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Fatigue analysis of connecting rod of universal tractor through finite element method (ANSYS)

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The connecting rod fatigue of universal tractor (U650) was investigated through the ANSYS software application and its lifespan was estimated. The reason for performing this research showed the connecting rod behavior affected by fatigue phenomenon due to the cyclic loadings and to consider the results for more savings in time and costs, as two very significant parameters relevant to manufacturing. The results indicate that with fully reverse loading, one can estimate longevity of a connecting rod and also find the critical points that more possibly the crack growth initiate from. Furthermore, the allowable number of load cycles and using fully reverse loading was gained 10^8. It is suggested that the results obtained can be useful to bring about modifications in the process of connecting rod manufacturing.

Key words: connecting rod, fatigue, longevity, simulation, optimization, finite element

Introduction

Connecting rods are widely used in variety of car engines. The function of connecting rod is to transmit the thrust of the piston to the crankshaft, and as the result the reciprocating motion of the piston is translated into rotational motion of the crankshaft. It consists of a pin-end, a shank section, and a crank-end. Pin-end and crank-end pin holes are machined to permit accurate fitting of bearings. One end of the connecting rod is connected to the piston by the piston pin. The other end revolves with the crankshaft and is split to permit it to be clamped around the crankshaft. The two parts are then attached by two bolts. Connecting rods are subjected to forces generated by mass and fuel combustion. These two forces results in axial and bending stresses. Bending stresses appear due to eccentricities, crankshaft, case wall deformation, and rotational mass force. Therefore, a connecting rod must be capable of

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transmitting axial tension, axial compression, and bending stresses caused by the thrust and pull on the piston and by centrifugal force (Afzal and Fatemi, 2003). The connecting rod of the tractors is mostly made of cast iron through the forging or powder metallurgy. The main reason for applying these methods is to produce the components integrally and to reach high productivity with the lowest cost (Whittaker, 2001; Repgen, 2005). Nevertheless, connecting rod design is complicated because the engine is to work in variably complicated conditions and the load on the rod mechanism is produced not only by pressure but also inertia (Augugliaro and Biancolini, 2000). When the repetitive stresses occur in connecting rod it leads to fatigue phenomenon which can cause so dangerous ruptures and damages. An example of the fatigue analysis and design was presented in 2003 by some researchers (Biancolini *et al*., 2003). A rupture due to the fatigue and the method of correcting the connecting rod design was also reported (Rabb, 1996). Beretta *et al*. (1997) presented a strengthening method for the connecting rod design. Finite element (FEM) method is a modern way for fatigue analysis and estimation of the component longevity which has the following advantages compared to the other methods. Through this method, we can access the stress/strain distribution throughout the whole component which enables us to find the critical points authentically. This achievement seems so useful particularly when the component doesn't have a geometrical shape or the loading conditions are sophisticated. The influential component factors are able to change such as material, cross section conditions etc. Component optimization against the fatigue is performed easily and quickly. Analysis is performed in a virtual environment without any necessity for prototype construction (Lo and Bevan, 2002). Totally these qualities, lead to savings in time and cost. For the reason that the connecting rod failure is usually due to the fatigue phenomenon, consequently in this research a U650 tractor connecting rod behavior, from the fatigue point of view, is investigated through the ANSIS software.

Materials and methods

Fatigue phenomenon is a complicated subject which seems to be not known a lot. The best theory for the explanation of fatigue phenomenon proposal, is the strain-life theory which is used for the fatigue strength estimation. But for the application of this theory there must be some assumptions made for the ideal state, so it results in some uncertainties. Rupture due to the fatigue is usually occurred in discontinuities or where we have the stress concentration. When in these places the existing stress, exceeds the allowable one it gives rise to the plastic strain. For the ruptures resulted from the fatigue, there must be some plastic cyclic strains. So, It was needed to seek for the component behavior during the cyclic deformations. Monsoon-koffin suggested the Equ.1 to present the relationship between fatigue life and the total strain. (Shigley and Mischke, 2001).

$$\frac{\Delta\varepsilon}{2} = \frac{\sigma_F}{E}\left(2N\right)^b + \varepsilon_F\left(2N\right)^c \qquad (1)$$

Where $\Delta\varepsilon$ is the total stress, N is the fatigue longevity, E is the Young's modulus, b and c are the exponents of fatigue strength and fatigue elasticity, and finally σ_F and ε_F are the coefficient of fatigue strength and elasticity respectively. The necessary parameters for determining the connecting rod material are brought in Table 1 and U650 connecting rod dimensions are represented in Fig.1. The next stage was to mesh the model. The 10 node pyramid elements were used as shown in Fig.2. The reason for choosing this element was to make the geometrical parts of a complicated mechanical component so enable us to gain more authentic results based on the high techniques of fatigue life calculation. First of all, the boundary conditions were difined, exerting a tension force. Afterwards, a compressive force, exactly with the same magnitude but in a reverse direction substituted the tension force and it was solved again. In every phase of loading by entering to the POST1 processor, the Von Misses stresses were activated and the critical points were determined. These nodes are shown in Fig.3 and Fig.4 which the following numbers as node 46 (a node around the piston pin-end), node 5232 (a node around the bearing) and 4887 (a node on the connecting rod stem near the bearing) through the tension loading while node 46 was the result of compressive loading. After determination of these critical points, they were elected as the points for fatigue investigation. Filling the fatigue parameter blanks, the S-N data collected from the fatigue test of the specific alloy into the software should import. 1.25 was taken as the stress concentration factor which was a representative of a difference between the real model and the operating condition with the sample under the test in fatigue test. Eventually a 10^6 force cycle was exerted to the model and partial consumption rate which indicated the number of exerted cycles to allowable ones for each node was gained.

Results and discussion

Through the fatigue analysis of the connecting rod, two loadings were taken into account. In tension loading which its results were shown in Fig.3, the maximum stress created was 29.4 while in pressure stress (Fig.4), the 24 was gained. The critical points/nodes of the model was shown as follows:- 46, 5232, and 4887 in tension loading, respectively and the node 46 in compressive one. The repetitive stresses created in nodes 46, 5232, 4887 are 26.793, 4.167 and 12.994, respectively. Partial consumption rate which indicated the number of exerted cycles to allowable ones for each node was gained 0.1 for all the nodes and based on the partial consumption rate definition, the number of allowable force exertion cycles reached 10^8.

Table 1. Specifications of the applied connecting rod.

values	Specification
621	Tensile Strength(MPa)
483	Yield Strength(MPa)
229-269	Hardness, Brinell (H_B)
207	E(GPa)
79	Shear module(GPa)
0.3	Poisson ratio
7.7	Density(Mg/m^3)
0.8	Correction factor

Conclusion

By the finite element analysis method and the assistance of ANSIS software, It is able to analyze the different car components from varied aspects such as fatigue and consequently save the time and the cost. The way that defined loadings was effective on the results achieved. So, they should fit as much as possible the real conditions. As the fatigue analysis requires some static analysis and to define the boundary conditions closest to the real. Stress concentration factors indicated the difference between the real and the working condition. Relating to the U650 connecting rod, the most critical node numbered 46 and the number of allowable force exertion cycles with the totally reverse loading were gained 10^8 which increased by decreasing in stress concentration factor.

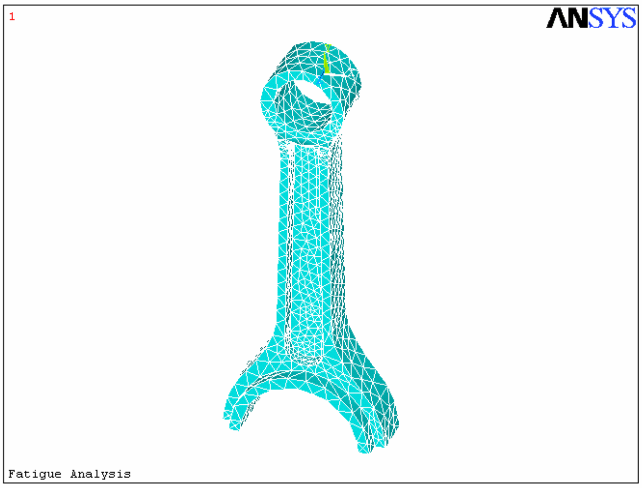


Fig. 1. The meshed model of the connecting rod in ANSIS.

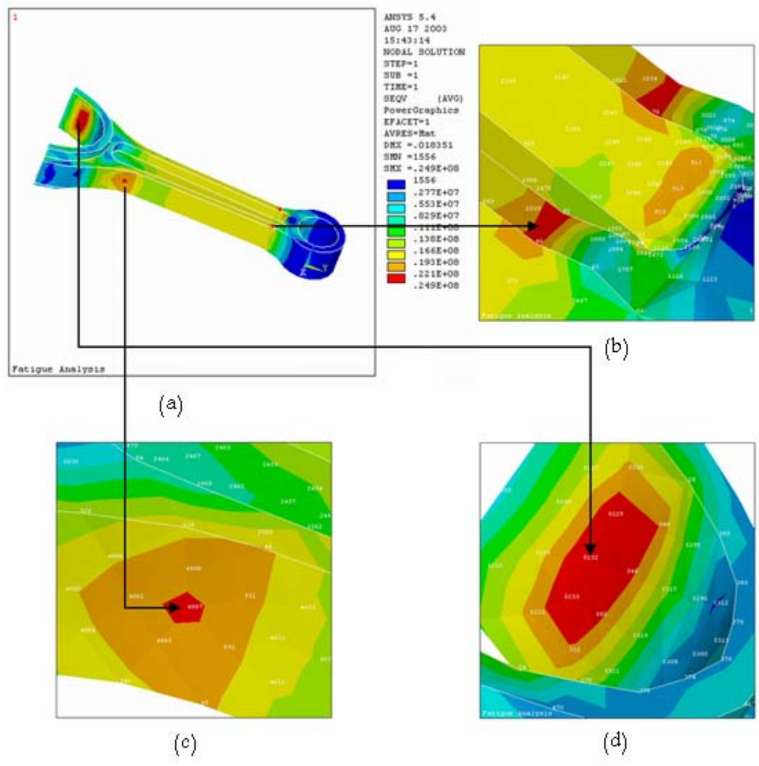


Fig. 2. a) Von Misses stresses in tension loading b) node 46 c) node 4887, d) node 5232

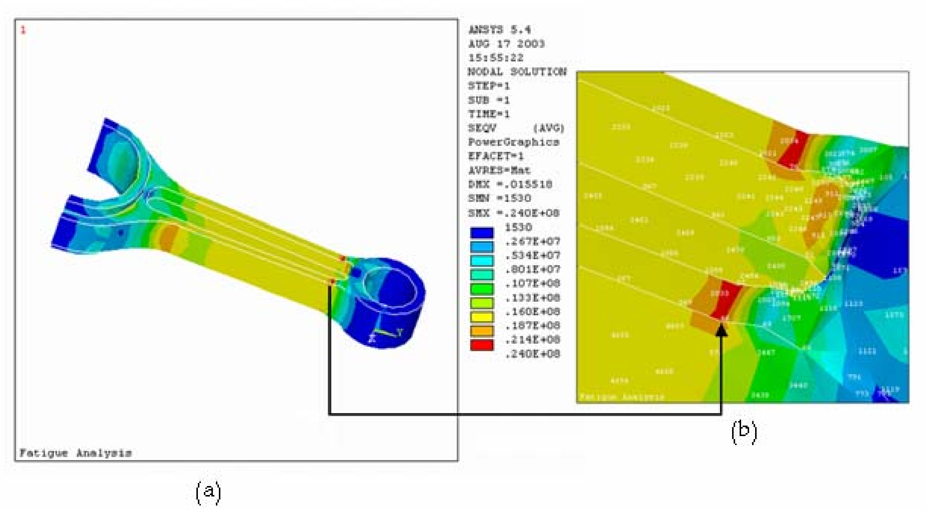
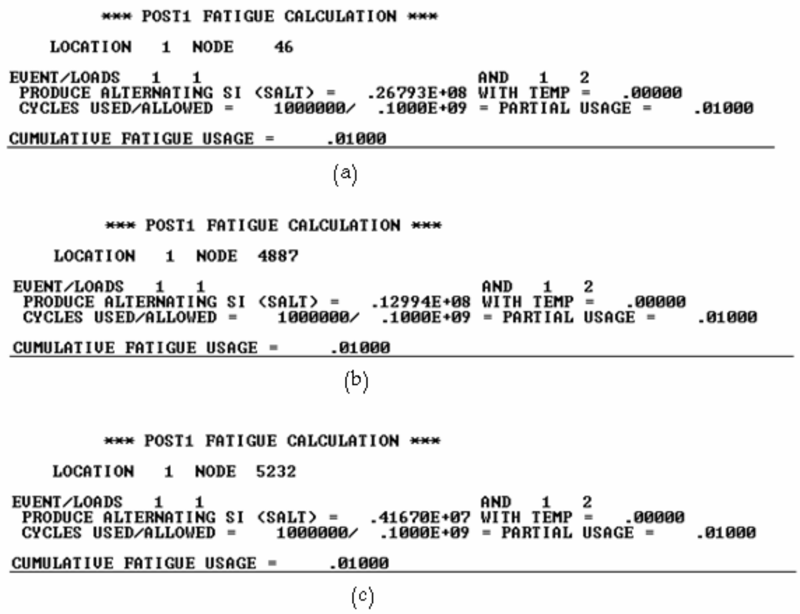


Fig. 3. a)Von Misses stresses in compressive loading b) node 46



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*** POST1 FATIGUE CALCULATION ***

LOCATION   1  NODE    46

EVENT/LOADS   1   1                         AND   1   2
 PRODUCE ALTERNATING SI (SALT) =   .26793E+08 WITH TEMP =    .00000
 CYCLES USED/ALLOWED =    1000000/  .1000E+09 = PARTIAL USAGE =    .01000

CUMULATIVE FATIGUE USAGE =    .01000
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(a)

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*** POST1 FATIGUE CALCULATION ***

LOCATION   1  NODE  4887

EVENT/LOADS   1   1                         AND   1   2
 PRODUCE ALTERNATING SI (SALT) =   .12994E+08 WITH TEMP =    .00000
 CYCLES USED/ALLOWED =    1000000/  .1000E+09 = PARTIAL USAGE =    .01000

CUMULATIVE FATIGUE USAGE =    .01000
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(b)

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*** POST1 FATIGUE CALCULATION ***

LOCATION   1  NODE  5232

EVENT/LOADS   1   1                         AND   1   2
 PRODUCE ALTERNATING SI (SALT) =   .41670E+07 WITH TEMP =    .00000
 CYCLES USED/ALLOWED =    1000000/  .1000E+09 = PARTIAL USAGE =    .01000

CUMULATIVE FATIGUE USAGE =    .01000
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(c)

Fig. 4. The results of fatigue calculations in a) node 46 b) node 4887 c) node 5232.

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