

ANALYSIS OF MULTITHROW CRANK SHAFT

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Abstract: All the engine components are subjected to constant varying load which also varies in direction and due to these, components may fail. Bending and shear stress due to twisting are common stresses acting on crankshaft. Due to the repeated bending and twisting, crankshaft fails, as cracks form at fillets between the journal and crank cheeks, and near the centre point journal. Hence, fatigue plays an important role in crankshaft development. Accurate prediction of fatigue life is very important to insure safety of components and its reliability. The main objective of this project is to modify the design to increase the fatigue life of four stroke diesel engine crankshaft. The drafting is done by using CREO 3.0 software, which is advanced modeling software for designing of simple to complex shapes. For the model developed, two types of analysis are performed, one is fatigue analysis and the other is modal analysis. Fatigue analysis is used to know the life and modal analysis for the natural frequencies of crankshaft before and after modification.

Key words: Crankshaft, Modal Analysis, Fatigue Analysis.

Introduction:

A crankshaft contains two or more centrally-located coaxial cylindrical ("main") journals and one or more offset cylindrical crankpin ("rod") journals. The two-plane V8 crankshaft has five main journals and four rod journals, each spaced 90° from its neighbors.

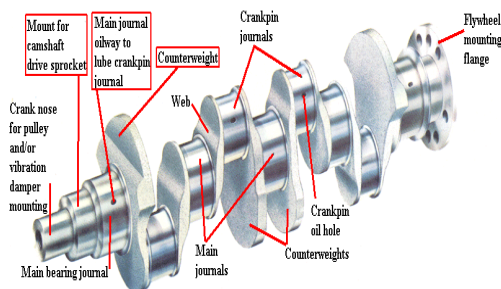


Fig-Main parts of a crankshaft

The crankshaft main journals rotate in a set of supporting bearings ("main bearings"), causing the offset rod journals to rotate in a circular path around the main journal centers, the diameter of which is twice the offset of the rod journals. The diameter of that path is the engine "stroke": the distance the piston moves up and down in its cylinder. The big ends of the connecting rods ("connecting rods") contain bearings ("rod bearings") which ride on the offset rod journals.

These acceleration forces combine in complex ways to produce primary and secondary shaking forces as well as primary and secondary rocking moments. The

combinations of forces and moments vary with the cylinder arrangement (inline, opposed, 60°V, 90°V, 120°V, etc.) and with the crankpin separation (60° / 90° / 120° / 180°, etc.). They must, to the maximum extent possible, be counteracted by the implementation of the crankshaft counterweights. Many of the common engine arrangements allow for complete balancing of primary and secondary forces and moments. Examples are inline six cylinder engines with 120° crankpin spacing and 90° V8 engines with conventional 90° crankpin spacing.

Certain other engine arrangements do not allow for the complete counteracting of all the forces and moments, so there are design compromises which must be optimized. For example, an inline-four has a secondary vertical shake as the result of the secondary piston acceleration forces. In road vehicles, the secondary vertical shake is often suppressed by unbalanced counterweight shafts rotating at twice crank speed. The 90° V8 engine with a single-plane crank 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"). Because the secondary piston acceleration forces are parallel with the cylinder axes, in this engine design the vertical components of those forces on a given crankpin cancel each other, but the horizontal components add together.

Crankshaft materials:

Crankshafts materials should be readily shaped, machined and heat-treated, and have adequate strength, toughness, hardness, and high fatigue strength. The following materials made by using crankshafts as follows.

- Carbon(C)
- Manganese(Mn)
- Chromium(Cr)
- Nickel(Ni)
- Molybdenum(Mo)
- Silicon(Si)
- Vanadium(V)

The steel alloys typically used in high strength crankshafts have been selected for what each designer perceives as the most desirable combination of properties. Medium-carbon steel alloys are composed of predominantly the element iron, and contain a small percentage of carbon (0.25% to 0.45%, described as '25 to

45 points' of carbon), along with combinations of several alloying elements, the mix of which has been carefully designed in order to produce specific qualities in the target alloy, including hardenability, nitridability, surface and core hardness, ultimate tensile strength, yield strength, endurance limit (fatigue strength), ductility, impact resistance, corrosion resistance, and temper-embrittlement resistance. The alloying elements typically used in these carbon steels are manganese, chromium, molybdenum, nickel, silicon, cobalt, vanadium, and sometimes aluminum and titanium.

Crankshaft heat treating:

Regarding the steel alloys typically used in high-grade crankshafts, the desired ultimate (and hence yield and fatigue) strength of the material is produced by a series of processes, known in aggregate as 'heat treatment'. The typical heat-treating process for carbon-steel alloys is first to transform the structure of the rough-machined part into the face-centered-cubic austenite crystalline structure by heating the part in an oven until the temperature throughout the part stabilizes in the neighbourhood of 843°C to 898°C

(depending on the specific material). Next, the part is removed from the heating oven and rapidly cooled ("quenched") to extract heat from the part at a rate sufficient to transform a large percentage of the austenitic structure into fine-grained martensite. The desired martensitic post-quench crystalline structure of the steel is the high-strength, high-hardness, form of the iron-carbon solution. The rate of cooling required to achieve maximum transformation varies with the hardenability of the material, determined by the combination of alloying elements.

Distortion and induced residual stress are two of the biggest problems involved in heat-treating. Less severe quenching methods tend to reduce residual stresses and distortion. Some alloys (EN-30B and certain tool steels, for example) can reach full hardness by quenching in air. Other alloys having less hardenability can be quenched in a bath of 204°C molten salt. Still others require quenching in a polymer-based oil, and the least hardenable alloys need to be quenched in water. The shock of water-quenching is often severe enough to crack the part or induce severe residual stresses and distortions. As the hardenability

of a material decreases, the hardness (thus strength) varies more drastically from the surface to the core of the material. High hardenability materials can reach much more homogeneous post-quench hardness. Cryogenic treatment, if used, directly follows quenching. The body of belief-based and empirical evidence supporting cryo is now supported by scientific data from a recent NASA study confirming that a properly-done cryo process does transform most of the retained austenite to martensite, relaxes the crystalline distortions, and produces helpful η ("eta") particles at the grain boundaries. The resulting material is almost fully martensitic, has reduced residual stress, more homogeneous structure and therefore greater fatigue strength. After quenching (and cryo if used), the alloy steel material has reached a very high strength and hardness, but at that hardness level, it lacks sufficient ductility and impact resistance for most applications. In order to produce the combination of material properties deemed suitable for a given application, the part is placed in a 'tempering' oven and soaked for a specific amount of time at a specific temperature (for that alloy) in order to

reduce the hardness to the desired level, hence producing the desired strength, ductility, impact resistance and other desired mechanical properties. In the case of certain alloys, a double-tempering process can further improve fatigue strength and notch toughness. The tempering temperature and time must be carefully determined for each specific steel alloy, because in mid-range temperature bands, martensitic steels exhibit a property known as temper embrittlement, in which the steel, while having high strength, loses a great deal of its toughness and impact resistance.

Figure shows the relative fatigue strength of 4340 material from heat treating alone, heat-treating plus shotpeening, and heat treating plus nitriding.

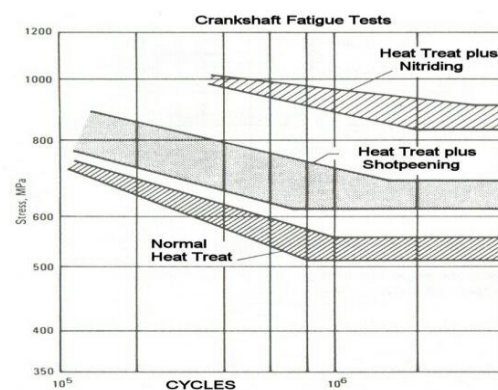


Figure Crank shaft fatigue test

Crankshaft design issues:

In the world of component design, there are competing criteria, which require the

engineers to achieve a perceived optimal compromise to satisfy the requirements of their particular efforts. Discussions with various recognized experts in the crankshaft field make it abundantly clear that there is no 'right' answer, and opinions about the priorities of design criteria vary considerably. In contemporary racing crankshaft design, the requirements for bending and torsional stiffness (see the Stiffness vs. Strength sidebar) compute with the need for low mass moment of inertia (MMOI). Several crankshaft experts emphasized the fact that exotic metallurgy is no substitute for proper design, and there's little point in switching to exotics if there is no fatigue problem to be solved. High stiffness is a benefit because it increases the tensional resonant frequency of the crankshaft, and because it reduces bending deflection of the bearing journals. Journal deflection can cause increased friction by disturbing the hydrodynamic film at critical points, and can cause loss of lubrication because of increased leakage through the greater radial clearances that occur when a journal's axis is not parallel to the bearing axis. At this point, it is important to digress

and emphasize the often-misunderstood difference between stiffness and strength.

Metal parts are not rigid. When a load is applied to a metal part, the part deflects in response to the load. The deflection can be very small (crankshaft, connecting rod, etc.) or it can be quite large (valve springs, etc). But to one degree or another, all parts behave like springs in response to a load. The ultimate strength of a material is a measure of the stress level which can be applied to a lab sample of the material before it fractures. The degree to which a given part resists deflection in response to a given loading is called stiffness. It is important to understand that the ultimate strength of a material has nothing whatever to do with stiffness. Stiffness is the result of two properties of a part: (1) the Young's Modulus of the material (sometimes called Modulus of Elasticity, but more appropriately named Modulus of Rigidity) and the cross-sectional properties of the part to which the load is applied. For example, suppose you have two components which are identical in all respects (same material, same dimensions) except the tensile strength to which those components have been heat-treated. If load

is applied to each component, both will deflect the same amount for each load value, until the component with the lower strength permanently deforms (and breaks if it is loaded and constrained in a certain way) at a relatively low stress level. The component with the higher strength will continue to deform with increasing load until its yield stress is reached, at which point it too will permanently deform.

Since the current crankshaft materials are alloy steels, the Young's Modulus is fairly constant. That means that altering the section properties of the highly-stressed portions of the crankshaft is the only way to increase stiffness. Of course, adding material works at cross-purposes to maintaining low MMOI.

Three major parameters which affect crank stiffness are length, journal diameter and crankpin overlap. The torsional rate of a cylindrical section varies directly with length and with the fourth power of diameter. Crankpin overlap is a measurement of how much crankpin material is horizontally aligned with the material of the adjacent main journals, as illustrated in Figure 7, showing a CPO of

0.225 with a 4.250" stroke crank having 2.100 rod journals and 2.600 main journals.

$$CPO = (\text{main diameter} + \text{crankpin diameter} - \text{stroke}) / 2$$

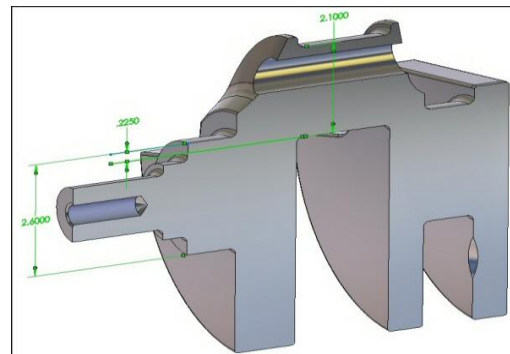


Fig: CPO of 0.225 with a 4.250" stroke crank having 2.100 rod journals

There is a continuing emphasis on research and design among F1 and Cup teams to increase stiffness with minimal impact on MMOI. From examining some available pictures and gathering data on other engine parameters, the connecting rod bearing widths are being reduced to make room for thicker webs. It is also possible that main bearing journals are being undercut to produce the required fillet radius at the intersection with the web, again making more room for thicker webs.

Basic procedures for creating a 3-d model in CREO 3.0:

Creation of a 3-D model in CREO 2.0 can be performed using three

workbenches i.e., sketcher, modeling and assembly.

Sketcher:

Sketcher is used to create two-dimensional representations of profiles associated within the part. It can create a rough outline of curves, and then specify conditions called constraints to define the shapes more precisely and capture our design intent. Each curve is referred to as a sketch object.

Creating a new sketch:

To create a new sketch, chose File→New→Part then select the reference plane or sketch plane in which the sketch is to be created.

Sketch plane

The sketch plane is the plane that the sketch is located on. The sketch plane menu has the following options. Face/Plane:With this option, usage of attachment face/plane icon to select a planar face or existing datum plane. With selection of a datum plane, the reverse direction button to reverse the direction of the normal to the plane.FRONT, TOP and TOP: With these options, it's easy to create a sketch on one of the WCS planes. With this method, a datum

plane and two datum axes are created as below.

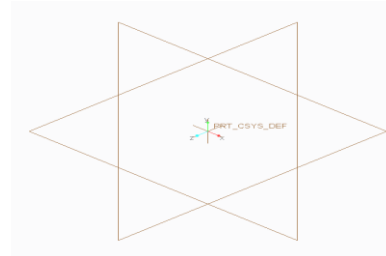


Fig.3.1.Modeling

Parameters of crankshaft:

Fly wheel Diameter(d)=85 mm

Thickness(t)=12 mm

Main bearing Diameter(d)=50 mm

Thickness(t)=24 mm

Crankpin Diameter(d)=45 mm

Thickness(t)=24 mm

Crankweb height(h)=130 mm

Thickness(t)=16 mm

Select revolve tool and select the horizontal axis to add the material up to 360degrees – Ok, as shown in below fig:

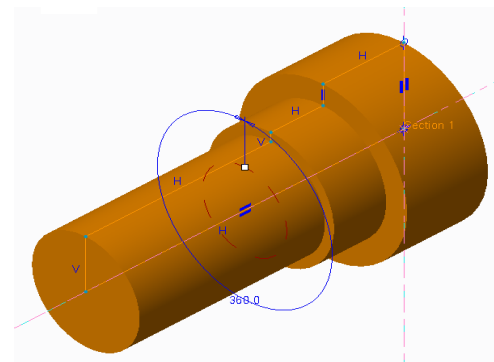


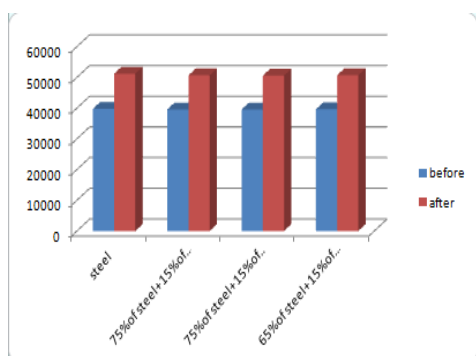
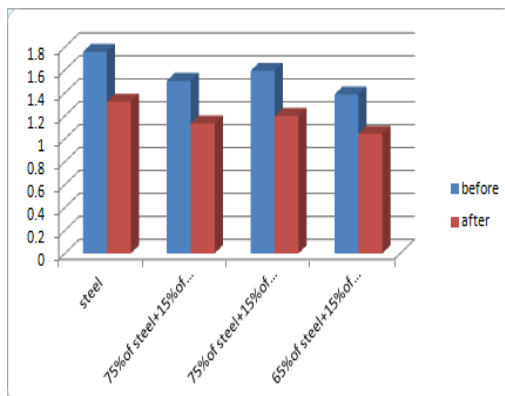
Fig. Revolve with 360°

Results and discussion:

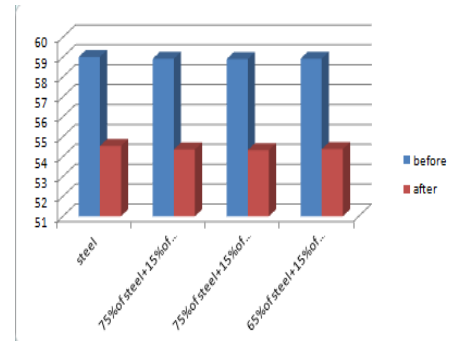
Fatigue analysis and Modal analysis are carried out on Crankshaft as discussed in earlier chapter. The results obtained are tabulated in Table-5.1 and Table-5.2

Fatigue analysis results:

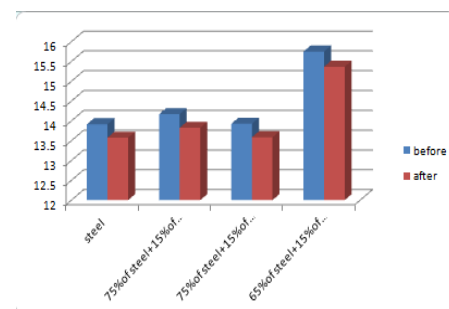
Total deformation (10^{-2})



Life in hours



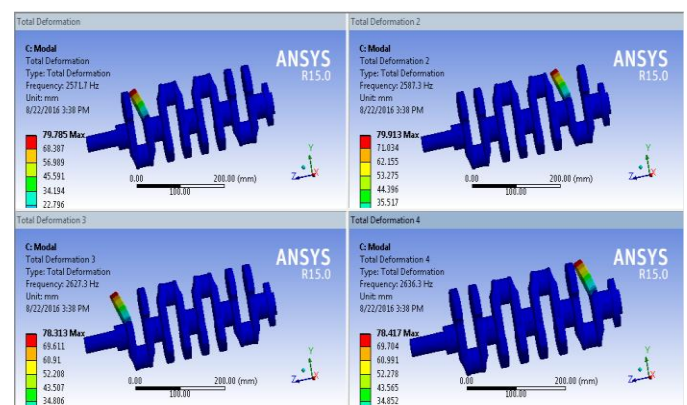
Principle stress

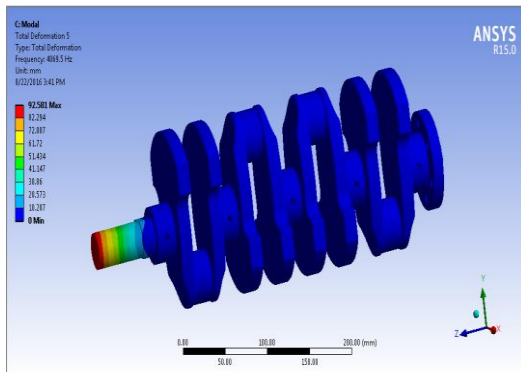


Weights in kg

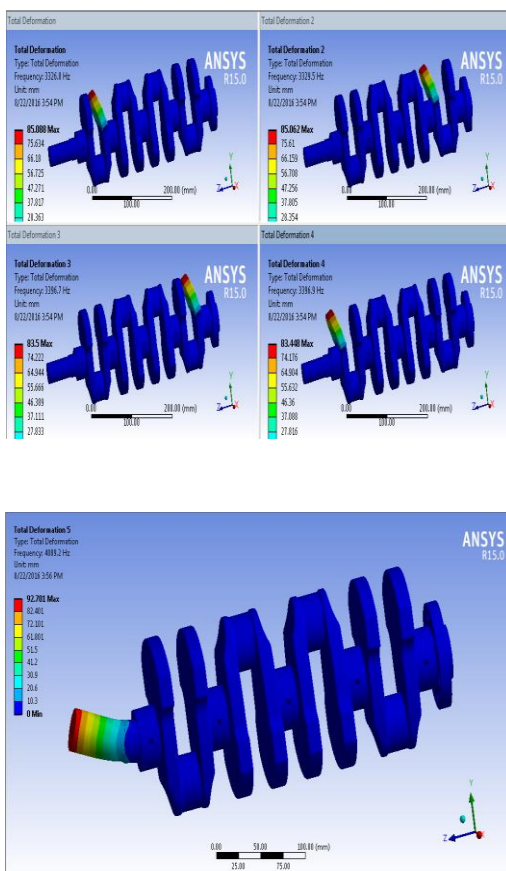
Total deformation by model

Before:



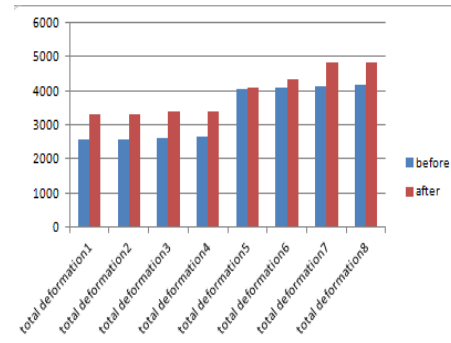


With 0.0% of deformation visualization
Total deformation by model
After:



With 0.0% of deformation visualization

Graph:



Conclusion

The induced stress in member must be less than allowable stress for safe design. By comparing the induced stress it is clear that the induced stress is reduced as follows for different materials after modification of design.

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