OPTIMIZATION OF BOLT STRESS

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The state of stress in bolts and nuts with ISO metric thread design is examined and optimized. The assumed failure mode is fatigue so the applied preload and the load amplitude together with the stress concentrations define the connection strength. Maximum stress in the bolt is found at, the fillet under the head, at the thread start or at the thread root. To minimize the stress concentration shape optimization is applied. Nut shape optimization also has a positive effect on the maximum stress.

Bolted connections play a key role in the function of many practical designs. Improvement in fatigue life of bolts can be achieved in three principally different ways

- Improving the joint stiffness factor by minimizing the bolt stiffness or/and maximizing the clamped material stiffness
- Improving the load distribution along the thread, by design changes made to the nut
- Minimizing the stress concentration factor in the bolt by applying shape optimization to the bolt design

The first bullet is a matter of practical design and selecting appropriate bolt nominal diameter relative to the thickness of the material clamped between the bolt head and the nut. The second bullet deals with the practical problem that for a traditional thread design the load is not evenly distributed along the thread, and the first turn of the thread can take up to 50% of the total load. The final bullet on minimization of stress concentration factor possesses the largest potential for overall maximum stress level reduction.

For bolts and nuts the central shape at the stress concentration is an arc of a circle which is the general choice in the design of machine elements. This shape is probably selected due to the simple parameterization or due to the ease of manufacturing. From shape optimization in general or specifically in relation to machine elements it is known that the circular arc shape seldom is optimal.

The optimization results show that designing a nut which results in a more evenly distribution of load along the engaged thread has a limited influence on the maximum stress due to the stress concentration at the first thread root. To further reduce the maximum stress the transition from bolt shank to the thread must be optimized. Stress reduction of up to 34% is found, still with the standard ISO thread. The design changes suggested in the paper also has the positive advantage of reducing the joint stiffness factor. The reduction in the bolt shank directly reduce the bolt stiffness but the design change to the bolt head and the nut has the positive indirect effect of increasing the member stiffness, all leading to a smaller joint stiffness factor.

Key words: Metric ISO thread, Design, Stress concentration, Optimization, Contact, FE.