Design and Analysis of Crank Shaft for Four Stoke Four Cylinder Diesel Engine

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Abstract : Crankshaft is large volume production component with a complex geometry in the Internal Combustion (I.C) Engine. This converts the reciprocating displacement of the piston in to a rotary motion of the crank. We are study selection of best material by comparing the Static analysis on a crankshaft from a 4-cylinder 4-stroke I.C Engine. The modeling of the crankshaft is created using CREO PARAMETRIC 3.0 Software. This model will be converted to Initial Graphic Exchange Specification (IGS). Finite element analysis (FEA) is performed to obtain the variation of stress at critical locations of the crank shaft using the ANSYS software and applying the boundary conditions. This load is applied to the FE model in ANSYS, and boundary conditions are applied according to the engine mounting conditions. The analysis is done for finding critical location in crankshaft. Stress variation over the engine cycle and the effect of torsion and bending load in the analysis are investigated. Von-mises stress is calculated using theoretical y and FEA software ANSYS. The relationship between n the frequency and the vibration modal is explained by the modal and harmonic analysis of crankshaft using FEA software ANSYS. The stress analysis of a 4-cylinder crankshaft are discussed using finite element method before and after modification in this paper Maximum stress areas and dangerous areas are found by the stress analysis of crankshaft and Deformation of the crank shaft for different materials. The Analysis was done before and after modification at stress concentrated areas with different loads by that the comparison was taken place. In the stress analysis we get the maximum stress values before and after modification. All the obtained values were plotted. Modifications are applied to reduce the stress of the crankshaft and by that the comparison was done with the previous design. By this the appropriate design optimization will be achieved.

IndexTerms - Crankshaft, PCD, Creo & Anysis Software.

I. INTRODUCTION

Crank shaft is a large component with a complex geometry in the I.C engine, which converts the reciprocating displacement of the piston to a rotary motion with a four bar link mechanism. Crankshaft consisting of shaft parts, two journal bearings and one crankpin bearing. The Shaft parts which revolve in the main bearings, the crank pins to which the big end of the connecting rod are connected, the crank arms or webs which connect the crank pins and shaft parts. In addition, the linear displacement of an engine is not smooth; as the displacement is caused by the combustion chamber therefore the displacement has sudden shocks.The concept of using crankshaft is to change these sudden displacements to as smooth rotary output, which is the input to many devices such as generators, pumps and compressors. It should also be stated that the use of a flywheel helps in smoothing the shocks. Crankshaft experiences large forces from gas combustion. This force is applied to the top of the piston and since the connecting rod connects the piston to the crank shaft, the force will be transmitted to the crankshaft. The magnitude of the forces depends on many factors which consist of crank radius, connecting rod dimensions, weight of the connecting rod, piston, piston rings, and pin. Combustion and inertia forces acting on the crankshaft.

1. Torsional load

2. Bending load.

Crankshaft must be strong enough to take the downward force of the power stroke without excessive bending so the reliability and life of the internal combustion engine depend on the strength of the crankshaft largely. The crank pin is like a built in beam with a distributed load along its length that varies with crank positions. Each web is like a cantilever beam subjected to bending and twisting.
1. Bending moment which causes tensile and
compressive stresses.
2. Twisting moment causes shear stress.
There are many sources of failure in the engine one of the most common crankshaft failure is fatigue at the fillet areas due to the bending load causes by the combustion. The moment of combustion the load from the piston is transmitted to the crankpin, causing a large bending moment on the entire geometry of the crankshaft. At the root of the fillet areas stress concentrations exist and these high stress range locations are the points where cyclic loads could cause fatigue crank initiation leading to fracture.Crankshaft is one of the most important moving parts in internal combustion engine. It must be strong enough to take the downward force of the power stroked without excessive bending. So the reliability and life of internal combustion engine depend on the strength of the crankshaft largely. And as the engine runs, the power impulses hit the crankshaft in one place and then

another. The torsional vibration appears when a power impulse hits a crankpin toward the front of the engine and the power stroke ends. If not controlled, it can break the crankshaft. Strength calculation of crankshaft becomes a key factor to ensure the life of engine. Beam and space frame model were used to calculate the stress of crankshaft usually in the past. But the number of node is limited in these models. With the development of computer, more and more design of crankshaft has been utilized finite element method (FME) to calculate the stress of crankshaft. The application of numerical simulation for the designing crankshaft helped engineers to efficiently improve the process development avoiding the cost and limitations of compiling a database of real world parts. Finite element analysis allows an inexpensive study of arbitrary combinations of input parameters including design parameters and process conditions to be investigated. Crankshaft is a complicated continuous structure. The vibration performance of crankshaft has important effect to engine calculation.

II. PROPOSED METHODOLOGY

1. Theoretical calculation of four cylinder crankshaft.
2. Creo 3.0 software has used for design the crankshaft
3. Solid model of four cylinder four stock engine crankshaft.
4. Meshing of 3-D entity of crankshaft.
5. Finite element analysis in ANSYS14.5
6. Computational results.
7. Experimentation on material.
8. Compare theoretical and experimental result.

➢ INPUT PARAMETERS

1. Rotational Velocity : 955 rpm and 100 radian/sec
2. Moment (Torque) : 50 N-m and 84 N-m
3. Force "F" : 2084 N and 3500 N

➢ MATERIAL PROPERTY

1. STRUCTURAL STEEL

S. NO	PARAMETER	VALUE	UNIT
1.	Density	7.850	g/cm^3
2.	Young's Modulus	2 E+11	Pa
3.	Poisson Ratio	0.3	-
4.	Bulk Modulus	1.6667 E+11	Pa
5.	Shear Modulus	7.6923 E+11	Pa
6.	Tensile Yield Strength	2.5 E+8	Pa
7.	Compressive Yield Strength	2.5 E+8	Pa
8.	Tensile Ultimate Strength	4.5 E+8	Pa

2. FORGED STEEL

S. NO	PARAMETER	VALUE	UNIT
1.	Density	7.9	g/cm^3
2.	Young's Modulus	2.208 E+11	Pa
3.	Poisson Ratio	0.3	-
4.	Bulk Modulus	1.84 E+11	Pa
5.	Shear Modulus	8.4923 E+10	Pa
6.	Tensile Yield Strength	6.8 E+8	Pa
7.	Compressive	6.8 E+8	Pa

	Yield Strength		
8.	Tensile Ultimate Strength	8.5 E+8	Pa

3. COMPOSITE MATERIAL

S. NO	PARAMETER	VALUE	UNIT
1.	Density	1.6	g/cm^3
2.	Young's Modulus	1.4 E+8	Pa
3.	Poisson Ratio	0.34	-
4.	Bulk Modulus	1.4583 E+8	Pa
5.	Shear Modulus	5.2239 E+7	Pa
6.	Tensile Yield Strength	1.9 E+9	Pa
7.	Compressive Yield Strength	1.9 E+9	Pa
8.	Tensile Ultimate Strength	4.6 E+8	Pa

III. SIMULATION RESULTS OF PROPOSED CRANK SHAFT BY USING SIMULATION SOFTWARE CREO 3.0 AND ANSYS

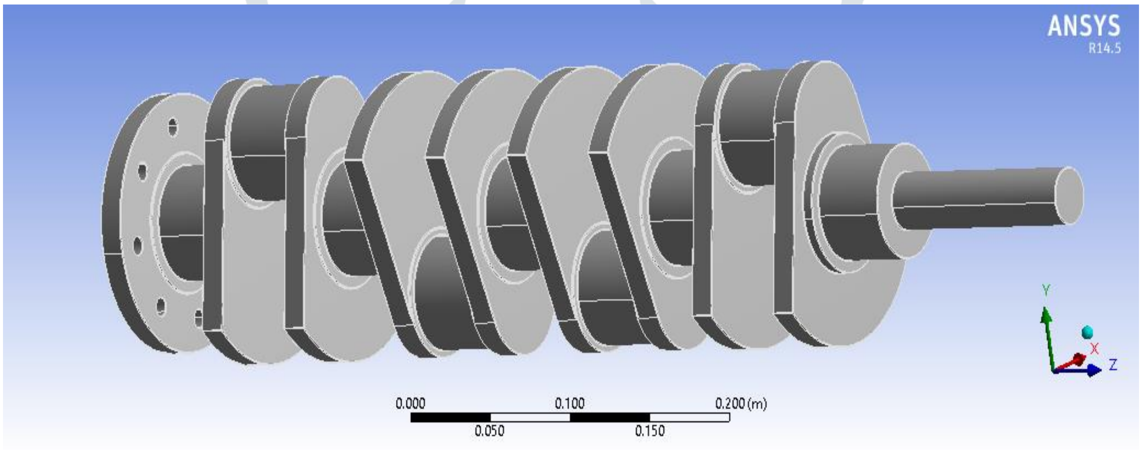

Fig. 1 Simple figure of Crankshaft

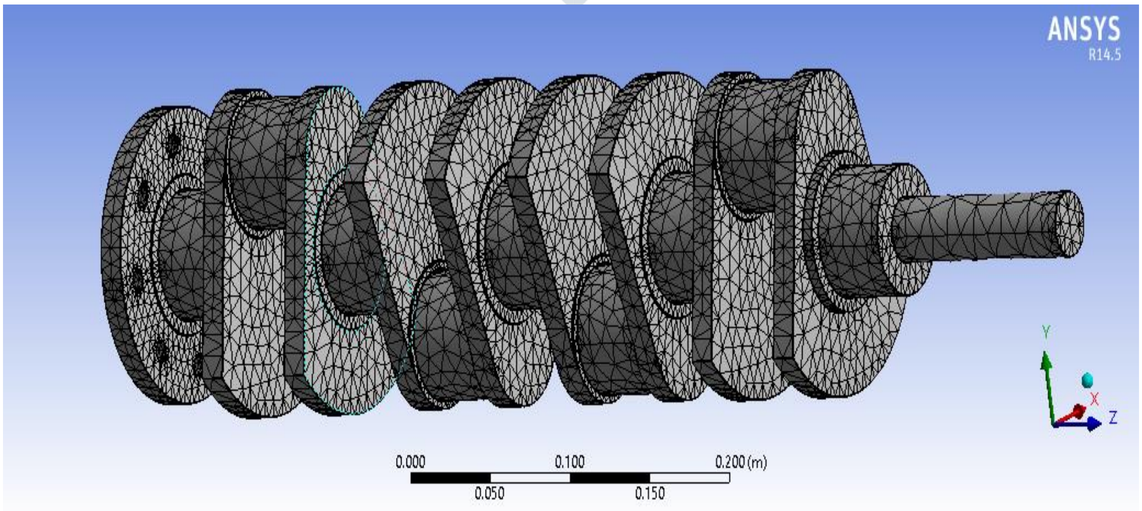

Fig.2 Meshing of crankshaft

IV. Different type of force obtain by using simulation software for structural steel

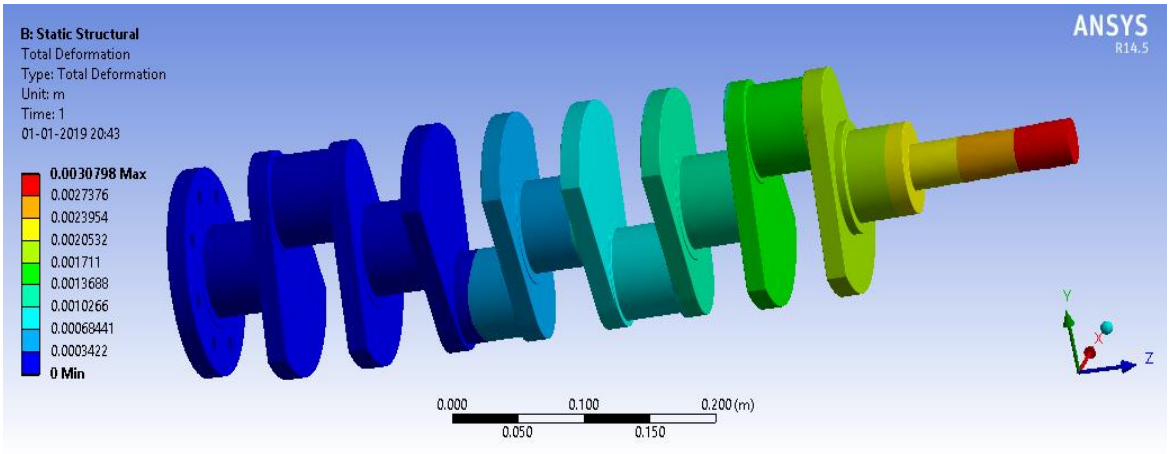

Fig.1 2084 N Lateral force

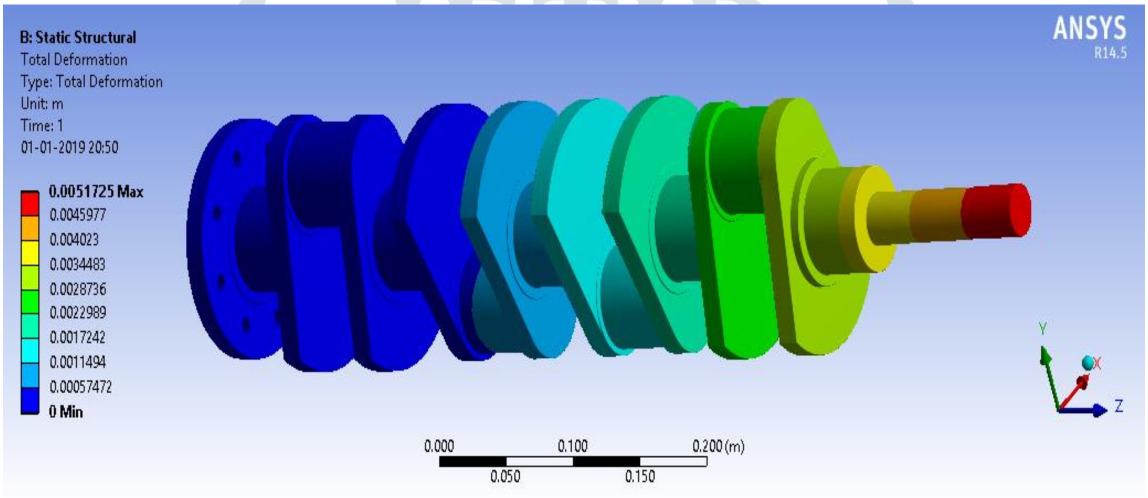

Fig . 2 3500N Lateral Force

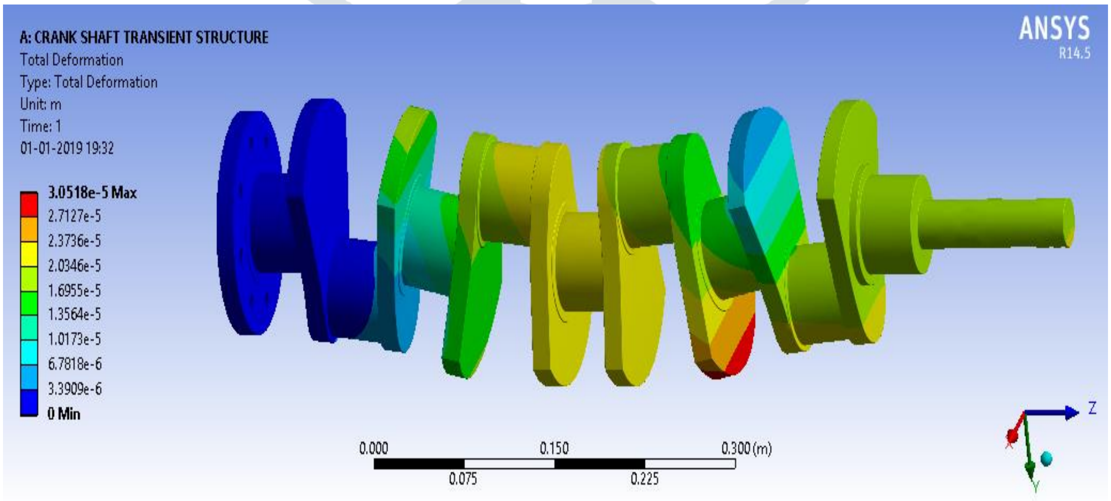

Fig . 3 2084N Longitudinal Force

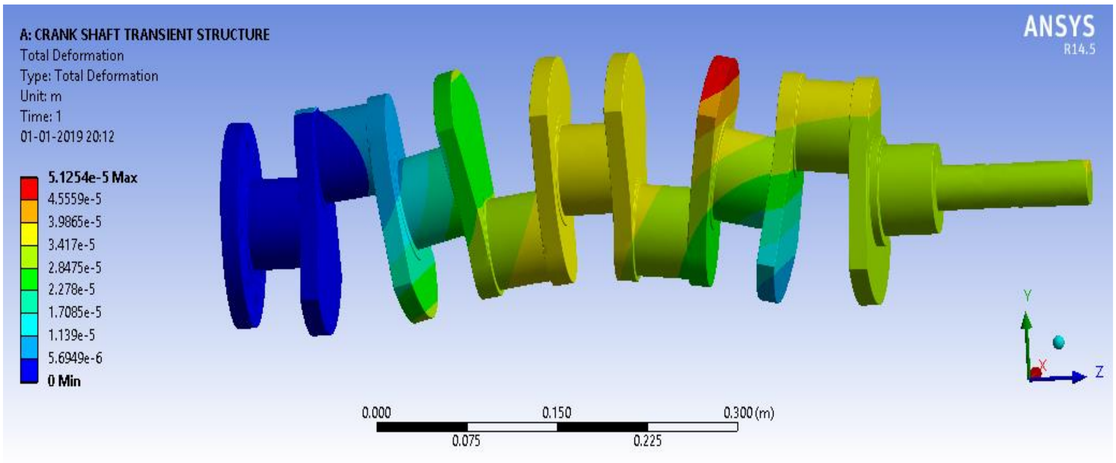

Fig . 4 3500N Longitudinal Force

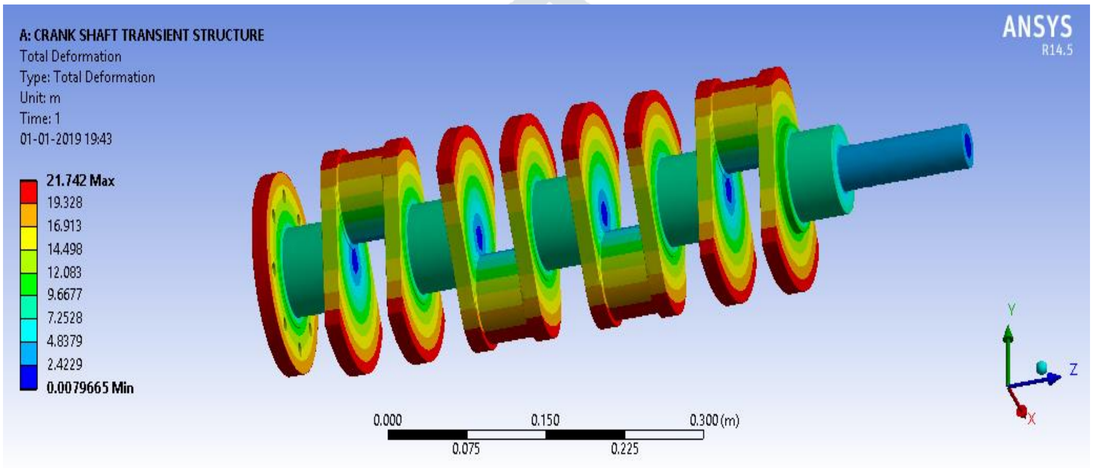

Fig . 5 2084N Torsional Force

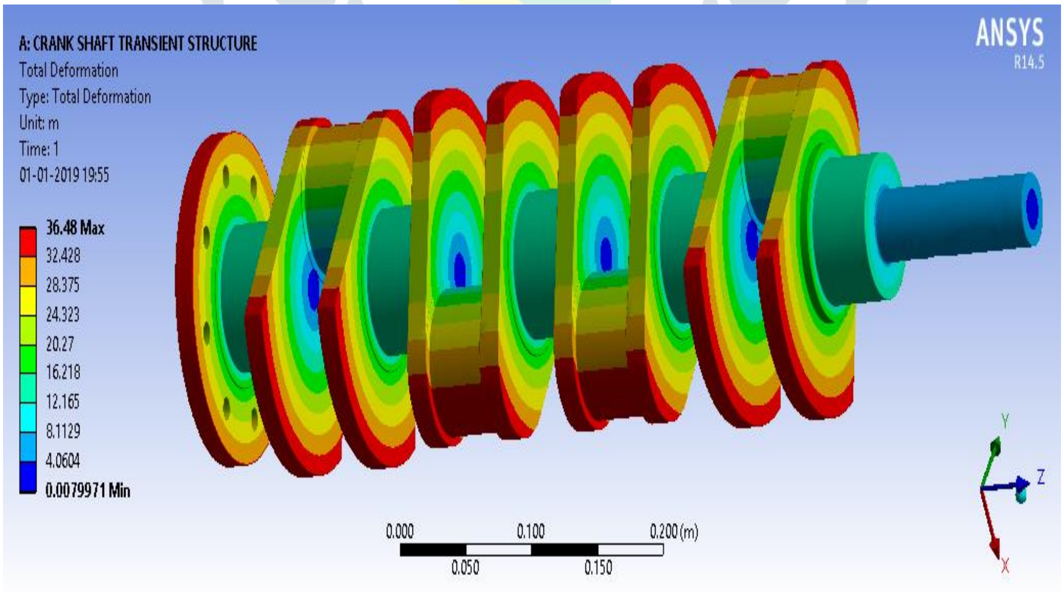

Fig . 6 3500N Torsional Force

V. DIFFERENT TYPE OF FORCE OBTAIN BY USING SIMULATION SOFTWARE FOR FORGED STEEL

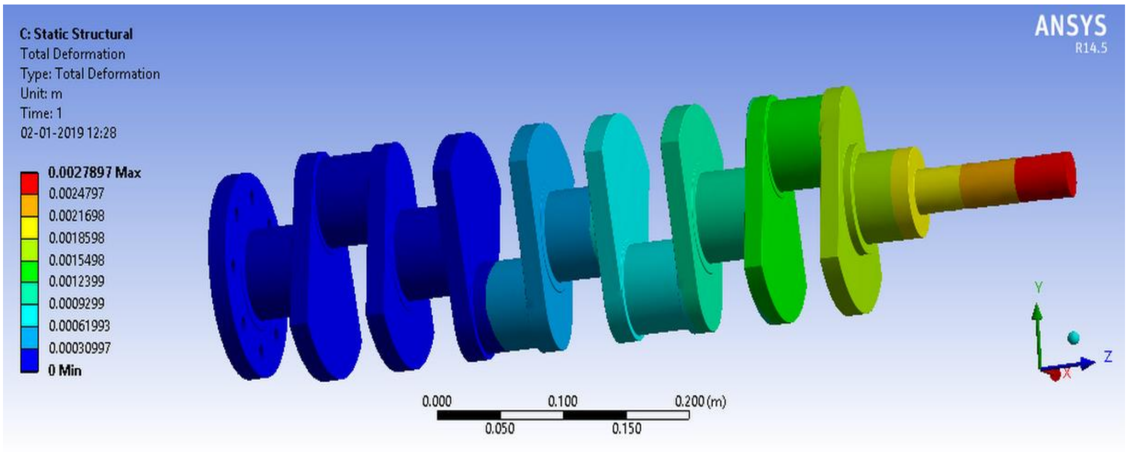

Fig.1 2084 N lateral force

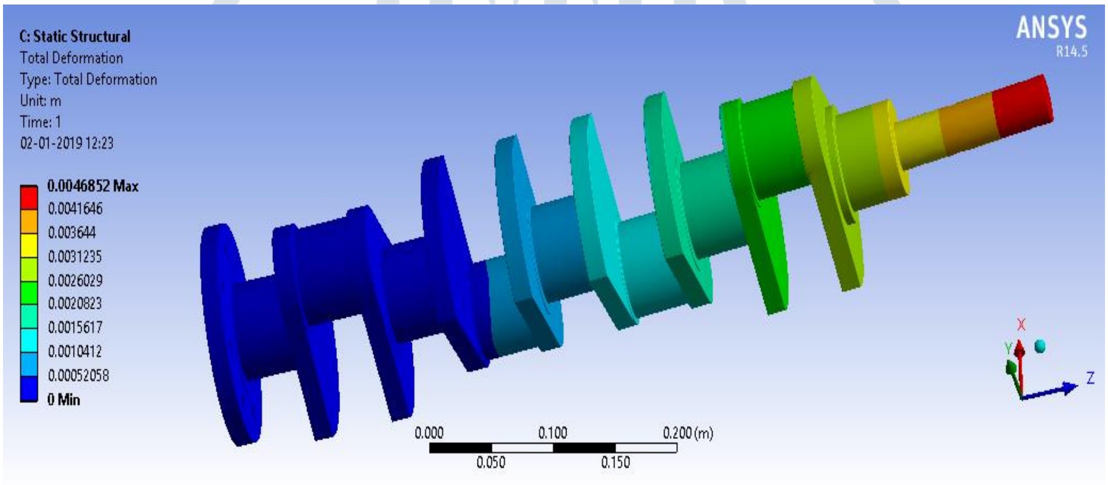

Fig . 2 3500N Lateral Force

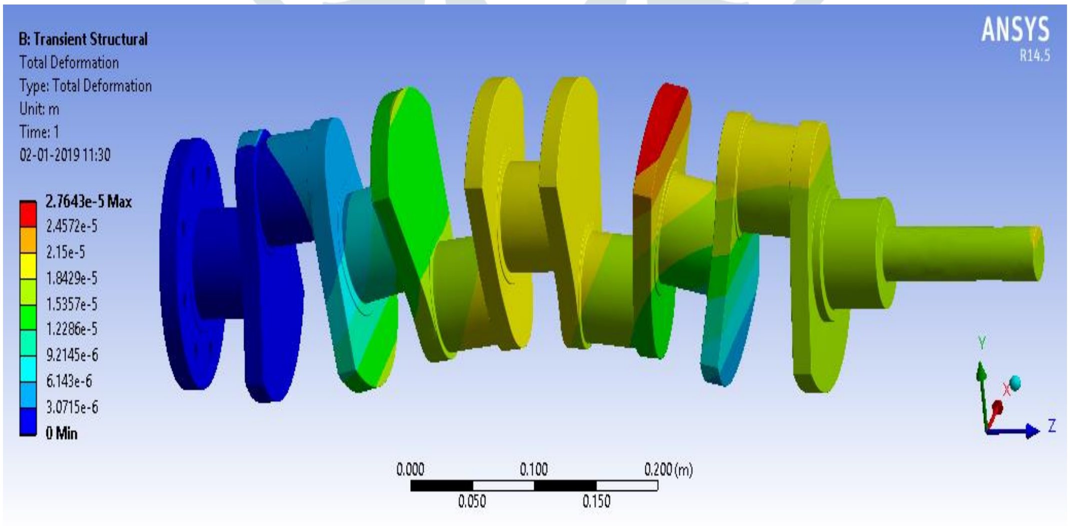

Fig . 3 2084N Longitudinal Force

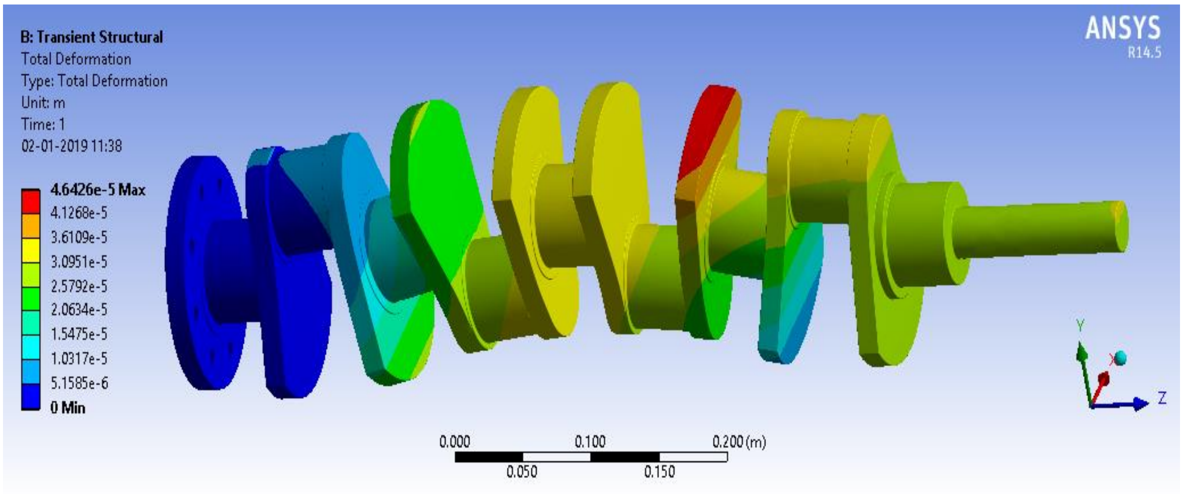

Fig . 4 3500N Longitudinal Force

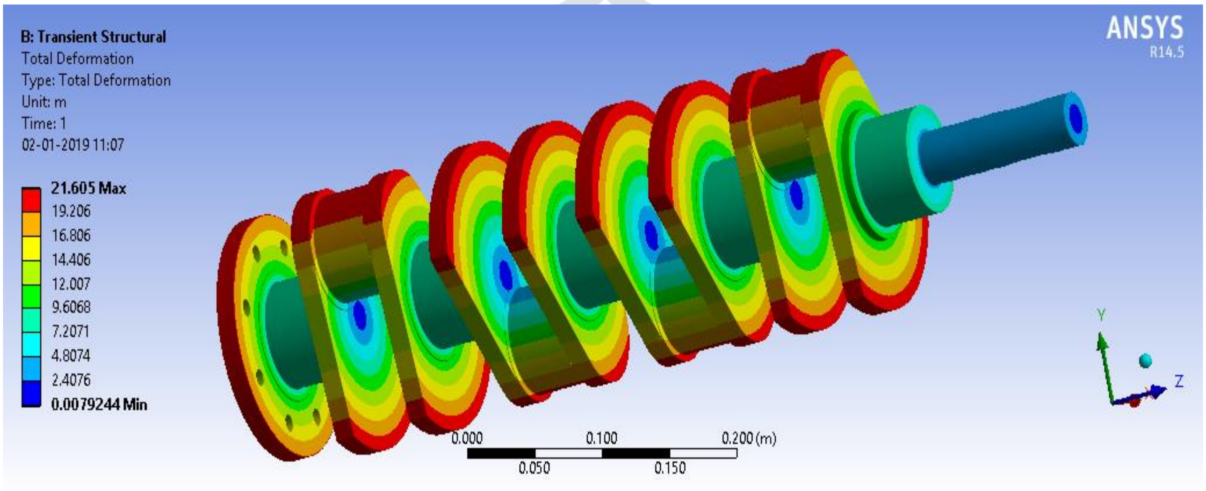

Fig . 5 2084N Torsional Force

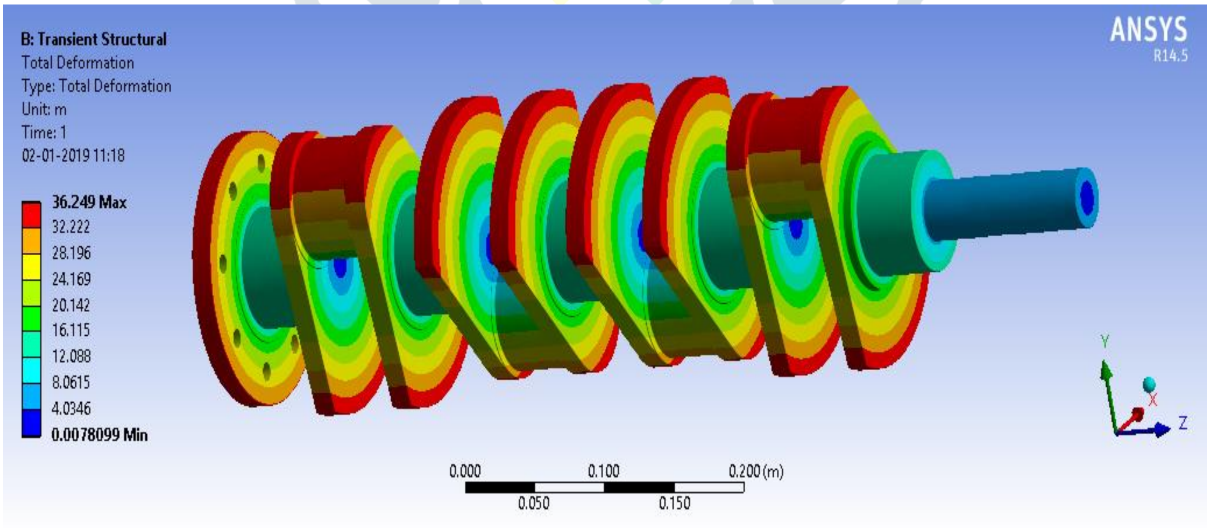

Fig . 6 3500N Torsional Force

VI. DIFFERENT TYPE OF FORCE OBTAIN BY USING SIMULATION SOFTWARE FOR COMPOSITE MATERIAL

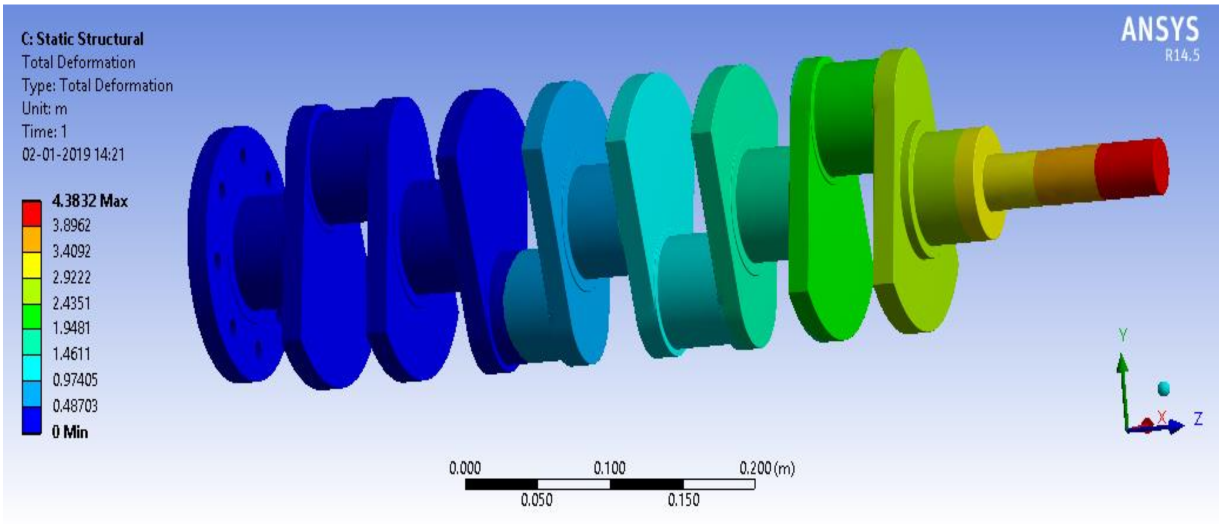

Fig.1 2084 N lateral force

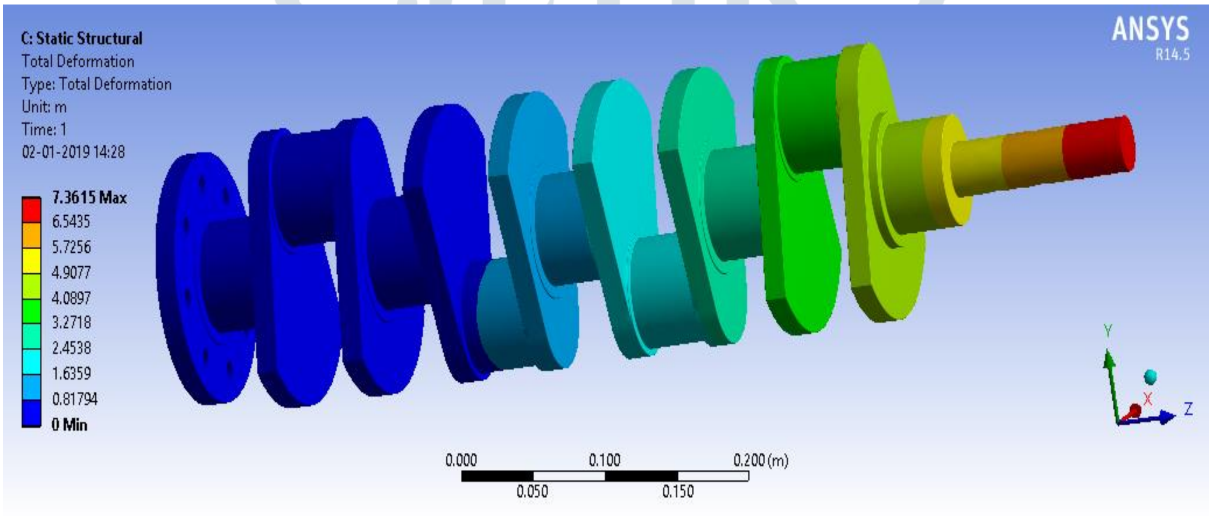

Fig . 2 3500N Lateral Force

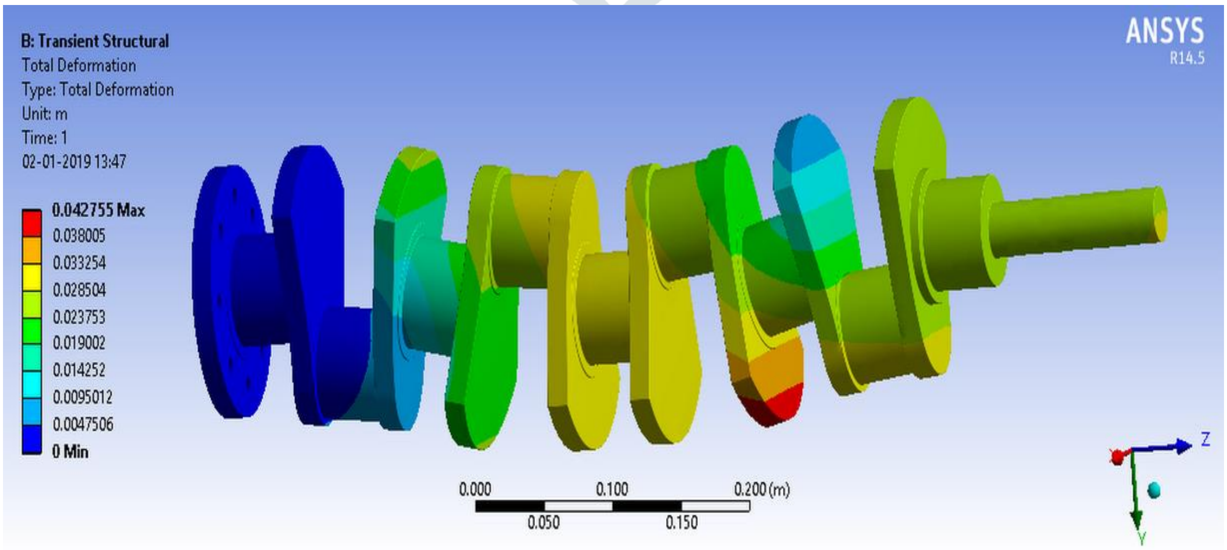

Fig . 3 2084N Longitudinal Force

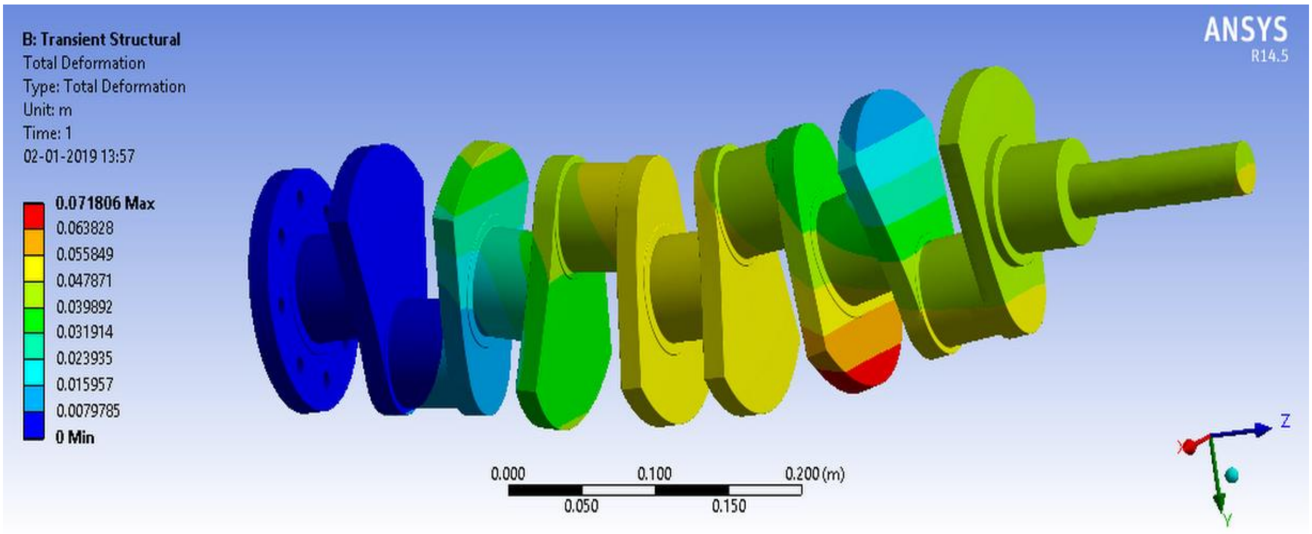

Fig . 4 3500N Longitudinal Force

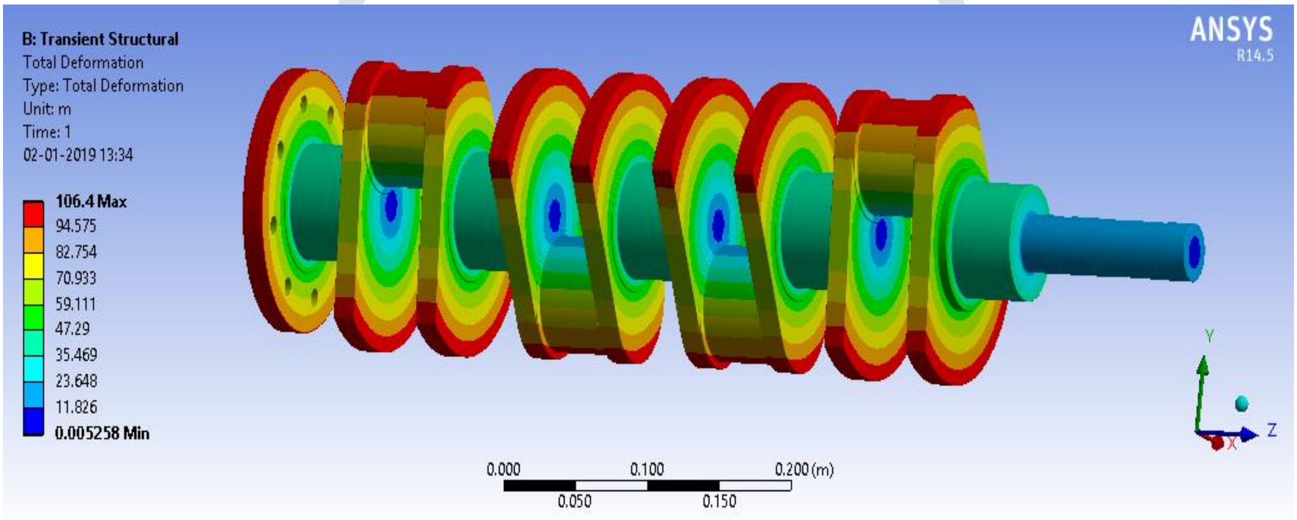

Fig . 5 2084N Torsional Force

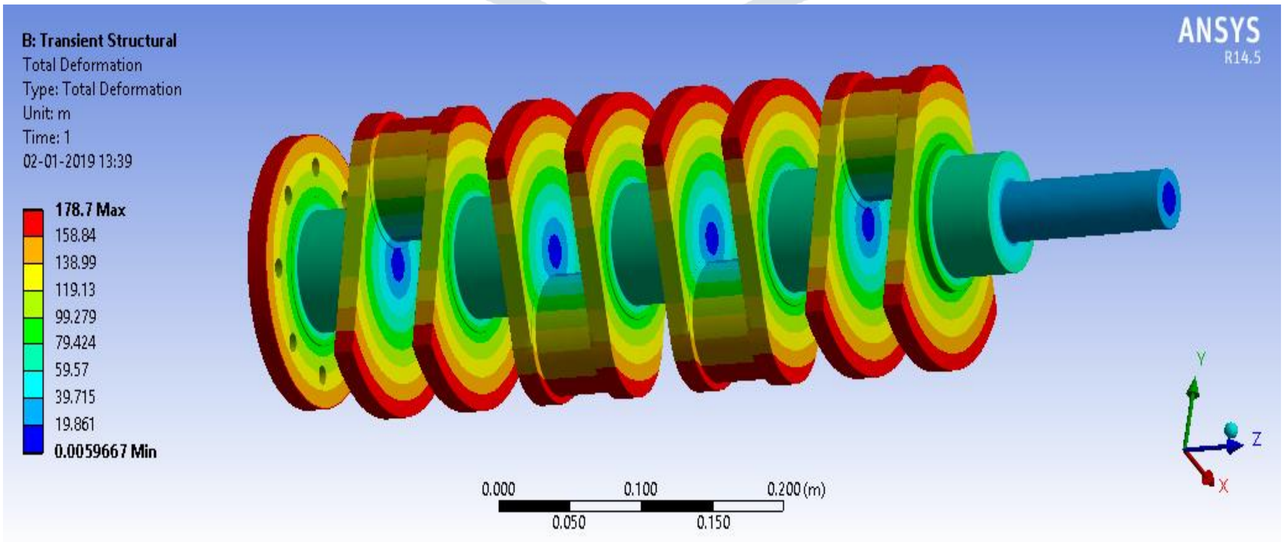

Fig . 6 3500N Torsional Force

VII. OUTCOMES

1. RESULT OF STRUCTURAL STEEL

1(A) Force (2084 N), Torque (50 N-m), Rotational Velocity (100 radian/sec)

S. NO	PARAMETER	LONGITUDENAL DIRECTION		LATERAL DIRECTION		TORSIONAL DIRECTION	
	RANGE →	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum
1.	Life	1 E+6	1 E+6	1 E+6	5035.2	1 E+6	1 E+6
2.	Safety Factor	15	3.8096	15	0.26351	15	6.7134
3.	Structural Error	7.6828 E-7 J	2.1364 E-18 J	0.00053174 J	4.0882 E-15 J	2.192 E-6 J	8.9198 E-19 J
4.	Equivalent Alternating Stress	1.988 E+7 Pa	313.87 Pa	NA	NA	1.1074 E+7 Pa	414.17 Pa
5.	Equivalent Elastic Strain	0.00019168 m/m	5.6028 E-9 m/m	0.0016397 m/m	1.3695 E-7 m/m	0.00010871 m/m	8.0753 E-9 m/m
6.	Equivalent (Von-Mises) Stress	3.8112 E+7 Pa	627.73 Pa	3.2712 E+8 Pa	9692.1 Pa	2.1627 E+7 Pa	730.05 Pa
7.	Total Deformation	3.0518 E-5 m	0 M	0.0030798 m	0 m	21.742 m	0.0079665 m
8.	Directional Deformation X	1.3305 E-7 m	-1.2603 E-7 m	0.0030773 m	-2.7403 E-6 m	21.677 m	-21.664 m
9.	Directional Deformation Y	1.9778 E-5 m	-1.7018 E-6 m	1.0052 E-5 m	-1.0162 E-5 m	19.496 m	-19.508 m
10.	Directional Deformation Z	2.6349 E-5 m	-7.6608 E-6 m	0.00040234 m	-0.0004022 m	0.014632 m	-0.014634 m

1(B) Force (3500 N), Torque (84 N-m), Rotational Velocity (100 radian/sec)

S. NO	PARAMETER	LONGITUDENAL DIRECTION		LATERAL DIRECTION		TORSIONAL DIRECTION	
	RANGE →	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum
1.	Life	1 E+6	1 E+6	1 E+6	1129.4	1 E+6	1 E+6
2.	Safety Factor	15	2.2683	15	0.1569	15	6.573
3.	Structural Error	2.167 E-5 J	6.0265 E-18 J	0.0014998 J	1.1531 E-14 J	2.2405 E-6 J	1.1158 E-18 J
4.	Equivalent Alternating Stress	3.4397 E+7 Pa	527.15 Pa	NA	NA	1.1316 E+7 Pa	263.65 Pa
5.	Equivalent Elastic Strain	0.00032192 m/m	9.4097 E-9 m/m	0.0027538 m/m	2.3 E-7 m/m	0.00011101 m/m	3.1499 E-9 m/m
6.	Equivalent (Von-Mises) Stress	6.4008 E+7 Pa	1054.3 Pa	5.4939 E+8 Pa	16277 Pa	2.2089 E+7 Pa	527.29 Pa
7.	Total Deformation	5.1254 E-5 m	0 M	0.0051725 m	0 m	36.48 m	0.0079971 m
8.	Directional Deformation X	2.2346 E-7 m	-2.1167 E-7 m	0.0051682 m	-4.6022 E-6 m	36.417 m	-36.399 m
9.	Directional Deformation Y	3.3216 E-5 m	-2.858 E-6 m	1.6881 E-5 m	-1.7067 E-5 m	32.757 m	-32.769 m
10.	Directional Deformation Z	4.4251 E-5 m	-1.2866 E-5 m	0.00067571 m	-0.0006756 m	0.014723 m	-0.014738 m

2. RESULT OF FORGED STEEL

2(A) Force (2084 N), Torque (50 N-m), Rotational Velocity (100 radian/sec)

S. NO	PARAMETER	LONGITUDENAL DIRECTION		LATERAL DIRECTION		TORSIONAL DIRECTION	
	RANGE →	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum
1.	**Life**	1 E+6	1 E+6	1 E+6	5035.2	1 E+6	1 E+6
2.	**Safety Factor**	15	4.107	15	0.26351	15	7.1927
3.	**Structural Error**	6.9591 E-6 J	1.9354 E-18 J	0.00048164 J	3.7016 E-15 J	2.0105 E-6 J	7.127 E-19 J
4.	**Equivalent Alternating Stress**	1.9493 E+7 Pa	313.88 Pa	NA	NA	1.1022 E+7 Pa	401.47 Pa
5.	**Equivalent Elastic Strain**	0.00017362 m/m	5.075 E-9 m/m	0.0014852 m/m	1.2405 E-7 m/m	9.9081 E-5 m/m	7.8153 E-9 m/m
6.	**Equivalent (Von-Mises) Stress**	3.8112 E+7 Pa	627.76 Pa	3.2712 E+8 Pa	9692 Pa	2.1762 E+7 Pa	802.94 Pa
7.	**Total Deformation**	2.7643 E-5 m	0 M	0.0027897 m	0 m	21.605 m	0.0079244 m
8.	**Directional Deformation X**	1.2052 E-7 m	-1.1416 E-7 m	0.0027874 m	-2.4822 E-6 m	21.54 m	-21.527 m
9.	**Directional Deformation Y**	1.7915 E-5 m	-1.5414 E-6 m	9.1048 E-6 m	-9.2051 E-6 m	19.373 m	-19.385 m
10.	**Directional Deformation Z**	2.3866 E-5 m	-6.9391 E-6 m	0.00036444 m	-0.00036438 m	0.014644 m	-0.014623 m

2(B) Force (3500 N), Torque (84 N-m), Rotational Velocity (100 radian/sec)

S. NO	PARAMETER	LONGITUDENAL DIRECTION		LATERAL DIRECTION		TORSIONAL DIRECTION	
	RANGE →	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum
1.	**Life**	1 E+6	1 E+6	1 E+6	1129.4	1 E+6	1 E+6
2.	**Safety Factor**	15	2.4454	15	0.1569	15	7.0442
3.	**Structural Error**	1.9629 E-5 J	5.4588 E-18 J	0.0013585J	1.0441 E-14 J	2.0545 E-6 J	1.0315 E-18 J
4.	**Equivalent Alternating Stress**	3.3256 E+7 Pa	527.15 Pa	NA	NA	1.1257 E+7 Pa	335.79 Pa
5.	**Equivalent Elastic Strain**	0.0002916 m/m	8.5233 E-9 m/m	0.0024944 m/m	2.0833 E-7 m/m	0.00010115 m/m	3.6507 E-9 m/m
6.	**Equivalent (Von-Mises) Stress**	6.4008 E+7 Pa	1054.3 Pa	5.4939 E+8 Pa	16277 Pa	2.222 E+7 Pa	671.57 Pa
7.	**Total Deformation**	4.6426 E-5 m	0 M	0.0046852 m	0 M	36.249 m	0.0078099 m
8.	**Directional Deformation X**	2.0241 E-7 m	-1.9173 E-7 m	0.0046814 m	-4.1687 E-6 m	36.186 m	-36.168 m
9.	**Directional Deformation Y**	3.0087 E-5 m	-2.5888 E-6 m	1.5291 E-5 m	-1.546 E-5 m	32.549 m	-32.562 m
10.	**Directional Deformation Z**	4.0083 E-5 m	-1.1654 E-5 m	0.00061206 m	-0.00061195 M	0.014694 m	-0.014682 m

3. RESULT OF COMPOSITE MATERIAL

3(A) Force (2084 N), Torque (50 N-m), Rotational Velocity (100 radian/sec)

S. NO	PARAMETER	LONGITUDENAL DIRECTION		LATERAL DIRECTION		TORSIONAL DIRECTION	
RANGE →		Maximum	Minimum	Maximum	Minimum	Maximum	Minimum
1.	**Life**	1 E+6	1 E+6	1 E+6	5253.8	1 E+6	1 E+6
2.	**Safety Factor**	15	3.8629	15	0.26716	15	15
3.	**Structural Error**	0.010692 J	4.8579 E-15 J	0.7387 J	8.9788 E-12 J	0.00015765 J	4.1035 E-17 J
4.	**Equivalent Alternating Stress**	1.9594 E+7 Pa	382.96 Pa	NA	NA	2.8027 E+6 Pa	35.792 Pa
5.	**Equivalent Elastic Strain**	0.27032 m/m	9.3918 E-6 m/m	2.3112 m/m	0.00021072 m/m	0.040235 m/m	7.7207 E-7 m/m
6.	**Equivalent (Von-Mises) Stress**	3.7586 E+7 Pa	765.92 Pa	3.2265 E+8 Pa	11971 Pa	5.5715 E+6 Pa	71.584 Pa
7.	**Total Deformation**	0.042755 m	0 M	4.3832 M	0 M	106.4 m	0.005258 m
8.	**Directional Deformation X**	0.00021794 m	-0.0002069 m	4.3797 M	-0.0049201 m	106.34 m	-106.31 m
9.	**Directional Deformation Y**	0.027645 m	-0.002504 m	0.014701 M	-0.01487 M	95.683 m	-95.69 m
10.	**Directional Deformation Z**	0.036964 m	-0.010714 M	0.57306 M	-0.57295 M	0.0117849 m	-0.018706 m

3(B) Force (3500 N), Torque (84 N-m), Rotational Velocity (100 radian/sec)

S. NO	PARAMETER	LONGITUDENAL DIRECTION		LATERAL DIRECTION		TORSIONAL DIRECTION	
RANGE →		Maximum	Minimum	Maximum	Minimum	Maximum	Minimum
1.	Life	1 E+6	1 E+6	1 E+6	1170.5	1 E+6	1 E+6
2.	Safety Factor	15	2.3001	15	0.15907	15	15
3.	Structural Error	0.030157 J	1.3702 E-14 J	2.0836 J	2.5326 E-11 J	0.00037976 J	8.8704 E-17 J
4.	Equivalent Alternating Stress	3.3887 E+7 Pa	643.17 Pa	NA	NA	4.0387 E+6 Pa	61.607 Pa
5.	Equivalent Elastic Strain	0.45399 m/m	1.5773 E-5 m/m	3.8815 m/m	0.00035389 m/m	0.05721 m/m	9.9859 E-7 m/m
6.	Equivalent (Von-Mises) Stress	6.3124 E+7 Pa	1286.3 Pa	5.4188 E+8 Pa	20104 Pa	8.0071 E+6 Pa	123.21 Pa
7.	Total Deformation	0.071806 m	0 M	7.3615 M	0 m	178.7 m	0.0059667 m
8.	Directional Deformation X	0.00036602 m	-0.0003474 m	7.3555 M	-0.0082631 m	178.65 m	-178.6 m
9.	Directional Deformation Y	0.046429 m	-0.0042054 m	0.024689 M	-0.024974 m	160.75 m	-160.76 m
10.	Directional Deformation Z	0.06208 m	-0.017994 m	0.96243 M	-0.96225 m	0.020108 m	-0.020935 m

VIII. **RESULTS**:-

In this project, the crankshaft model is taken from a vehicle which have 1200cc capacity used with four cylinder engine (like in Maruti Suzuki Swift (Diesel). The crankshaft model is created in Creo Software. Then the model is imported in ANSYS software where various load experiments are performed. The model materials are taken as steel, forged steel and composite materials. The results come out from ANSYS Software are shown in the table. The Comparison between the results from different materials shows the Forged steel gives best results than others. Usually Crankshaft is made from steel but we can use Forged Steel as a material for made up of Crank Shaft. This Forged steel gives better performance in load wearing capacity at lower cost than other materials.

4. COMPERATIVE RESULT OF STRUCTURAL STEEL, FORGED STEEL, COMPOSITE MATERIAL

MATERIAL →		STRUCTURAL STEEL			FORGED STEEL			COMPOSITE MATERIAL		
WORKING DIRECTION →		LONGITUDENAL	LATERAL	TORSIONAL	LONGITUDENAL	LATERAL	TORSIONAL	LONGITUDENAL	LATERAL	TORSIONAL
2084 N 50 N-m 100 rad/s	Equivalent (Von-Mises) Stress	38.112 Mpa	327.12 Mpa	21.627 Mpa	38.112 Mpa	327.12 Mpa	21.762 Mpa	37.586 Mpa	322.65 Mpa	5.5715 Mpa
	Total Deformation	3.0518 E-5 m	0.0030798 m	21.742 m	2.7643 E-5 m	0.0027897 m	21.605 m	0.042755 m	4.3832 m	106.4 m
3500 N 84 N-m 100 rad/s	Equivalent (Von-Mises) Stress	64.008 Mpa	549.39 Mpa	22.089 Mpa	64.008 Mpa	549.39 Mpa	22.22 Mpa	63.124 Mpa	541.88 Mpa	8.0071 Mpa
	Total Deformation	5.1254 E-5 m	0.0051725 m	36.48 m	4.6426 E-5 m	0.0046852 m	36.249 m	0.071806 m	7.3615 m	178.7 m
		2nd BEST RESULTS			1st BEST RESULTS			3rd BEST RESULTS		

IX. CONCLUSION

1. Results show the improvement in the strength of crankshaft with Forged steel compared with other materials.
2. The weight of crankshaft is decreased so the performance of the system is increased.
3. The Cost of the Crankshaft with forged steel is less so it being economical with other materials.

X. FUTURE SCOPE

Analysis of Crankshaft can be done with other materials with same or other different parameters in future.

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