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Modeling Structural and Thermal Analysis of Conrod Using Composite Materials.

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A B S T R A C T

The connecting rod is the intermediate member between the piston and the Crankshaft. It's primary function is to transmit the push and pull from the piston pin to the crank pin, thus converting the reciprocating motion of the piston into rotary motion of the crank. Existing connecting rod is manufactured by using Forged steel. This paper describes modeling and analysis of connecting rod. In this project connecting rod is replaced by Composite materials 6061-T6. A 2D drawing is drafted from the calculations. A parametric model of connecting rod is modeled using SOLIDWORKSV13-14 software. Analysis is also carried out by using SOLIDWORKS V13-14software.

Finite element analysis of connecting rod is done by considering 20 materials. The best combination of parameters like Von misses stress and strain, displacement, Factor of safety and weight were done in SOLIDWORKS software. Compared to Forged steel and other materials6061-T6 is found to have working factor of safety is nearer to theoretical factor, reduced weight, increased stiffness and reduced stress.

Introduction:

Connecting rods are also known as Conrods. Connecting rods are widely used in variety of engines. The function of connecting rod is to transmit the thrust of the piston to the crank shaft, and as the result the reciprocating motion of the piston is translated into rotational motion of the crank shaft. It consist of a pin - end. A shank section, and crank an end .Pin end and crank end holes are machined to permit accurate fitting of bearings. One end of the connecting rod is connected to the piston by the piston pin. Connecting rods are subjected to forces generated by mass and fuel combustion .Theses two forces results in axial load and bending stresses. A connecting rod must be capable of transmitting axial tension, axial compression, and bending stress caused by the thrust and full of the piston and by centrifugal force. Finite element (FEM) Modal is a modern way for fatigue analysis and estimation of the component .The influential component factors are able to change such as material .cross section conditions etc.

The technology surrounding the methods of connecting rod production and materials used has rapidly advanced in the past 50 years. These advancements have enabled the auto industry to develop engines with more power and reliability while decreasing the volume of space they occupy. The industry must continue to challenge itself to advance connecting rod technology in order to propel the auto industry to manufacture more cost and fuel efficient vehicles. Connecting rod for automotive applications are typically manufactured by forging from either wrought steel or powder metal. Schematic diagram for connecting rod as shown in figure1.

Figure: 1. Schematic Diagram of Conrod

Specification of the Problem:

This project describes modeling and analysis of connecting rod. In this project connecting rod material forged steel is replaced by Composite materials 6061-T6. A 2D drawing is drafted from the calculations. A model of connecting rod is modeled using SOLIDWORKSV13-14 software. Analysis is also carried out by using SOLIDWORKS V13-14 software.

Finite element analysis of Conrod is done by considering 20 materials. The best combination of parameters like Von misses stress and strain, displacement, Factor of safety and weight were done in SOLIDWORKS software. Compared to Forged steel, and other materials 6061-T6 is found to have working factor of safety is nearer to theoretical factor , reduced weight, increased stiffness and reduced stress.

Nomenclature of Conrod:

A = cross sectional area of the connecting rod.
L = length of the connecting rod.
C = compressive yield stress.
W_{cr}= crippling or buckling load.
I_{xx}= moment of inertia of the section about x-axis
I_{yy}= moment of inertia of the section about y-axis respectively.
K_{xx}= radius of gyration of the section about x-axis
K_{yy}= radius of gyration of the section about y- axis respectively.
D = Diameter of piston
r = Radius of crank

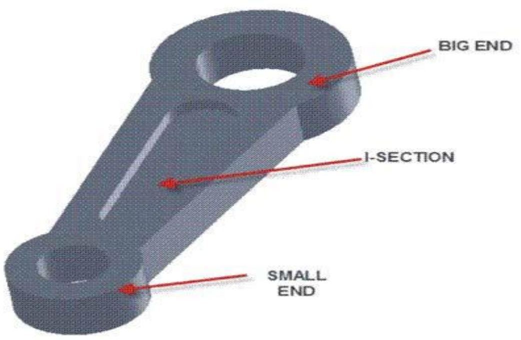


Figure: 2. Specifications of Conrod

Design of Conrod:

A Conrod is a machine member which is subjected to alternating direct compressive and tensile forces. Since the compressive forces are much higher than the tensile force, therefore the cross-section of the connecting rod is designed as a strut and the Rankine formula is used. A connecting rod subjected to an axial load W may buckle with x-axis as neutral axis in the plane of motion of the connecting rod,{or} y-axis is a neutral axis. The connecting rod is considered like both ends hinged for buckling about x-axis and both ends fixed for buckling about y-axis. A connecting rod should be equally strong in buckling about either axis.

According to rankine formulae:

W_{cr}about x-axis = $[\sigma c\times A]/1+[LKxx]2$ = $[\sigma c\times A]/1+a[lKxx]2$ $[\ \therefore forbothendshingedL=l]$

W_{cr} about y-axis = $[\sigma c\times A]/1+[LKyy]2=[\sigma c\times A]/1+a[l2Kyy]2$ $[\ \therefore forbothendsfixedL=l/2]$

In order to have a connecting rod equally strong in buckling about both the axis, the buckling loads must be equal.

i.e.

= $[\sigma c\times A]/1+[lKxx]2$ = $[\sigma c\times A]/1+a[l2Kyy]2$ [or] $[l/Kxx]2=[l/2Kyy]2$

$K^2xx = 4K^2yy$ [or] I xx = 4Iyy $[\therefore I=A\times K2]$

This shows that the connecting rod is four times strong in buckling about y-axis than about-axis. If I xx > 4Iyy, Then buckling will occur about y-axis and if I xx < 4Iyy, then buckling will occur about x-axis .In Actual practice I xx is kept slightly less than 4Iyy. It is usually taken between 3 and 3.5 and the Connecting rod is designed for buckling about x-axis. The design will always be satisfactory for buckling about y-axis. The most suitable section for the connecting rod is I-section with the proportions shown mfg

Area of the cross section = $2[4t \times t] + 3t \times t=11t^2$

Moment of inertia about x-axis,

$I_{xx} = 1/12\ [\ 4t(5t)^3- 3t(3t)^3] = (419/12)t^4$.

Moment of inertia about y-axis,

$I_{yy} = [2\times 1/12\times t(4t)^3] + 1/12\times 3t\times t^3 = (131/12)t^4$

Therefore $I_{xx}/I_{yy} = 3.2$

Since the value of I xx/I yy lies between 3 and 3.5 m therefore I-section chosen is quite satisfactory

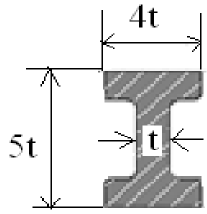


Figure: 3 Standard Dimension of I – Section

Design Specifications of Conrod:

Table: 1 Design specifications of a connecting rod

S. No	Parameters(mm)
1	Thickness of the connecting rod (t) = 7
2	Width of the section (B = 4t) = 28
3	Height of the section(H = 5t) = 35
4	Height at the big end = (1.1 to 1.125)H = 38.5
5	Height at the small end = 0.9H to 0.75H= 31.5
6	Inner diameter of the small end = 29
7	Outer diameter of the small end = 43
8	Inner diameter of the big end = 44
9	Outer diameter of the big end = 65
10	Length of the Conrod = 380

Design of Conrod:

Solid Works is a 3D mechanical CAD (computer-aided design) program that runs on Microsoft Windows and is being developed by DassaultSystèmes Solid Works Corporation. Dimensions of Width and height of the Conrod are considered. A 3- D model of Conrod is used for analysis in SOLIDWORKS V13-14. The loading conditions are assumed to be static. Analysis done with pressure load applied at the piston end and restrained at the crank end or other load applied at the crank end and restrained at the piston end. The element chosen is 3-D SOLID, it was used with the tetrahedral option, making it a 10-node element with 3 degrees of freedom at each node.

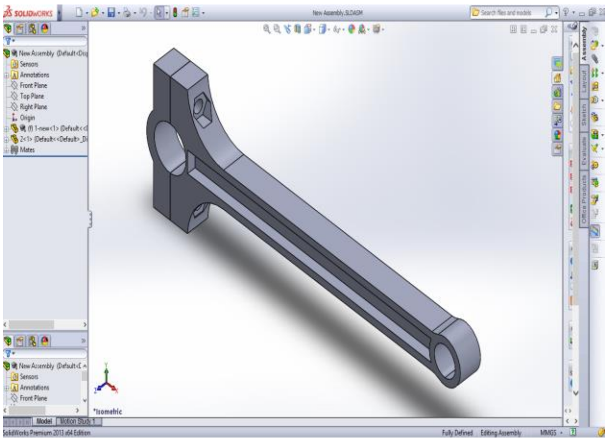


Figure: 4.1 Assembly of the Conrod

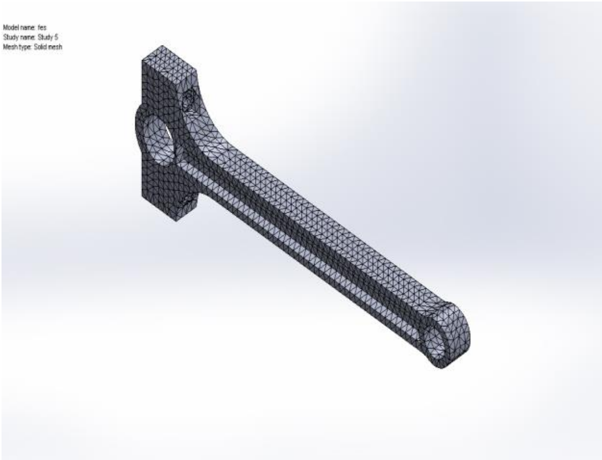


Figure: 4.2 Finite Element Mesh of the Conrod Assembly

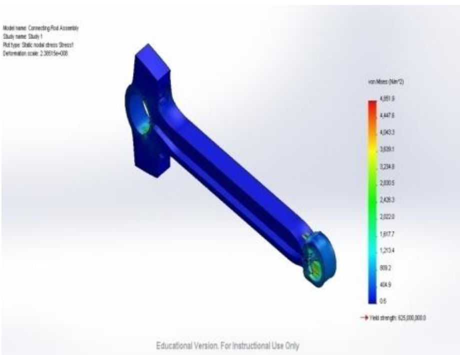
Structural Analysis of Conrod:

The finite element analysis is carried out on 20 elements for both Compressive and Tensile load. From the analysis the equivalent stress (Von-misesstress), strain, displacements, factor of safety, and weight were determined and are shown in figures from 5.1 - 5.4. Table 2 shows the comparative of various factors for 5 different materials. The comparison between the Forged Steel and top 4 materials are shown with the figures and the graphs.

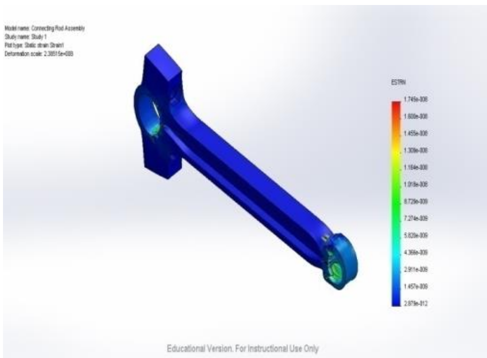
Table: 2. Static analysis of conrodAnalysis of stress for compressive load (3.15mpa):

S. No	TYPE OF MATERIAL	STRESS(N\m^2)		DISPLACEMENT(mm)		STRAIN(mm)		FOS		WEIGHT (Kg)
		MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	
1	6061-T6	0.817802	4628.05	2.1835*10^-11	4.188*10^-7	9.166*10^-12	4.1596*10^-8	65299.8	4.3409*10^8	1.043279
2	AA356	0.778319	4685.83	2.0876*10^-6	9.999*10^-7	2.9389*10^-7	9.8759*10^-8	33847.6	2.4411*10^8	0.928596
3	SILUMIN	0.759717	4710.54	7.8007*10^-11	5.2148*10^-7	1.0387*10^-11	5.1273*10^-8	39524.1	2.96163*10^8	0.940625
4	MAGNESIUM	0.719186	4753.82	1.18662*10^-10	8.9494*10^-7	1.678*10^-11	8.7422*10^-8	16276	1.3209*10^8	0.601377
5	FORGED STEEL	0.613154	4851.89	1.21428*10^-11	1.8199*10^-7	2.8788*10^-12	1.7454*10^-8	101059	1.01932*10^9	2.723879

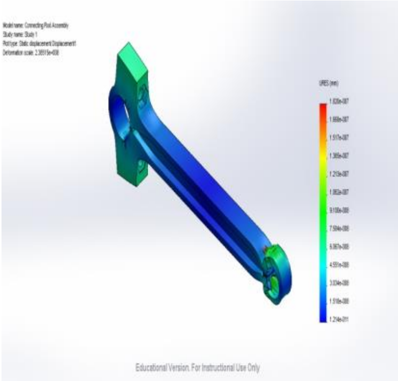
Forged Steel:



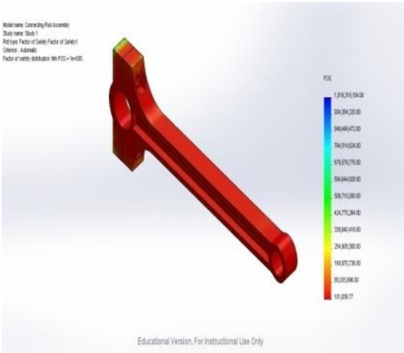
STRESS



STRAIN

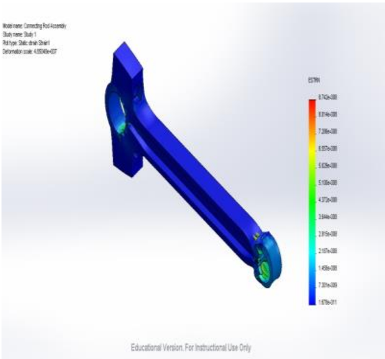


Displacement

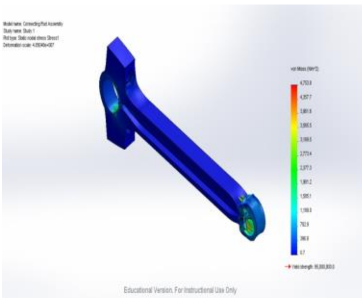


Factor of Safety

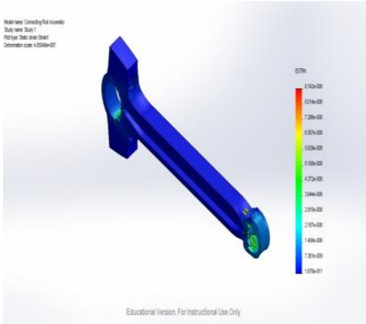
Magnesium:



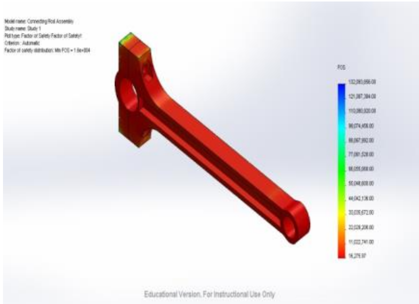
Stress



Strain

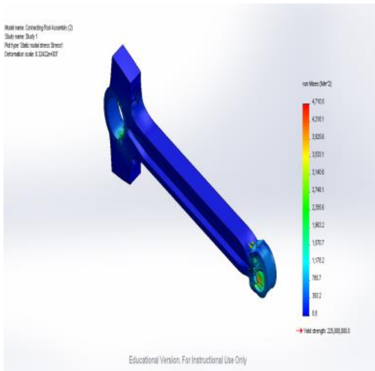


displacement

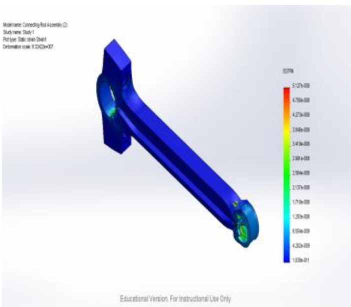


factor of safety

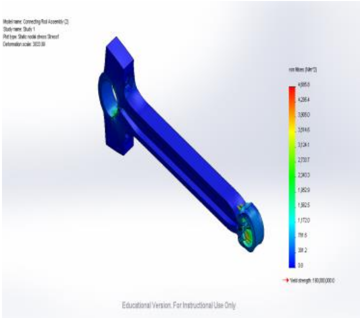
Silumin:



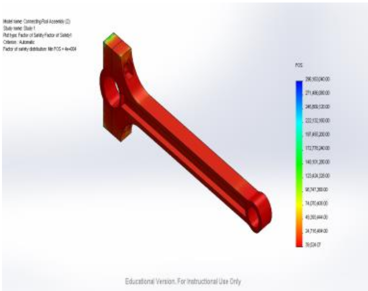
Stress



Strain

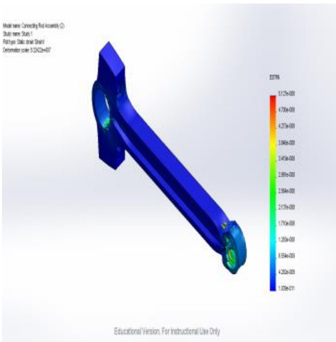


Displacement

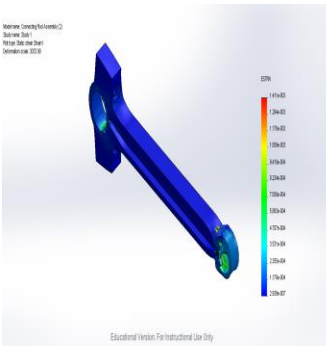


Factor of safety

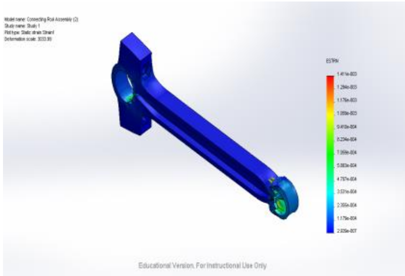
<u>Aa3556:</u>



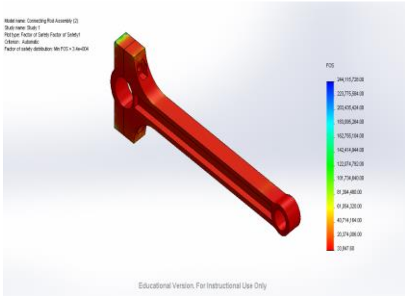
Stress



Strain

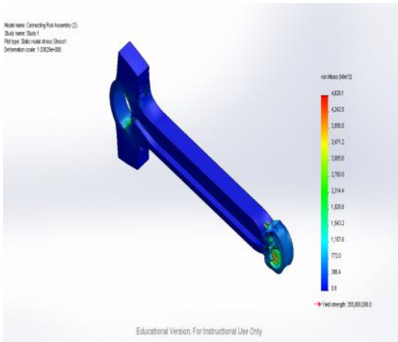


Displacement

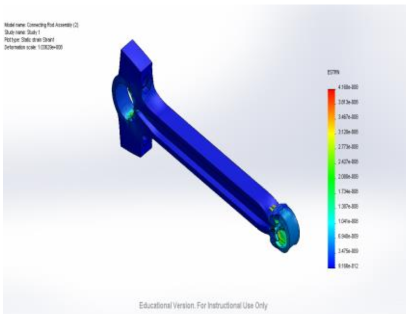


Factor of Safety

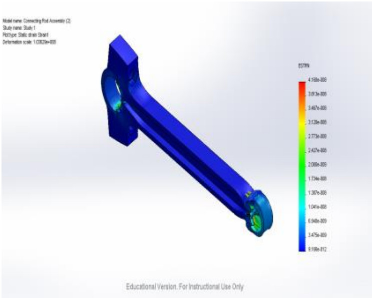
<u>6061-t6:</u>



Stress



Strain



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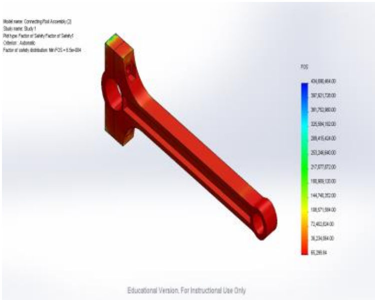


Factor of safety

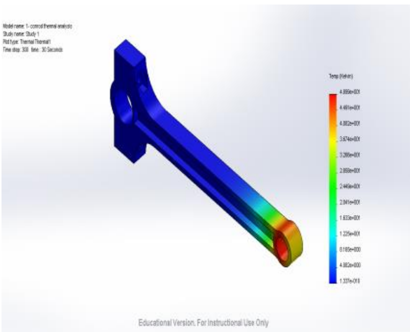
Thermal analysis of conrod

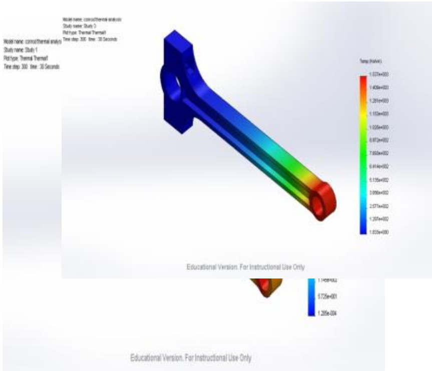
The Thermal analysis is also done for the different 20 materials based on the thermal conductivity of the materials and the Table 3 shows the comparative study for 5 materials.

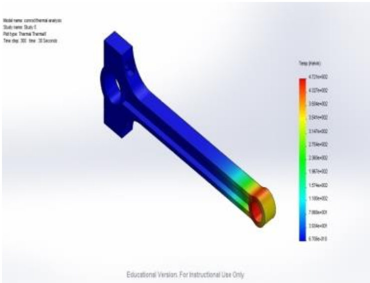
Table:3. Thermal Analysis of conrod

SNO	TYPE OF MATERIAL	HEAT FLUX W/m^2	TEMPERATURE(°K)	
			MIN	MAX
1	6061-T6	1230526.315	2.46598*10^-9	487.57
2	AA356	112631.578	1.33696*10^-10	48.9884
3	SILUMIN	1008000	6.7063*10^-10	472.085
4	MAGNESIUM	1105263.158	1.83251	1536.79
5	FORGED STEEL	1662.315	0.000128529	687.021

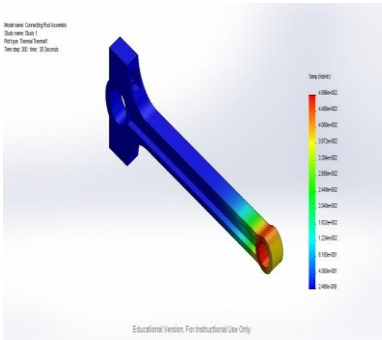
Forged Steel







Magnesium



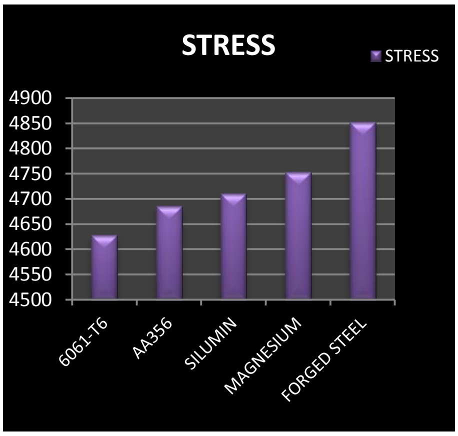
Silumin

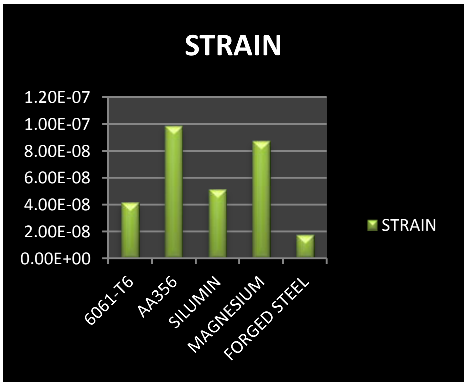
AA3566

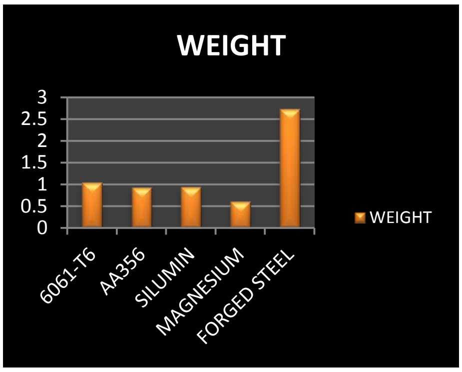
6061-T6

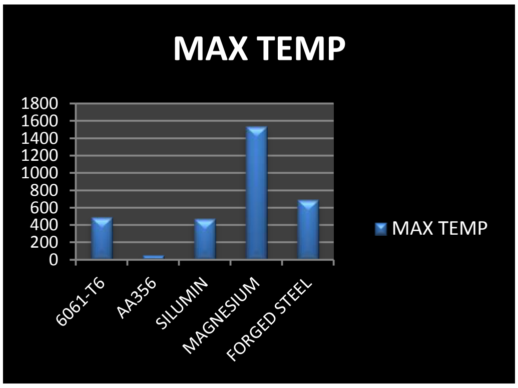
GRAPHS

The graphs are drawn by considering the forged steel and top 4 materials.









Conclusion

By checking and comparing the results of materials from the above tables and finalizing the results are shown in below:

- By comparing all the five materials, 6061-T6, AA356, SILUMIN, MAGNESIUM, FORGED STEEL the material 6061-T6 have developed less compressive stress when compared to the other materials.
- 6061-T6 material has developed moderate displacement when compared with the other materials.
- The weight of 6061-T6 material is very less when compared to forged steel.
- Thermal stresses for 6061-T6 material are less when compared to forged steel
- So this material (6061-T6) was concluded to be the better material for the manufacturing of Conrod’s.

Future Scope

Dynamic Analysis can be done by applying cyclic load.

- Optimization can be performed to reduce weight and manufacturing cost.
- By using other facture crackable materials such as micro-alloyed steels having higher yield strength and endurance limit, the weight at the piston pin end and the crank end can be further reduced.
- Large amount of CNTs adversely affect the material strength.

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