RMS Rotating Machinery Services, Inc.

STEAM TURBINES - HOW MANY STAGES?

By Sydney Gross

To understand the question of how many stages does your steam turbine need, let's start with an example.

Suppose your turbine is driving a wet gas centrifugal compressor and operates at a design speed of 7,000 rpm. This example turbine has four Rateau stages, each of which has an approximate pitch diameter of 21 inches. The pitch diameter is the diameter at mid-height of the rotor blade. We want to calculate the ideal number of stages for this turbine application and see how it compares to what's in the field.

With the information above, we can calculate the blade speed, V_b, in feet per second.

$$V_b = \frac{7000 \frac{\text{revolutions}}{\text{minute}}}{60 \frac{\text{seconds}}{\text{minute}}} \times 2\pi \frac{\text{radians}}{\text{revolution}} \frac{\frac{21}{2} \text{ inches}}{12 \frac{\text{inches}}{\text{foot}}} \qquad V_b = 641 \frac{\text{feet}}{\text{second}}$$

The ideal velocity ratio for a Rateau stage is V_b/V_j, .5. That would make the ideal steam jet velocity from the nozzle for each stage 1,282 feet/second. We also know that the steam jet velocity from the nozzle is proportional to the energy drop across the stage. The equation for calculating the jet velocity from the energy drop is as follows:

$$V_j \text{ (feet/second)} = 223.7 \times \sqrt{\Delta H_{is}}$$

Where ΔH_{is} is the Isentropic Enthalpy drop across the turbine stage in BTU/lbm. If we solve the stage $_{is}$ using our ideal steam jet velocity of 1,282 feet/second calculated above, we get 32.8 BTU/lbm. You will recall we introduced the Isentropic Enthalpy concept in the last issue and calculated ΔH_{is} for the entire turbine as:

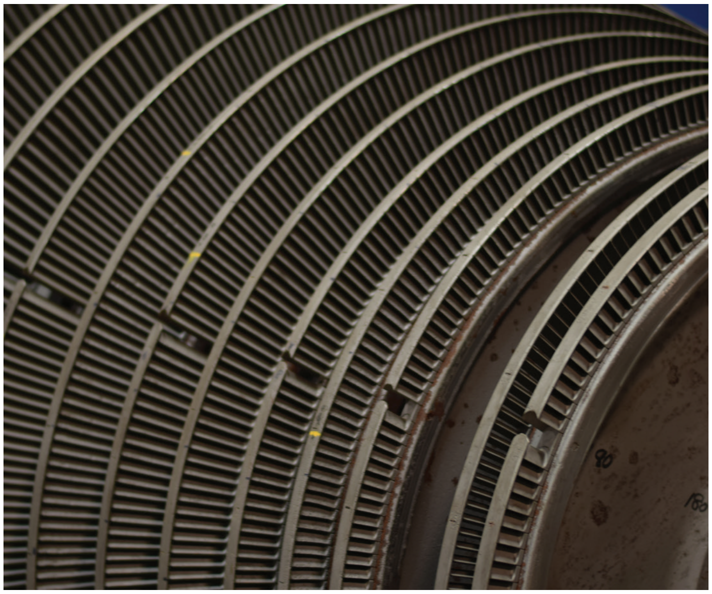
$$\Delta H_{A\text{-}Bis} = 1347.9 \text{ BTU/lbm} - 1200.1 \text{ BTU/lbm} = 147.8 \text{ BTU/lbm}$$

Dividing the turbine Isentropic Enthalpy drop by the ideal stage Isentropic Enthalpy drop gives us the ideal number of stages for the turbine operating under the specified conditions.

$$147.8/32.8 = 4.5 \text{ stages}$$

We know that we can't have half a stage so we will settle on 4 stages being less expensive to manufacture and maintain than 5 stages.

We have been able to match the number of stages that the original manufacturer used in the design of this turbine by using similar methods. The original manufacturer would have started with a speed and power requirement as well as steam inlet and exhaust conditions. Based on the power and an approximate efficiency, the necessary steam flow would have been determined. Due to stress limitations, the wheel diameter for the stages would have been limited based on speed. This information would have allowed the manufacturer to select a turbine frame size. The number of stages would have followed as we calculated above. In later issues, we will look at rerate possibilities for this turbine.



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