CURRENT
RESEARCH ACTIVITIES

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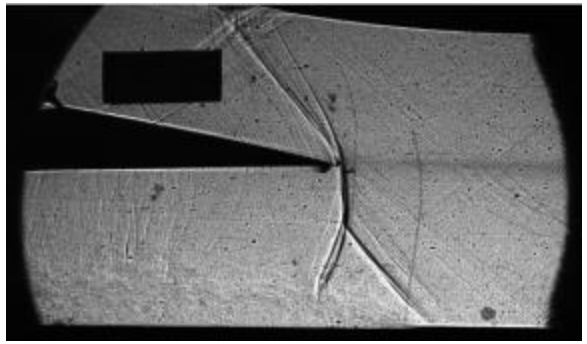
UAH
Propulsion Research Center

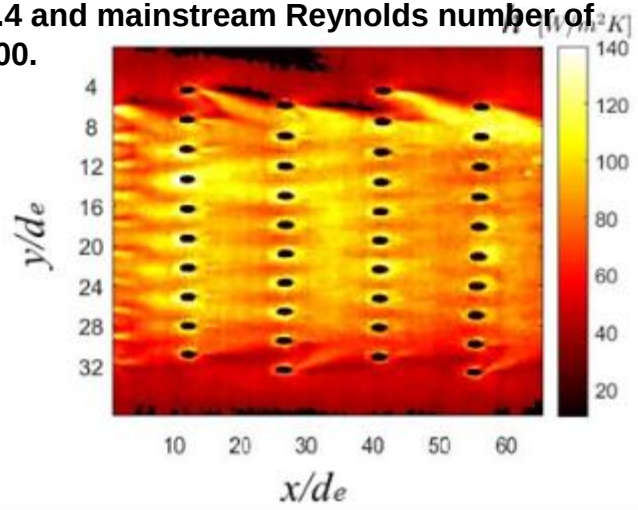
Energy and Power Systems

Sponsors: National Science Foundation, Solar Turbines Inc., IHI Corp., Alabama Innovation Fund, OVPRED of UAH, Arnold Engineering Development Center

Shadowgraph flow visualization image showing normal shock wave, including lambda foot, and separated turbulent boundary layer. Flow direction is from right to left. Test section inlet Mach number is 1.54.



Surface, local heat transfer coefficient variation for hot side of effusion plate for BR=7.4 and mainstream Reynolds number of 142,000.



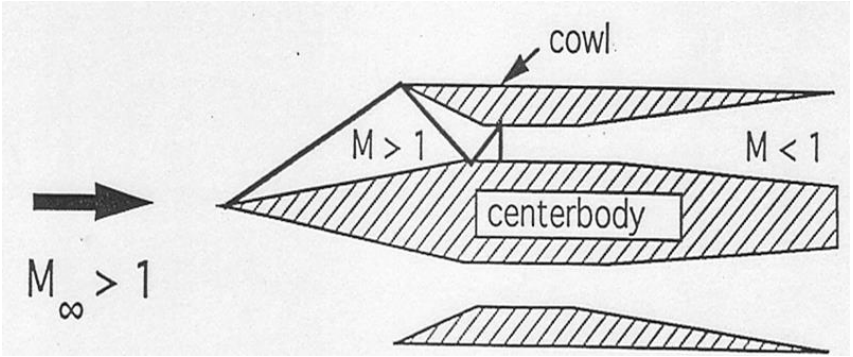
Research activities consider supersonic flows, flows and heat transfer within air breathing engine components, heat transfer augmentation technologies, and micro-scale and millimeter-scale flows, including the effects of elastic turbulence, and micro-scale slip from rarefaction.

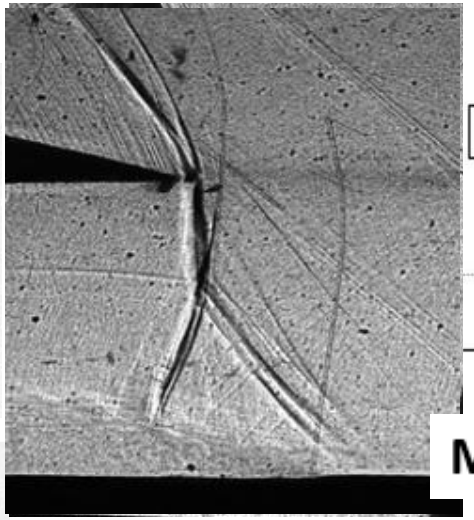
Expertise and Areas of Application

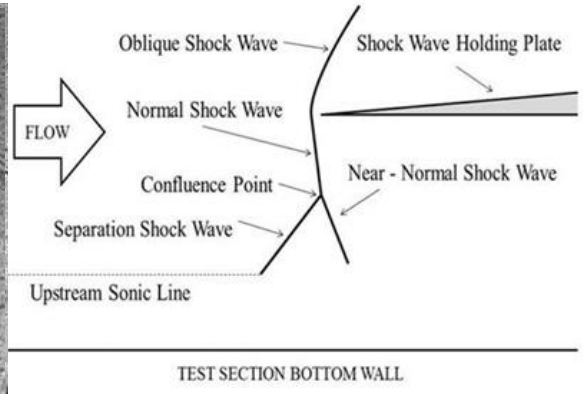
- **Supersonic Flow and Shock Wave Interaction Investigations**
- **Elastic Turbulence Investigations**
- **Double Wall Cooling Investigations**
- **Surface Roughness Effects on Impingement Array Surface Heat Transfer**
- **Internal Passage Heat Transfer Augmentation Methods and Associated Unsteady Flow Structural Characteristics**
- **Second Law Losses Around a Turbine Guide Vane**
- **Unsteady Milliscale Impingement Jets and Associated Vortices for Surface Heat Transfer Augmentation**
- **Dean Flow Dynamics and Cell Separations in Low-Aspect Ratio Spiral Microchannels**

SWBLI RESEARCH
SHOCK WAVE BOUNDARY LAYER INTERACTIONS
Mechanical and Aerospace Engineering

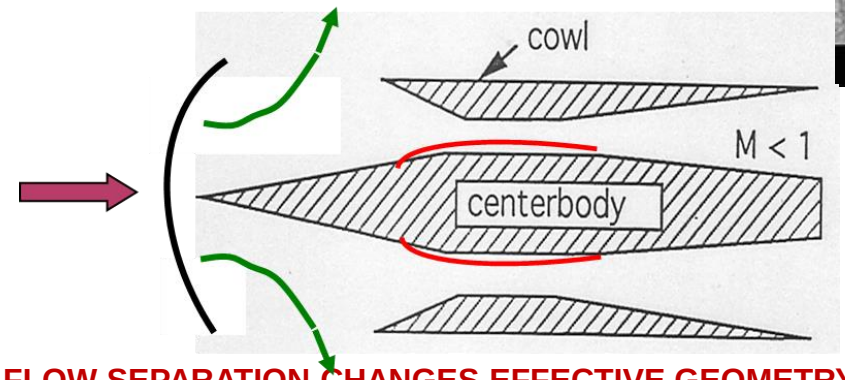
CONSEQUENCES OF SHOCK-INDUCED SEPARATION





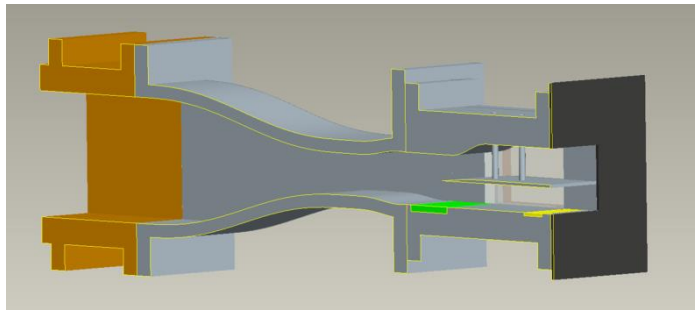


Mach number = 1.54



SHOCK-WAVE—BOUNDARY-LAYER-INTERACTIONS

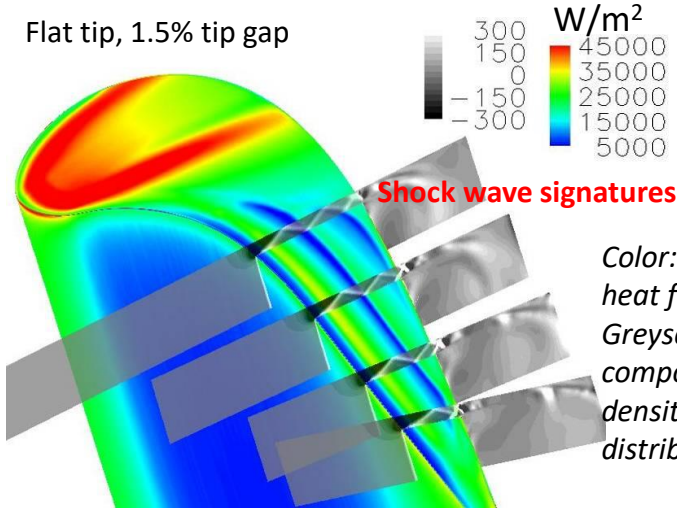
FLOW SEPARATION CHANGES EFFECTIVE GEOMETRY: SHOCK WAVE POPS OUT and ENGINE UNSTARTS !



Centerline view of TEST SECTION.

FLOW AND HEAT TRANSFER ON AND NEAR A TRANSONIC TURBINE BLADE TIP - INCLUDING EFFECTS OF A VARYING TIP GAP

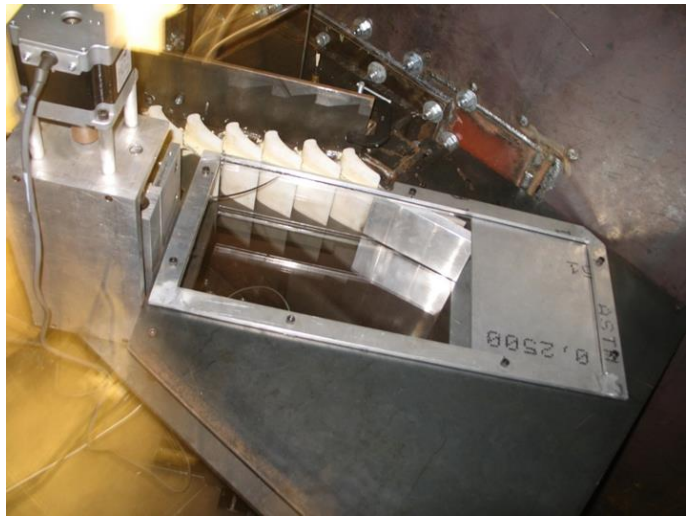
Flat tip, 1.5% tip gap



Color: Tip surface heat flux
Greyscale: x-components of density gradient distributions

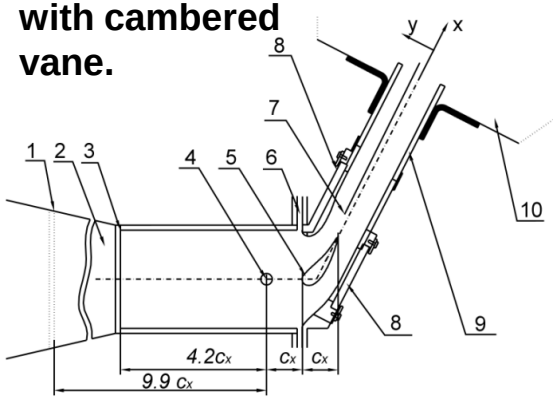
HIGH-SPEED SUPERSONIC, COMPRESSSIBLE FLOW RESEARCH

Mechanical and Aerospace Engineering
Aerodynamics Losses, Aero-Propulsion, Heat Transfer

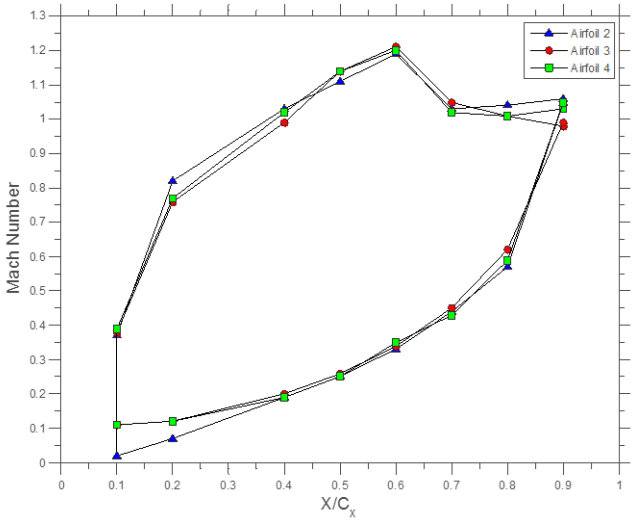


AERODYNAMIC LOSSES IN TURBINES WITH AND WITHOUT FILM COOLING

Test section with cambered vane.

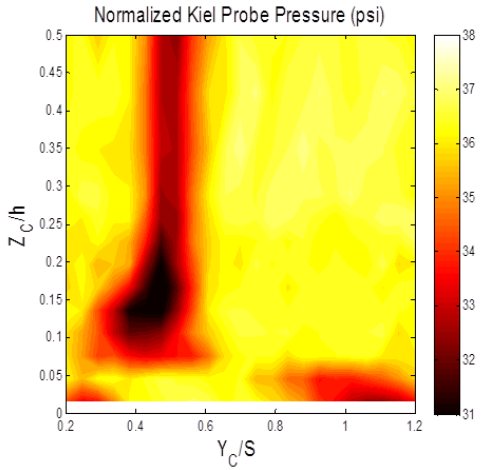


1. Bar Grid Position 2. Nozzle 3. Fine Mesh Grid Position
4. Inlet Pressure Probe and Thermocouple
5. Test Blade 6. Bleeding System
7. Exit Pressure Probe and Thermocouple
8. Zinc-Selenide Window 9. Tailboard 10. Exit Plenum



MACH NUMBER distributions along cambered AIRFOIL

Transonic CASCADE Test Section.

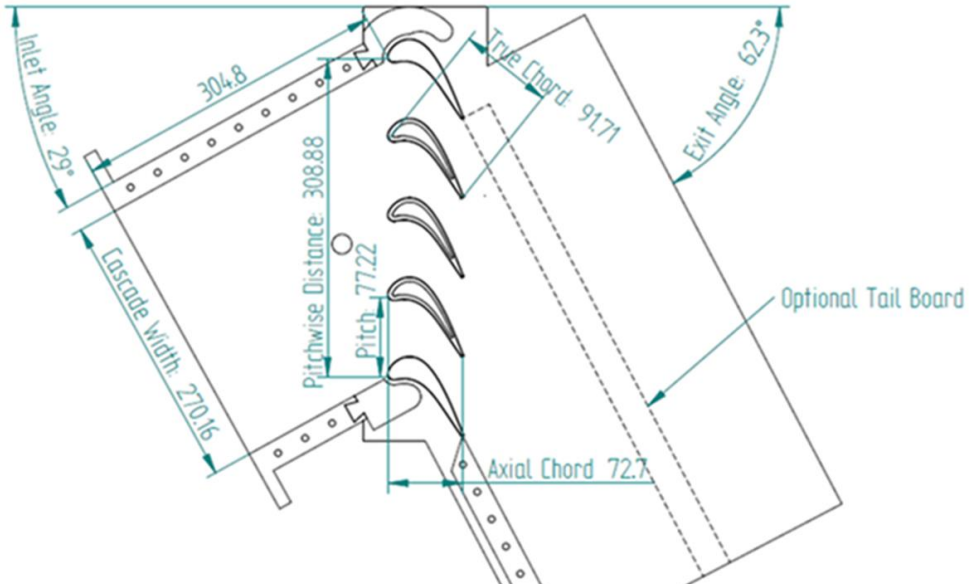


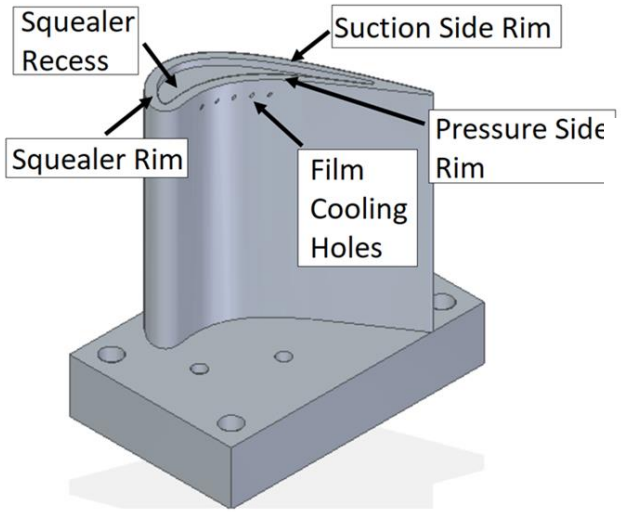
Dimensional pressure loss distribution, downstream of two-dimensional cascade.

INVESTIGATIONS OF TRANSONIC TURBINE BLADE SQUEALER TIPS WITH UNIQUE FILM COOLING ARRANGEMENTS

Surface Heat Transfer Coefficients, Adiabatic Film Cooling Effectiveness, Mach Number Distributions, Effects of Viscous Dissipation

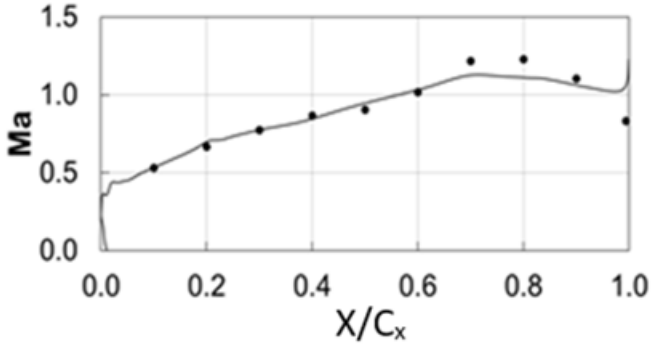
Transonic linear cascade.

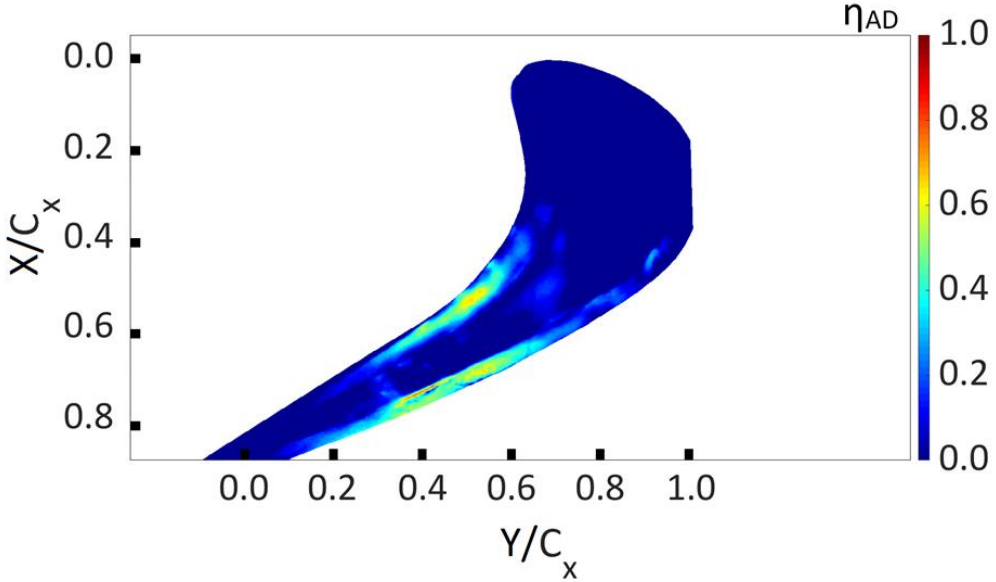




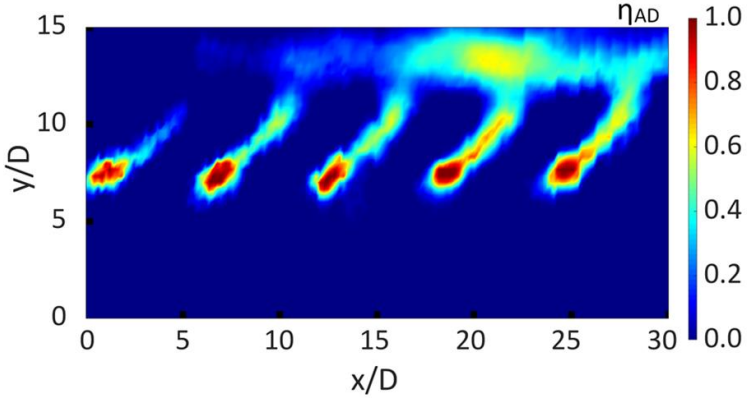
Details of the B1 pressure side film cooled blade showing film cooling and squealer tip configurations

Central blade isentropic Mach number distributions for suction surface at 90 percent span.



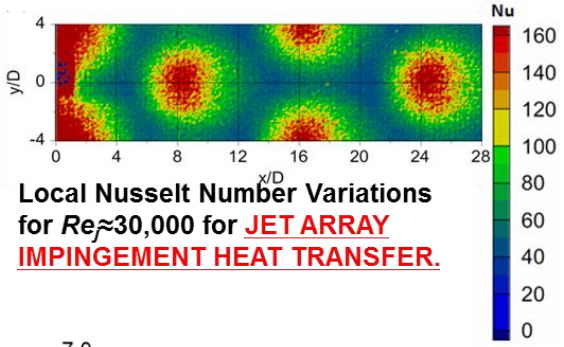


Adiabatic film cooling effectiveness data along the squealer tip surface with B1 film cooling, BR=3.02, and a tip gap of 0.8 mm.



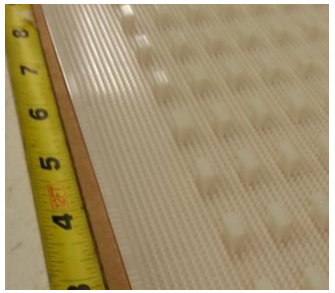
Adiabatic film cooling effectiveness data along the upper pressure side of the blade with B1 film cooling, BR=3.16, and a tip gap of 0.8 mm.

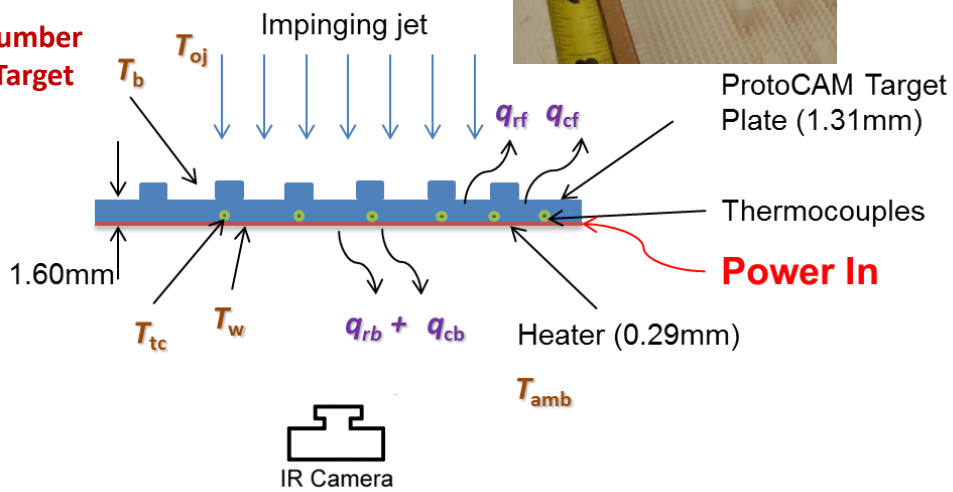
Internal Cooling – Heat Transfer Augmentation RESEARCH
Mechanical and Aerospace Engineering

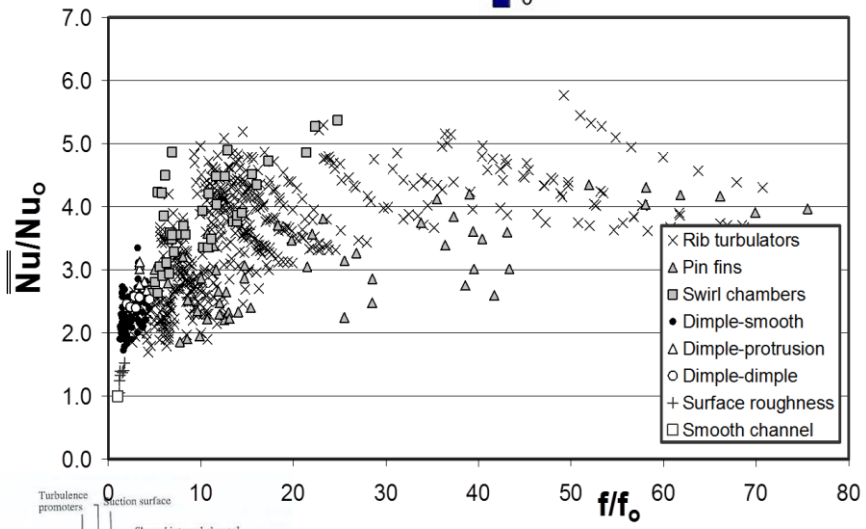


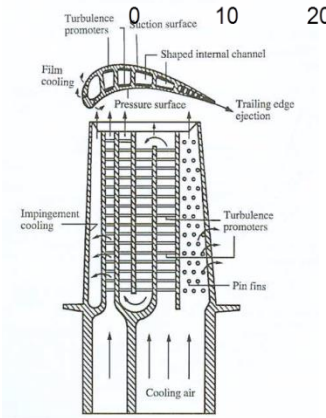
Local Nusselt Number Variations for *Re*≈30,000 for JET ARRAY IMPINGEMENT HEAT TRANSFER.

ProtoCAM Nusselt Number Determination with Target Surface ROUGHNESS

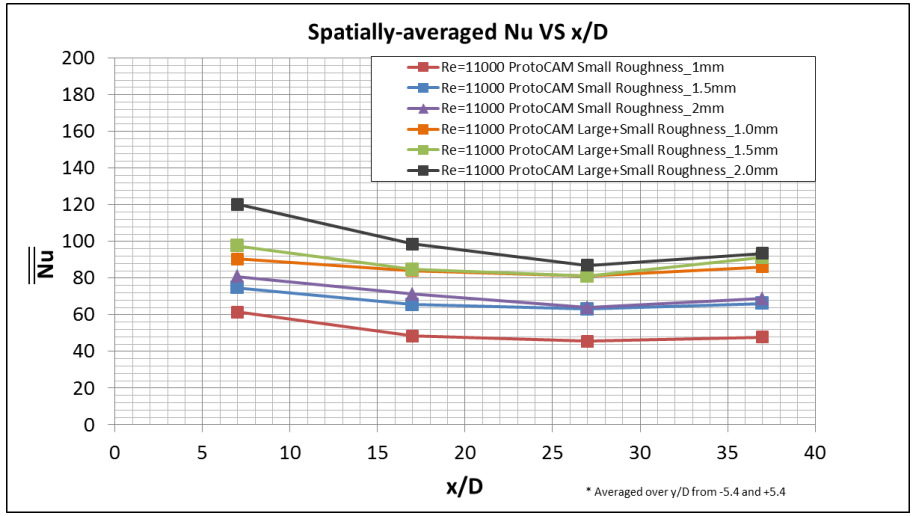








Relative performance of rib turbulators, pin fins, swirl chambers, dimple-smooth arrangements, dimple-protrusion arrangements, dimple-dimple arrangements, surface roughness, and smooth-walled channels from investigations prior to 2003.

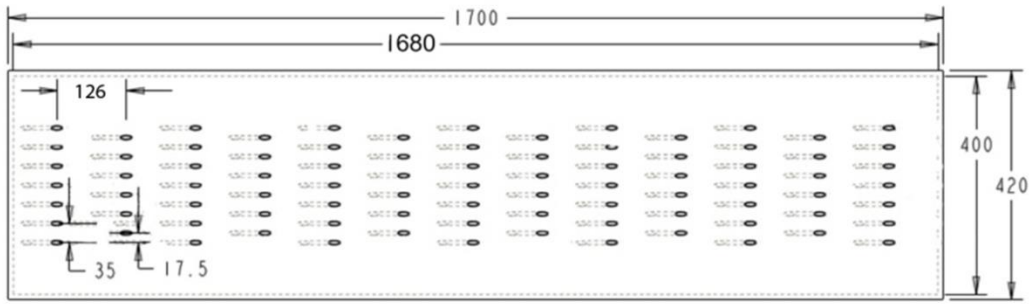


Spatially-averaged Nusselt numbers as dependent upon *x/D*, for six rectangle roughness arrangements for Re=11000.

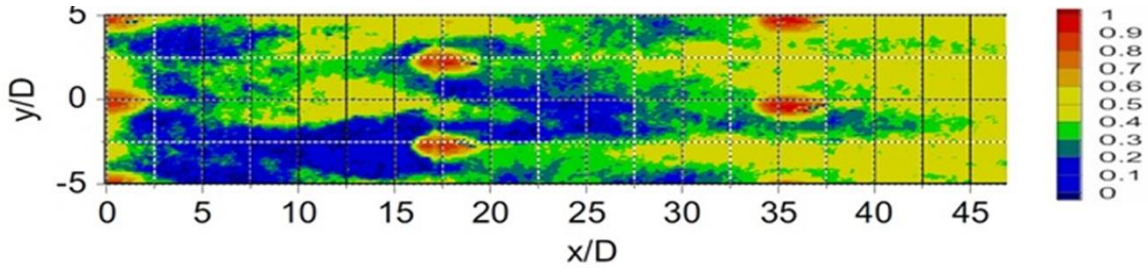
FILM COOLING RESEARCH
DOUBLE WALL COOLING RESEARCH
Mechanical and Aerospace Engineering

FILM COOLING INVESTIGATIONS

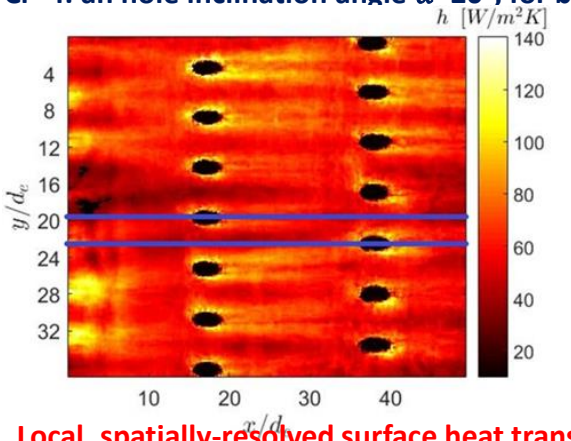
Full-coverage film cooling is employed to manage the resulting heat loads, by providing a layer of coolant which remains close to the surface to provide a heat sink, as well as an insulating layer between the hot gas freestream and the surface which is intended to be cooled.



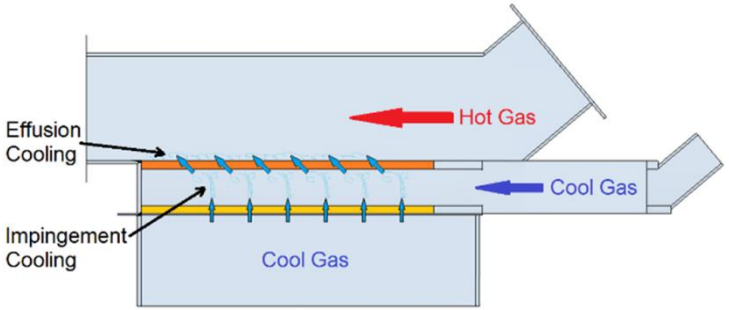
Film cooling test plate for X/D = 18, Y/D = 5 and hole angle 20º.



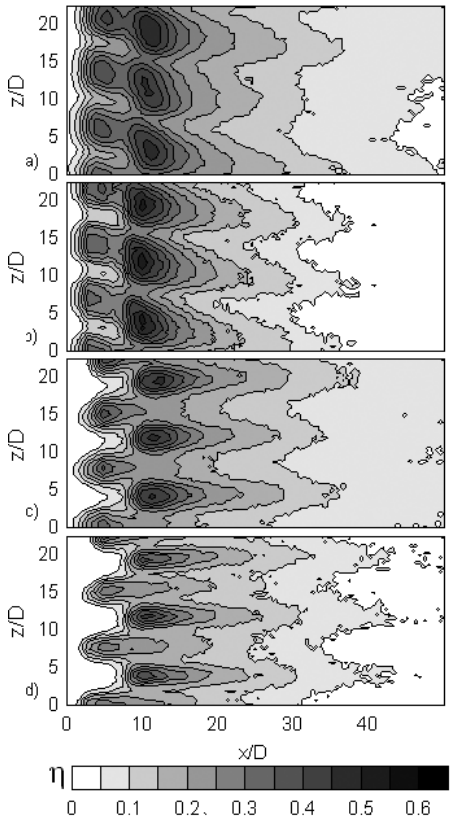
Spatially-resolved surface adiabatic effectiveness for hole spacing X/D=18, Y/D=5, contraction ratio Cr=4. an hole inclination angle α=20°, for blowing ratio BR of 10.0.



Local, spatially-resolved surface heat transfer coefficient distribution with main flow velocity of 7.6 m/s, main flow temperature of 301 K, and blowing ratio of 5.3.

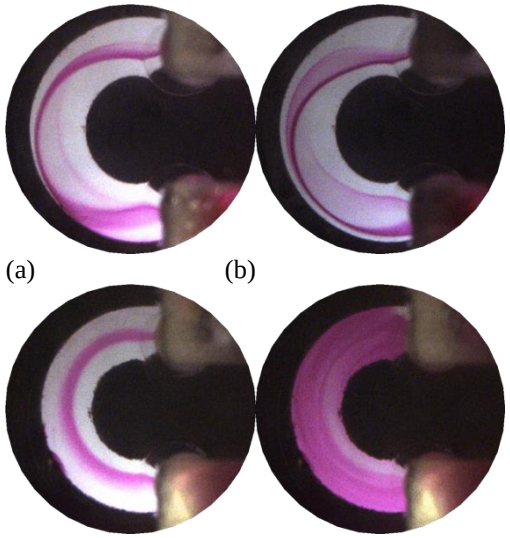


Double wall cooling combines effusion cooling, impingement cooling, and coolant cross flow.

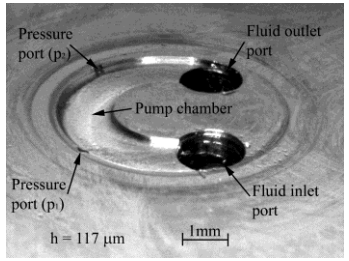


Local adiabatic effectiveness distributions for *m*=0.6 for both rows of holes.
(a) RC hole configuration.
(b) RR hole configuration.
(c) SA hole configuration.
(d) RA hole configuration

MICRO-FLUIDICS RESEARCH
Slip Phenomena -- Elastic Turbulence -- Micro-Propulsion with Plasmas
Mechanical and Aerospace Engineering



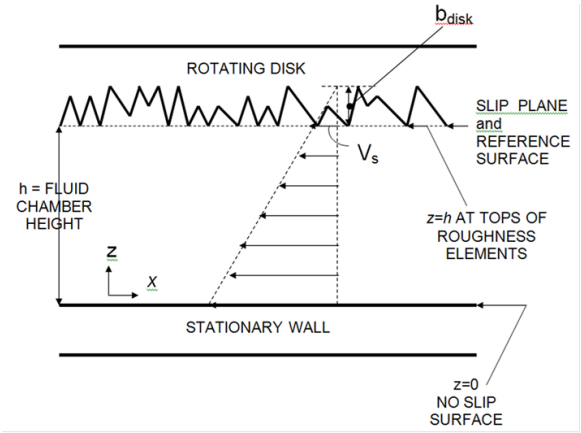
Flow visualization images. Illustrating the development of elastic turbulence. (a) Water at a rotational speed Ω of 200 RPM and a shear rate of 162.5 1/s. (b) Water at a rotational speed Ω of 1200 RPM and a shear rate of 975 1/s. (c) 3000 ppm polyacrylamide solution at a rotational speed Ω of 200 RPM and a shear rate of 162.5 1/s. (d) 3000 ppm polyacrylamide solution at a rotational speed Ω of 1200 RPM and a shear rate of 975 1/s. The Viscous Disk Pump chamber height is 640 µm for all cases.



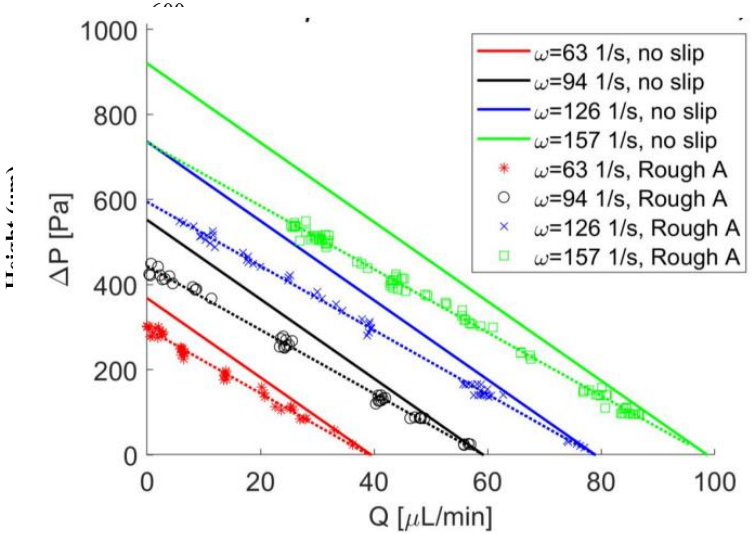
ELASTIC TURBULENCE EFFECTS IN LIQUIDS *as Investigated Within a Micro-Scale Viscous Disk Pump*

The VDP offers a unique environment to ***investigate microscale phenomena***, such as slip, elastic turbulence, viscous dissipation, compressibility, surface roughness in ***gases*** and ***liquids***.

Fluid chamber flow passage. Flow vectors, slip-length, and coordinate system relative to the rotating disk reference frame.



Static pressure rise variation with volumetric flow rate for different disk rotational speeds for surface roughness A, helium, a channel height of 9.8 µm, and Kn=2.15*10^{-2}.



Controlled surface roughness causes flow to slip