STEAM TURBINE UPRATES, PERFORMANCE ISSUES

By Sydney Gross

In the last issue, we examined two important mechanical components that would seriously limit the feasibility of the steam turbine rerate, the casing and the shaft. Assuming, you've put those hurdles behind you and plan to use both in your rerate, it would be useful to have an understanding of the internal changes to expect based on reasonable performance assumptions. When we talk about internal changes, we are referring to the stationary blading, or nozzles and diaphragms, and the rotating blading, often referred to as buckets in an impulse style turbine, which is our primary focus here. Before we get into the reasons for changing components, a little background is necessary.

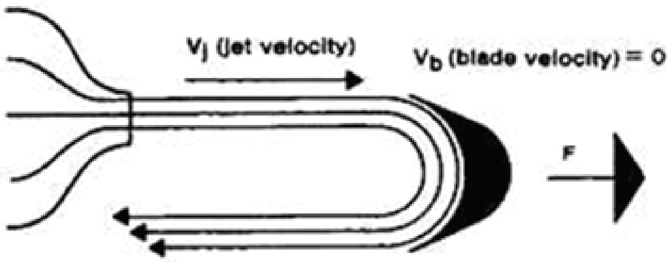
It would be useful at this point to understand how an Impulse turbine works on a basic level. Steam turbine designs are classified as either Impulse or Reaction depending on how the pressure drops occur through the steam path. If the turbine is designed so that the pressure drops occur predominantly across the stationary components, the turbine is an Impulse design. A Reaction turbine is designed so that pressure drops occur across both the stationary and rotating components. The term Impulse refers to the way in which work is derived from the steam jet, simply from the force of the steam jet being turned by the blading or buckets.

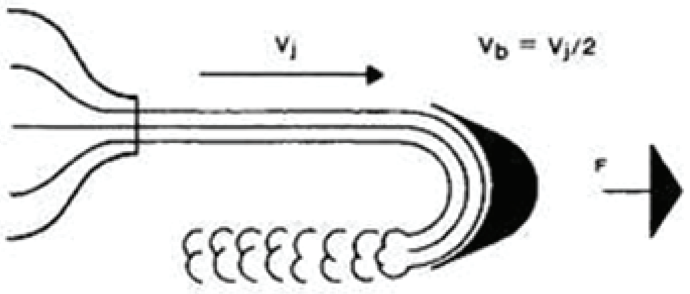
Do you have an Impulse turbine? Let's see. Visually distinguishing features of these two types of turbines can be seen in the rotor. Reaction turbines utilize a drum style rotor where the blades are mounted on a large diameter drum body. Impulse turbine rotors, on the other hand, have a disc-on-shaft design where the blades are mounted on thin discs, which may be mounted or integral to a relatively small diameter shaft. Other differences include sealing arrangements. Since the Impulse turbine has little or no pressure drop across the rotating blades, preventing steam from going around or over their tips is not nearly as critical to the performance as for the Reaction turbine. Therefore, there will almost always be tight clearance radial blade tip seals on a Reaction turbine and not on the Impulse turbine. There are other differences but that should be enough to go on for now. If you have an Impulse turbine, read on.

In Volume 1, Issue 1 of the RMS Newsletter, I said that the way to get more power out of the turbine was to put more steam through it. True enough. I also said that horsepower was roughly proportional to steam flow. Minor caveat here. The use of the word roughly refers to the turbine efficiency. The same turbine with the same inlet pressure and temperature and the same exhaust pressure will have different efficiencies for different steam flow rates. Fundamental to understanding how this pertains to the rerate of your turbine is understanding the Impulse Principle.

For a given set of steam conditions there is an optimum number of stages for your turbine based on rotational speed and wheel diameter. Why is that? Consider the figures to the right. Steam exits a nozzle or a diaphragm at the left side of each figure with a velocity of V_j and is turned by the concave surface of the rotor blade moving at a speed V_b.

In the first figure, the rotor blade does not move ($V_b = 0$). The force on the blade is a maximum because the

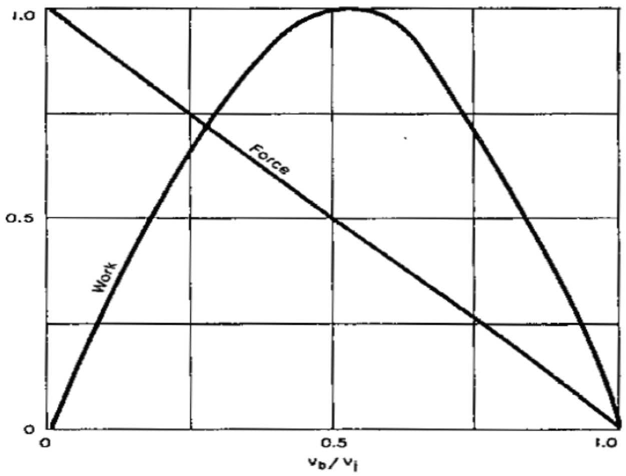




steam is experiencing maximum acceleration (subtract vectors to prove this), it has the same speed entering the rotor blade as it does exiting except in the opposite direction. Since the blade doesn't move, no work is being done and the steam jet has the same Kinetic Energy.

Although not shown, consider the other end of the spectrum where V_b is equal to V_j. The steam would never catch the rotor blade and no force would be imparted on it resulting in no work being done.

Now look at the figure top right. V_b is one half of V_j resulting in the steam exiting the rotor blade with zero velocity and hence, zero Kinetic Energy. This magic ratio of velocities, $V_b/V_j=0.5$, is the most efficient combination because it uses up all the Kinetic Energy of the steam. We refer to the ratio of V_b/V_j as the blade velocity ratio and we use it to judge the efficiency of the turbine stages. It is shown graphically in the figure below.



If the rotational speed and wheel diameter of a stage are fixed, then V_b is also fixed. The only way to change our velocity ratio to get close to the magic ratio is by changing V_j. So how do we do that? The steam jet velocity is proportional to the stage energy drop. There is a total available energy between the inlet steam state and the exit steam pressure. We take that total energy and divide it up equally to yield a change in energy that gives us the right V_j.

The number that we divide the total energy by will be the number of stages.

So far, we haven't introduced flow rate into our calculations, just wheel speeds and steam states. The power requirement placed on the turbine by the driven equipment will dictate the steam flow rate. Our turbine stage flow path sizes will be designed to accommodate that flow while yielding the energy drop that we calculated above. Since the stage sizes, or areas, in our turbine are for the most part fixed, a change in the flow rate will change the distribution of energy drops across the stages and therefore change the stage efficiencies.

In the upcoming issues, we will see some of the equations used to do what we did above and go through an example of how to apply it to your turbine. But first we will need to understand steam a little better.

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