RMS
Rotating Machinery Services, Inc.

STEAM TURBINE UPRATES, STEAM ISSUES

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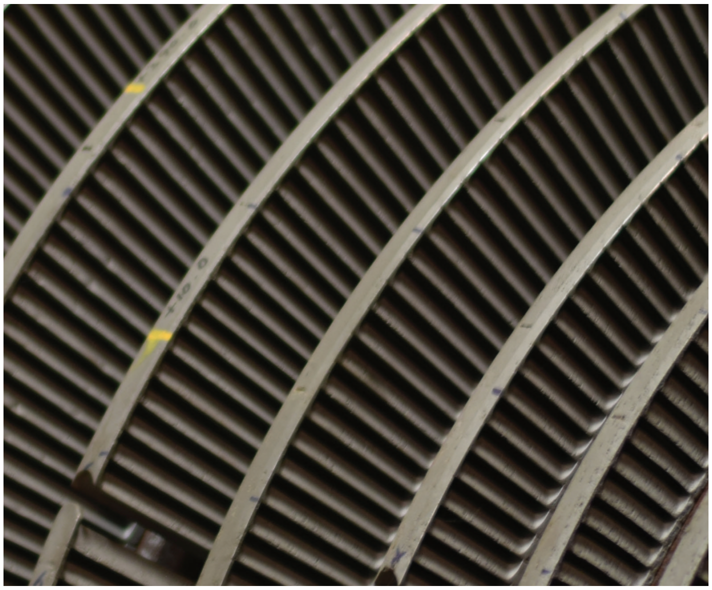

Before you get to the turbine, you have water, just plain water. Put the water in a pot and heat it on the stove, no lid. You've added energy. All the heat energy added to the water will result in raising the water's temperature. When the water reaches boiling temperature, it won't get any hotter whether you keep heating it or not. The heat energy you add to the water from this point on will go into changing the water from liquid to gas (or vapor). The steam is called "Saturated" because a reduction in energy will cause it to start condensing. For simplicity, we will be talking about the properties of steam per unit mass and we will use the English system. In our case mass is pound-mass or lbm.

We can't do anything else with the vapor because it flew off into the surrounding air. However, if we contained the water in a closed system such as a plant steam system, we could continue to heat it after it turned into a vapor. It would then be Superheated steam. If we limit the volume of the system, or pressurize it, some of the heat energy added to the vapor goes into raising the pressure of the steam. We can identify the amount of energy in the steam at any time as a combination of its internal energy, kinetic energy and potential energy. The kinetic energy is associated with the steam velocity which we will assume for the time is zero. The potential energy is associated with the height (altitude) of the steam and the energy that could be recovered if it fell from that height such as in a hydro-electric turbine. Again we will assume this is zero. The internal energy is a property associated with temperature pressure and volume of the steam. Although not entirely correct, we will use the term Enthalpy to identify the amount of internal energy. Enthalpy has the units BTU/(lbm).

Before we put the steam into the turbine, we need to understand one more property of steam called Entropy. Entropy is a measure of chaos or randomness in a system and has the units BTU/(lbm*F). We use it in a process that goes from point A to point B to measure efficiency. For instance, we have a backpressure (non-condensing) turbine and steam enters with a certain temperature and pressure. Those two properties are enough to define the state of the steam as well as all the other properties we are interested in such as Enthalpy and Entropy. We'll call that point A. The steam leaves the turbine with a lower temperature and pressure again defining a steam state we will call point B. If the Entropys at points A and B are the same, then the process is ideal or 100% efficient. But we know it's not because there is no 100% efficient machine. The Entropy will increase (it always goes toward more chaos). However, if we forget for a moment the temperature at B and assume the steam leaving the turbine has the correct final pressure and the same Entropy as the steam at point A, we have the basis for calculating the turbine efficiency. Here's how we do it.

First find the steam Enthalpy at point A for the pressure and temperature. Call it H_A. (You need steam tables or a Mollier chart to find steam properties for a specific state. You can find steam table calculators on the internet.) While you're looking for the Enthalpy at point A, find the Entropy too and write it down. Now find the Enthalpy of the steam at point B using the steam tables and the pressure and temperature at point B. Call it H_B. The difference, $H_A - H_B$, is the Actual Enthalpy Drop across the turbine. We will call it ΔH_{A-B}. This quantity, together with the mass flow can be used to calculate the actual turbine power. Now, using the pressure of point B and the Entropy of point A, go back to the steam tables and find the Enthalpy for this hypothetical state. Call it H_{Bis}. What you have done is found the Enthalpy at the end of a 100% efficient process. Calculate the Isentropic Enthalpy Drop across the turbine as $H_A - H_{Bis}$ and call it ΔH_{A-Bis}. The Efficiency,η, of the turbine is the ratio $\Delta H_{A-B}/\Delta H_{A-Bis}$.

Here’s an example:

Steam enters a turbine at 650 psi and 700°F. It exits at 150 psi and 450°F. What is the turbine efficiency?

1. Find the inlet properties from the steam tables:

  - T_A = 700°F
  - P_A = 650 psi
  - H_A = 1347.9 BTU /lbm
  - E_A = 1.5768 BTU /lbm*F

2. Find the exit properties from the steam tables:

  - T_B = 450°F
  - P_B = 150 psi
  - H_B = 1247.6 BTU /lbm
  - E_B = 1.6317 BTU /lbm*F

3. Find the enthalpy at the exit pressure and inlet entropy:

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