STEAM TURBINE UPRATES, PRELIMINARY CHECKS

By Sydney Gross

In the last issue we raised two questions the turbine engineer would ask when looking to rerate a steam turbine. Since you've already decided whether the inlet and exhaust flanges are large enough to pass additional steam at a reasonable velocity, you must now ask, is the shaft suitable for the higher power?

Question 2 deals with the shaft end and its ability to transmit the higher torque. You can conservatively calculate the torque capability of the shaft end, provided you know the geometry and a few other bits of information. Our focus here is shearing the shaft end off from torsion loading. We will calculate a value for the torsional shear stress and compare it to a conservative value for the shear stress limit of the material.

What is a conservative limit for the shaft shear stress? Our experience has shown that using one fifth of the material tensile strength provides a suitable preliminary value. So, if the shaft has a tensile strength of 90 ksi, you would use 18 ksi as the limit. In fact, if you don't know what the shaft is, a 90 ksi tensile strength is a reasonable assumption.

If you're just dealing with a straight, solid shaft of diameter d, the equation relating power to torsional shear stress is:

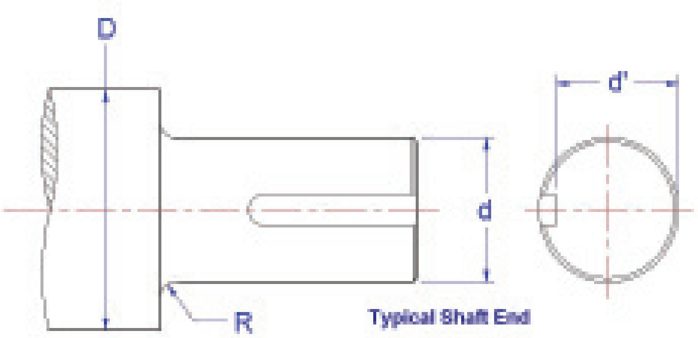
$$\tau = 321{,}000 \times \text{horsepower} / N \times d^3$$

where:

τ is shear stress in lb/in^2

N is speed in rpm and

d is shaft diameter in inches.



However, shaft ends are generally not featureless cylinders. They often have keyways and steps in diameters. Calculate the shear stress separately for each area of the shaft. For instance, calculate τ for the area with the keyway first then calculate τ for the area with a step up in diameter. Compare the two and the higher value will be the limiting area.

In order to conservatively calculate the shear stress in the area of a keyway (or two), use the largest diameter circle that will fit completely within the cross section of the shaft metal. Therefore, if you have a 5" diameter shaft with one ½" deep keyway, use a shaft diameter of 4½". A step up in diameters with a fillet radius is a little more complicated because you need to multiply τ by a stress concentration factor. The factor depends on the two shaft diameters and the fillet radius between them. The most common source of the stress concentration factor is from Peterson's Stress Concentration Factors. Peterson's is a book of graphs of stress concentration factors for various configurations of stress concentrating features. Stress concentration factors for most applications range from about 1.1 to 2. Rather than go to Peterson's, an assumed stress concentration factor of 1.5 is reasonable for a quick calculation.

Once you calculate τ, compare it to your shaft material limit. If you're under the limit, you should be OK. If it's over the limit but close, it warrants some more detailed analysis. If it's way over, well you know.

That should get you through the first steps of determining the rerateability of your turbine. Later we will get into some performance aspects of rerating the turbine.

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