GOODMAN DIAGRAM

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The Goodman diagram is a chart used to show graphically the risk of high cycle fatigue failure of a component. For RMS, most Goodman diagrams or, more correctly, modified Goodman diagrams, address stress levels in blade roots, disk attachments and at the fillets where airfoils meet the blade root platforms.

A typical modified Goodman diagram for a rotor blade root is shown in Figure 1. The “Design Envelope” of this diagram shows both the maximum allowable alternating stress to avoid high cycle fatigue cracking and the maximum allowable steady stress to prevent excessive yielding across the necks (or to ensure adequate creep rupture life in high temperature applications).

The steady stresses are plotted along the X-Axis of the Goodman diagram. These stresses, which are mostly due to centrifugal load, are averaged across the necks of the attachment (See Figure 2).

The alternating stresses are plotted along the Y-Axis of the Goodman diagram. The alternating stresses, which are based on peak stresses at the fillets, are produced chiefly by the change in gas load as the blades pass through the wakes of the upstream vanes. For design work, the alternating stresses that would be caused by cycling the full gas load are plotted. This is done to ensure that there is sufficient margin for both off-design operation and unforeseen resonances. For failure analyses, much lower load changes are assumed, usually about 10% of the full gas load, to better replicate the actual vane wake passing effect.

The uppermost diagonal line in Figure 1 is the Goodman line. The line is drawn from the fatigue strength of the blade material on the Y-Axis to the engineering ultimate tensile strength (UTS) on the X-Axis. For steels and nickel base alloys, the fatigue strength is the stress level at which the fatigue life of the material is essentially infinite (greater than 10^6 cycles). As a rule of thumb, the fatigue strength is about ½ of the UTS for these materials.

The fatigue strength of a material applies to smooth, defect-free specimens. Sudden changes in thickness, machining marks, internal flaws, etc. all reduce the effective fatigue strength. The effective fatigue strength for turbine disks and blades averages about 60% of the perfect specimen fatigue strength. The actual reduction depends on the specific application, material and geometry.

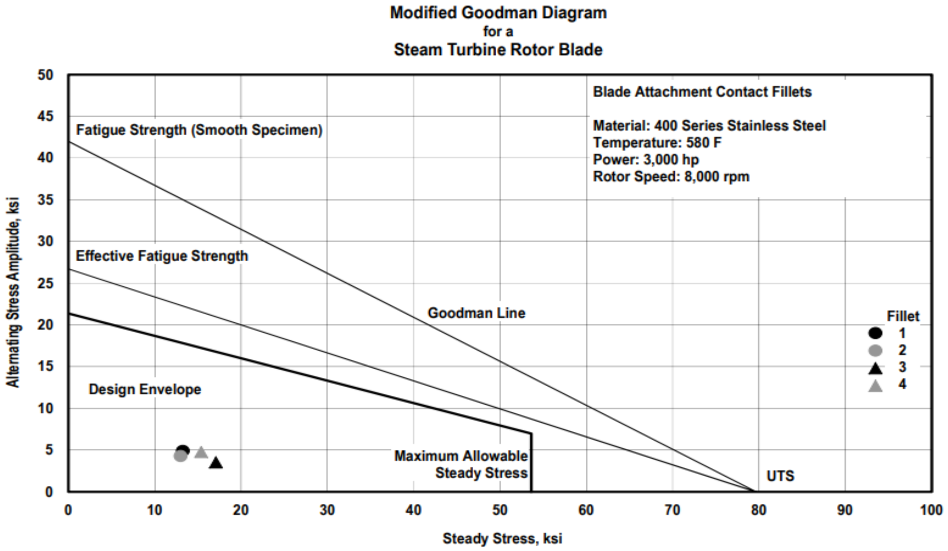

Figure 1

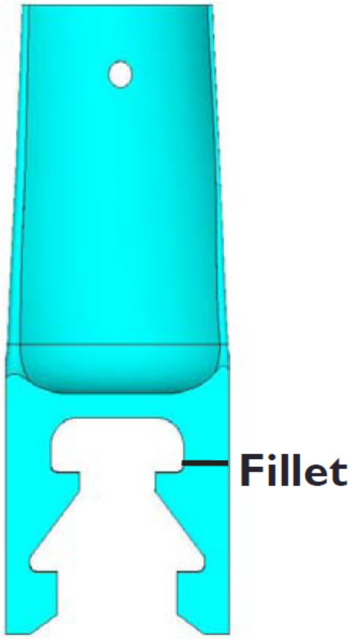

Figure 2

The final design limit is based on a combination of expected load variation, material property variation, the presence of corrosives in the gas, the effect of wear and experience. After taking these additional factors into account, the design limit on alternating stress could range from 30% to 50% of the perfect specimen fatigue strength.

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