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Fem Analysis on IC Engine Connecting Rod Material with Optimized Design

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Abstract—*A connecting rod is an engine component that transfers motion from the piston to the crankshaft and functions as a lever arm. Finite element analysis (FEA) is a computerized method for predicting how a product reacts to real-world forces, vibration, heat, fluid flow, and other physical effects. Finite element analysis shows whether a product will break, wear out, or work the way it was designed.*

Keywords*: Connecting Rod, FEA, Modal, Static Analysis.*

1. INTRODUCTION

The connecting rod is under tremendous stress from the reciprocating load represented by the piston, actually stretching and being compressed with every rotation, and the load increases to the third power with increasing engine speed.

2. MATERIAL STANDARDS:

Table 1: Material Properties List

Material	EM (MPa)	Poisson Ratio	Density kg/m^3	Cs (MPa)	YTS (MPa)	UTS (MPa)
GCI	66000	0.21	7200	570	120	200
AISI 4340	205000	0.29	7850	710	710	1110
Al 2014 T6	72400	0.33	2850	470	470	590
Al 7068	73100	0.33	2850	425	655	681

3. ENGINE SPECIFICATIONS:

Piston diameter = 112 mm, Piston Weight = 22.12 N, Weight of Reciprocating mass = 23.06 N, Bore = 112 mm , stroke = 127 mm, Speed of Engine = 1200 Minimum , 2200 Maximum, C.R = 17.: , Explosive Pressure = 2.63 Mpa, Length of connecting rod = 214 mm.

4. DESIGN CALCULATIONS:

Table 2: Summary of the Deisgn Values * indicates Induced Values

Material	t (mm)	σt (MPa)	σc (MPa)	* σc (Mpa)	* σb (MPa)
Al 7068	5.9	655	425	98.60	27.77
Al 2014 –T6	5.67	470	470	106.10	27.77
CI	5.64	1500	570	122.77	27.77
ALSI 4340 Steel	4.65	1110	710	146.10	27.77

5. FEM ANALYSIS :

Table 3: Summary of FEM Values

Materials	Loading			
	Tensile		Compressive	
	On piston end	On crank end	On piston end	On crank end
GCI	0 (min) 0.00021158(max)	0 (min) 0.00020555(max)	0 (min) 0.00021158(max)	0 (min) 0.00020555(max)
AISI 4340 Steel	0 (min) 8.761e-5(max)	0 (min) 8.5911e-5(max)	0 (min) 8.761e-5(max)	0 (min) 8.5911e-5(max)
Al 2014 T6	0 (min) 0.00019074(max)	0 (min) 0.00018573(max)	0 (min) 0.00019074(max)	0 (min) 0.00018573(max)
Al 7068	0 (min) 0.00018891(max)	0 (min) 0.00018395(max)	0 (min) 0.00018891(max)	0 (min) 0.00018395(max)

Table 4: Summary of Equivalent elastic strains (m/m)

Materials	Loading			
	Tensile		Compressive	
	On piston end	On crank end	On piston end	On crank end
GCI	9.525e-8 (min) 0.001754(max)	1.4609e-7 (min) 0.001704(max)	9.525e-8 (min) 0.001754(max)	1.4609e-7 (min) 0.001704(max)
AISI 4340 Steel	4.4803e-8 (min) 0.00078684(max)	5.908e-8 (min) 0.00078566(max)	4.4803e-8 (min) 0.00078684(max)	5.908e-8 (min) 0.00078566(max)
Al 2014 T6	1.108e-7(min) 0.0016284(max)	1.9824e-7(min) 0.0015483(max)	1.108e-7(min) 0.0016284(max)	1.9824e-7(min) 0.0015483(max
Al 7068	1.0974e-7(min) 0.0016128(max)	1.9634e-7(min) 0.0015334(max)	1.0974e-7(min) 0.0016128(max)	1.9634e-7(min) 0.0015334(max)

Table 5: Summary of Equivalent elastic stress (m/m)

Materials	Loading			
	Tensile		Compressive	
	On piston end	On crank end	On piston end	On crank end
GCI	1783.4(min) 1.1282e8(max)	4481.3(min) 1.1247e8(max)	1783.4(min) 1.1282e8(max)	4481.3(min) 1.1247e8(max)
AISI 4340 Steel	5019.2(min) 1.6021e8(max)	6680.1(min) 1.5999e8(max)	5019.2(min) 1.6021e8(max)	6680.1(min) 1.5999e8(max)
Al 2014 T6	4463.9(min) 1.1544e8(max)	7783.3(min) 1.1167e8(max)	4463.9(min) 1.1544e8(max)	7783.3(min) 1.1167e8(max)
Al 7068	4463.9(min) 1.1544e8(max)	7783.3(min) 1.1167e8(max)	4463.9(min) 1.1544e8(max)	7783.3(min) 1.1167e8(max)

Table 6 Summary on Factor of Safety Values

Materials	Loading			
	Tensile		Compressive	
	On piston end	On crank end	On piston end	On crank end
GCI	1.0637(min)	1.0669(min)	1.0637(min)	1.0669(min)
AISI 4340 Steel	4.4317(min)	4.4379(min)	4.4317(min)	4.4379(min)
Al 2014 T6	4.0715(min)	4.2089(min)	4.0715(min)	4.2089(min)
Al 7068	5.6741(min)	5.8655(min)	5.6741(min)	5.8655(min)

Table 7: Summary on Weight Comparison

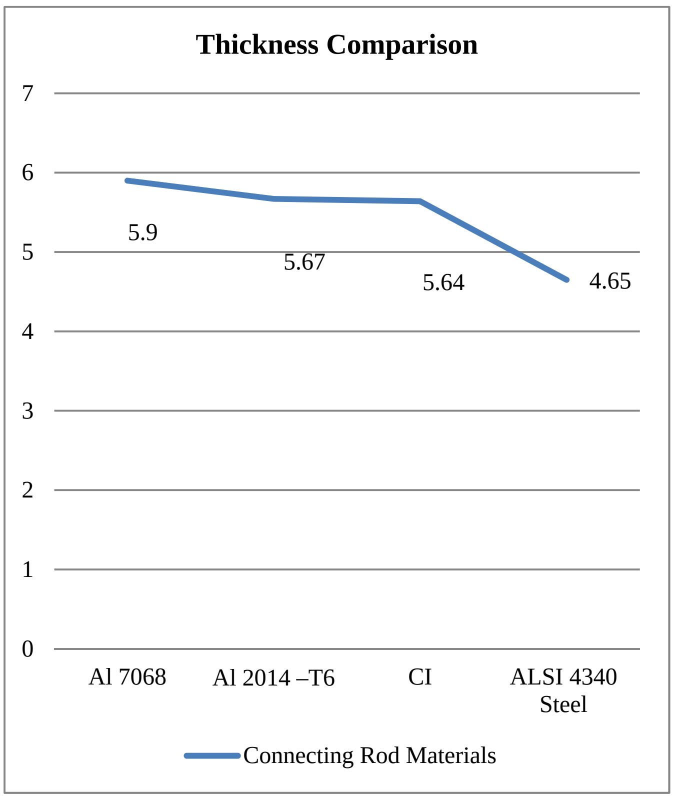
Material	Density (kg/m^3)	Connecting Rod Volume(m^3)	Mass/Weight (kg)
GCI	7200	0.00031189	2.2456
AISI 4340 Steel	7850	0.00031189	2.4483
Al 2014 T6	2850	0.00031189	0.8888
Al 7068	2850	0.00031189	0.8888

Table 9: Comparison table between old and new geometry

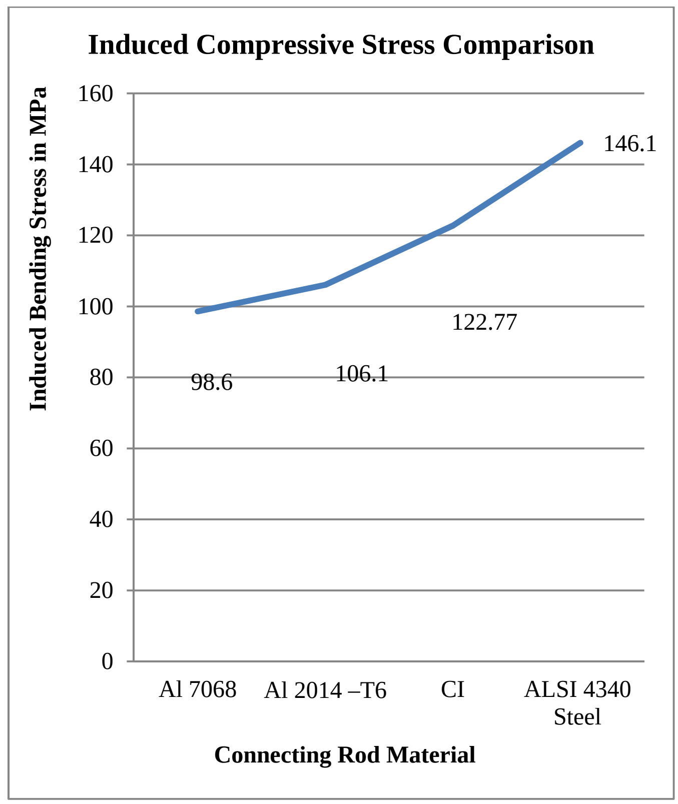
Geometry	Equivalent (Von-Misses Stress) (Pa)		Factor of Safety		Natural Frequency (crank end constraint) (Hz.)			
	Loading at piston end	Loading at crank end	Loading at piston end	Loading at crank end	Mode 1	Mode 2	Mode 3	Mode 4
Old	4463.9(min) 1.1544e8(max)	7783.3(min) 1.1167e8(max)	5.6741 (min)	5.8655 (min)	220.48	381.34	487.82	1720.8
New	161.46(min) 1.8878e8(max)	130.35(min) 1.8433e8(max)	3.4696 (min)	3.5534 (min)	176.7	333.69	535.49	1682.1

Geometric Features	Old model	New model
Outer diameter of the piston end bearing (d_p)	55.5 mm	44.4 mm
Outer diameter of the crank end bearing (d_c)	69 mm	55.2 mm
Fillets	No fillets	Radius Minimum = 3 mm Maximum = 250 mm
Volume	0.00031189 m^3	0.00014822 m^3

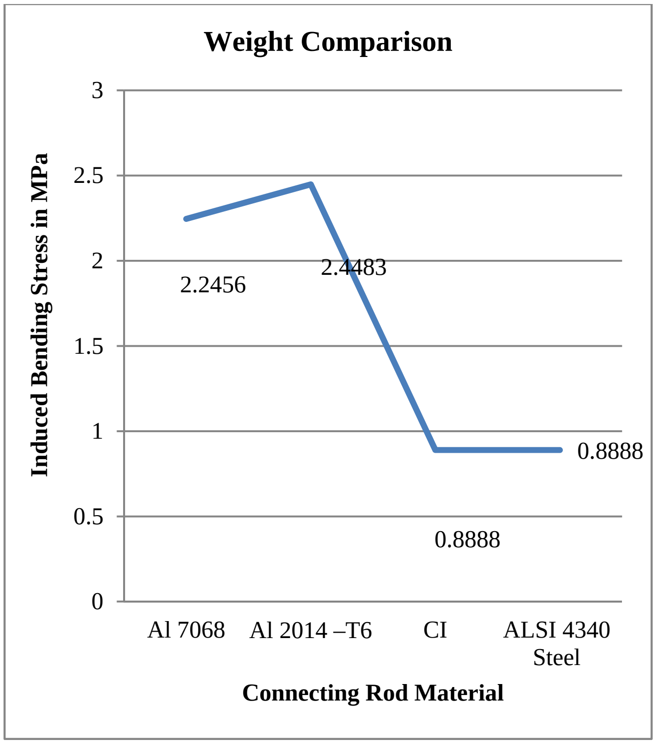
1. Graphs:



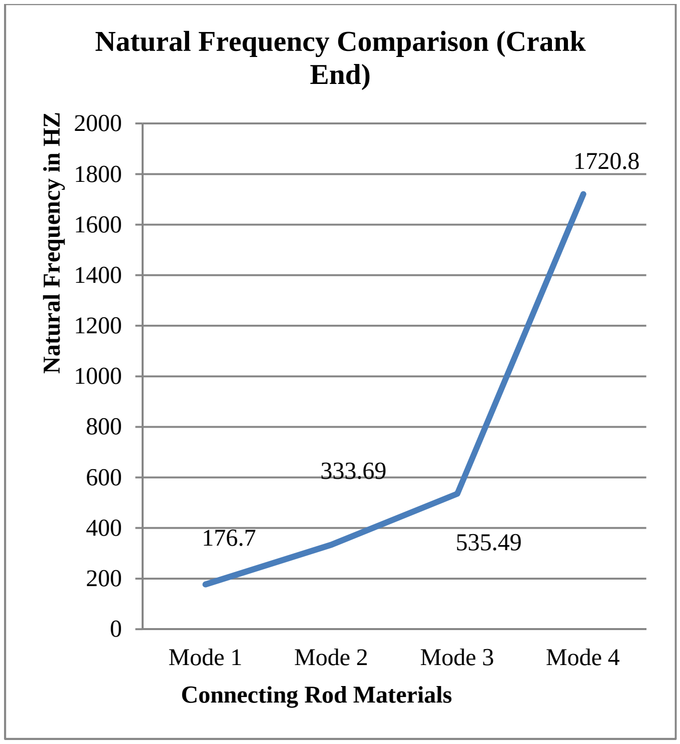
Graph 1: Thickness Comparison



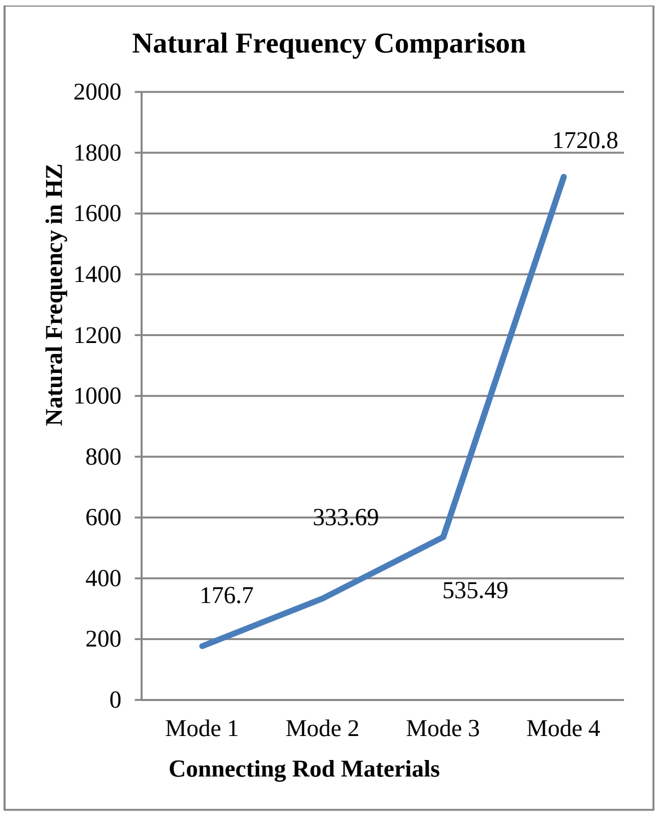
Graph 2: Induced Bending Stress



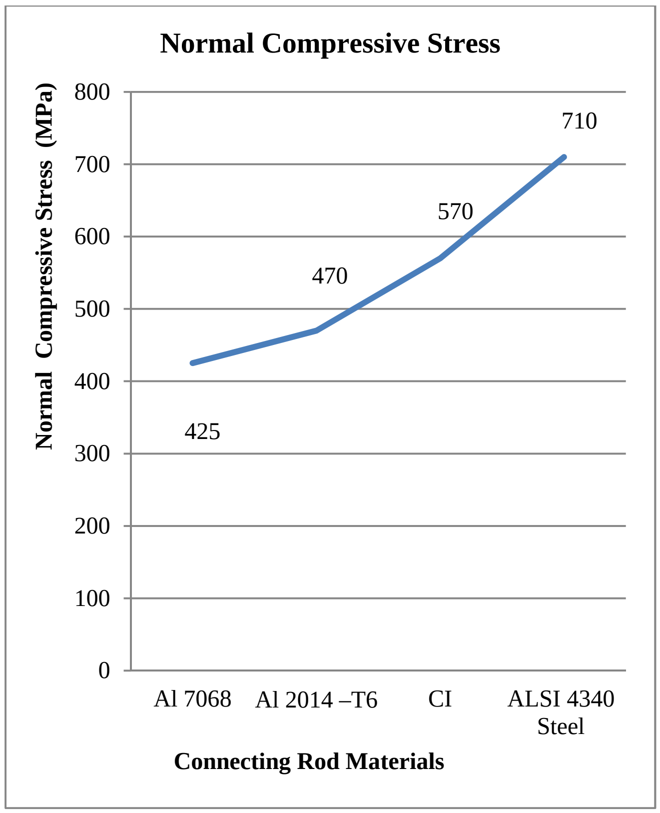
Graph 3: Optimized Weight Comparison



Graph 4: Old Material Natural Frequencies



Graph 5: Optimized Material Natural Frequencies



Graph 6: Normal Compressive Stress Values

6. CONCLUSION

Among the four materials, i.e., Grey Cast Iron, AISI 4340 Steel (Normalized), Al 2014 T6, and Al 7068, the equivalent stress induced in the connecting rod is least in Al 7068, which has been validated by both analytical calculations and software analysis. Moreover, the weight of the connecting rod made up of Al 7068 is the lightest. Hence, considering both factors, Al 7068 is chosen as the best material for the connecting rod among other materials .Further, Al 7068 made connecting rod has been optimized with some geometric alteration keeping the factor of safety in the safe range i.e. 3-5. Weight of Old model = density * Volume (factor of safety = 5.8655) = 2850 kg/m^3 * 0.00031189 m^3 = 0.8888 kg. Weight of Optimized Model = density * volume (factor of safety = 3.55). = 2850 kg/m^3 * 0.00014822 m^3 = = 0.4224 kg % reduction in weight = 52.47 % . Thus, optimized Al 7068 design is favorable and promising.