REMAINING LIFE ASSESSMENT

By William Sullivan, PE

Turbomachinery rotors and related high temperature components typically have an expected life that is specified in hours of operation or in some specified number of cycles (stop to operating speed to stop, for example) or both. At the end of the time period or when the number of cycles is reached, the machine is expected to be removed from service and either replaced or completely refurbished.

However, replacement or a full refurbishment can be expensive, both in the direct cost of the new machinery or refurbishments, and in the cost of lost production while replacement or refurbishment is being conducted. This can be particularly expensive in times when cash reserves are low and the turbomachinery users are trying to produce as much product, and positive cash flow, as possible.

An untimely replacement or refurbishment can have an unneeded and unwanted impact if the replacement or refurbishment is not really necessary, as often is the case. This could be because either the original design criterion was overly conservative or the actual operation parameters (rotor speeds temperatures, etc.) were less than the design parameters. Actually, the two are the same thing. The turbo machine did not exceed its useful life because it did not accumulate sufficient time or cycles.

Fortunately, there is a way to obtain a reasonable estimate of the remaining life of a turbo machine. The process is called a Remaining Life Assessment and it involves visual inspections, non-destructive testing and metallurgical evaluations of the components, and a stress analysis of the rotor. The stress analysis, which is the subject of this article, involves calculating the original life using temperatures and stress levels in the machine during actual operation; estimating actual life (time and cycles) based on the actual operating conditions and materials of construction; and establishing the current life, which usually is done by examining the operating records. The remaining life is simply the difference between the original life and the current life.

Whether or not a remaining life assessment can be performed on a particular machine depends on several things including the availability of the dimensions and materials of the parts, flowpath conditions, cooling system details, actual operating conditions and time spent at specific operating points. Acceleration and deceleration rates may be required for cycling units as well.

Someone who routinely performs remaining life assessments often will have the appropriate geometry and material data from past projects. Flowpath conditions can be estimated using standard equations for isentropic closed systems with efficiencies based on experience or ascertained from actual operating data. If there is blade or disk cooling, those parameters generally are supplied in the instruction book for the turbine. If not in the instruction book, cooling flow parameters will have to be be obtained from the customer or based on experience with earlier assessments for the same turbine model. Operating conditions and history must be obtained from the customer.

Once all of the data is collected, performance calculations will be performed to establish the temperatures and pressures in the flowpath. Next, the analyst will conduct heat transfer analyses to determine the temperatures of the blades and disks and the thermal gradients in the disks. The heat transfer analyses generally will include disk pumping analyses, along with the heat transfer analyses, to establish the temperatures in the inter-disk cavities and to estimate the film heat transfer coefficients in the disk surfaces. Depending on the disk rim sealing arrangement, some amount of flowpath gas will enter the inter-disk cavities if the disk pumping flow requirement is not met by the cooling flow to the cavities.

When the heat transfer analyses are completed, the analyist will have blade and disk temperatures and disk thermal gradients at various stages in the operating cycle of the turbine. With this information the analyst can determine what points in the operating cycle will have the most severe combinations of stress and metal temperature. Stress analyses will be conducted at these most severe points in the operating cycle. Average stresses and temperatures will be tabulated for various sections around the disk and peak stresses and local temperatures will be tabulated for all high-stress locations on the disks. The high stress locations typically will include the blade attachment fillets, the minimum section through the disk, holes in or through the disk and various fillets around the disk.

The stresses and temperatures, along with the disk mechanical properties at various temperatures, will be used to estimate the maximum life of the disk. Time typically will be based on creep-rupture analyses and the number of operating cycles will be based on low cycle fatigue calculations. Finally, using the operating history of the turbine, which will include both time and operating cycles, the current life of the disk will be estimated. Depending on the extent and quality of the operating data, additional life may be added to the estimated life to better ensure that the true current life is not underestimated. The remaining life is simply the current life subtracted from the maximum life.

In the next newsletter, we will explore some aspects of the disk pumping and heat transfer analyses.

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