Internal Thermal Barrier Coating Near Blade Tip

Tips of turbine blades are known for the short design lifespan because of their constant exposure to deterioration mechanisms. In addition to the high temperatures and friction forces, high thermal gradients can also be present between the pressure and suction side of the airfoil. It can induce different thermal expansion effects of opposite walls at the tip, as well as high stress (at transition radii between airfoil and internal ribs).

The main cause of the thermal gradient is the vortex created due to different pressure values of hot gas that are acting on and the suction side effect of the airfoil.

Dynamic loading and corresponding High Cycle Fatigue (HCF) utilizations also reach peak values in these radii, especially for blades with an open tip region. Thus, a combination of high thermal and dynamic stress can be extremely critical and any crack initiation in these zones is to be prevented.

In Figure 1 below a turbine blade is schematically represented with a typical thermal gradient between the airfoil walls and the corresponding low life position at blade tip.

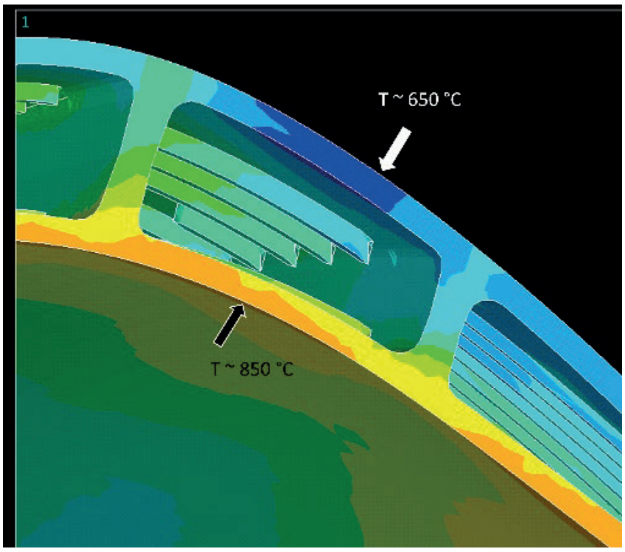

Figure 1.Thermal gradient at blade tip

Cold cooling air is pushes towards the suction side of the tip; this is caused by the higher value in pressure of the hot gas that is coming from the corresponding side.

There are several proposals on how to enhance the longevity of the design life at the turbine blade tip.

Predominantly, these include various patterns of film cooling holes in close proximity to the blade tip and/or modifications to the squealer tip. These characteristics are typical for the first and second row of turbine blades. For elongated blades, such as those found in the third and fourth row, additional alterations (e.g., the suction side being lower than the pressure side) have been identified as potential solutions.

The current proposal for enhancing the design life at a turbine blade tip is depicted in Figure 2. As illustrated, a thermal barrier coating (TBC) can be implemented on both the inner wall (represented by the red color) and outer wall of the blade (represented by the blue color), which serves to lessen thermal gradients and the associated stress. High porosity 8YSZ HHP is the material used for the TBC.

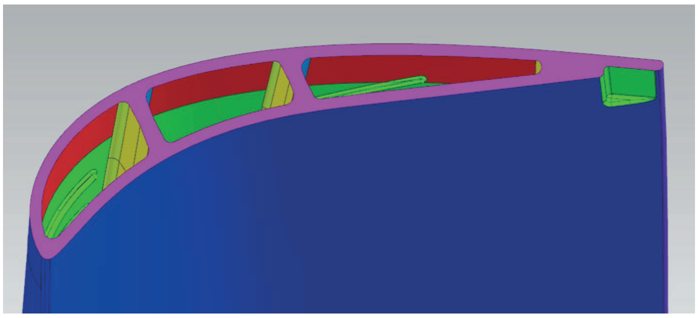

Figure 2. Representation of the proposed TBC applied for both (hot and cold) sides of suction.

The positioning of the TBC near the blade tip is deemed feasible from a manufacturing perspective, considering the presence of TBC overspray already noticeable in this area.

The function of the TBC, in this instance, is not to directly lower the metal temperature but rather to increase it on the suction side (SS). To be more specific, the cooling air at the tip will not directly interact with the metal due to the TBC's presence. Consequently, the temperature will rise through the TBC layer until the effect reaches the metal on the inner side.

It's important to mention that the current TBC thickness at the blade tip is 0 (the end of the transition zone), a measure implemented to alter the mode 1 frequency. The present proposal does not significantly impact the mode 1 frequency but does contribute to enhanced stiffness near the blade tip, thereby reducing high-cycle fatigue (HCF) utilizations in this area.

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In conclusion, the proposed idea offers several significant advantages that contribute to the optimization of turbine blade functionality. Firstly, it reduces the thermal gradient and thermal stress at the blade tip, which leads to an increased design life at this crucial area. Furthermore, it contributes to a reduction in high-cycle fatigue (HCF) utilization owing to the increased stiffness provided by the thermal barrier coating.

From a manufacturing perspective, the proposal is relatively easy to implement. Additionally, it can be applied to service parts, increasing its practical applicability.

A key benefit of this proposal is that it achieves all these improvements without requiring an increase in cooling air consumption, thus avoiding any efficiency loss. This balance of enhanced performance and maintained efficiency underscores the value of this proposed solution for turbine blade design.