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FEA of the Forged Steel Crankshaft by Hypermesh

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In this study a static analysis is conducted on this crankshaft, with single crankpin of crankshaft. Finite element analysis is performed to obtain the variation of stress magnitude at critical locations. With the help of maximum gas pressure at time of combustion, total load acting on the crankpin of the crankshaft is calculated. In this static analysis of crankshaft, loading and boundary condition depend upon the maximum gas pressure acting on the crankpin. For the FEA analysis of crankshaft we selected the different element length size for the meshing.

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Strictly as per the compliance and regulations of :

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For the FEA analysis of crankshaft we selected the different element length size for the meshing. Meshing is done using the HYPERMESH software with the tetra element shape. The static analysis is done analytically. This resulted in the load spectrum applied on crankpin area of crankshaft. This load is applied to the FE model in ANSYS and boundary conditions were applied according to the engine mounting conditions. The analysis is done for maximum loading condition. Finally analytical stress calculated value and ANSYS stress value of crankshaft are verified.

Index terms :forging, forging limit diagram (FLD), hyper mesh, simulation, 3d modeling, computational analysis, stress, strain.

I. Introduction

The Crankshaft

Figure 1 : Functional layout diagram of crankshaft

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The primary function of the crankshaft is to convert the translational mechanical energy of the piston being driven back and forth by the pneumatic energy provided by pressure change as a result of the combustion reaction. Crankshafts are high volume production engine components and their most common application is in an automobile engine. In an internal combustion engine, the reciprocating motion of the piston is linear and is converted into rotary motion through the crankshaft. There are many other applications of a crankshaft which range from small one cylinder engines to very large multi cylinder marine crankshafts. The connection of the piston to the crankshaft via the connector pin provides for the transfer of this energy; the force of the connector pin to the small portion of crankshaft axel that is offset from the main axis causes the rotation about the main crankshaft axis. The crankshaft is also connected to the pull-start by the pull-start connection cup. When the pull-start chord is pulled, the energy is transferred to rotational energy of the crankshaft.

Now that the crankshaft has converted the translational mechanical energy of the piston to rotational mechanical energy, its next function is to transfer this energy to the driver pulley of the pulley-belt system. This is a critical transfer of energy because it is the belt-pulley system that ultimately displaces this rotational mechanical energy to the auger, causing it to rotate and collect the snow and other material that is imported by the auger. The flow that is associated with the crankshaft is just this energy conversion. The crankshaft is located directly adjacent to the two-cycle gas engine, since it is connected to the piston by the connector pin. This location next to the engine is a hot environment that is caused by the convection of thermal energy off of the engine block's heat sink. The high temperatures in this environment are cause for consideration when choosing the material for the crankshaft, which will be discussed in the following section, along with the geometry and appearance of the component.

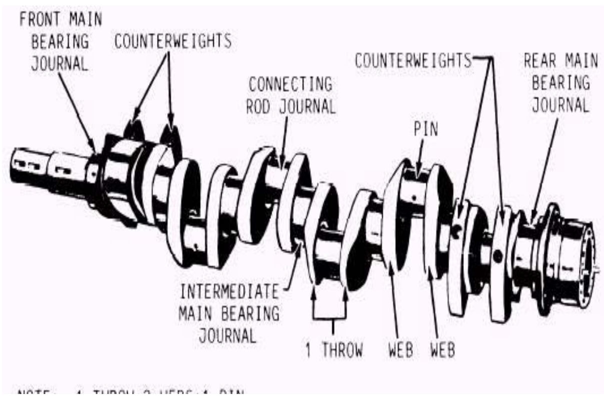

Figure 2 : Basic crankshaft with its nomenclature

II. History

In the past, the crankshaft was developed without using any analytical software's. So, in those days not only crankshaft, but all other products also were developed with doing various kinds of iterations in manufacturing technology. Due to which it affects the total production cost, time consumption & all overall project cost.

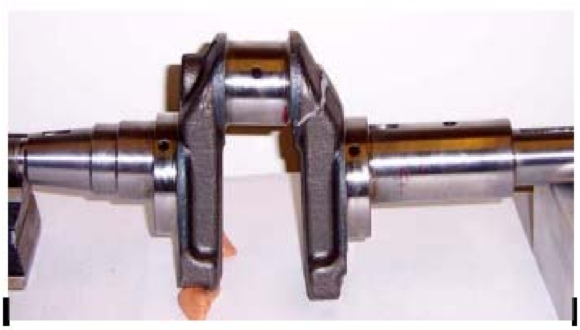

Figure 3 : Failure occurred area of crankshaft (i)

Figure 4 : Failure occurred area of crankshaft (ii)

Figure 5 : Final stage of failure occurred in the crankshaft (iii)

III. Problem Definition

For the FEA analysis of crankshaft we selected the different element length size for the meshing. Meshing is done using the HYPERMESH software. The element type used for crankshaft is solid 3D. For the analysis of crankshaft the tetra element shape is used. The static analysis is done analytically. This resulted in the load spectrum applied on crankpin of crankshaft. This load is applied to the FE model in ANSYS, and boundary conditions were applied according to the engine mounting conditions.

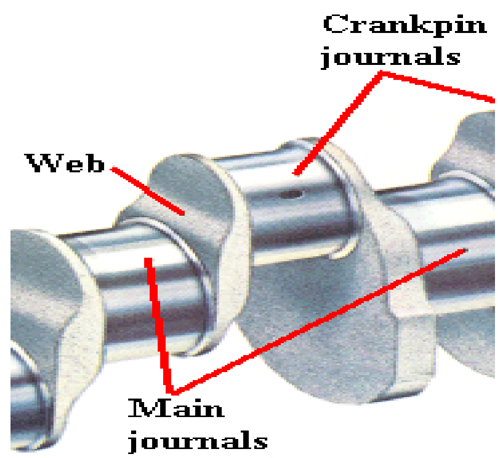

Figure 6 : Introduction of area where failure occurred most probably

Figure 7 : Side view of crankshaft showing changes in its lob shape

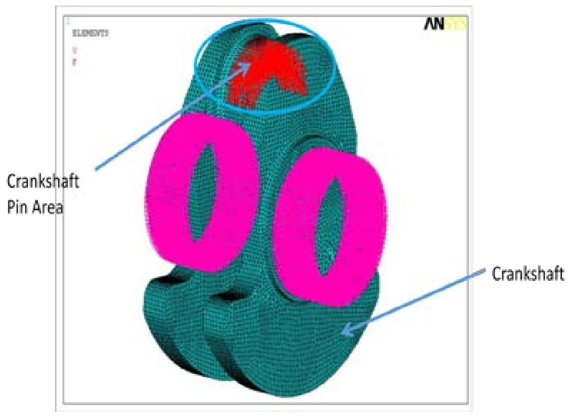

Figure 8 : Stress concentration area of crankshaft showing in hypermesh

IV. Design Calculation by Analytically

In a reciprocating engine, the crankpins, also known as crank journals are the journals of the big end bearings, at the ends of the connecting rods, opposite to the pistons. If the engine has a crankshaft, then the crank pins are the journals of the off-centre bearings of the crankshaft. In a beam engine the single crank pin is mounted on the flywheel. In a steam locomotive the crank pins are often mounted directly on the driving wheels.

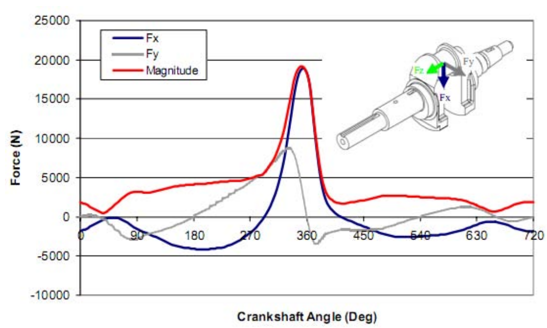

Figure 9 : Forces applied in various directions in crankshaft

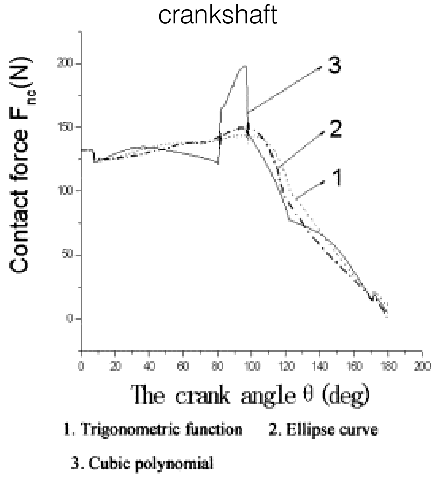

Figure 10 : Graphical analysis of contact forces & diff. crank angles

V. Steps of Simulation for Validation

There are following steps followed for simulation:

i. Exact defining the critical area of load acting on crankshaft.
ii. Load Distribution of crankshaft.
iii. Meshing of crankshaft with different shapes of element.
iv. Graphical analysis for calculating critical load area.
v. Target the area to minimize the load completely (i.e. uniformly distributed).

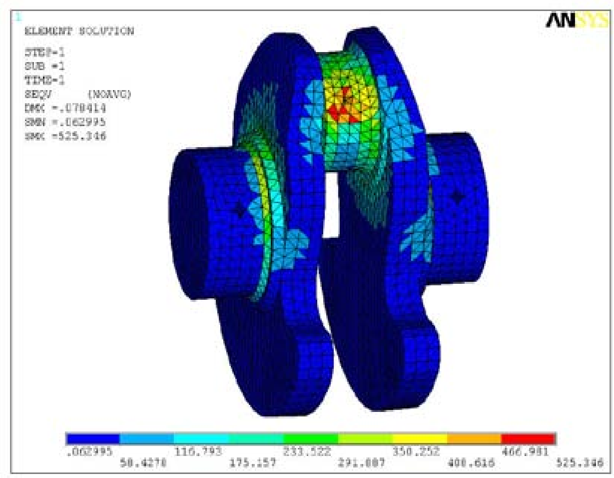

Figure 11 : Meshing of crankshaft with different shapes of elements

a) No. of Iterations with Different Case Studies

There are following case studies applied for simulation:

i. Meshing of crankshaft with triangular shapes of element with considering only bending load.
ii. Meshing of crankshaft with triangular shapes of element with considering only torsional load.
iii. Meshing of crankshaft with tetra shapes of element with considering only bending load.
iv. Meshing of crankshaft with tetra shapes of element with considering only torsional load.
v. Meshing of crankshaft with tetra shapes of element with considering only bending & torsion load.

Finite element analyses of the crankshafts were conducted to obtain stress distributions, determine the critical location of the crankshafts and to determine the stress concentration factors. Based on the finite element analysis performed for the two crankshafts, life predictions were performed using the properties obtained from the strain-controlled specimen fatigue tests. Both the S-N and the strain-life approaches were used, results of which were then compared with the component test data.

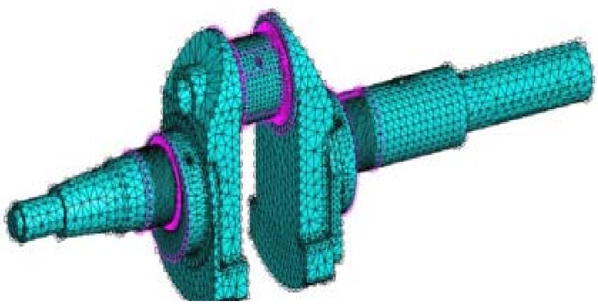

Figure 12 : Meshing of crankshaft with triangular shape of elements

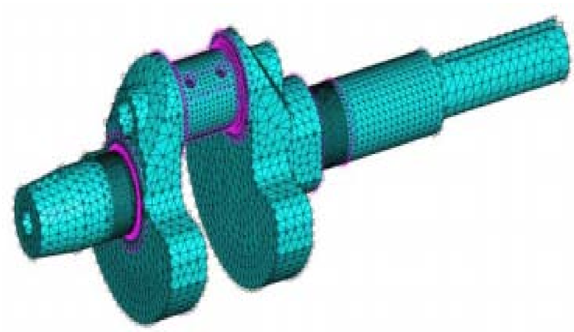

Figure 13 : Meshing of crankshaft with polygonal shape of elements

VI. EXPERIMENTAL SET-UP

For specimen testing, strain-controlled monotonic and fatigue tests of specimens made of the forged steel and cast iron crankshafts were conducted. From these experiments, both static as well as baseline cyclic deformation and fatigue properties of both materials were obtained. Such data provide a direct comparison between deformation, fatigue performance, and failure mechanisms of the base materials, without introducing the effects and interaction of complex design parameters such as surface finish, component size, residual stress, stress concentration, etc. ASTM standard test methods and recommended practices were followed in all tests. Charpy V-notch specimen tests were also conducted due to the occasional impact loads applied to the crankshaft.

A number of load-controlled fatigue tests of crankshafts made of forged steel and ductile cast iron were also conducted. Such data provide a direct comparison between fatigue performance of the components made of each base material and manufacturing process. Such comparison inherently includes design effects such as surface finish, component size, residual stress, and stress concentration.

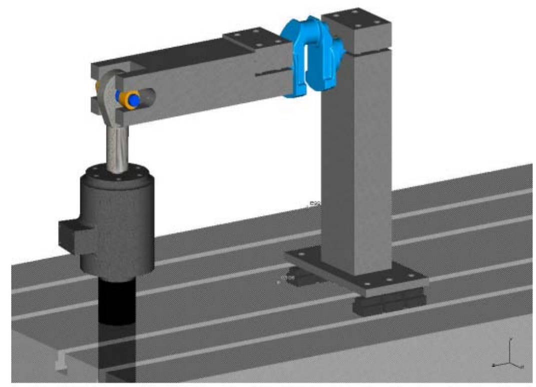

Figure 14 : Experimental set-up diagram (i)

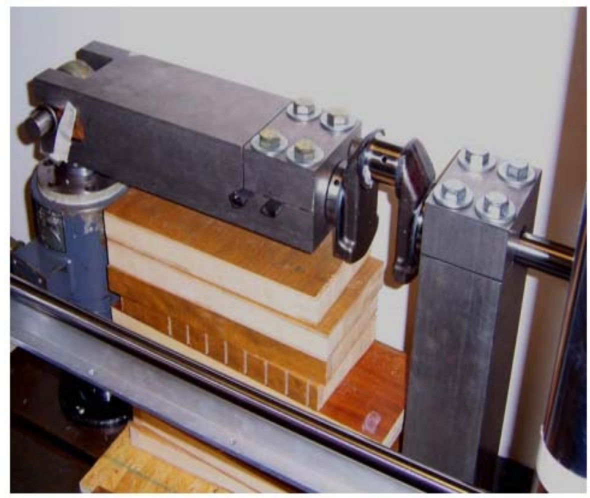

Figure 15 : Experimental set-up diagram (ii)

VII. RESULT

This section presents the final results for the forming simulations after spring back compensation. Analytical stress calculated value & ANSYS stress value of crankshaft are verified. Maximum stresses are generated on oil hole of the crank pin, fillet area of crankpin and journal bearing surface of the crankshaft.

Finite element analyses of the crankshafts were conducted to obtain stress distributions, determine the critical location of the crankshafts and to determine the stress concentration factors. Based on the finite element analysis performed for the two crankshafts, life predictions were performed using the properties obtained from the strain-controlled specimen fatigue tests. Both the S-N and the strain-life approaches were used, results of which were then compared with the component test data.

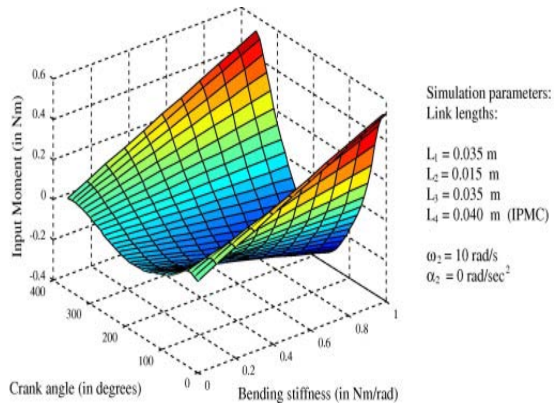

Figure 16 : Simulation result of bending stiffness with diff crank angle at crank pin area

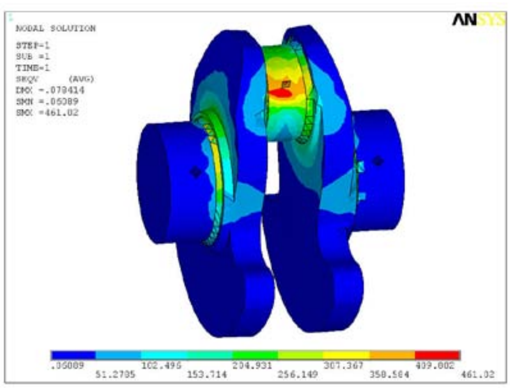

Figure 17 : More stress occurred at crank pin fillet area

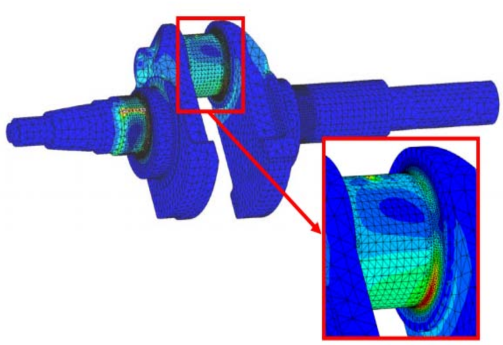

Figure 18 : Minimized stress area at crank pin fillet area

VIII. Conclusion

There are some main conclusions that can be drawn from this project. The main objectives were met and even though the hope was to be able to design the crankshaft with considering torsional & bending load, we finally reached a feasible solution. The main objective was to design the crankshaft and then evaluate if investment in simulation software would be profitable. The answer to the question if this would be profitable, as can be understood from reading the discussion, depends greatly on how We chooses to profligate. If we focus on especially advanced meshing tools, an investment in simulation software would most certainly be profitable in terms of more orders, faster and cheaper production and safer production.

However, if we only produce meshing tools per year, buying product externally, only when necessary, would maybe be a better option. But from a future perspective, one can expect the meshing operations to be even more complicated & software will rise quickly as the demands on the products get higher.

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Appendix : List of Publications and Presentations on the Study

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