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Static and Dynamic Analysis of Crankshaft by Using Different Materials

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ABSTRACT

Crankshaft is a large component with a complex geometry in the engine, which converts the reciprocating displacement of the piston to a rotary motion with a four link mechanism. Since the crankshaft experiences a large number of load cycles during its service life, fatigue performance and durability of this component has to be considered in the design process. Design developments have always been an important issue in the crankshaft production industry, in order to manufacture a less expensive component with the minimum weight possible and proper fatigue strength and other functional requirements. These improvements result in lighter and smaller engines with better fuel efficiency and higher power output. Crankshaft must be strong enough to take the downward force of the power stroke without excessive bending.

This project deals with the problem occurred in single cylinder engine crank shaft. It consists of static structural and modal analysis of single cylinder engine crank shaft. It identifies and solves the problem by using the modelling and simulation techniques. The topic was chosen because of increasing interest in higher payloads, lower weight, higher efficiency and shorter load cycles in crankshaft. The main work was to model the crank shaft with dimensions and then simulate the crank shaft for static structural and modal analysis. The modelling software used is Pro-e/creo-2 for modelling the crank shaft. The analysis software ANSYS will be used for structural and modal analysis of crank shaft for future work. The material for crank shaft is Cast Iron and other alternate materials on which analysis will be done are SAE 1045, SAE 1137,and EN9. The objectives involve modelling and analysis of crank shaft, so as to identify the effect of stresses on crank shaft, to compare various materials and to provide possible solution.

INTRODUCTION

Crankshaft is a large component with a complex geometry in the engine, which converts the reciprocating displacement of the piston to a rotary motion with a four link mechanism. Since the crankshaft experiences a large number of load cycles during its service life, fatigue performance and durability of this component has to be considered in the design process. Design developments have always been an important issue in the crankshaft production industry, in order to manufacture a less expensive component with the minimum weight possible and proper fatigue strength and other functional requirements. These improvements result in lighter and smaller engines with better fuel efficiency and higher power output. 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. And as the engine runs, the power impulses hit the crankshaft in one place and then another.

A single-cylinder engine is a basic piston engine configuration of an internal combustion engine. It is often seen on motorcycles, auto rickshaws, motor scooters, mopeds, dirt bikes, go-karts, radio-controlled models, power tillers and has many uses in portable tools and garden machinery. It has been used in automobiles and tractors.

Single-cylinder engines are simple and compact, and will often deliver the maximum power possible within a given envelope. Cooling is simpler than with

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multiple cylinders, potentially saving further weight, especially if air cooling can be used.

Single-cylinder engines require more flywheel effect than multi-cylinder engines, and the rotating mass is relatively large, restricting acceleration and sharp changes of speed. In the basic arrangement they are prone to vibration - though in some cases it may be possible to control this with balance shafts.

A variation known as the split-single makes use of two pistons which share a single combustion chamber.

Single-cylinder engines are simple and economical in construction. The vibration they generate is acceptable in many applications, while less acceptable in others. Counterbalance shafts and counterweights can be fitted but such complexities tend to counter the previously listed advantages.

Components such as the crankshaft of a single-cylinder engine have to be nearly as strong as that in a multi-cylinder engine of the same capacity per cylinder, meaning that some parts are effectively four times heavier than they need to be for the total displacement of the engine. The single-cylinder engine will almost inevitably develop a lower power-to-weight ratio than a multi-cylinder engine of similar technology. This can be a disadvantage in mobile operations, although it is of little significance in others and in most stationary applications.

FORGED CRANKSHAFT

Crankshafts can be forged from a steel bar usually through roll forging or cast in ductile steel. Today more and more manufacturers tend to favour the use of forged crankshafts due to their lighter weight, more compact dimensions and better inherent damping. 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. Carbon steels are also used, but these require additional heat treatment to reach the desired properties. Iron crankshafts are today mostly found in cheaper production engines (such as those found in the Ford Focus diesel engines) where the loads are lower. Some engines also use cast iron crankshafts for low output versions while the more expensive high output version use forged steel.

MACHINING

Crankshafts can also be machined out of a billet, often a bar of high quality vacuum remelted steel. Though the fibre flow (local in homogeneities of the material's chemical composition generated during casting) doesn’t follow the shape of the crankshaft (which is undesirable), this is usually not a problem since higher quality steels, which normally are difficult to forge, can be used. These crankshafts tend to be very expensive due to the large amount of material that must be removed with lathes and milling machines, the high material cost, and the additional heat treatment required. However, since no expensive tooling is needed, this production method allows small production runs without high costs.

In an effort to reduce costs, used crankshafts may also be machined. A good core may often be easily reconditioned by a crankshaft grinding process. Severely damaged crankshafts may also be repaired with a welding operation, prior to grinding, that utilizes a submerged arc welding machine. To accommodate the smaller journal diameters a ground crankshaft has, and possibly an over-sized thrust dimension, undersize engine bearings are used to allow for precise clearances during operation.

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 radius in most cases is rolled, this also leaves some compressive residual stress in the surface, which prevents cracks from forming.

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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 re-hardening. But high performance crankshafts, billet crankshafts in particular, tend to use nitridization instead. Nitridization is slower and thereby more costly, and in addition it puts certain demands on the alloying metals in the steel to be able to create stable nitrides.

The advantage of nitridization is that it can be done at low temperatures, it produces a very hard surface, and the process leaves some compressive residual stress in the surface, which is good for fatigue properties. The low temperature during treatment is advantageous in that it doesn't have any negative effects on the steel, such as annealing. With crankshafts that operate on roller bearings, the use of carburization tends to be favored due to the high Hertzian contact stresses in such an application. Like nitriding, carburization also leaves some compressive residual stresses in the surface.

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.

STRESS ON CRANKSHAFT

The shaft is subjected to various forces but generally needs to be analysed in two positions. Firstly, failure may occur at the position of maximum bending; this may be at the centre of the crank or at either end. In such a condition the failure is due to bending and the pressure in the cylinder is maximal. Second, the crank may fail due to twisting, so the conrod needs to be checked for shear at the position of maximal twisting. The pressure at this position is the maximal pressure, but only a fraction of maximal pressure.

CAST IRON

Cast iron is a group of iron-carbon alloys with a carbon content greater than 2%. The alloy constituents affect its colour when fractured: white cast iron has carbide impurities which allow cracks to pass straight through. Grey cast iron has graphite flakes which deflect a passing crack and initiate countless new cracks as the material breaks.

Carbon (C) and silicon (Si) are the main alloying elements, with the amount ranging from 2.1–4 wt% and 1–3 wt%, respectively. Iron alloys with less carbon content are known as steel. While this technically makes these base alloys ternary Fe–C–Si alloys, the principle of cast iron solidification is understood from the binary iron–carbon phase diagram. Since the compositions of most cast irons are around the eutectic point of the iron–carbon system, the melting temperatures closely correlate, usually ranging from 1,150 to 1,200 °C (2,100 to 2,190 °F), which is about 300 °C (572 °F) lower than the melting point of pure iron.

Cast iron tends to be brittle, except for malleable cast irons. With its relatively low melting point, good fluidity, castability, excellent machinability, resistance to deformation and wear resistance, cast irons have become an engineering material with a wide range of applications and are used in pipes, machines and automotive industry parts, such as cylinder heads (declining usage), cylinder blocks and gearbox cases (declining usage). It is resistant to destruction and weakening by oxidation (rust).

The earliest cast iron artefacts date to the 5th century BC, and were discovered by archaeologists in what is now Jiangsu in China. Cast iron was used in ancient China for warfare, agriculture, and architecture. During the 15th century, cast iron became utilized for artillery in Burgundy, France, and in England during the Reformation. The first cast iron bridge was built during the 1770s by Abraham Darby III, and is known as The Iron Bridge. Cast iron is also used in the construction of buildings.

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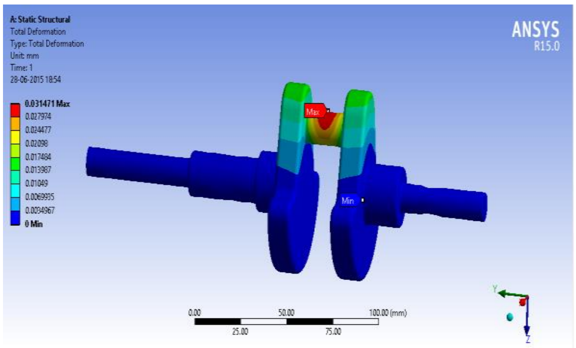
RESULTS:

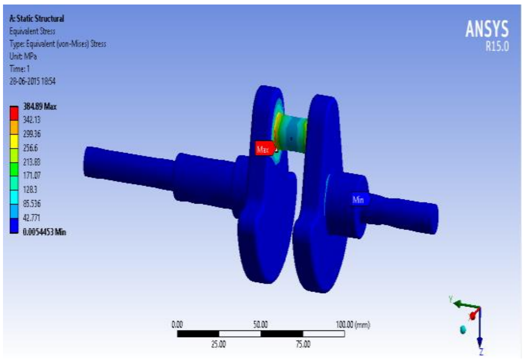
a. MATERIAL : CAST IRON

Deformation



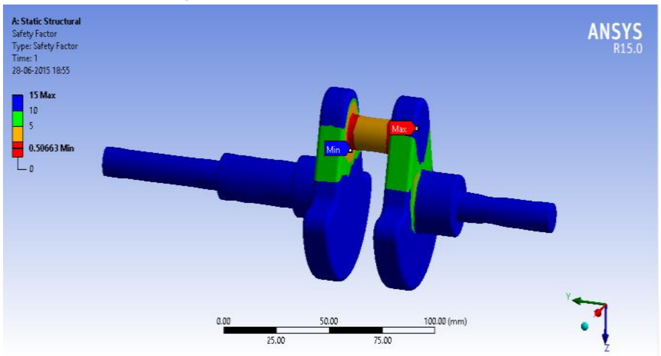
Deformation Analysis on Cast Iron at pressure 8*10^6 pa, Load 180 n-m & Inertia 500 rad/s

Von mises stress



Von mises stress Analysis on Cast Iron at pressure 8*10^6 pa, Load 180 n-m & Inertia 500 rad/s

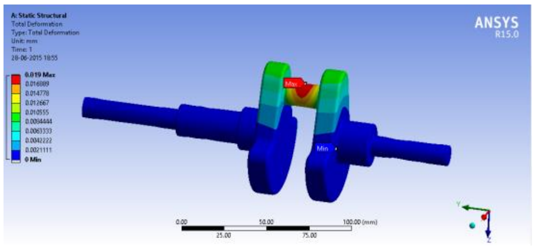
Factor of safety



Factor of Safety Analysis on Cast Iron at pressure 8*10^6 pa, Load 180 n-m & Inertia 500 rad/s

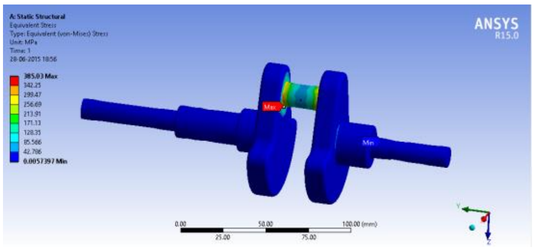
b. MATERIAL : SAE 1045

Deformation:



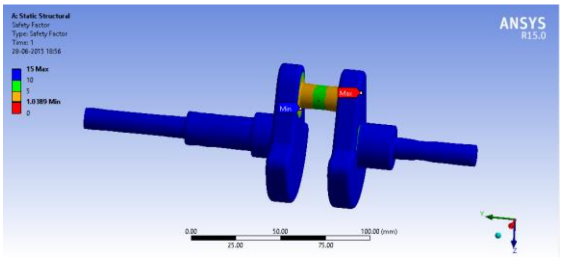
Deformation Analysis on SAE 1045 at pressure 8*10^6 pa, Load 180 n-m & Inertia 500 rad/s

Von mises stress



Von mises stress Analysis on SAE 1045 at pressure 8*10^6 pa, Load 180 n-m & Inertia 500 rad/s

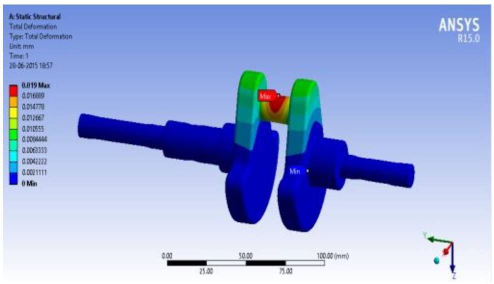
Factor of Safety



Factor of Safety Analysis on SAE 1045 at pressure 8*10^6 pa, Load 180 n-m & Inertia 500 rad/s

c. MATERIAL : SAE 1137

Deformation



Deformation Analysis on SAE 1137 at pressure 8*10^6 pa, Load 180 n-m & Inertia 500 rad/s

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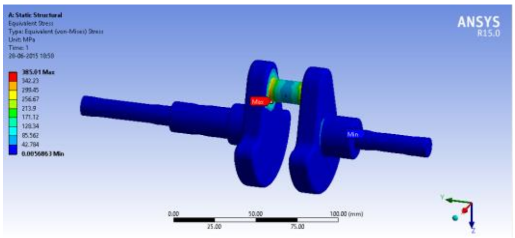
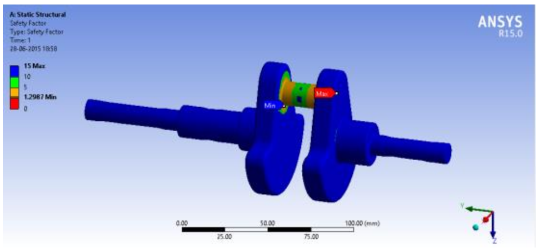
Von Mises stress



Von mises stress Analysis on SAE 1045 at pressure 8*10^6 pa, Load 180 n-m & Inertia 500 rad/s

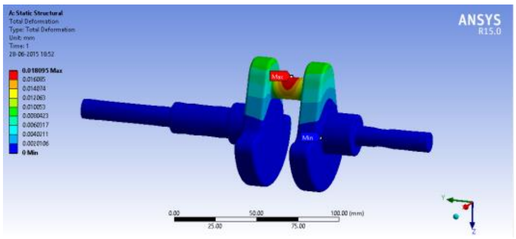
Factor of safety



Factor of safety Analysis on SAE 1045 at pressure 8*10^6 pa, Load 180 n-m & Inertia 500 rad/s

d. MATERIAL : EN9

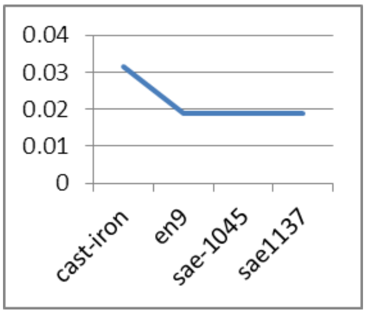
Deformation



Deformation Analysis on EN9 at pressure 8*10^6 pa, Load 180 n-m & Inertia 500 rad/s

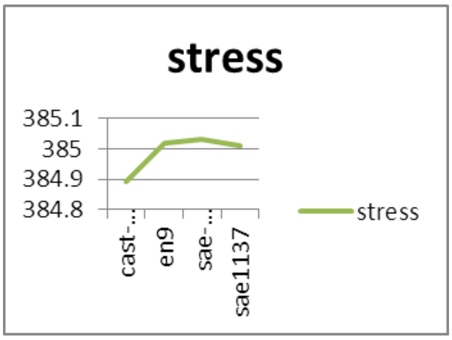
Graphs

Deformation



Deformation at pressure 8*10^6 pa, load 180 n-m & inertia 500 rad/s

Von mises stress



Von mises stress at pressure 8*10^6 pa, load 180 n-m & inertia 500 rad/s

CONCLUSION

The single cylinder crankshaft model was created by creo-2 software. Then, the model imported into ANSYS software. Then we analysing our model with four different cases in each case we applying four different material properties, we found deformations, von-mises stress, safety factor, by considering all results in cases SAE1137 material having good strength and low stress values at high rotational velocity and high pressure and torque respectively.

By this changes we can say, this crankshaft can run at high velocity high rpm condition without braking and producing good strength to weight ratio also.

The Value of Von-Misses Stresses that comes out from the analysis is far less than material yield stress so our design is safe and we should go for optimization to reduce the material and cost.

After Performing Static Analysis we performed Dynamic analysis of the crankshaft which results shows more realistic whereas static analysis provides an overestimate results. Accurate stresses and deformation are critical input to fatigue analysis and optimization of the crankshaft. At mode 1 SAE1137 having 504.47 hz.

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