STEAM TURBINES - CURTIS OR VELOCITY COMPOUNDED STAGE

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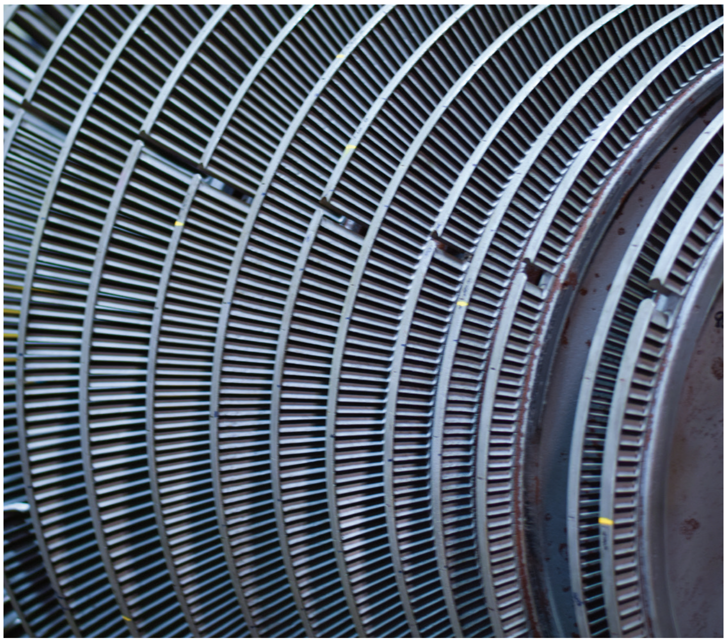

We calculated the number of stages for a hypothetical turbine using an impulse stage design called Rateau in the last issue. Recall that a Rateau stage is comprised of a single row of stationary and a single row of rotating blades and that almost all of the pressure drop occurs across the stationary row. Recall also that the ideal velocity ratio, V_b/V_j, is approximately .5 for that stage meaning the steam is traveling twice as fast as the blade when it enters the rotating row and has next to 0 speed when it leaves.

Frequently it is desirable or necessary to create a stage where the steam jet velocity is four or five times the rotor blade speed. For a conventional Rateau stage, this would mean that the steam exiting the rotor blades would still have considerable tangential velocity and therefore considerable kinetic energy that has not been converted to work.

However, if we install a second set of stationary vanes or reversing blades to turn the steam flow without reducing the pressure into a second set of rotor blades, we can make effective use of the remaining energy in the steam. We call this a velocity compounded or Curtis stage after its inventor, Charles Gordon Curtis, who patented the concept in 1896. To the right is a diagram of a Curtis stage and its pressure and velocity relationships across the blade passages.

It is distinguishable from the Rateau stage in that the rotating blades are most frequently mounted on a single wheel. And, rather than having a diaphragm or nozzle before the second row of rotating blades, the Curtis stage has what is often called a reversing segment with airfoils more closely resembling the rotating blades instead of the nozzle. The function of the reversing segment is to redirect the steam from the first row of rotor blades to the second without a change in pressure or speed.

While the approximate ideal velocity ratio for the Rateau stage is .5, the Curtis stage has an ideal velocity ratio of approximately .25 in order to leave us with next to 0 steam velocity after the second row of rotating blades.

There are a few reasons why a Curtis stage might be favored over a Rateau. As we will see shortly, one Curtis stage can do the work of several Rateau stages therefore reducing the overall size of the turbine and lowering initial cost. A Curtis stage is also used where wheel speed is low and a second row of blades is needed to remove the energy from the steam. Typical Curtis stage blade speeds are in the range of 450 to 650 feet/second while Rateau stages are typically 600 to 800 feet/second. Curtis stages are most commonly used in single stage machines where efficiency is not important and as control stages, or the first stage of the turbine followed by either Rateau or reaction stages.

Going back to our last discussion where we calculated the number of Rateau stages in a hypothetical turbine, we're going to see what happens if we use a Curtis stage of the same diameter, 21 inches, and speed, 7,000 rpm.

Our blade speed is calculated in the same way to give us 641 feet/second. With an ideal Curtis stage velocity ratio of .25, we would want a steam velocity of 2,564 feet/second. Using our equation for calculating jet velocity from the Isentropic Enthalpy drop,

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

we rearrange using the jet velocity of 2,564 feet/second to calculate an Isentropic Enthalpy drop of 131.4 Btu/lbm. As calculated previously, our total Isentropic Enthalpy drop across the entire turbine is 147.8 BTU/lbm. So we could replace almost four Rateau stages with a single Curtis stage for this application, theoretically.

As mentioned earlier, both Curtis and Rateau stages operate on the Impulse principle as opposed to reaction. In practice, there is some degree of reaction in all stages and it varies from the hub to the tip of the airfoil. With increasing degrees of reaction, sealing becomes more important in maintaining efficiency in a turbine. In the upcoming issue, we will be looking at the various sealing designs and applications in the steam turbine.

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