AXIAL AND RADIAL TURBINES

HOW DO THEY COMPARE IN THE 1-TO-3 MW POWER RANGE?

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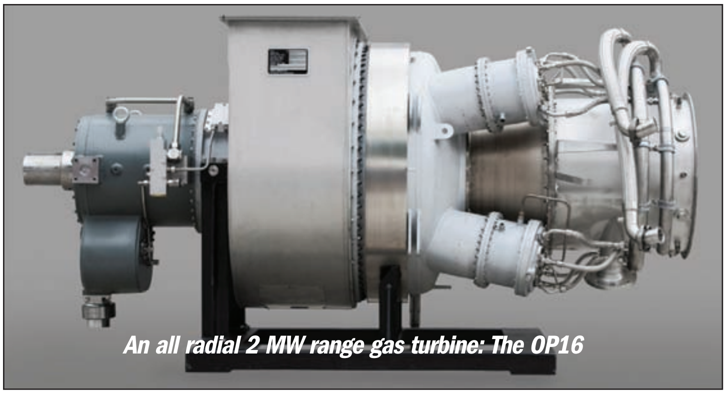
Axial gas turbine technology is the dominant and appropriate configuration for large gas turbines. Major power plants and industrial plants deploy axial gas turbines to provide power and heat for district heating, process, facilities and electricity to the grid.

Less discussed, though, are the lower power ranges where both axial and radial gas turbines are available. It is worthwhile to compare axial and radial turbines where the technologies overlap.

Engines with radial compressors and radial turbines can effectively be used in single shaft turbines in power ranges from as low as 1 kW up to approximately 2 MW. If the configuration is combined with an axial power turbine, these types of turbines would be applicable for a power range up to around 4 MW.


An all radial 2 MW range gas turbine: The OP16

Consequently, industrial turbine engines below 2 MW normally use radial compressors (centrifugal), but the choice of turbine type varies. As the range lowers, radial turbines have more advantages over the axial turbines.

The chief difference between axial and radial turbines is the way the air flows through the compressor and turbine. In a radial turbine, the inlet airflow is radial to the shaft, whereas an axial turbine is a turbine in which the airflow is parallel to the shaft.

Generally, the axial turbine disc is protected from the heat that the turbine blades are exposed to. Not so with the radial turbine where the hot mass-flow expands in both the impeller portion and the exducer portion of the turbine.

However, a radial turbine can accommodate an expansion ratio of about 9 to 1 in a single stage. An axial turbine would commonly require three stages to handle such an expansion.

This difference in expansion between axial and radial turbines can be explained by the following equation:

$$W_s = U_2 * C_{w2} - U_3 * C_{w3}$$

Where Ws is the stage work per unit mass flow, U_2 is the inlet blade speed, U_3 is the exit blade speed, C_{W2} is the inlet tangential velocity and C_{W3} is the exit tangential velocity.

In an axial turbine U_2 and U_3 are approximately equal, whereas in a radial turbine U_2 is greater than U_3. Looking at the above equation one can see that the stage work, for the same change in tangential velocity, is larger for a radial turbine compared to an axial turbine.

In a centrifugal compressor, the air receives greater energy as it accelerates at increasing diameters. This velocity energy is converted into pressure energy when slowed down in the static diffusor. An axial compressor flows the air parallel to the axes providing increasing lift (pressure) depending on the number of stages and intermediate stators.

In the combustor, heat is added causing the volume of the air to be increased. The hot gasses would enter the turbine via fixed nozzle guide vanes directing the flow against the turbine. If the turbine is of the radial type, the peripheral speed of the turbine should be at or close to the speed of the gas stream entering the turbine. In this way, the added "stagnation" temperature, which a lower speed axial turbine would encounter would not be there.This enables the radial turbine to operate uncooled at up to around 100°C above axial turbines.

Radial turbines are able to do this due to the "Eiffel Tower" cross section of the turbine with a substantial hub and thinner blades.

The radial turbine functions in the opposite way to a centrifugal compressor: As the flow loses speed and temperature transferring energy to the turbine, the flow enters the exhaust diffusor at lower than atmospheric pressure providing some suction before exhausting at atmospheric pressure at the end.

An axial turbine blade is similar to a small airplane wing. If too much power is extracted from it, it will stall, the equivalent of lost lift in an aircraft. That is why it takes two to three stages and intermediate stator blades to match one radial turbine stage.

The most convenient rotor arrangement for an all-radial configuration utilizing a centrifugal compressor and radial turbine would be a cantilevered arrangement with both bearings located in front of the compressor in the cold part of the turbine.

This would be difficult to achieve using axial turbines. The bearings would have to be in the hot section of axial turbines and they would have a shorter life as a result. However, if there is a requirement to combine the radial configuration with an independent power turbine, bearings in the hot part of the engine would be needed.

One distinct advantage of an axial turbine is the possibility of being air cooled. In this way axial turbines can be operated at much higher temperatures than radials and achieve greater efficiencies in higher power ranges. Cooling of radial turbines have been attempted in the past, but has not been successful.

Cooling of small axial turbines, however, also poses problems as intricate cooling holes become smaller and more complex. The clogging of the cooling holes is a source of performance degradation during the turbine life time. Since the radial turbine normally does not include cooling holes, its performance during the operation remains nearly the same.

It would appear, therefore, that for single-shaft turbine engines below 2 MW an all radial concept has certain advantages. Radial turbines have the capability to operate uncooled at a higher turbine inlet temperature than uncooled axial turbines.

The radial configuration has fewer stages, is shorter in length and is more robust than the axial configuration and can achieve longer life and less maintenance. These features are generally sufficient to give radial turbines the edge below around 2 MW.

But, if a separate power turbine is needed, axial turbines might be preferred. For higher power ratings, the cooled axial turbine is the logical choice. The limitation in size prevents the radial concept being used for larger sizes. TI

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