**2002 ME Graduate Student Conference**
**April 13, 2002**

# EFFECT OF TIP GEOMETRY ON BLADE TIP FLOW AND HEAT TRANSFER

David Kontrovitz
M.S. Candidate

Faculty Advisor: Dr. Srinath Ekkad

## ABSTRACT

In an attempt to increase thrust to weight ratio and efficiency of modern gas turbines, engine designers are always interested in increasing turbine operating temperatures. The benefits are attributed to the fact that higher temperature gases yield a higher energy potential. However, the detrimental effects on the components along the hot gas path can offset the benefits of increasing the operating temperature. The HPT first stage blade is one component that is extremely vulnerable to the hot gas.

The cause for tip failures are fairly well understood and can be explained as follows. A clearance gap between the rotating blade tip and stationary shroud is necessary to allow for the blade's mechanical and thermal growth during operation. Unfortunately, the gap allows for leakage flow from the pressure side to the suction side. The gas is accelerated as it passes through the small gap. This leads to enhanced heat load to the blade tip region. Leakage flow, or clearance flow, also leads to undesirable aerodynamic losses not unlike the losses associated with airplane wing tips. In fact, one third of the losses through the turbine section can be attributed to leakage flow. Other relevant studies by Azad et al. [1-2], Bunker et al. [3], Bunker and Bailey [4-5] presented detailed heat transfer results on high-pressure turbine blade tips with different pressure ratios. The effect of tip geometry was also considered in some of these studies.

The present study explores the effects of gap height and squealer depth on heat transfer and flow distribution. This investigation differs from those in the other studies because the tip profile is for an in-service High Pressure Turbine of an aircraft engine. Other experiments have used the $E^3$ test blade or a power generation blade that have different characteristics. The pressure ratio used was 1.2, which is lower than the actual pressure ratio this blade sees in service (PR = 1.7). A transient liquid crystal technique was used to obtain the tip heat transfer distributions. Pressure measurements were made on the blade surface and on the shroud for different tip geometries and tip gaps.

## FIGURES AND TABLES

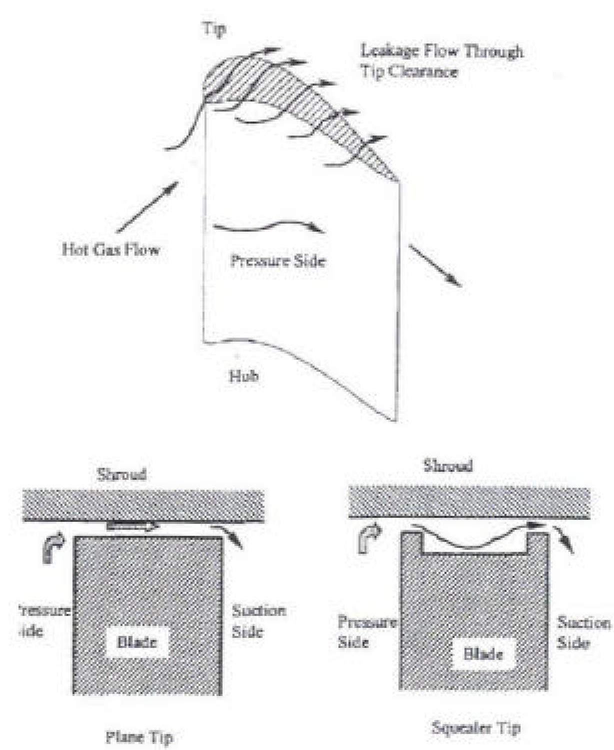


**Figure 1. Leakage Flow**

Figure 1 shows the typical leakage flow behavior for a turbine blade [1]. The plain tip is a flat tip and flow leaks through a constant area across the blade. The squealer tip has a groove cut on top of the blade which increases the area and stalls the flow thus creating back pressure and restricts leakage flow and reduces heat transfer. In this study, we focus on the plain tip and two different squealer depths (shallow and deep).

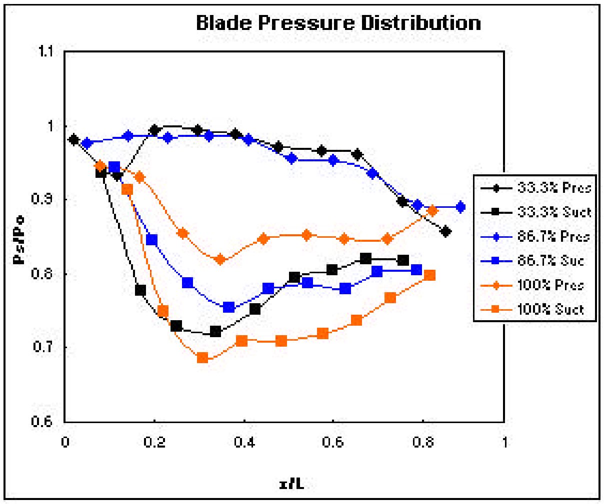


**Figure 2: Blade Pressure Distribution**

Figure 2 shows the pressure distribution on the blade surface at different span of the blade. The 100% span is on the tip of the blade with clearance gap. The pressure distribution changes as the blade span moves towards the gap as expected. Figure 3 shows the pressure distributions on the shroud for a blade with squealer tip. The reduced static pressures are the cause of reduced leakage flows.

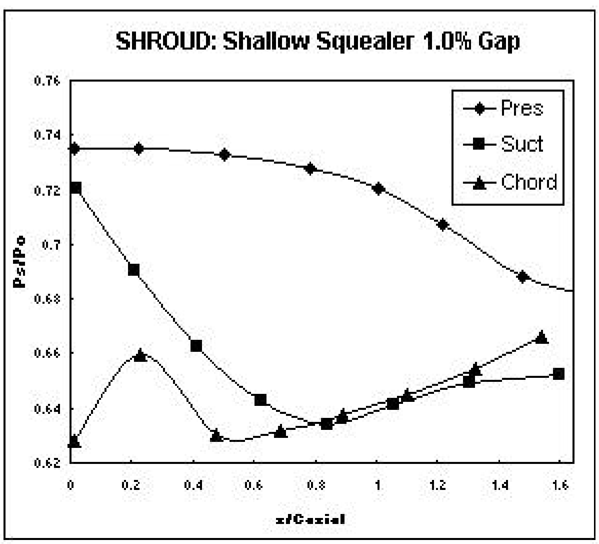


**Figure 3: Shroud Measurements**

Figure 4 presents a typical heat transfer distribution on the blade tip with a shallow squealer. The heat transfer distributions show the local hot spots near the leading edge on the floor of the cavity and the reduced heat transfer towards the trailing edge of the blade. The leakage flow is stronger at the leading edge and weaker along the trailing edge of the blade.

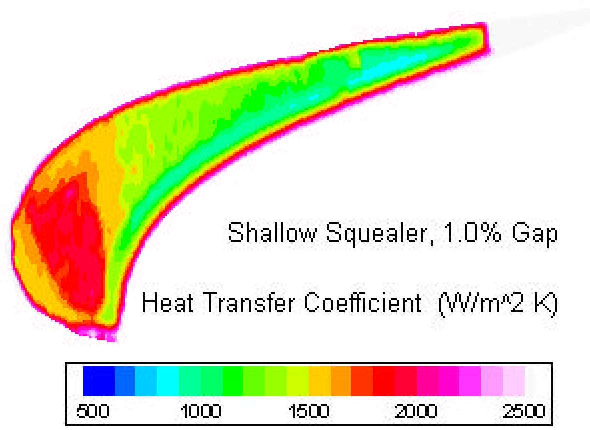


**Figure 4: Heat Transfer Distribution**

## ACKNOWLEDGMENTS

This study was sponsored by the NSF through a GOALI grant. The author would like to acknowledge Drs. Srinath Ekkad and Sumanta Acharya for their instruction and advice. Also, thanks to Dr. Ron Bunker, at G.E. Corporate Research and Development, for his input to this project. Acknowledgments are also due to my colleagues in the Turbine Blade Research Lab.

## REFERENCES

1. G.S. Azad, J.C. Han, R.S. Bunker, C.P. Lee, *Effect of Squealer Geometry Arrangement on Gas Turbine Tip Heat Transfer*, in Proceedings of the ASME International Mechanical Engineering Congress and Exposition, New York, November 2001, HTD-24314
2. G.S. Azad, J.C. Han, R.J. Boyle, *Heat Transfer and Flow on the Squealer Tip of a Gas Turbine Blade*, in Proceedings of the 2000 ASME Turboexpo, Munich, Germany, May 2000, 2000-GT-1955
3. R.S. Bunker, J.C. Bailey, A.A. Ameri, *Heat Transfer and Flow on the First Stage Blade Tip of a Power Generation Gas Turbine Part1: Experimental Results*, in Proceedings of the 1999 ASME International Gas Turbine Conference, Indianapolis, 1999, ASME 99-GT-169.
4. R.S. Bunker, J.C. Bailey, *Effect of Squealer Cavity Depth and Oxidation on Turbine Blade Tip Heat Transfer*, in Proceedings of the 2001 ASME International Gas Turbine Conference, New Orleans, June 2001. 5. R.S. Bunker, J.C. Bailey, *An Experimental Study of Heat Transfer and Flow on a Gas Turbine Blade Tip With Various Tip Leakage Sealing Methods*, in Proceedings of the 4th ISHMT / ASME Heat and Mass Transfer Conference, Pune, India, 2000, HNT-2000-055 p. 411-416.