Design and optimization of air compressor Crankshaft using FEA and strain gauge

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Abstract : Crankshaft strength is straightforwardly identified with its fatigue quality since it works under cyclic stacking conditions during working cycle. Crankshaft by and large outcomes in calamitous failure of the Reciprocating compressor. Examination on the fracture execution of the crankshafts have an incredible significance in car industry. The greater part of these examinations is focused on the filet region which is one of the geometrically most basic zones where stresses are concentrated. Design of existing crankshaft in CATIA software. Finite element analysis investigations were performed to acquire the variety of stress greatness at basic areas. Static analysis investigation will be done ANSYS workbench. Different fillet range will be explored for accomplishing ideal fatigue life. A current model will be figured out for testing and examination reason. Strain gauges will be utilized and entire arrangement will be mounted on UTM for utilization of single stacking cycle. Estimated strains will be approved with FEA strains. Result and ends will be drawn and reasonable future degree will be proposed.

***Keywords*—FEA, UTM, Crankshaft, Fillet region.**

I. INTRODUCTION

Crankshaft is one of the most significant moving parts in internal combustion engine. It must be sufficiently able to take the descending power of the force stroked without over the top bending. So, the unwavering quality and life of internal burning engine rely upon the quality of the crankshaft to a great extent. Furthermore, as the engine runs, the force driving forces hit the crankshaft in one spot and afterward another. The torsional vibration shows up when a force motivation hits a crankpin toward the front of the engine and the force stroke closes. If not controlled, it can break the crankshaft. Quality estimation of crankshaft turns into a key factor to guarantee the life of engine. Pillar and space outline model were utilized to ascertain the pressure of crankshaft as a rule previously. The utilization of numerical simulation for the planning crankshaft helped architects to productively improve the procedure advancement staying away from the expense and impediments of incorporating a database of true parts. Crankshaft is a muddled nonstop structure. The vibration execution of crankshaft has significant impact to engine. Compressors are perpetually utilized for all applications requiring high weight air. Some of well-known utilizations of compressor are, for driving pneumatic apparatuses and air worked equipment's, shower painting, compacted air engine, supercharging surface cleaning, refrigeration and cooling, compound industry and so on compressors are provided with low weight air (or any liquid) at delta which comes out as high weight air (or any liquid) at outlet. Work required for expanding weight of air is accessible from the main player driving the compressor. By and large, electric engine, inner burning engine or steam engine, turbine and so on are utilized as central players. Compressors are like fans and compressors yet contrast as far as weight proportions. Fan is said to have pressure proportion up to 1.1 and compressors have pressure proportion between 1.1to 4 while compressors have pressure proportions more than 4. Crankshaft is the key segment in air compressor, which transmits power from main player to the cylinder.

II. LITERATURE REVIEW

Farzin H et al. [1] in this paper it presents the dynamic simulation concentrate on a crankshaft from a solitary chamber four stroke engine. They use pressure-volume graph to compute the heap limit condition in unique recreation model, and other simulation inputs were taken from the engine determination outline. The dynamic examination was done scientifically and was checked by simulation in ADAMS which brought about the heap range applied to crank pin bearing. This heap was applied to the FE model in ABAQUS, and limit conditions were applied by the engine mounting conditions. In this work investigation was accomplished for various engine rates and thus basic engine speed and basic area on the crankshaft were gotten. Stress variety over the engine cycle and the impact of torsional load in the examination are explored by creator, which shows results that strain gages appended to a few areas on the crankshaft. These outcomes demonstrate non-symmetric twisting weights on the crankpin bearing, while utilizing diagnostic strategy predicts bending worries to be symmetric at this area. From this examination specialists presume that the absence of evenness is a geometry misshaping impact, demonstrating the requirement for FEA modelling because of the generally mind-boggling geometry of the crankshaft.

Gul Cevik et al. [2] In this paper an examination of the impact of filet moving on fracture conduct of a ductile cast iron crankshaft utilized in diesel engine applications is finished by specialists. Break surface assessment was led perceptibly and by filtering electron magnifying instrument. Fracture perseverance limits estimated for un-rolled and moved crankshafts are 201 MPa and 811 MPa separately, underscoring a critical exhaustion continuance limit improvement by filet moving procedure. This examination tests the Fatigue continuance limits for un-rolled and moved crankshafts which are 201 MPa and 811 MPa individually. It was seen that filet moving with 15 kN moving burden expands weakness quality of the flexible iron crankshaft utilized in this examination with a factor of 4.04. creator close the outcome that prompted compressive lingering stresses, expanded surface hardness and expanded separation thickness because of the moving procedure are the primary factors that give exhaustion quality improvement. The fracture splits were seen to start on the top focal point of the filet district and engender roughly a similar edge through the cross-segment of the example. The break inception locale is where the most extreme stresses instigate on the crankshaft.

M. Fonte et al. [3] This examination is completed to discover the failure mode investigation of a fighter diesel engine crankshaft. Crankshafts are segments which test serious and complex unique loadings due to turning bending joined with torsion on principle diaries and rotating bending on crankpins. Since the weakness crack close the crankpin-web filet districts is one of the essential failure systems of car crankshafts, the best for improving its weariness quality. It is inferred that current failure happened at around 2000 made engines, and after around 95,000 km in administration. Each balance some portion of the crankshaft has an orientation surface known as crankpin to which the interfacing pole is connected. It changes over the straight (Reciprocating) movement of cylinders into a rotational movement that can be transmitted through a drive line framework. The force from the consumed gases in the burning chamber is conveyed to the crankpin through the cylinders and interfacing poles. The crankshaft bending adequacy increments from the weakness of split steel shells and furthermore the scaffolds of the bedplate which are underneath them. From this examination creator presume that the cataclysmic failure of crankshaft is by all accounts an outcome of poor structure of steel bolster shells and bedplate spans.

V. C. Shahane et al. [4], In this investigation creator did this examination dependent on static basic and dynamic investigation. Crankshaft is one of the most basic parts for compelling and exact working of the inside ignition engine. Limited component investigation is finished by analysts utilizing ANSYS software under the static and dynamic condition to get the variety of worries at various basic areas of the crankshaft. Limit conditions were applied on limited component model as per engine detail graph and engine mounting conditions. Streamlining of the crankshaft was concentrated in the zone of geometry and shape on the current crankshaft. In light of the outcome acquired from the examination the upgraded crankshaft configuration ought to be supplanted with existing crankshaft, without changes in the engine square and chamber head. This streamlining investigation of the crankshaft assists with decreasing 4.37% of the weight in the first crankshaft. The first crankshaft is improved by expelled the material from the crankpin geometry with the specialized presumptions and assembling perspectives by considered 20 mm bored measurement. The current crankshaft was upgraded by dimensional changes in the stabilizer geometry with edge 12^0 to 22^0.

P. Thejasree et. al [5] In this examination, modelling and investigation of crankshaft for traveller vehicle by utilizing ANSYS is finished by creator. Crank Shaft is one of the significant segments of an IC Engine. The investigation of crank toss bending and stress offers a theoretical help to upgrade the plan by gauge decrease. Scientists will dissect the impact of gas powers at crankpin and fundamental diaries of the crankshaft. Due to this it is discovered that most extreme burden following up on the crankpin was seen as 22163 N for the seat mark model while for the created ideas 1, 2 and 3, it was seen as 22624 N, 22066 N and 22303 N separately. Consequence of this examination shows that most extreme worry for the seat mark model was seen as 67 MPa and though for the created ideas 1, 2 and 3, it was seen as 80MPa, 71 MPa and 79 MPa separately. From the auxiliary static investigation creator infer that the pressure fixation locales are situated at the filets of crank pin and primary diaries. The heaviness of the crankshaft for idea 2 has been decreased by 1.6 kg which is a 12.8% decrease in weight absent a lot of increment in the pressure.

III. PROBLEM STATEMENT

Reciprocating compressor assumes a significant job in oil and substance industry. With a sharp increment in stream process, Reciprocating compressor is being created to the enormous scope and multi-cranks. The weakness failure cause and time are diverse on compressors. The huge scope Reciprocating compressor has generally application in the cutting-edge industry because of its broadly scope of weight and high dependability. Be that as it may, as the working load and number of chamber increment, the fatigue of crankshaft brought about by the vibration turns into an incredible issue compromising unwavering quality of the compressor.

IV. OBJECTIVES

1. Design of existing crankshaft in CATIA software.
2. To study the mechanism and force analysis on crankshaft.
3. Static analysis to determine deformation and stress for existing and modified designed to obtain optimized model.
4. To perform static, modal and fatigue analysis of crankshaft using different radius fillet to reduce stress concentration at edges using ANSYS 19 software to determine stress at respective edges.
5. Experimental testing of optimized crankshaft using strain gauging technique.
6. Validation of numerical and experimental results

V. METHODOLOGY

Step 1:- Initially research paper are studied to find out research gap for project then necessary parameters are studied in detail. After going through these papers, we learnt about fillet effect on crankshaft.
Step2:- Research gap is studied to understand new objectives for project.
Step 3: - After deciding the components, the 3 D Model and drafting will be done with the help of software.
Step 4: - The components will be manufactured and then testing will be performed using strain gauge technique under UTM.
Step 5: -Validation of experimental and numerical results.

VI. CATIA MODEL

Existing air compressor piston cylinder bore diameter – 70 mm
Cylinder bore diameter = D = 70 mm
Cylinder Centre distance = 1.20 D = 84 mm
Big-end journals diameter = 0.65 D = 45.5 mm
Main-end journal diameter = 0.75 D = 52.5 mm
Big-end journal width = 0.35 D = 24.5 mm
Main-end journal width = 0.40 D = 28 mm
Web thickness = 0.25 D = 17.5 mm

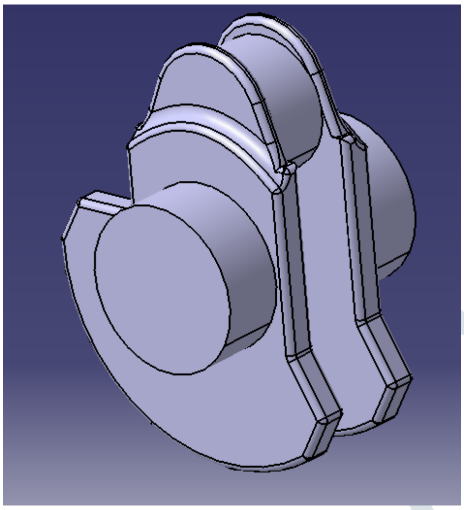


Fig. CATIA model of crankshaft

Table. Material Properties

Properties of Outline Row 3: Structural Steel

	A	B	C
1	Property	Value	Unit
2	Material Field Variables	Table	
3	Density	7850	kg m^-3
4	Isotropic Secant Coefficient of Thermal Expansion		
5	Coefficient of Thermal Expansion	1.2E-05	C^-1
6	Isotropic Elasticity		
7	Derive from	Young's Modulus and Pois...	
8	Young's Modulus	2E+11	Pa
9	Poisson's Ratio	0.3	
10	Bulk Modulus	1.6667E+11	Pa
11	Shear Modulus	7.6923E+10	Pa

2. Finite Element Analysis:

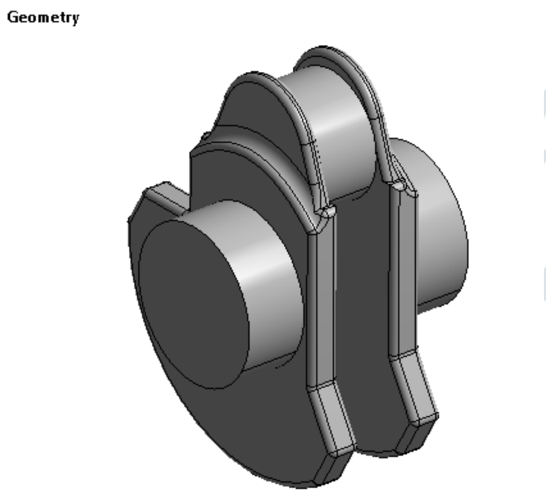
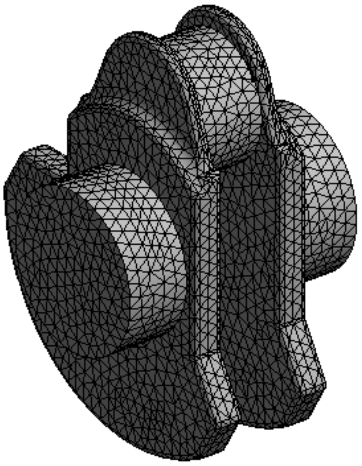
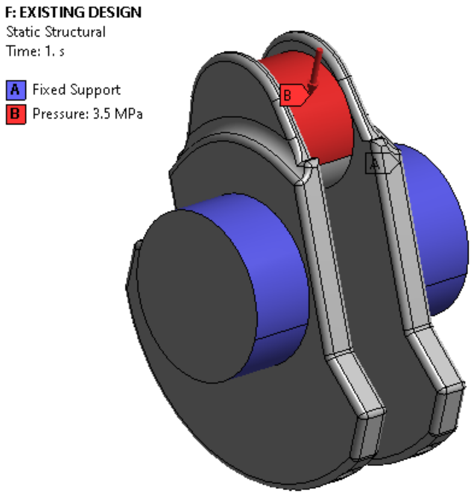


Fig. CATIA model imported in ANSYS

3. Mesh

In ANSYS meshing is performed as similar to discretization process in FEA procedure in which it breaks whole components in small elements and nodes. So, in analysis boundary condition equation are solved at this elements and nodes. ANSYS Meshing is a general-purpose, intelligent, automated high-performance product. It produces the most appropriate mesh for accurate, efficient Multiphysics solutions. A mesh well suited for a specific analysis can be generated with a single mouse click for all parts in a model. Full controls over the options used to generate the mesh are available for the expert user who wants to fine-tune it.





Statistics	
Nodes	56827
Elements	36932

Fig. Details of meshing

Fig. Boundary condition for existing design

1. Fixed support is applied at surface and pressure of 3.5 MPa as per research paper mentioned and generally applied.
2. from research paper and calculation pressure of generally 3.5 MPa is applied at top surface of crankpin
3. For compressive loading of the connecting rod, the crank and the piston pin ends are assumed to have a uniformly distributed loading through 120° contact surface.
4. So, pressure is calculated as
5. Pressure = force exerted by gas on piston / Area of piston
6. Force – pressure of compressed gas x area of piston
7. Compressed air pressure maximum value – 8 bar, area of piston – (π/4) x D^2
8. D- diameter of piston – 70 mm
9. Force – 8 bar x 3.84 x 10^{-3} (1 bar – 10^5 N/m^2)
10. Force – 3072 N
11. Pressure on pin is calculated by standard formula –

$$p_0 = \frac{P_c}{rt\sqrt{3}}$$

Force – 3072 / (17.5 x 30 x sqrt (3))
Pressure – 3.37 MPa but for maximum condition 3.5 MPa

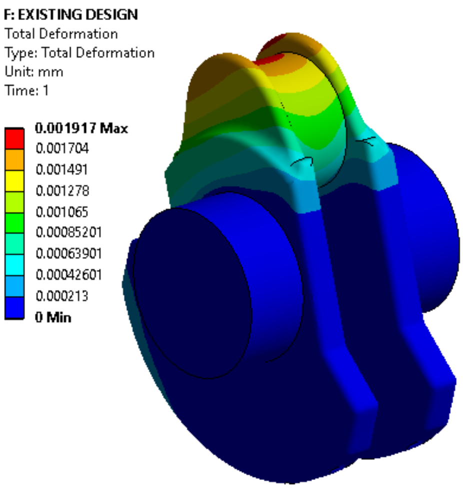


Fig. Deformation results for existing design

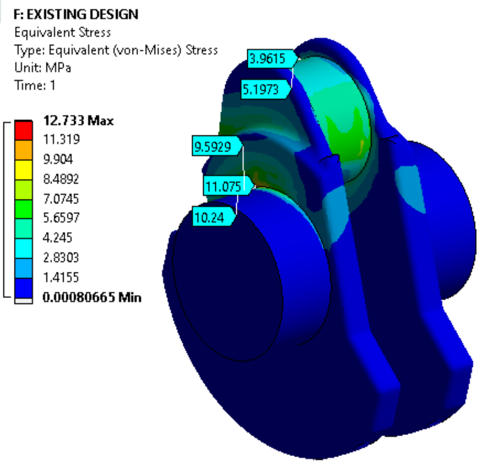


Fig. Equivalent stress results for existing design

Existing air compressor stress induced at edge are equal to mean of probed stress equal to 10.30 Mpa and at inner side is around 4.57 Mpa.

VII. MODIFIED CRANKSHAFT

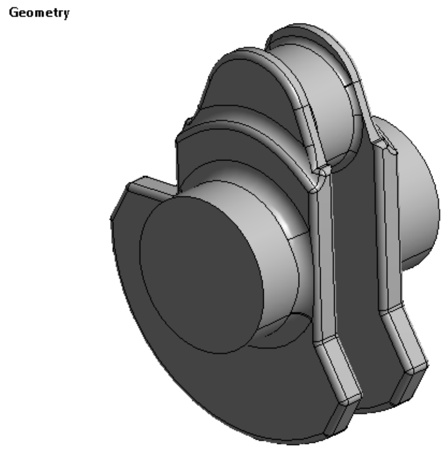


Fig. Geometry with fillet (OPTIMIZED DESIGN)

Fillet of 5 mm is applied at outer edges while 2 mm is applied inner side. In present study stress induced at edges is to be reduced by applying fillet at edges.

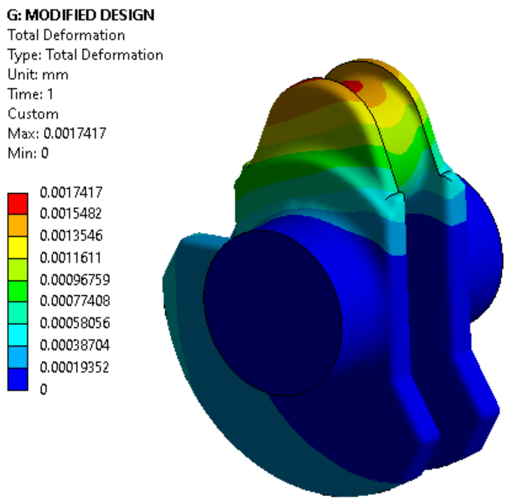


Fig. Deformation results for optimized design

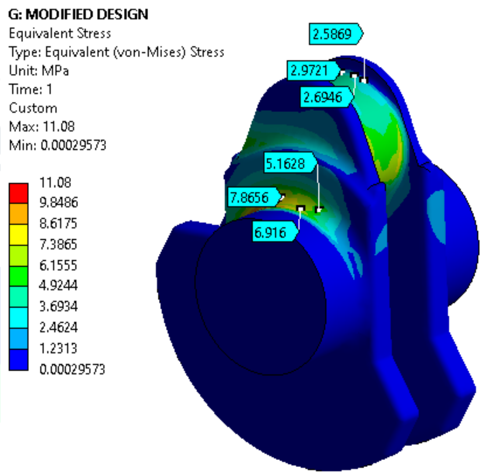


Fig. Equivalent stress results for optimized design

VIII. FATIGUE ANALYSIS

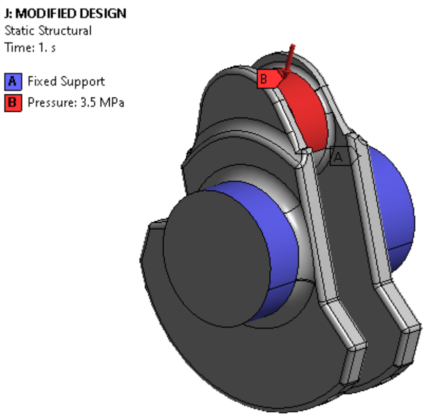


Fig. Optimized design

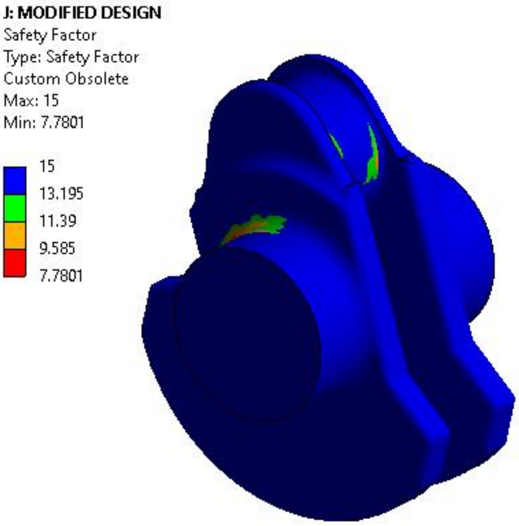


Fig. Safety factor result

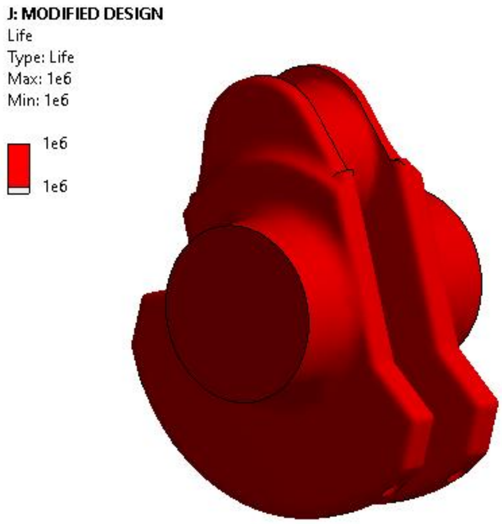


Fig. Fatigue life result

IX. MODAL ANALYSIS

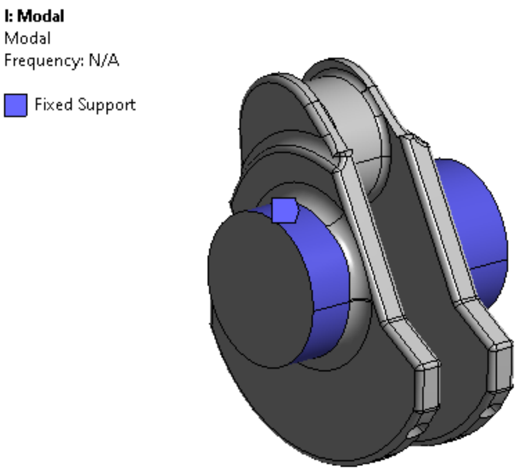


Fig. Boundary condition for modal analysis

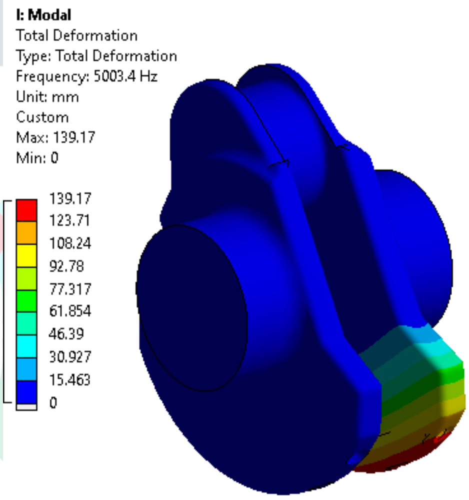


Fig. Mode shape1

Table. Tabular data of mode shape

Tabular Data

	Mode	Frequency [Hz]
1	1.	5003.4
2	2.	5069.
3	3.	5936.6
4	4.	5976.5
5	5.	8334.3
6	6.	8366.7

X. Experimental setup analysis

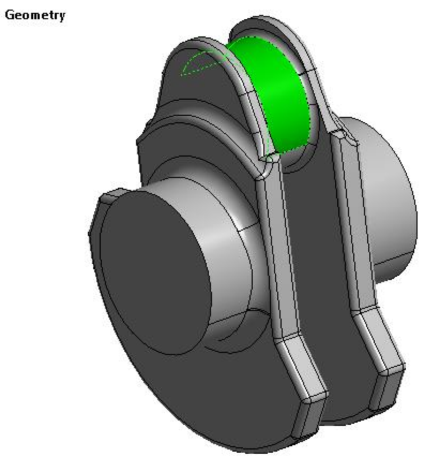
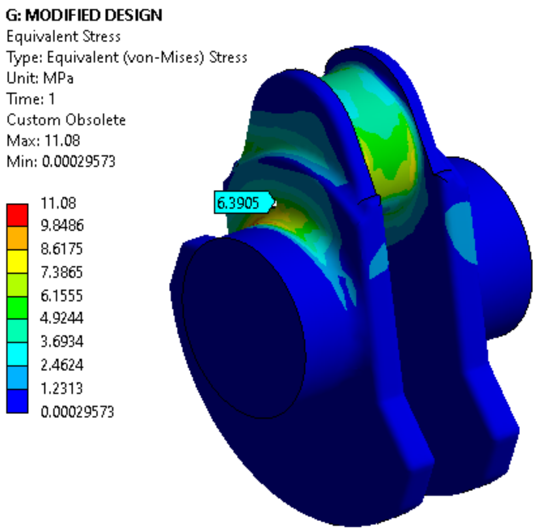


Fig. Optimized design

FORCE – PRESSURE X AREA
FORCE – 3.5 X 1006 – 3521 N FORCE IS TO BE APPLIED



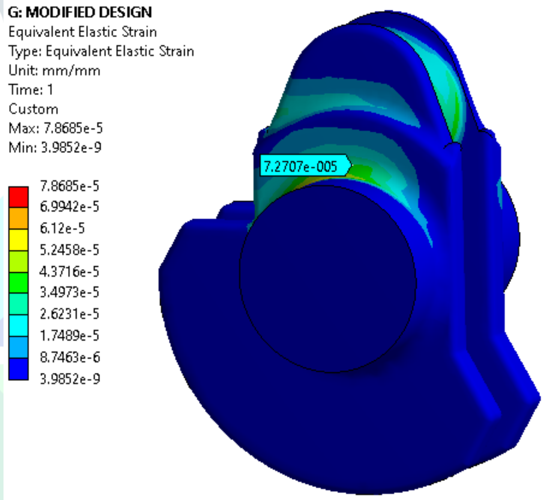


Fig. Equivalent stress results for optimized design

Fig. Equivalent strain results for optimized design

XII. EXPERIMENTAL SETUP

A universal testing machine (UTM), also known as a universal tester, materials testing machine or materials test frame, is used to test the tensile strength and compressive strength of materials. An earlier name for a tensile testing machine is a tensometer. The "universal" part of the name reflects that it can perform many standard tensile and compression tests on materials, components, and structures (in other words, that it is versatile). The set-up and usage are detailed in a test method, often published by a standards organization. This specifies the sample preparation, fixturing, gauge length (the length which is under study or observation), analysis, etc. The specimen is placed in the machine between the grips and an extensometer if required can automatically record the change in gauge length during the test. If an extensometer is not fitted, the machine itself can record the displacement between its cross heads on which the specimen is held. However, this method not only records the change in length of the specimen but also all other extending / elastic components of the testing machine and its drive systems including any slipping of the specimen in the grips. Once the machine is started it begins to apply an increasing load on specimen. Throughout the tests the control system and its associated software record the load and extension or compression of the specimen.

Fig. Experimental setup

Specification of UTM

1	Max Capacity	400KN
2	Measuring range	0-400KN
3	Least Count	0.04KN
4	Clearance for Tensile Test	50-700 mm
5	Clearance for Compression Test	0- 700 mm
6	Clearance Between column	500 mm
7	Ram stroke	200 mm
8	Power supply	3 Phase , 440Volts , 50 cycle. A.C
9	Overall dimension of machine (L*W*H)	2100*800*2060
10	Weight	2300Kg

XIII. Experimental procedure

1. Fixture is manufactured according to component designed.
2. Single force is applied as per FEA analysis and reanalysis is performed to determine strain by numerical and experimental testing.
3. Strain gauge is applied as per FEA results to maximum strained region and during experimental testing force is applied as per numerical analysis to check the strain obtained by numerical and experimental results.
4. During strain gage experiment two wires connected to strain gage is connected to micro controller through the data acquisition system and DAQ is connected to laptop. Strain gage value are displayed on laptop using DEWESOFT software.

Fig. Experimental setup and results

XIV. CONCLUSION

In present investigation existing air compressor crankshaft modification in design have been performed to understand the effect of fillet radius on crankshaft.

It is observed from static analysis of crankshaft in ANSYS that stress at edges is reduced by application of fillet radius with existing design.

From existing design stress have been concentrated on edges. So, to reduce stress effect fillet of suitable radius are provided. It is observed from strain gage result that strain values for 72 micron and 98 microns for FEA and experimental results.

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