AIAA 2003-4147

Stability of Hypersonic Boundary Layer on Porous Wall with Regular Microstructure

A. Fedorov and V. Kozlov
Moscow Institute of Physics and Technology, Zhukovski, 140180, Russia

A. Shiplyuk, A. Maslov, A. Sidorenko and E. Burov
Institute of Theoretical and Applied Mechanics, Novosibirsk, 630090, Russia

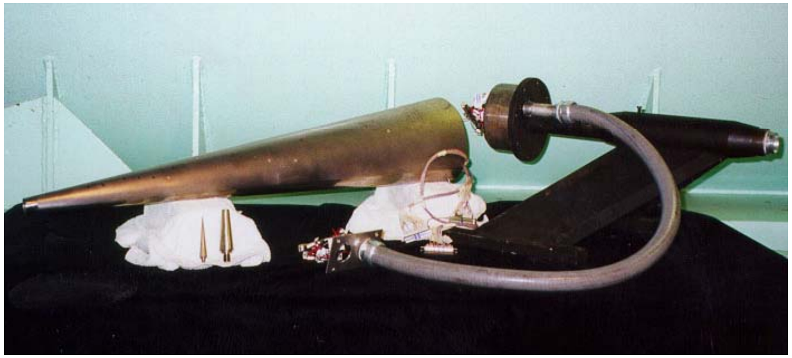
N. Malmuth
Rockwell Scientific Company, Thousand Oaks, California 91360, USA

Speaker Could Not Present due to Visa Problems. Paper is Available. Here, a Brief Summary by the Session Chair

---

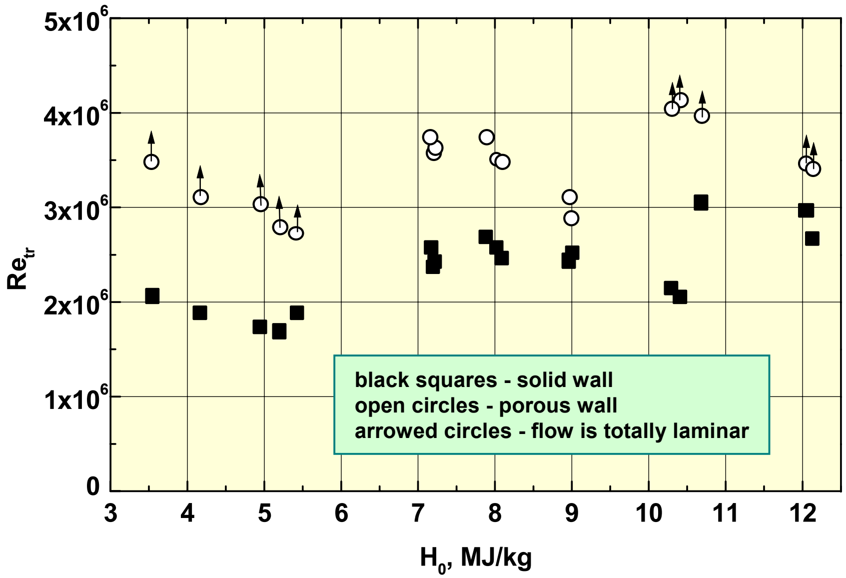
This effort was supported by the European Office of Aerospace Research and Development under the International Science and Technology Center (ISTC) partner grant No. 1863.
The authors are grateful to Dr. John Schmisseur and Dr. Steven Walker for support of this research project.

Caltech* experiments confirm the theoretical concept† of hypersonic laminar flow control



Sharp cone model with porous surface

Ultrasonically absorptive coating with equally-spaced cylindrical blind micro-holes was able to increase laminar run on a sharp hypersonic cone more than twice

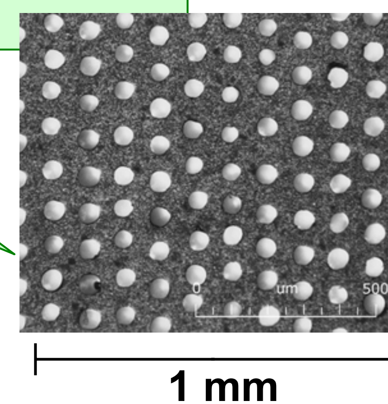


Summary of Caltech data (H_0 is total enthalpy)

Perforated sheet with blind cylindrical holes:

- hole diameter 60 microns
- hole depth 500 microns
- spacing 100 microns

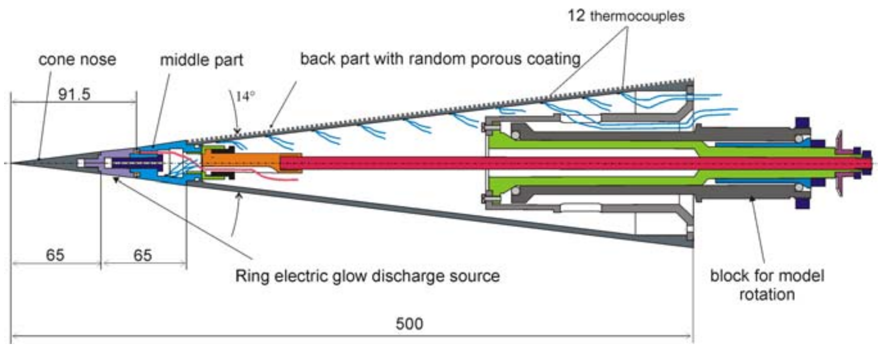
~100 holes per 1 mm²

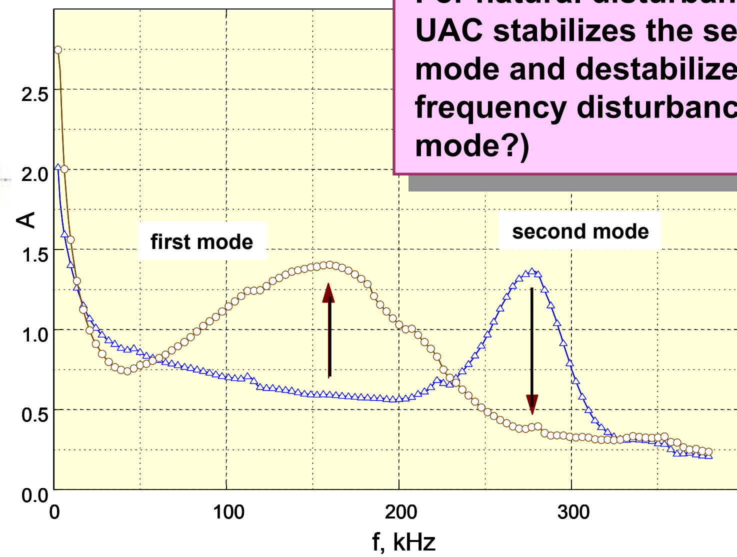


*Rasheed, A., Hornung, H.G., Fedorov, A.V., and Malmuth, N.D., *AIAA J.*, 40, No. 3, 2002.

†Fedorov & Malmuth et al., *AIAA J.*, 39, No. 4, 2001

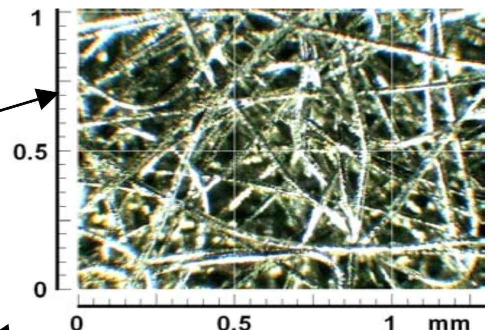
ITAM stability experiments on felt-metal coating agree well with LST*

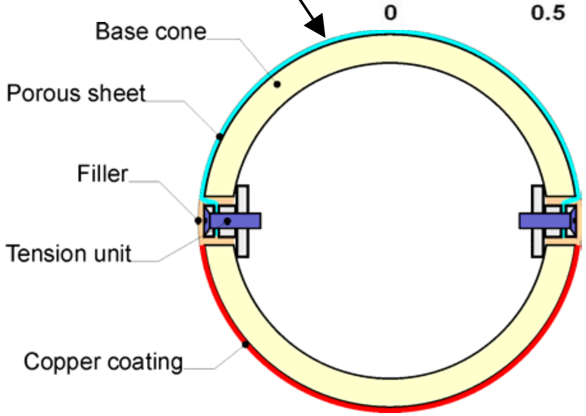




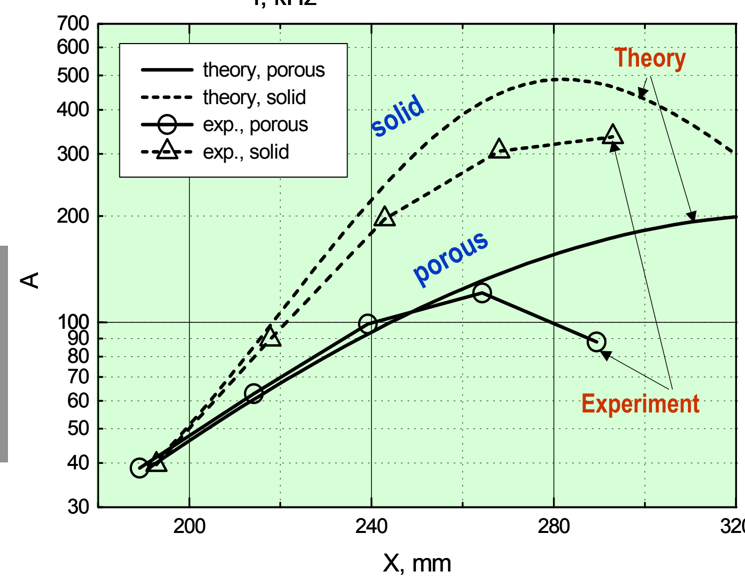
For natural disturbances UAC stabilizes the second mode and destabilizes fow-frequency disturbances (first mode?)

Felt-metal coating of 0.75 mm thickness





Amplitudes of artificially excited wave packet of 280 kHz agree well with LST

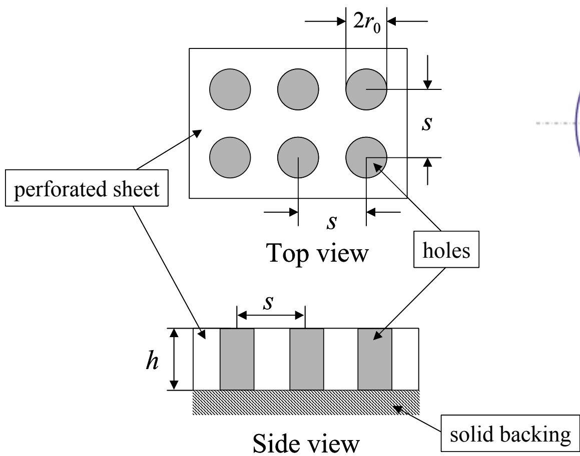


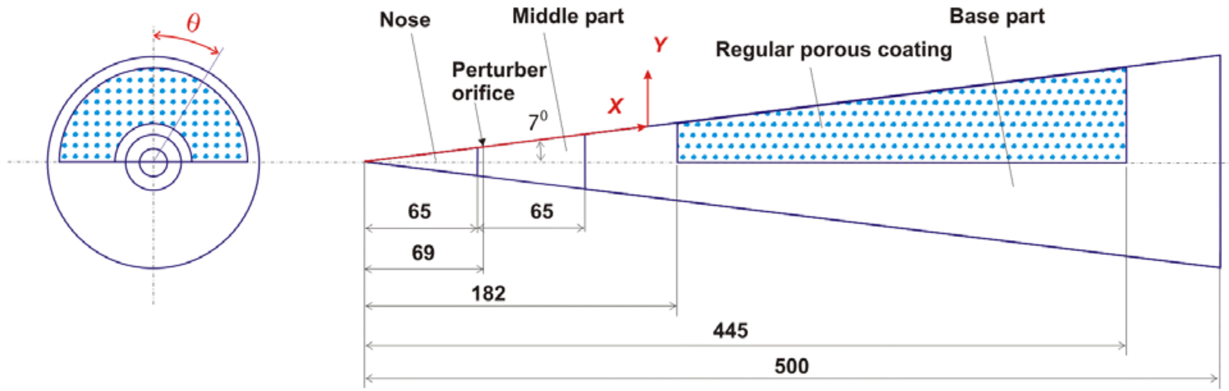
*Fedorov A., Shiplyuk, A., Maslov, A., Burov, E., and Malmuth, N., AIAA Paper No. 2003-1270, 2003; *JFM*, Vol. 479, 2003, pp. 99-124.

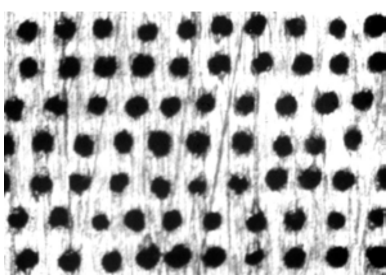
Objectives

- Perform theoretical and experimental studies of porous coating of regular microstructure
- Include gas rarefaction effect in theoretical model of acoustic absorption
- Conduct stability measurements of natural and artificially excited disturbances
- Compare LST predictions with experiment

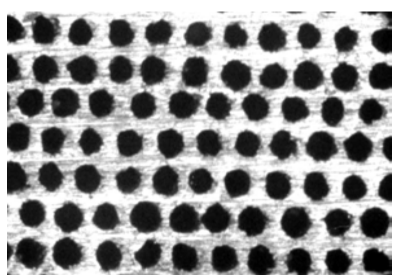
Porous coating is similar to UAC of Caltech experiments*







Face side, d= 50 μm



Back side, d= 64 μm

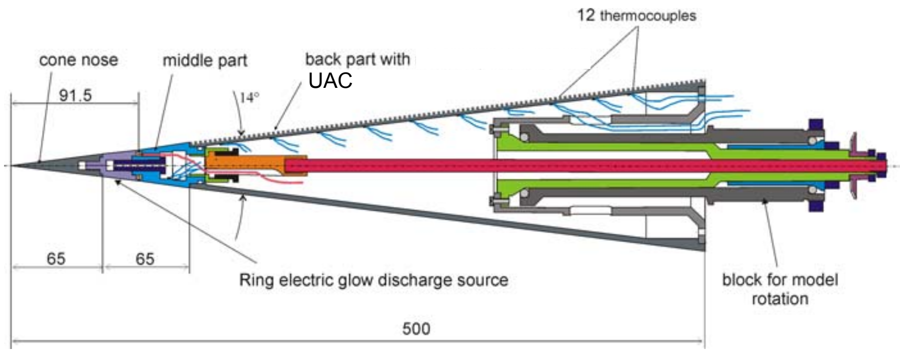
Pores are conical, taper angle~0.9°

Stainless steel sheet perforated with equally spaced cylindrical holes:

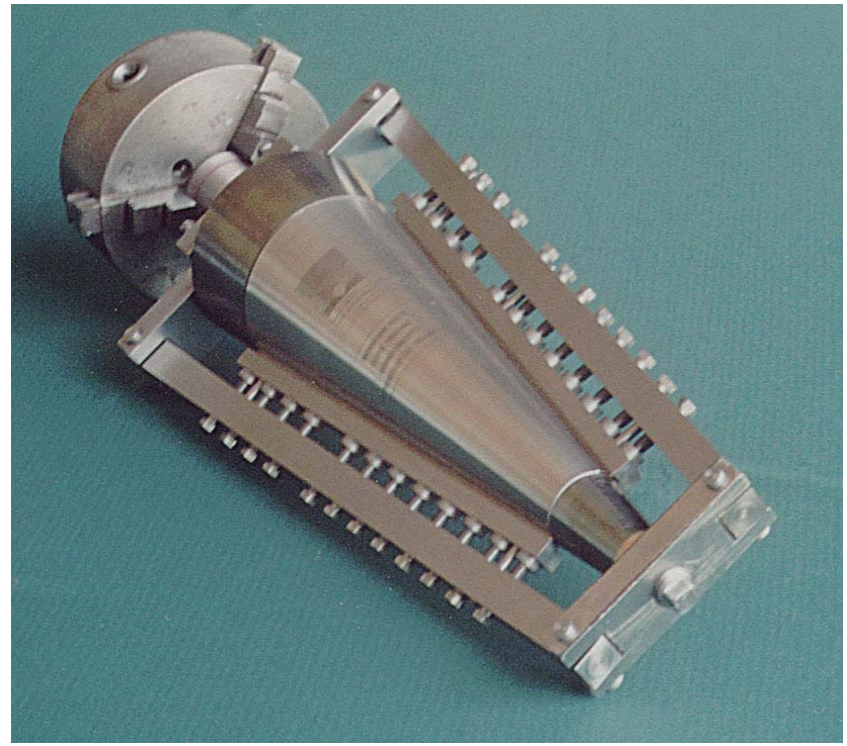
- **Diameter 50 μm on face side**
- **Spacing 100 μm**
- **Depth 450 μm**
- **Porosity 20%**

*Rasheed, A., Hornung, H.G., Fedorov, A.V., and Malmuth, N.D., *AIAA J.*, 40, No. 3, 2002.

Sharp-cone model tested in the T-326 wind tunnel of ITAM

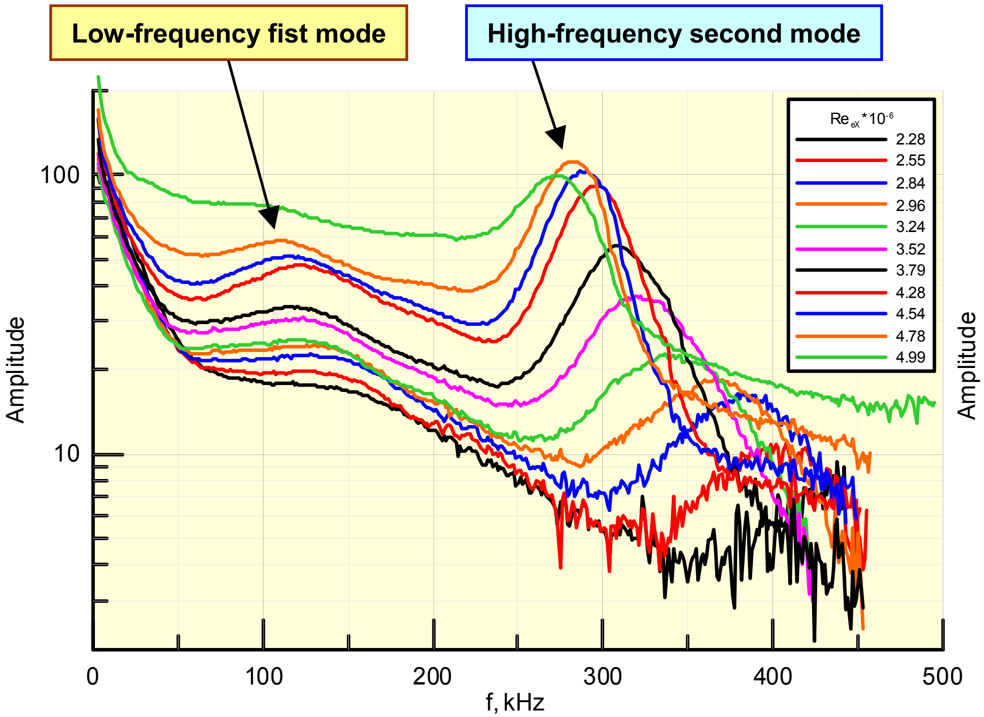


Base part with the porous coating

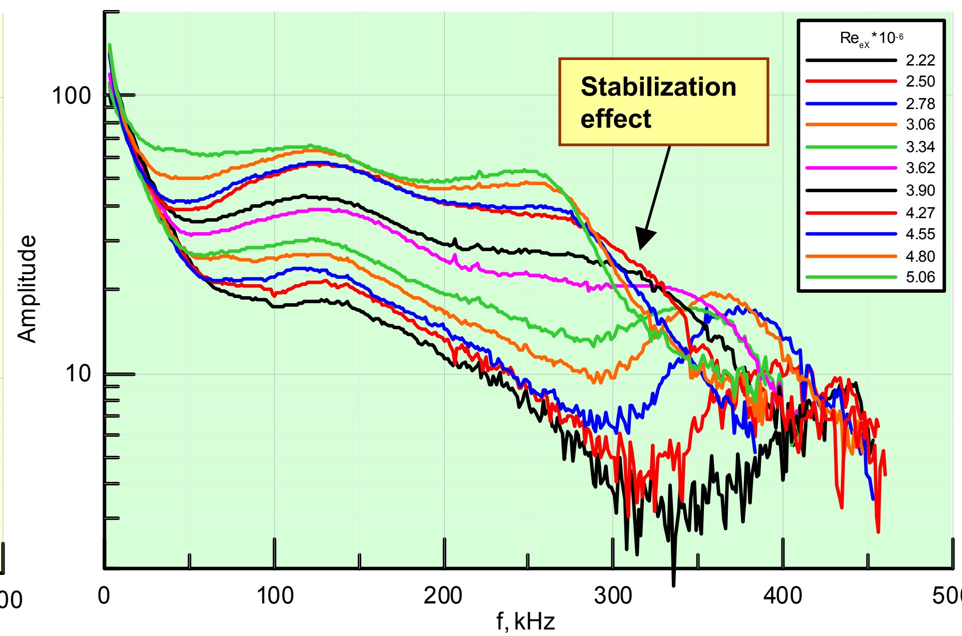


Perforated sheet was tensed onto the model to avoid cavities

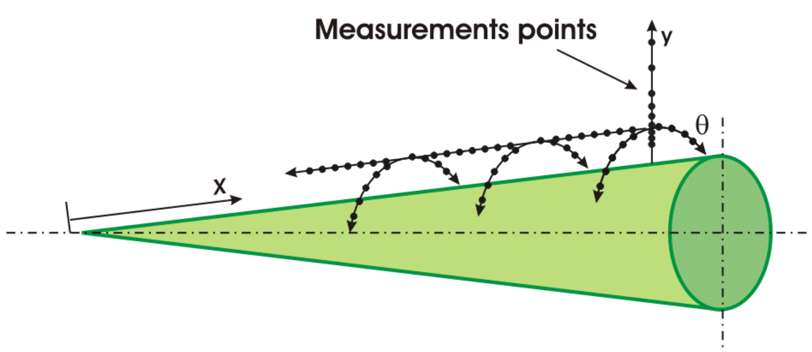
Spectra of Natural Disturbances on Solid and Porous Sides (M=5.95, T0=390K, Tw/T0=0.80-0.84)



Solid side

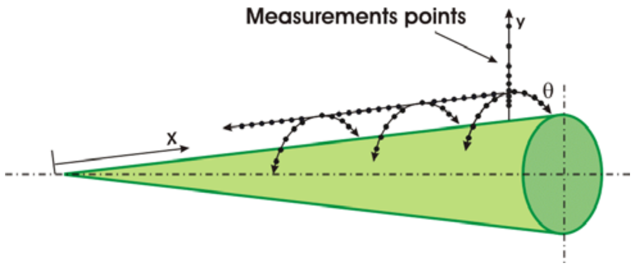


Porous side

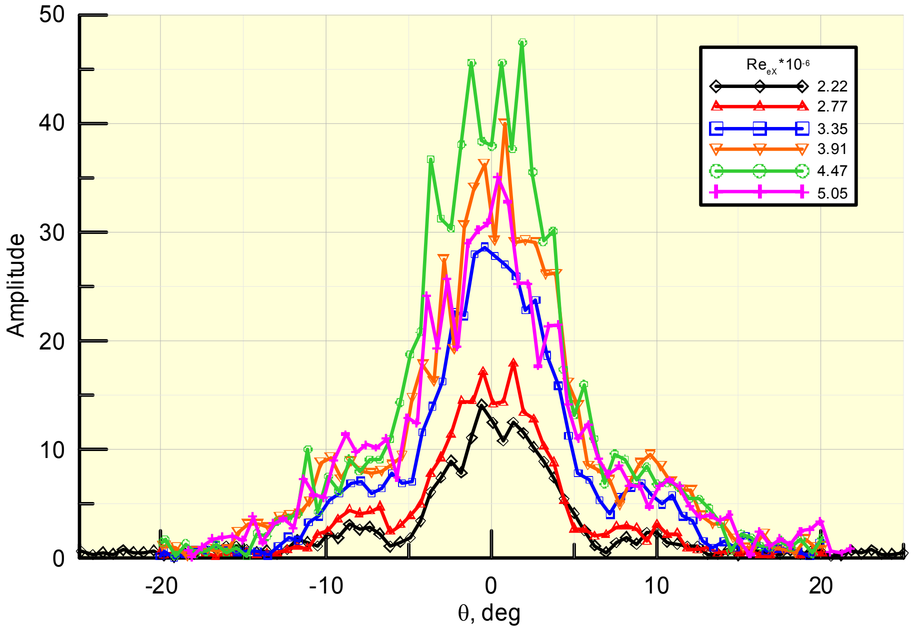


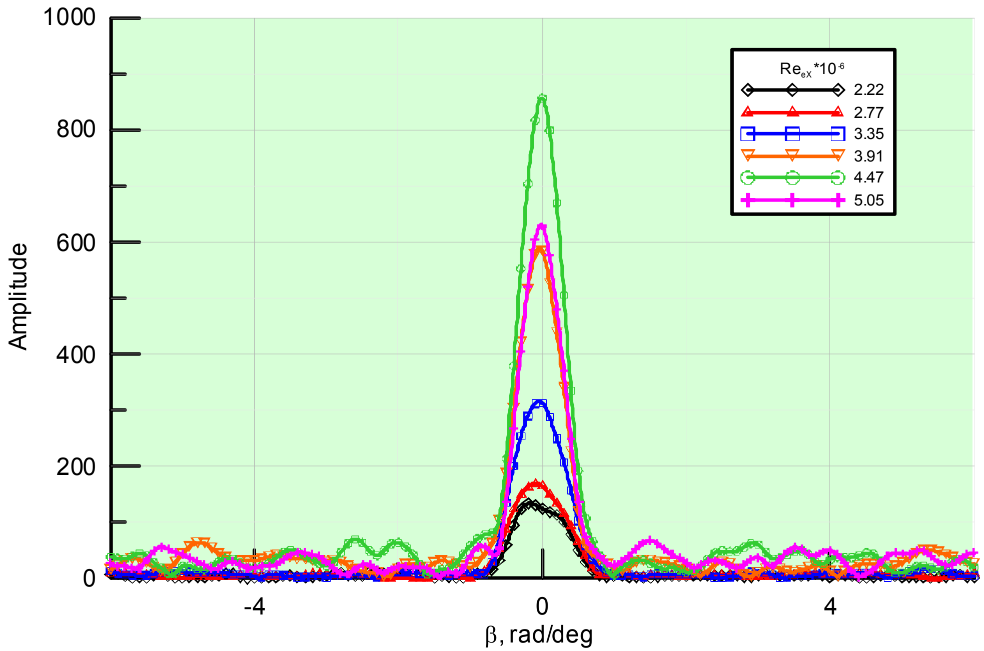
Porous coating stabilizes the second mode and weakly affects the first mode

Artificially Excited Wave Packets in Boundary Layer on Porous Walls



frequency 275 kHz



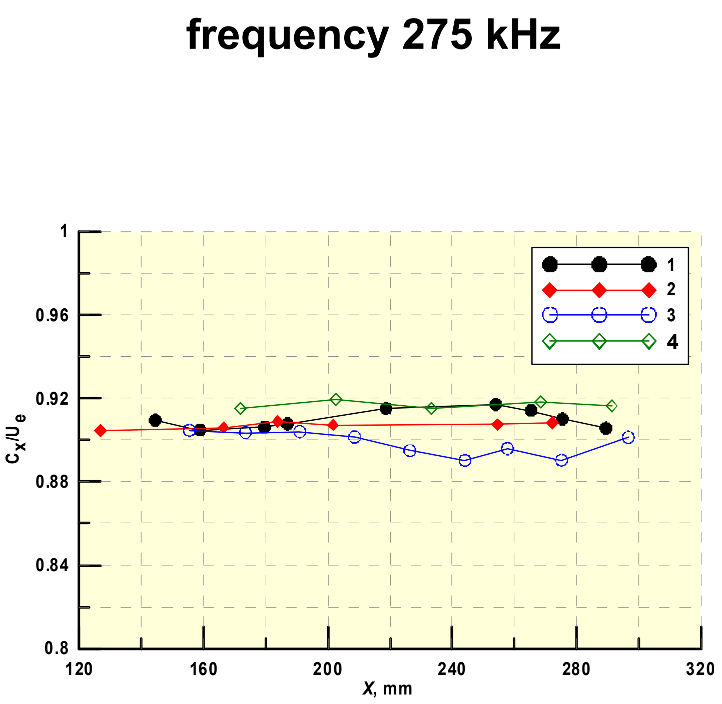


Amplitude vs. circumferential angle

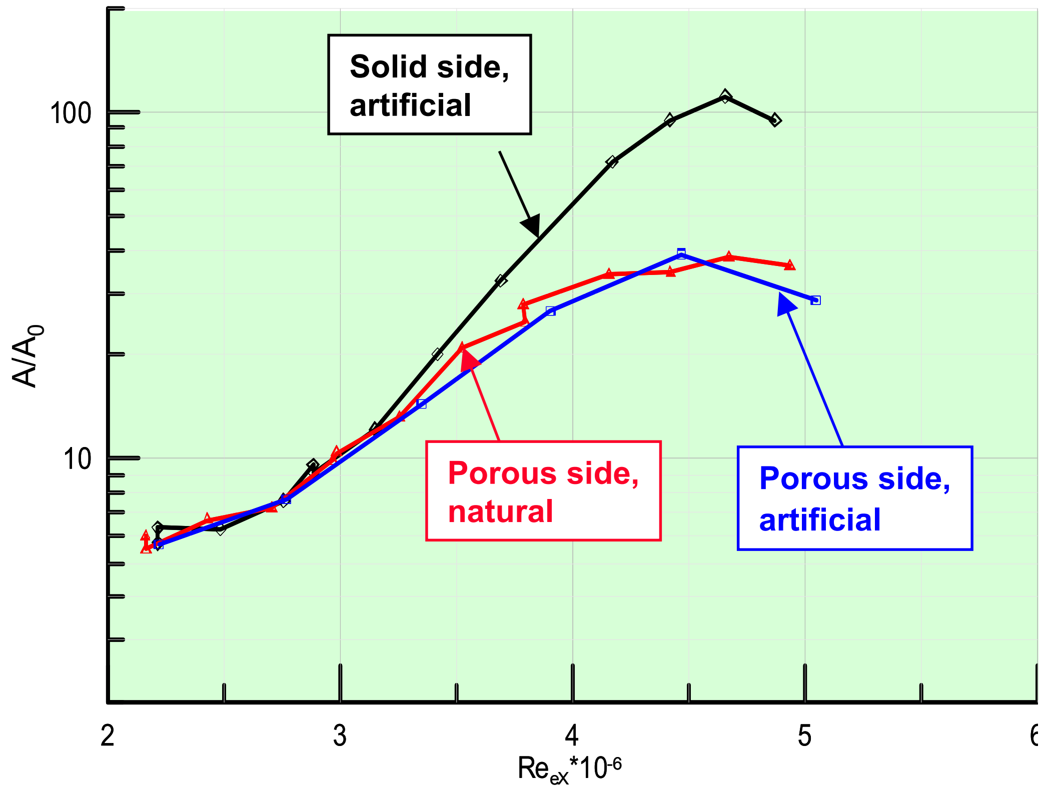
***β*-spectra**

Dominant component of artificially excited wave packet is two-dimensional wave of β=0

Phase Speeds and Amplitudes of Natural and Artificial Disturbances



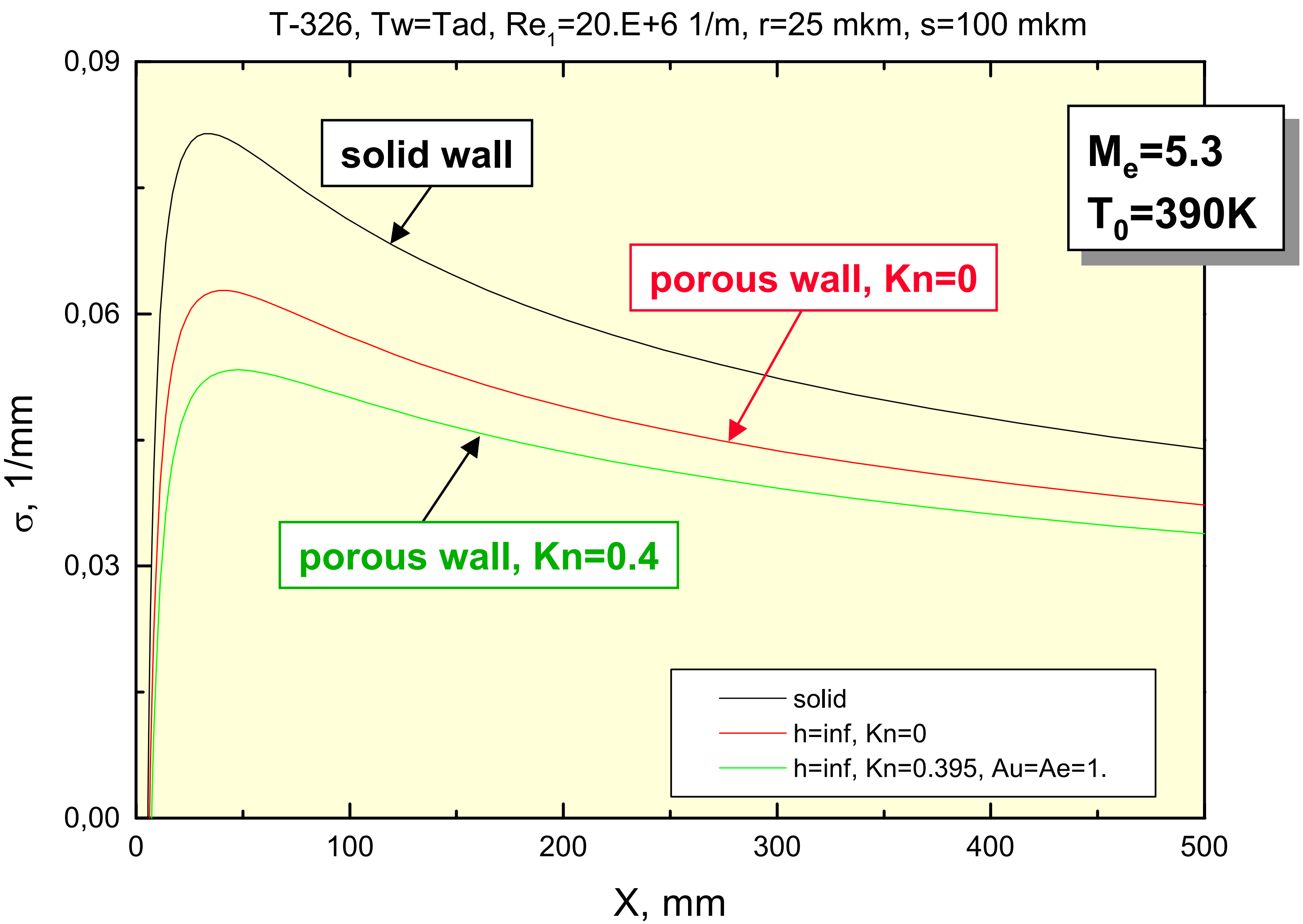
Phase speeds of artificially excited wave packets



Amplitude growth of artificial and natural disturbances

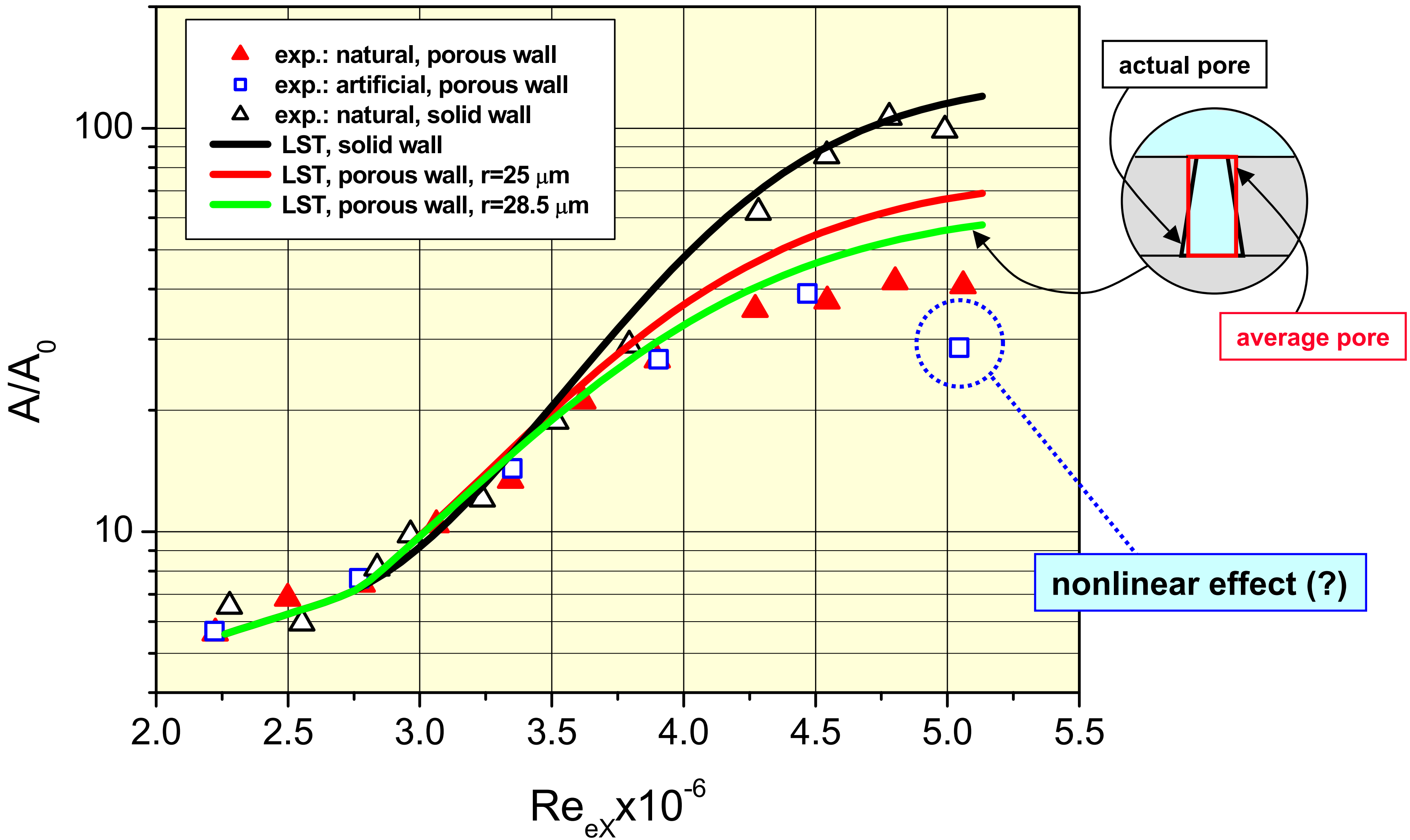
Natural disturbances of high frequency are predominantly 2-D waves of the second mode.

For Kn<1, gas rarefaction increases performance of porous coating



Maximum (versus frequency) growth rate of second mode

Amplification of Artificial and Natural Disturbances of 275kHz (Experiment and LST)



Theory agrees well with experiment on both porous and solid walls

Conclusions

- **Experimental and theoretical studies of hypersonic boundary layer stability were performed for ultrasonically absorptive coatings (UAC) of regular microstructure**

- **Under natural conditions, UAC stabilizes the second mode and weakly affects the first mode that is consistent with theoretical predictions**

- **Natural disturbances of high-frequency band are predominantly 2-D waves of the second mode**

- **UAC stabilizes high-frequency wave packets of second-mode instability**

- **Theoretical predictions of second-mode growth agree well with experiment for both solid and porous walls**

- **For Kn<1, gas rarefaction increases UAC performance**