ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

Modeling and Analysis of IC Engine Crankshaft with Different Materials

Dr. Kareem Dakhil Jasym
Assistant Professor,
Mechanical Engineering,
AL-Qadissiya University College of Engineering, Iraq.

ABSTRACT:

A crankshaft related to crank is a mechanical part able to perform conversion between reciprocating motion and rotational motion. In a reciprocating engine, it translates reciprocating motion of the piston into rotational motion; whereas in a reciprocating compressor, it converts the rotational motion into reciprocating motion. In order to do the conversion between two motions, the crankshaft has “crank throws” or “crankpins”, additional bearing surfaces whose axis is offset from that of the crank, to which the “big ends” of the connecting rods from each cylinder attach.The structural analysis is done using FEA Software ANSYS Workbench which resulted in the load spectrum applied to crank shaft. This load is applied to the FE model in ANSYS workbench, and boundary conditions are applied according to the engine mounting conditions. The analysis is done for finding critical location in crankshaft and Stress variation over the engine cycle and the effect of torsion and bending load in the analysis are investigated.The analysis is carried out with two different materials and the bending stresses of a crank shaft are compared and the best material is chosen to reduce the stresses in the critical location.

I.INTRODUCTION TO CRANKSHAFT:

The crankshaft, sometimes casually abbreviated to crank, is the part of an engine which translates reciprocating linear piston motion into rotation. To convert the reciprocating motion into rotation, thecrankshaft has “crank throws” or “crankpins”, additional bearing surfaces whose axis is offset from that of the crank, to which the “big ends” of the connecting rods from each cylinder attach. It typically connects to a flywheel, to reduce the pulsation characteristic of the four-stroke cycle, and sometimes a torsional or vibrational damper at the opposite end, to reduce the torsion vibrations often caused along the length of the crankshaft by the cylinders farthest from the output end acting on the torsional elasticity of the metal.

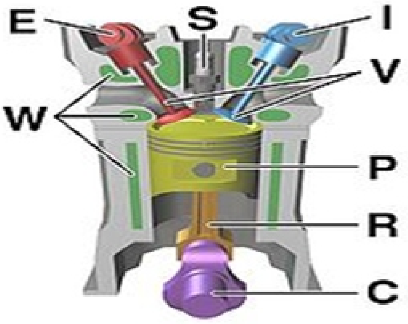


Fig 1:Crankshaft Design

Components of a typicalfour stroke cycle, DOHC piston engine. (E) Exhaust camshaft, (I) Intake camshaft, (S) Spark plug, (V) Valves, (P) Piston, (R) Connecting rod, (C) Crankshaft, (W) Water jacket for coolant flow.Large engines are usually multi-cylinder to reduce pulsations from individual firing strokes, with more than one piston attached to a complex crankshaft. Many small engines, such as those found in mopeds or garden machinery, are sin.

Piston stroke:

The distance the axis of the crank throws from the axis of the crankshaft determines the piston stroke measurement, and thus engine displacement. A common way to increase the low-speed torque of an engine is to increase the stroke. This also increases the reciprocating vibration, however, limiting the high speed capability of the engine.

Engine balance:

For some engines it is necessary to provide counterweights for the reciprocating mass of each piston and connecting rod to improve engine balance. These are typically cast as part of the crankshaft but, occasionally, are bolt-on pieces. While counter weights add a considerable amount of weight to the crankshaft it provides a smoother running engine and allows higher RPMs to be reached.

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

Rotary engines:

Many early aircraft engines (and a few in other applications) had the crankshaft fixed to the airframe and instead the cylinders rotated, known as a rotary engine design. Rotary engines such as the Wankel engine are referred to as piston less rotary engines.

Fatigue strength:

The fatigue strength of crankshafts is usually increased by using a radius at the ends of each main and crankpin bearing. The radius itself reduces the stress in these critical areas, but since the radii in most cases are rolled, this also leaves some compressive residual stress in the surface which prevents cracks from forming.

Hardening:

Most production crankshafts use induction hardened bearing surfaces since that method gives good results with low costs. It also allows the crankshaft to be reground without having to redo the hardening.

Counterweights:

Some expensive, high performance crankshafts also use heavy-metal counterweights to make the crankshaft more compact. The heavy-metal used is most often a tungsten alloy but depleted uranium has also been used. A cheaper option is to use lead, but compared with tungsten its density is much lower.

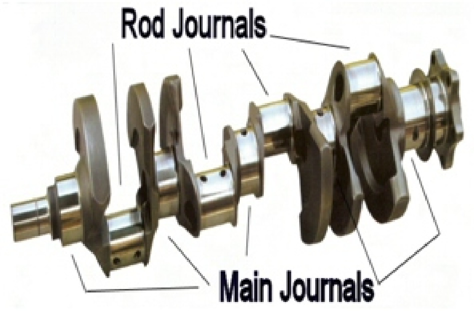
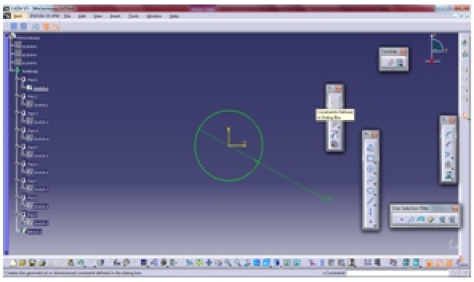


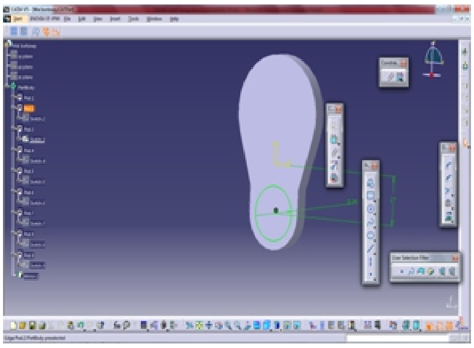
Fig 2: (2-plane) Crankshaft

II.MODELING OF CRANK SHAFT DESIGNING OF CRANKSHAFT USING CATIA:

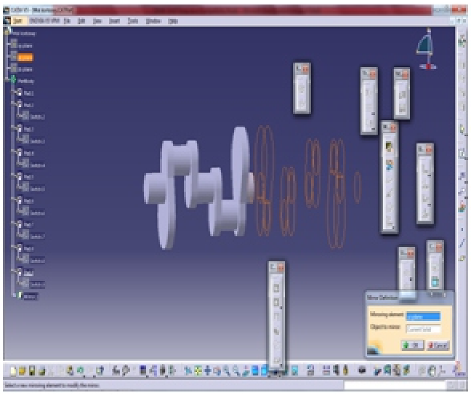
To create the crankshaft first draw a circle and pad the circle



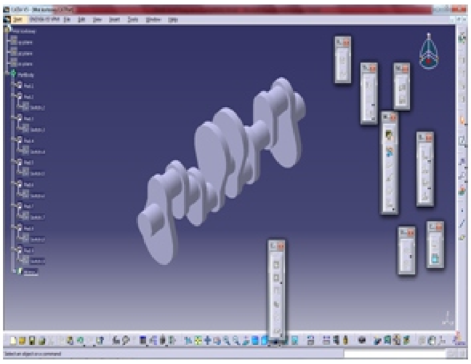
To create the counter weight select the extrude tool and draw the required sketch on the journel surface the sketch will be extruded as below.



From the above select the counter weight and mirror it with respect to center plane by using mirror tool as shown below.



An Isometric view of a multi crankshaft



ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

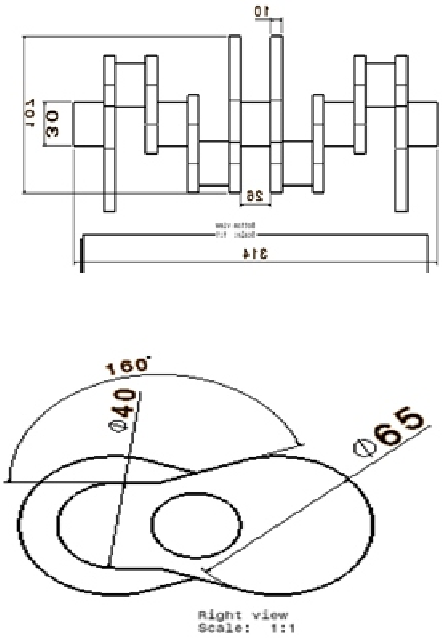


Fig 3: Drafting of multi crankshaft

III.FORCES IMPOSED ON A CRANKSHAFT:

The obvious source of forces applied to a crankshaft is the product of combustion chamber pressure acting on the top of the piston. High-performance, normally-aspirated Spark-ignition (SI) engines can have combustion pressures in the 100-bar neighborhood (1450 psi), while contemporary high-performance Compression-Ignition (CI) engines can see combustion pressures in excess of 200 bar (2900 psi). A pressure of 100 bar acting on a 4.00 inch diameter piston will produce a force of 18,221 pounds. A pressure of 200 bar acting on a 4.00 inch diameter piston produces a force of 36,442 pounds.

Since the force it takes to accelerate an object is proportional to the weight of the object times the acceleration (as long as the mass of the object is constant), many of the significant forces exerted on those reciprocating components, as well as on the conrod beam and big-end, crankshaft, crankshaft, bearings, and engine block are directly related to piston acceleration. The 90° V8 engine with a single-plane crank (180° crankpin spacing as shown in Figure 2) such as is used in Formula One, IRL and Le Mans-style V8 engines produces a substantial external horizontal shaking force at twice the crankshaft frequency ("second order.

Fig 4:Single-Plane V8 Crank shaft (Courtesy of Bryant Racing)

However, the counterweights are not always directly opposite the rod journals. For example, the commonly-used production version of a two-plane 90° V8 crankshaft has no counterweights around the center main journal, as shown in Figure 2 above. In that case, the centroid of each counterweight, instead of being 180° from its respective journal, is offset (to approximately 135°) in order to place the net counterbalancing forces in the optimal location. Note also (in Figure 2) that the front and rear counterweights are larger (thicker) than the others in order to fully counterbalance the end-to-end moments.

IV.CRANKSHAFT MATERIALS:

The steel alloys typically used in high strength crankshafts have been selected for what each designer perceives as the most desirable combination of properties. Figure 5 shows the nominal chemistries of the crankshaft alloys discussed here.

Composition of Forged alloy steel:

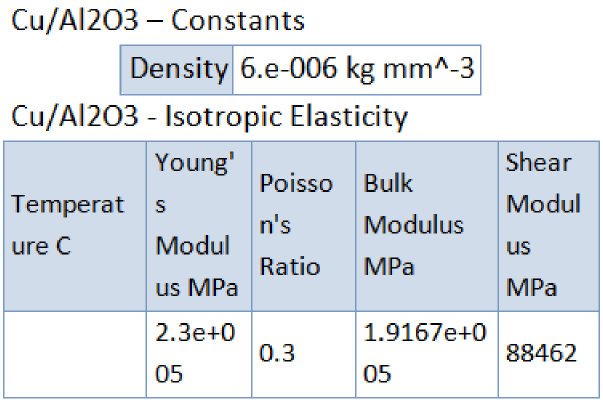
Carbon % -	.35 to.45
Sulphur %-	. 12-.35
Manganese %-	.45-.7
Phosphurus %-	.035
Molybdenum %-	.15-.35

In addition to alloying elements, high strength steels are carefully refined so as to remove as many of the undesirable impurities as possible (sulfur, phosphorous, calcium, etc.) and to more tightly constrain the tolerances, which define the allowable variations in the percentage of alloying elements.

Forging and casting:

Crankshafts can be forged from a steel bar usually through roll forging or cast in ductile steel. Today more and more manufacturers tend to favor the use of forged crankshafts due to their lighter weight, more compact dimensions and better inherent dampening. With forged crankshafts, vanadium micro alloyed steels are mostly used as these steels can be air cooled after reaching high strengths without additional heat treatment, with exception to the surface hardening of the bearing surfaces. The low alloy content also makes the material cheaper than high alloy steels.

Material Data
Cu/Al2O3

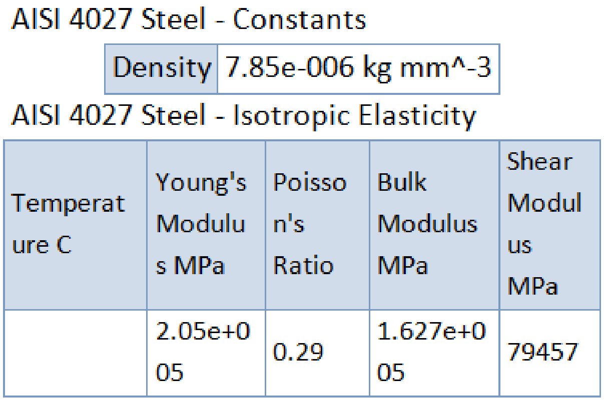

Cu/Al2O3 – Constants

Density	6.e-006 kg mm^-3

Cu/Al2O3 - Isotropic Elasticity

Temperature C	Young's Modulus MPa	Poisson's Ratio	Bulk Modulus MPa	Shear Modulus MPa
	2.3e+005	0.3	1.9167e+005	88462

AISI 4027 Steel


AISI 4027 Steel - Constants

Density	7.85e-006 kg mm^-3

AISI 4027 Steel - Isotropic Elasticity

Temperature C	Young's Modulus MPa	Poisson's Ratio	Bulk Modulus MPa	Shear Modulus MPa
	2.05e+005	0.29	1.627e+005	79457

The crankpin is like a built in beam with a distributed loadalong its length that varies with crank position. Each web likea cantilever beam subjected to bending & twisting. Journalswould be principally subjected to twisting.

1. Bending causes tensile and compressive stresses.
2. Twisting causes shear stress.
3. Duetoshrinkageofthewebontothejournals,compressive stresses are set up in journals & tensile hoopstresses in the webs.

V.FAILURE ANAYLSIS OF CRANKSHAFT

Fatigue crack growth analysis of a diesel engine forged steelcrankshaft was investigated by Guagliano and Vergani andGuagliano. They experimentally showed that withgeometry like the crankshaft, the crack grows faster on thefree surface while the central part of the crack front becomesstraighter. Based on this observation, two methods werecompared; the first considers a three dimensional model witha crack modeled over its profile from the internal depth to theexternal surface. In order to determine the stress intensityfactors concerning modes I and II a very fine mesh near thecrack tip is required which involves a large number of nodesand elements, and a large computational time.

The secondapproach uses two dimensional models with a straight crackfront and with the depth of the real crack, offering simplermodels and less computational time.Osman Asi performed failure analysis of a diesel enginecrankshaft used in a truck, which is made from ductile castiron. The crankshaft was found to break into two pieces at thecrankpin portion before completion of warranty period. Thecrankshaft was induction hardened. An evaluation of thefailed crankshaft was undertaken to assess its integrity thatincluded a visual examination, photo documentation, chemicalanalysis, micro-hardness measurement, tensile testing, andmetallographic examination. The failure zones were examinedwith the help of a scanning electron microscope equipped withEDX facility. Results indicate that fatigue is the dominantmechanism of failure of the crankshaft.

V.DURABILITY ASSEMENT ON CRNAKSHAFT:

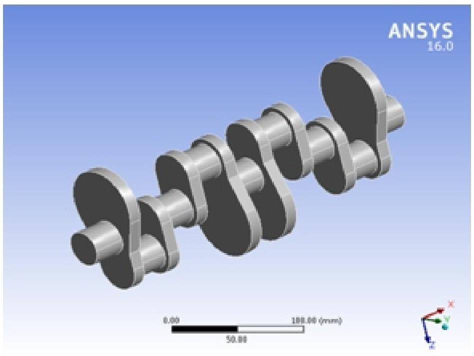
Durability assessment of crankshafts was carried out byZoroufi, M. and Fatemi, A.,includes material andcomponent testing, stress and strain analysis, and fatigue orfracture analysis. Material testing includes hardness,monotonic, cyclic, impact, and fatigue and fracture tests onspecimens made from the component or from the basematerial used in manufacturing the component. This procedure consists of four main steps. Thefirst step is modeling and load preparation that includes meshgeneration, calculation of internal static loads (mass), externalloads (gas and inertia) and torsional dynamic response due torotation. The second step is the finite element methodcalculation including generating input files for separateloading conditions. Third step is the boundary condition filegeneration. The final step involves the fatigue safety factordetermination. This procedure was implemented for a nodularcast iron diesel engine crankshaft.

APPLICATIONS:

The crankshaft is used everywhere that energy and power are transformed into rotational movements. It has a very wide variety of applications, ranging from chainsaws to automotive engines, all the way up to diesel generators in marine engines. Typical areas of application include:

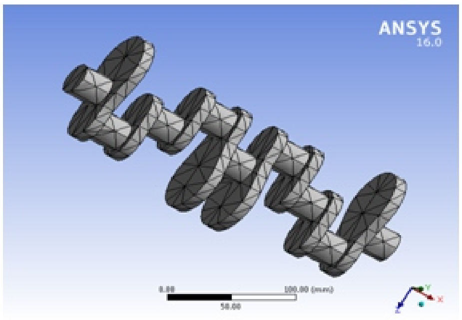
- Chainsaws
- Compressors / chillers
- Power generators
- (Gas) lawnmowers
- Racecars
- Aircraft
- Rail vehicles
- Motor vehicles such as motorcycles, cars and trucks
- Marine engine

VI.SIMULATION RESULTS:



Properties	
Volume	4.603e+005 mm³
Mass	3.6134 kg
Scale Factor Value	1.

Material	
Assignment	AISI 4027 Steel
Nonlinear Effects	Yes
Thermal Strain Effects	Yes
Bounding Box	
Length X	314. mm
Length Y	65. mm
Length Z	120. mm
Properties	
Volume	4.603e+005 mm³
Mass	3.6134 kg
Centroid X	2.5029e-003 mm
Centroid Y	-4.5555e-011 mm
Centroid Z	8.0549e-008 mm
Moment of Inertia Ip1	2739.5 kg·mm²
Moment of Inertia Ip2	30221 kg·mm²
Moment of Inertia Ip3	28504 kg·mm²
Statistics	
Nodes	2348
Elements	1081
Mesh Metric	None



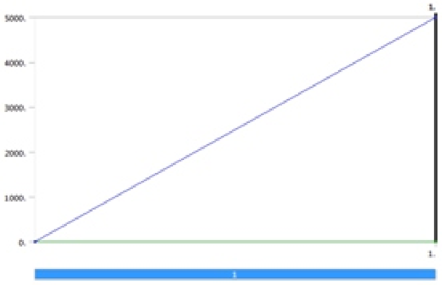
Static Structural (A5)

Model (A4)-Static Structural (A5)-Loads

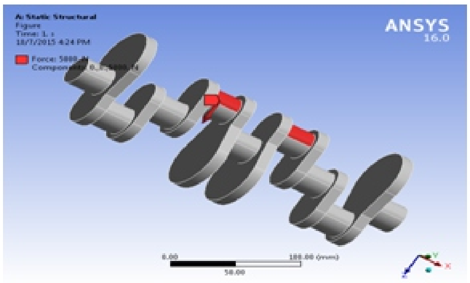
Object Name	*Force*	*Fixed Support*
State	Fully Defined	
Scope		
Scoping Method	Geometry Selection	
Geometry	2 Faces	4 Faces

Definition		
Type	Force	Fixed Support
Define By	Components	
Coordinate System	Global Coordinate System	
X Component	0. N (ramped)	
Y Component	0. N (ramped)	
Z Component	5000. N (ramped)	
Suppressed	No	

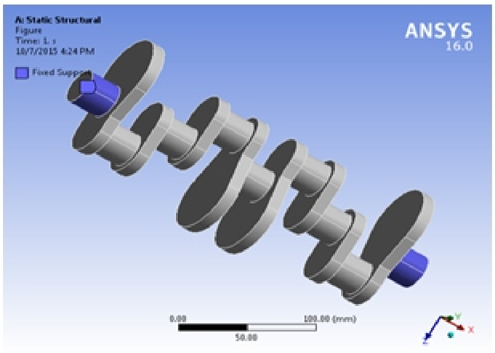
Model (A4) -Static Structural (A5)-Force



Model (A4) - Static Structural (A5) - Force - Figure



Model (A4) - Static Structural (A5) - Fixed Support - Figure



FOR ALLOY STEEL

Solution (A6)

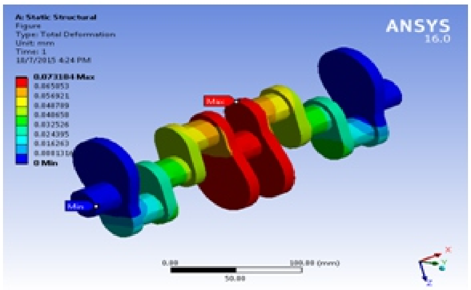
Model (A4) - Static Structural (A5) - Solution (A6) - Results

Object Name	*Total Deformation*	*Equivalent Stress*	*Equivalent Elastic Strain*
State	Solved		
Scoping Method	Geometry Selection		
Geometry	All Bodies		
Definition			
Type	Total Deformation	Equivalent (von-Mises) Stress	Equivalent Elastic Strain
Results			
Minimum	0. mm	8.0165e-002 MPa	5.5722e-007 mm/mm
Maximum	7.3184e-002 mm	45.2 MPa	2.53e-004 mm/mm

Model (A4) - Static Structural (A5) - Solution (A6) - Total Deformation

Time [s]	Minimum [mm]	Maximum [mm]
1.	0.	7.3184e-002

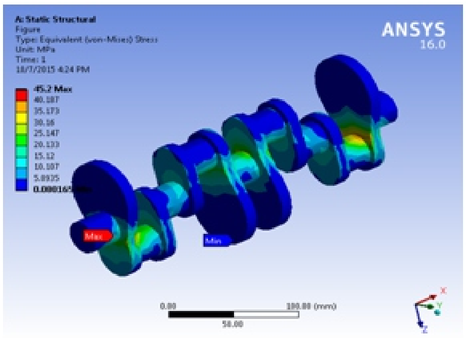
Model (A4) - Static Structural (A5) - Solution (A6) - Total Deformation - Figure



Model (A4) - Static Structural (A5) - Solution (A6) - Equivalent Stress

Time [s]	Minimum [MPa]	Maximum [MPa]
1.	8.0165e-002	45.2

Model (A4) - Static Structural (A5) - Solution (A6) - Equivalent Stress – Figure



Model (A4) - Static Structural (A5) - Solution (A6) - Equivalent Elastic Strain

Time [s]	Minimum [mm/mm]	Maximum [mm/mm]
1.	5.5722e-007	2.53e-004

Material Data

AISI 4027 Steel

AISI 4027 Steel – Constants

Density	7.85e-006 kg mm^-3

AISI 4027 Steel - Isotropic Elasticity

Temperature C	Young's Modulus MPa	Poisson's Ratio	Bulk Modulus MPa	Shear Modulus MPa
	2.05e+005	0.29	1.627e+005	79457

FOR Copper Composites

Material	
Assignment	Cu/Al2O3
Nonlinear Effects	Yes
Thermal Strain Effects	Yes

Bounding Box	
Length X	314. mm
Length Y	65. mm
Length Z	120. mm
Properties	
Volume	4.603e+005 mm³
Mass	2.7618 kg
Centroid X	2.5029e-003 mm
Centroid Y	-4.5555e-011 mm
Centroid Z	8.0549e-008 mm
Moment of Inertia Ip1	2093.9 kg·mm²
Moment of Inertia Ip2	23099 kg·mm²
Moment of Inertia Ip3	21787 kg·mm²
Statistics	
Nodes	2348
Elements	1081
Mesh Metric	None

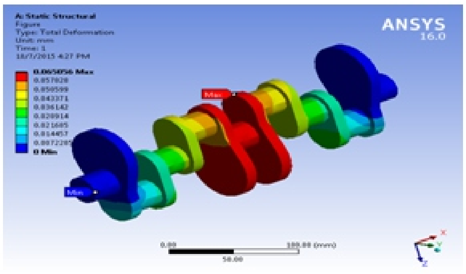
Model (A4) - Static Structural (A5) - Solution (A6) – Results

Type	Total Deformation	Equivalent (von-Mises) Stress	Equivalent Elastic Strain
Results			
Minimum	0. mm	8.0576e-002 MPa	5.0678e-007 mm/mm
Maximum	6.5056e-002 mm	45.203 MPa	2.2488e-004 mm/mm

Model (A4) - Static Structural (A5) - Solution (A6) - Total Deformation

Time [s]	Minimum [mm]	Maximum [mm]
1.	0.	6.5056e-002

Model (A4) - Static Structural (A5) - Solution (A6) - Total Deformation - Figure

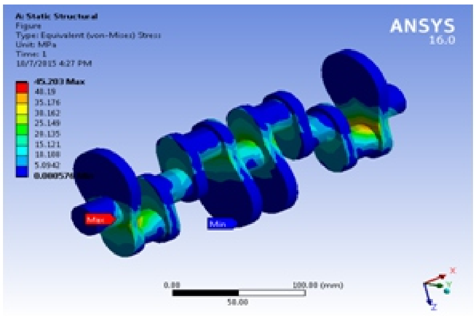


Model (A4) - Static Structural (A5) - Solution (A6) - Equivalent Stress

Time [s]	Minimum [MPa]	Maximum [MPa]
1.	8.0576e-002	45.203

Model (A4) - Static Structural (A5) - Solution (A6) - Equivalent Stress - Figure

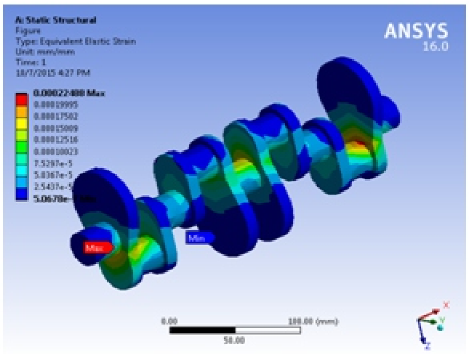
\



Model (A4) - Static Structural (A5) - Solution (A6) - Equivalent Elastic Strain

Time [s]	Minimum [mm/mm]	Maximum [mm/mm]
1.	5.0678e-007	2.2488e-004

Model (A4) - Static Structural (A5) - Solution (A6) - Equivalent Elastic Strain - Figure



Material Data

Cu/Al2O3

Cu/Al2O3 - Constants

Density	6.e-006 kg mm^-3

Cu/Al2O3 - Isotropic Elasticity

Temperature C	Young's Modulus MPa	Poisson's Ratio	Bulk Modulus MPa	Shear Modulus MPa
	2.3e+005	0.3	1.9167e+005	88462

VII.CONCLUSION:

The Engine one of the main part is crank shaft and it exhibits high contact forces are transmitted mechanically with piston to get output of high torque.The engine multi crankshaft is modeled in a 3d modeling software(CATIA V5) and analyzed with Alloy steel and Copper composite materials which having low density to reduce stresses and the weight of the crankshaft using FEA(Ansys Workbench).Copper composite materials are having low stresses than the alloy steels and less weight than the alloy steels.

REFERENCES:

1.al-Hassan & Hill 1992, pp. 45, 61.

2.Banu Musa, Donald Routledge Hill (1979), the bookof ingenious devices (Kitāb al-iyal), Springer, pp. 23–4,ISBN 90-277-0833-9.

3. Ahmad Y Hassan, Crank-Connecting Rod Systemin a Continuously Rotating Machine.

4.Sally Ganchy, Sarah Gancher (2009), Islam and Science,Medicine, and Technology, The Rosen PublishingGroup, p. 41, ISBN 1-4358-5066-1.

5.N.Sivin; Needham, Joseph (August 1968), “Review:Science and Civilisation in China by Joseph Needham”,Journal of Asian Studies (Association for Asian Studies)27 (4): 859–864 [862], doi:10.2307/2051584, JSTOR2051584

6.“Camshaft definition by Merriam-Webster”. Merriam-webster.com.2010-08-13. Retrieved 2010-11-07.

7. Wilson, Andrew (2002):“Machines, Power and theAncient Economy”, The Journal of Roman Studies, Vol. 92, pp. 1–32 (16).

8.Georges Ifrah (2001). The Universal History of Computing:From the Abacus to the Quatum Computer, p.171, Trans. E.F. Harding, John Wiley & Sons, Inc. (See[1]) .

9.A. Lehr (1981), De Geschiedenis van het AstronomischKunstuurwerk, p. 227, Den Haag. (See [2]).

10.retrieved June 21, 2007[dead link] .

11.Carspector definition: Quad-cam http://carspector.com/dictionary/Q/quad-cam-engine/.