load is called critical buckling stress.

Buckling analysis is performed on the "I" section of connecting rod. The "I" section connecting rod is preferred because the connecting rod can buckle about x axis and y axis. In connecting rod we assume both ends of connecting rod are hinged about x axis and there are fixed about y axis. The relation between area moment or inertia of x axis and y axis i.e. $I_{xx} = 4I_{yy}$ must be satisfied which is satisfied by "I" section. Therefore mostly I section connecting rod is preferred.

The slenderness ratio [ratio of length of column to least radius of gyration] is the important deciding radius for the design of connecting rod. If the ratio is less than 40, design of connecting rod is based on compressive load and if this ratio is more than 40 the design the connecting rod will be based upon buckling load which will be based less than compressive strength of connecting rod. For best performance without buckling the crippling load should always be less than compressive load subjected to connecting rod.

(B) *Buckling stress calculation through Rankines formula –*

The design parameters of connecting rod and its cross section of shank are shown in fig.2. The various parameters of connecting rods are shown in table. The buckling stress for connecting rod based on shank parameters can be represented as: effective length L, radius of gyration r and buckling constant k. First calculation of Euler stress has been done from:

$$\sigma^{e}_{cr} = \frac{\pi^2 E}{(K_y L/r_y)^2}$$

Where E= elastic modulus
K= buckling constant
=1 (For pined-pined joint)
L/r = slenderness ratio
r= radius of gyration
A= area of connecting rod
Ixx= moment of inertia

Classical buckling stress is of connecting rod is calculated from Rankines formula. Rankines formula is harmonic mean of Euler formula and yield strength than can be written as:

$$\sigma_{cr} = (1/\sigma^{e}_{cr} + 1/\sigma^{p}_{cr})^{-1}$$

The above formula is modified form of rankine's formula because the Euler formula used is valid only when column is slender with uniform cross section and defined boundary condition. However the present connecting rod doesn't fulfill these three conditions. First the shank is not uniform along its length second ends of connecting rod and it is connected with pin joint. Last it's not possible to define

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effective length of connecting rod. Therefore modified formula is required.

V. FINITE ELEMENT MODELLING & ANALYSIS

(A) ***Modelling of Connecting Rod*** - Connecting rod model is generated using Solidworks software. Dimensions of the connecting rod are taken from reference research paper. All the dimensions are in mm.For finite Element analysis it is necessary to have a model of specific product then on this model we can perform different analysis and can predict the result and its behaviour. The geometry of connecting rod used for finite element analysis is shown in fig 1. Table 1 show all the design parameters used for calculation of buckling stress

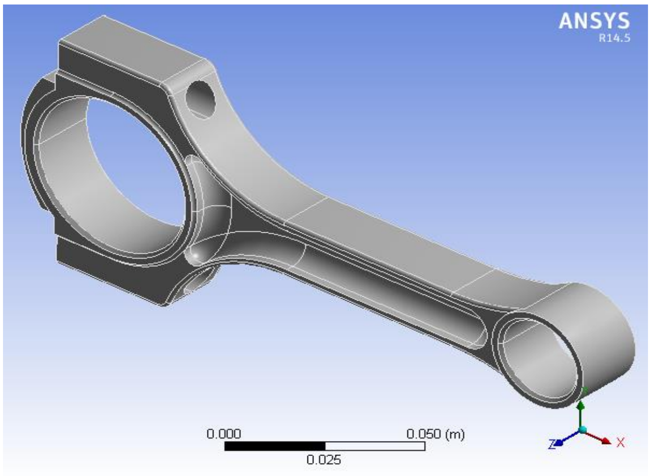

Fig 2 Model of connecting rod used in ANSYS

(B) ***Generation of mesh*** - Meshing of connecting rod is done by selecting tetrahedral elements with various element lengths. Then equivalent stress is checked at four location of connecting rod of shank region. The results are shown in table for approx all the regions of connecting rod convergence is achieved with uniform length of element. A finite element mesh generation of connecting rod is generated using global element length and at the area of chamfer an element length is changed. Number of elements and nodes are 6947 element and 13124. The convergence at chamfer area is obtained with local size of mesh.

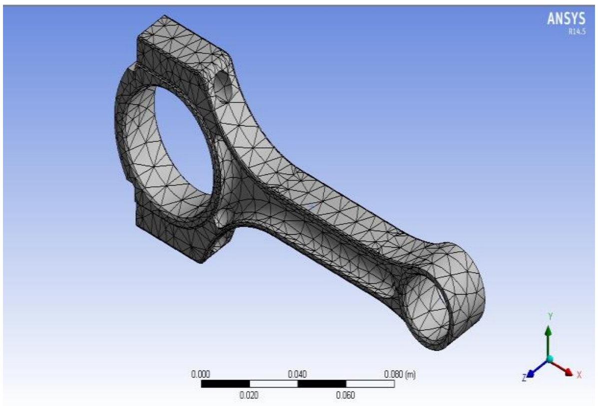

Fig 3 Mesh generation in connecting rod

VI. INTRODUCTION OF NEW MATERIAL

(A) In this work the existing material of connecting rod has been replaced with new material viz. ultra-fine grained material Aluminum Alloy 2618 (AA2618). Ultra Grained Fine Material AA2618 is used for as a new material for the analysis work. Ultrafine-grained (UFG) metallic materials are great interest of research and development of modern materials science as these materials exhibit outstanding properties which make them very interesting for prospective structural or functional engineering applications. During the last decade there is enormous progress in severe plastic deformation techniques which is used to produce the Ultrafine-grained (UFG) metallic materials. Because of recent advancement in severe plastic deformation process ultrafine-grained microstructures are no longer only restricted to easy to deform single-phase materials, but can also be introduced in complex and hard to deform alloys of technological relevance. UFG materials have good hardening effect and high mechanical properties because of that it usage is various applications.

One of the most interesting techniques for the production of the UFG material is severe plastic deformation (SPD).Various other techniques are available to produce high values of plastic deformation, such as Equal Channel Angular Extrusion (ECAE), High pressure torsion (HPT), Accumulative Roll Bonding (ARB), among others, severe plastic deformation (SPD) being a favorable method to conform and to control the mechanical behavior of the materials.

(B) **Chemical Composition -** The following table shows the chemical composition of Aluminium / Aluminum 2618 alloy.

Element Content	(%)
Aluminium / Aluminum,Al	93.7
Copper, Cu	2.3
Magnesium,Mg	1.6
Iron,Fe	1.1
Nickel,Ni	1.0
Silicon,Si	.18
Titanium,Ti	.07

(C) Properties of AA2618 –

Properties	Metric
Tensile strength	440Mpa
Yield strength	370Mpa
Shear strength	260Mpa
Elastic modulus	75Gpa
Poisson's ratio	.33
Fatigue strength	125Mpa
Elongation	10%

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VII. RESULTS AND DISCUSSION

Width (mm)	Critical Buckling Stress (Rankine's Formula)		Critical Buckling Stress (FEM)	
	C70S6	AA2618	C70S6	AA2618
18	426.6	234.41	317.29	153.62

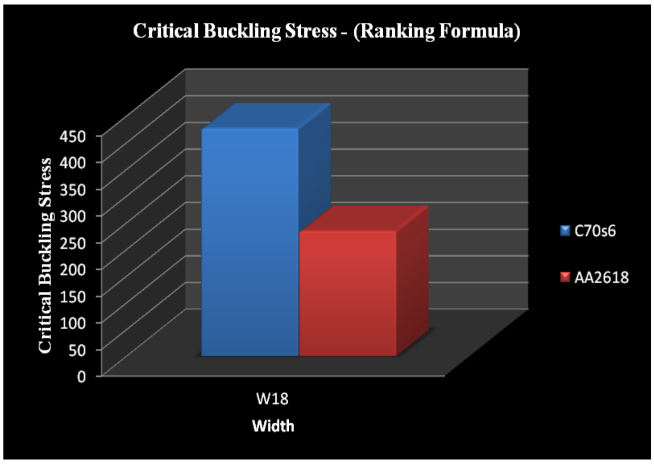

Fig. 4 Comparison of Critical Buckling Stress by Rankine's Formula for C70S6 and AA2618

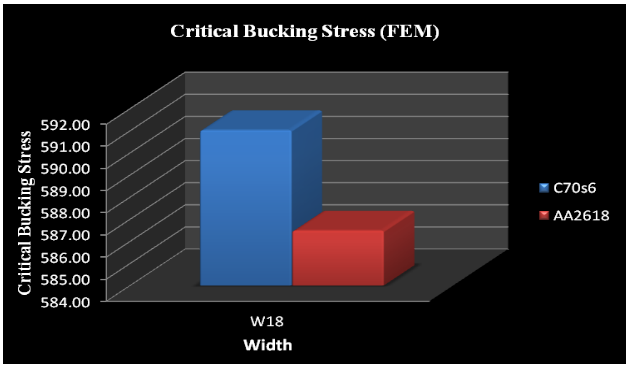

Fig.5 Comparison of Critical Buckling Stress by FEM for C70S6 and AA2618

Discussion –

1. In this analysis first buckling analysis is performed on the C70S6 material by the theoretical analysis and after that by FEM analysis. In the second step critical buckling stress is found by the FEM Analysis for same material (C70S6

2. After that analysis is performed for new material AA2618 by both theoretical and FEM method and value of critical stress is are calculated.

3. In both the above cases difference in the value of critical buckling stress by the Rankine formula and by the FEM analysis is 25% to 30%.Value of Critical Buckling stress by Rankine formula is more because Rankine formula is based on the various assumptions. These are follows:

a) Initially column (Connecting rod) is considered perfectly straight and load applied is truly axial.
b) Cross section of shank area is considered uniform throughout its length.
c) Material of connecting rod is assumed perfectly elastic, homogeneous and isotropic and thus obeys Hooke's law.

4. While comparing the values of critical buckling stress for both the material it is found that Critical Buckling stresses (Rankine Formula) for AA2618 is 45.05% is less compared to C70S6 material and Critical Buckling stress (FEM) for AA2618 is 51.58% is less compared to C70S6 material.

VIII. FUTURE SCOPE

1) Fatigue analysis is an important analysis during the designing of connecting rod. So Fatigue analysis can be performed for this connecting rod to check the performance under cyclic loading conditions.
2) In the present study Buckling analysis is carried out, Static & Dynamic analysis can be done for checking the various stresses acting during static and dynamic load conditions.
3) Deformation of connecting rod can be done for both the two materials and experimental analysis can be performed to get more accurate results.
4) The shank section of connecting rod can be changed.
5) Stress analysis is done by applying load on piston pin side only. This analysis can be done by applying stress on crank pin side also.

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