# INVESTIGATION OF BLOWING EFFECTS ON TURBULENT FLOW OVER A ROUGH SURFACE

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Entry of spacecraft into an atmosphere occurs at hypersonic speeds, generating extremely complex flow fields, with aerothermodynamic effects which can cause the surface to be subjected to extreme heating. It is therefore important to protect the vehicle and its payload using a thermal protection system (TPS). Heat shields, which are an important part of a TPS, can be of either ablative or non-ablative types. For an ablative TPS, the energy is dissipated through surface material charring and ablation, as well as releasing gasses which serve to carry energy away from the TPS and thus reduce the total heat flux into the vehicle.

One of the many difficulties with designing such a system is accurately modeling the flow physics near the TPS surface itself. One important consideration is the state of the boundary layer forming over the surface which, if it has transitioned to turbulence, can drastically increase the transport of mass, momentum and energy. In addition, as an ablative TPS pyrolyzes, the surface will become rough and pyrolysis gasses will be injected into the flow, which can potentially alter the structure and organization of the turbulence over the TPS surface. Understanding the behavior of wall-bounded turbulence under these conditions can benefit modeling of the near-wall flow phenomena critical in designing and optimizing an ablative TPS.

Figure 1: Blowing rig in place on test section of turbulent channel flow facility.

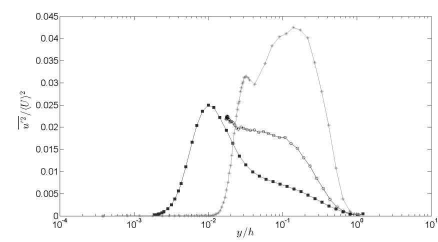


Figure 2: Comparison of turbulence intensity as a function of normalized wall distance for the: smooth walled case (-▪-), the rough walled case (-○-) and the rough walled case with flow injection (-*-).

The current effort investigates the fluid dynamics of a turbulent wall layer over a rough surface subject to additional momentum injection through the surface, which is intended to represent the conditions experienced by an ablative TPS when the near-wall flow has transitioned to a turbulent state. The current research seeks to understand the effects and interaction of both surface roughness and flow injection on a turbulent wall layer. Experiments are currently underway which utilize a turbulent channel flow facility and a specialized blowing apparatus (pictured in Fig. 1) used to inject flow through the geometrically simple, sinusoidal, quasi-2D, rough surface. Measurements are being made of the wall-normal dependence of the streamwise component of velocity using hot-wire anemometry.

Figure 2 shows the wall-normal dependence of the streamwise Reynolds stress for a smooth-walled case, a case with surface roughness and a case with both surface roughness and momentum injection, at matched Reynolds number. These results indicate a significant impact of both the roughness and combined roughness-and flow injection when compared to the baseline smooth-walled case. As expected, the additional roughness increases the Reynolds stress further away from the wall. More interestingly, the addition of momentum injection is found to shift the near-wall peak away from the surface, as well as producing a second peak in the outer- scaled region, indicating a strong modification of the turbulence production cycle within the wall-layer. Ongoing work is being performed to examine the spectral content of the turbulence as well as the influence of the momentum-injection to bulk velocity ratio on the turbulence structure.