Flow and noise from supersonic plug nozzles

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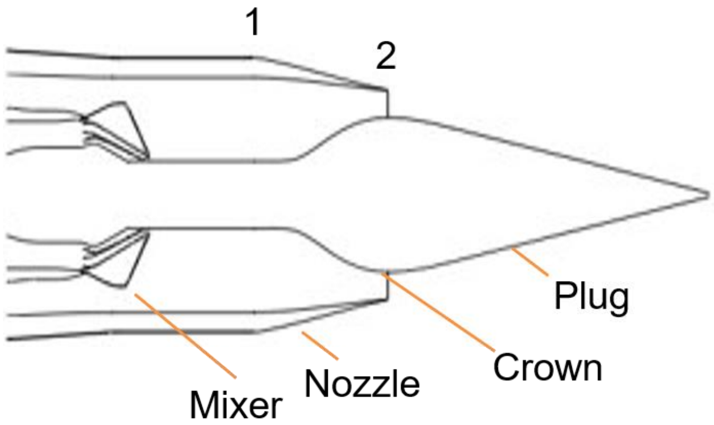
28th AIAA/CEAS Aeroacoustics Conference
Southampton, UK
14-17 June 2022

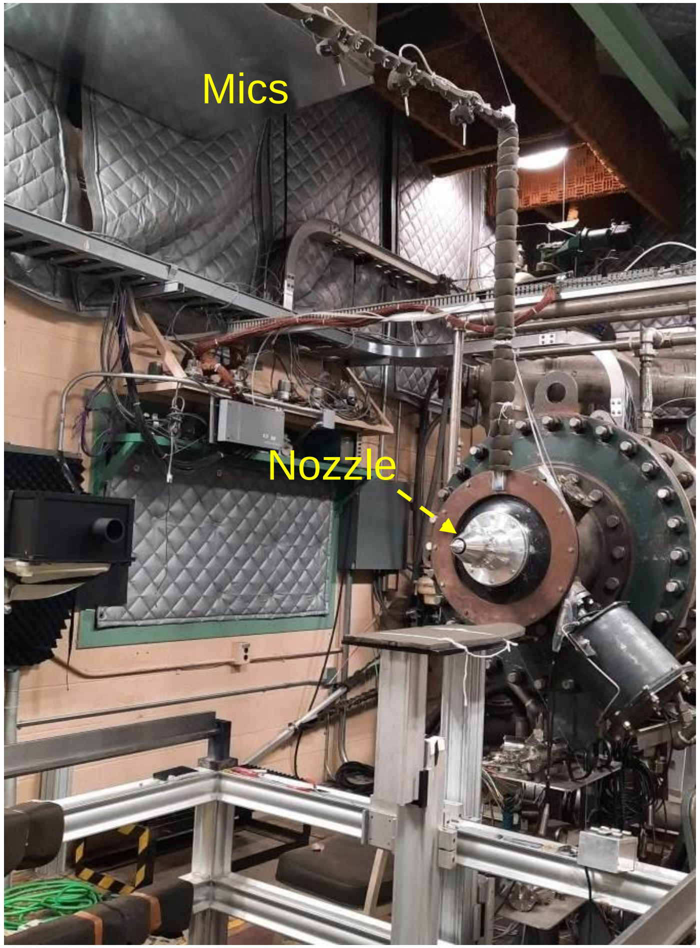
Background

-- Plug nozzle is a candidate for future supersonic aircraft concepts
-- This is a fundamental study with focus on the effect of external plug geometry on flow and noise

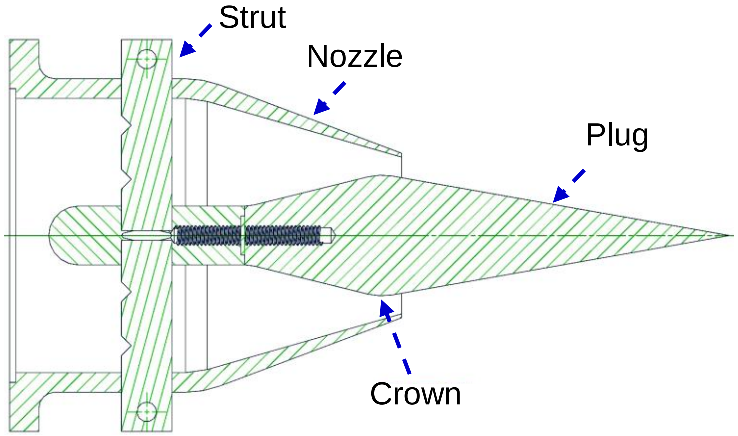


History of plug nozzle research and flow mechanisms were discussed in AIAA 2021-2304 (Zaman/Heberling)

Experimental Facility

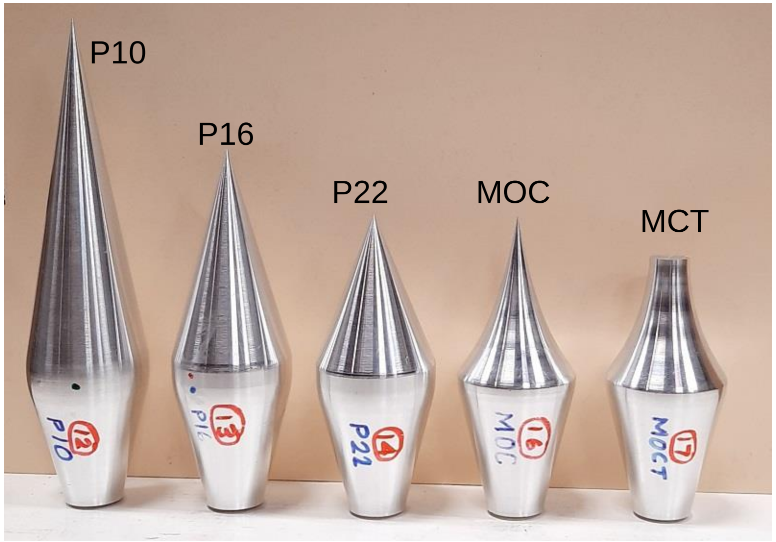


Open jet facility

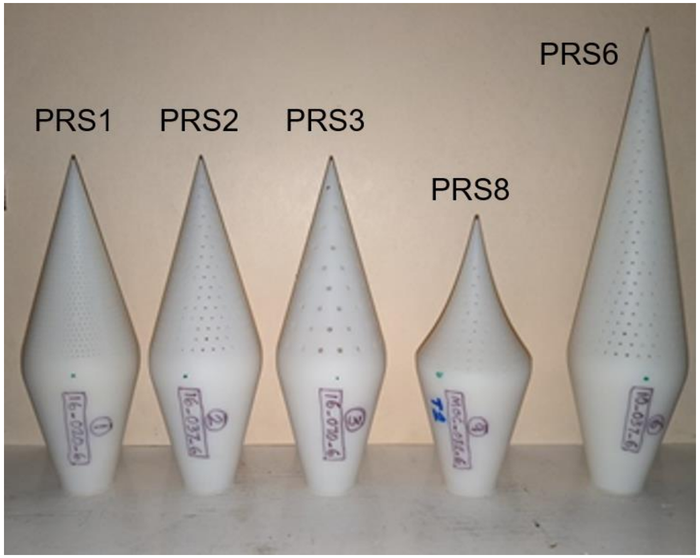


Plug nozzle schematic

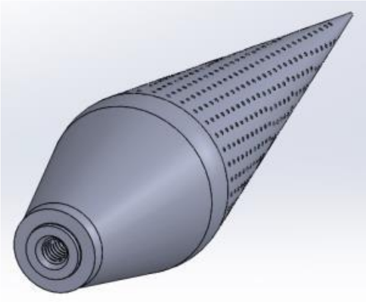
Experimental Facility

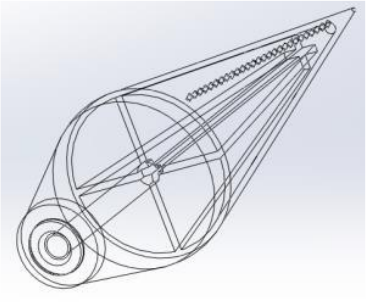


Solid plugs



Porous plugs





CAD drawings of PRS6

Experimental Procedure

SPL spectra at 90° and Schlieren

M_J = 0.9, 1.10, 1.38, 1.52 and 1.61

(NPR=2.14) (NPR=4.36)

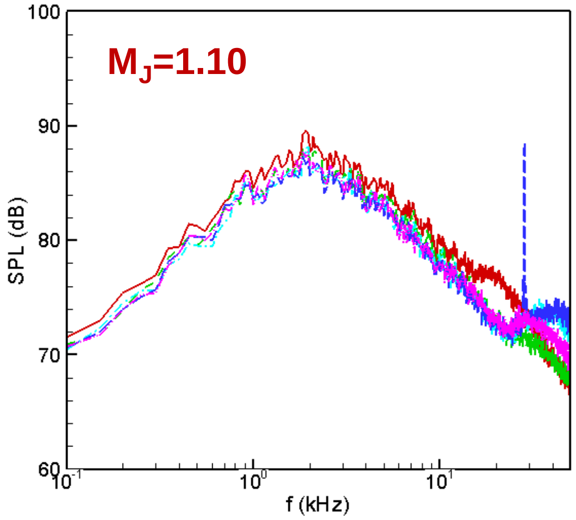
'LTO' → 'Cruise'

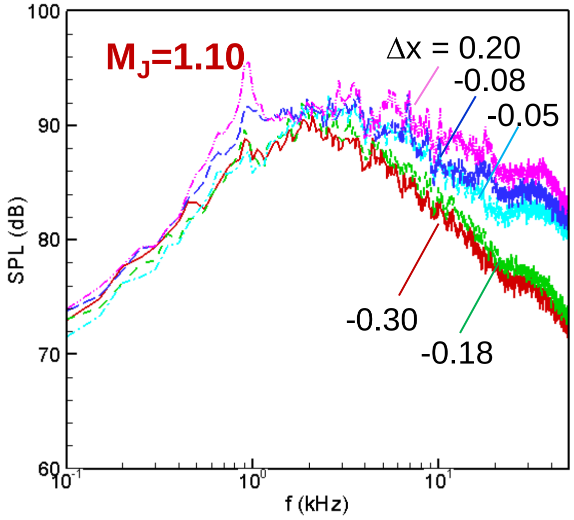
Unheated flow, Static tests (no external stream)

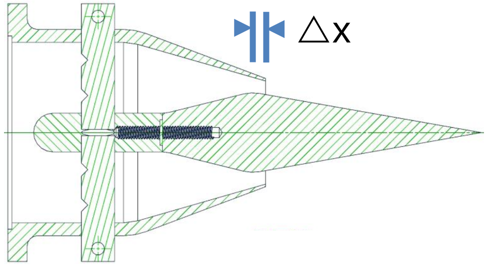
Effect of crown axial location

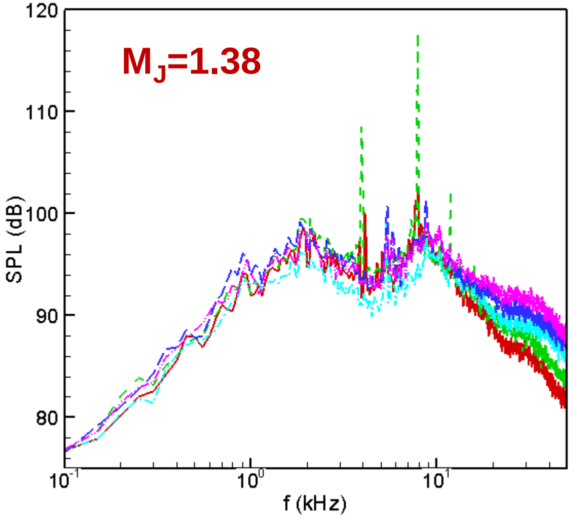
P16

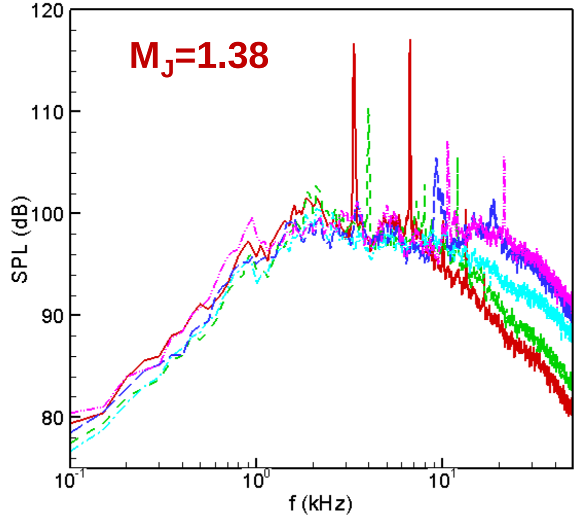
MOC









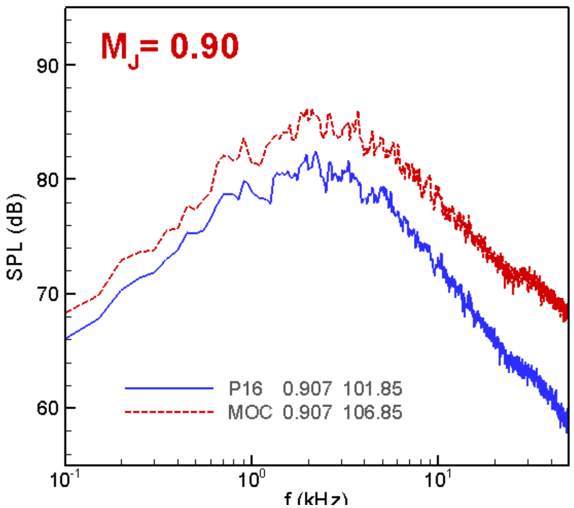


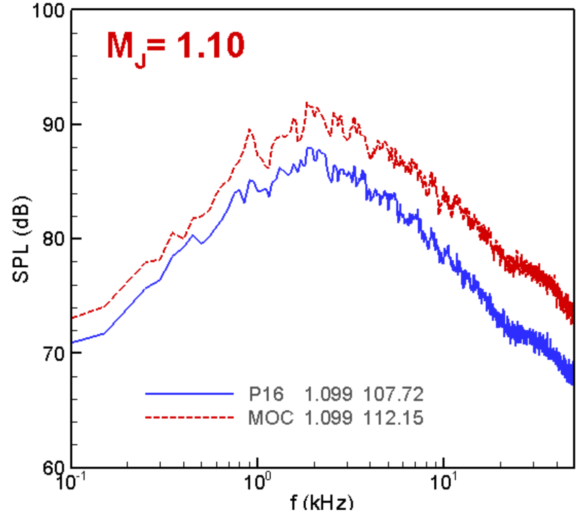
Crown location of -0.18 to -0.30 yield minimum OASPL

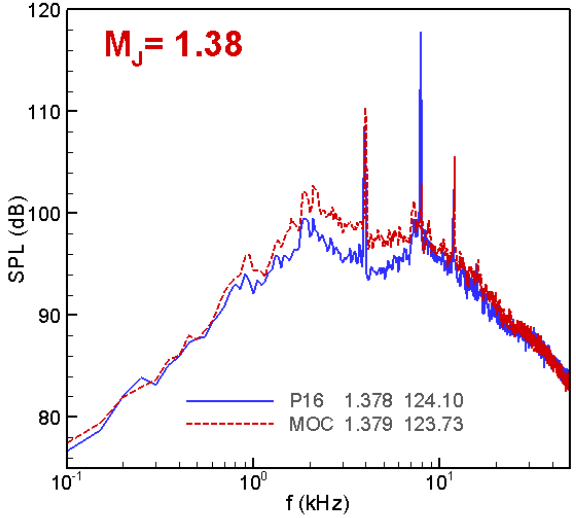
At high SS condition data beset with screech

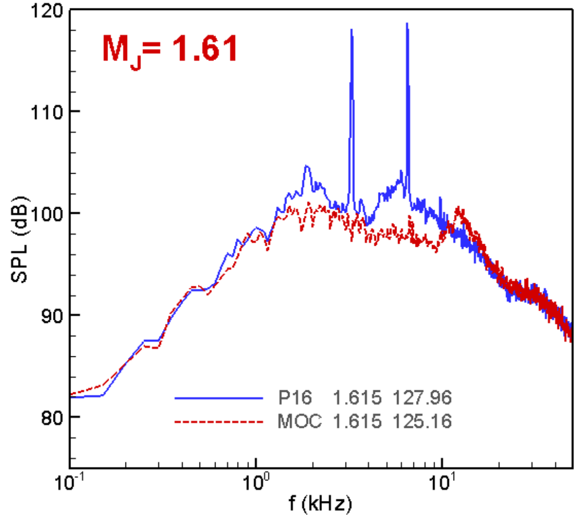
P16 vs MOC

Crown location: -0.18









At low M_J (LTO) MOC is noisier!

At high M_J (Cruise) trend reverses but screech makes comparison difficult

Schlieren P16 vs MOC

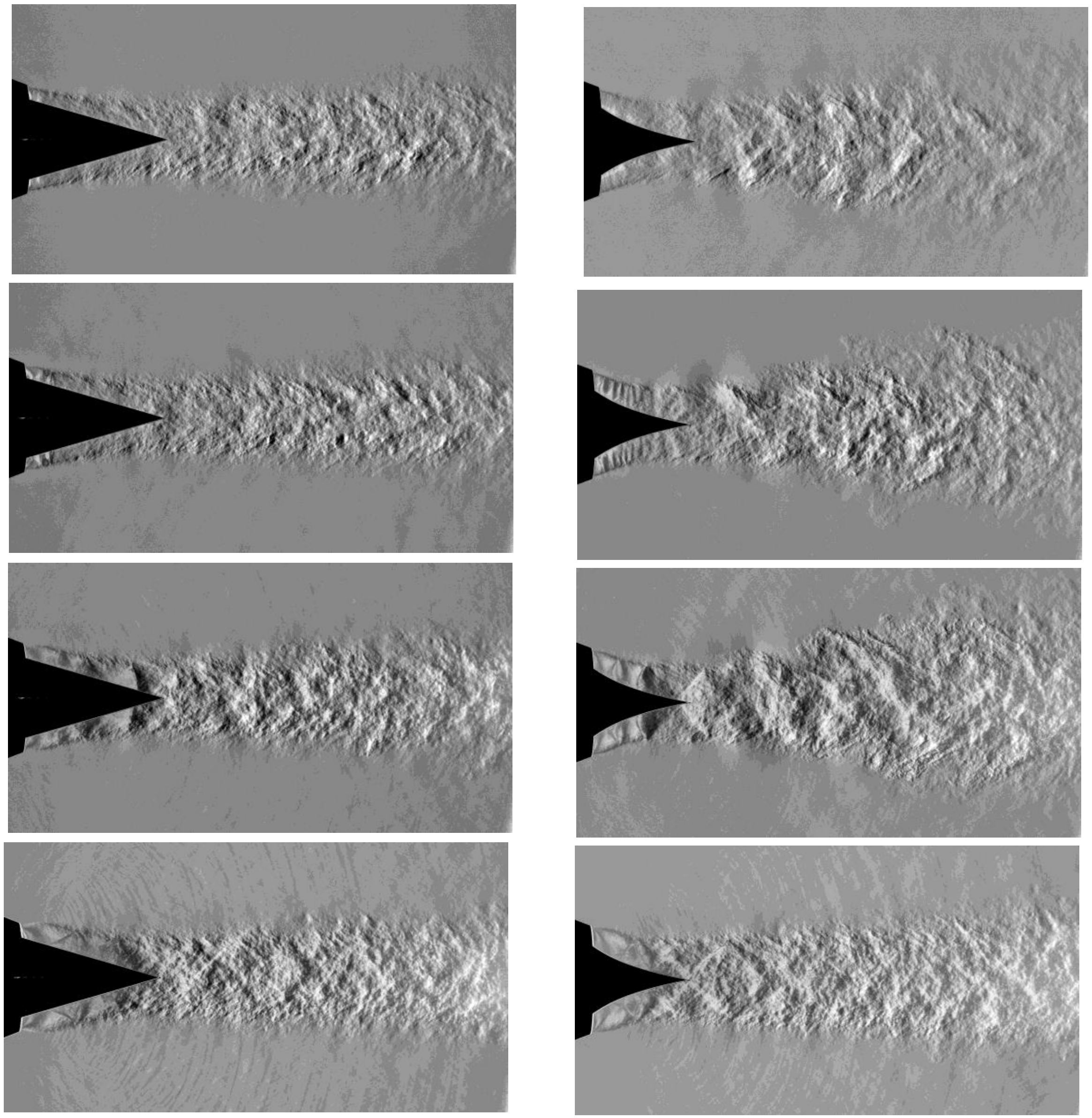
P16 | MOC

M_J=0.90

M_J=1.10

M_J=1.38

M_J=1.61

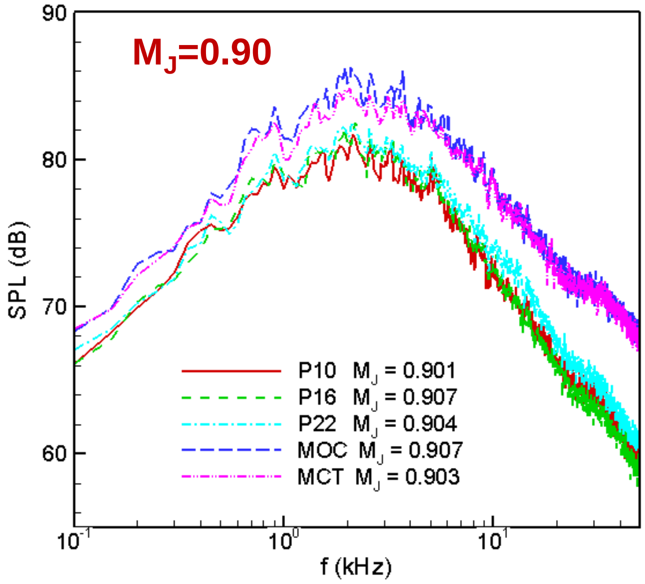


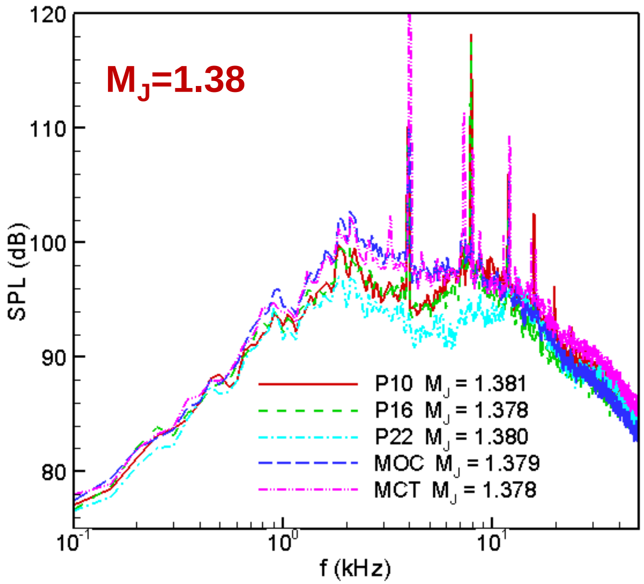
Flow with MOC has unsteadiness and faster jet spread

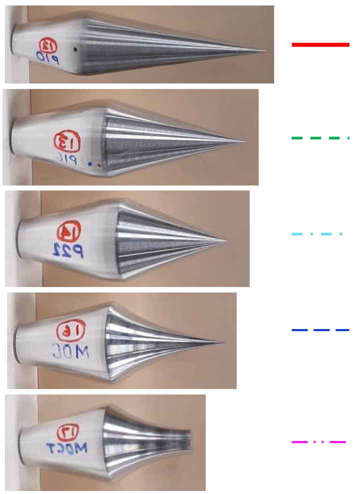
Similar to overexpanded flow from C-D nozzle (Zaman, Bridges, Brown *AIAAJ* 2010)

Effect of various plug shapes

Crown location: -0.18



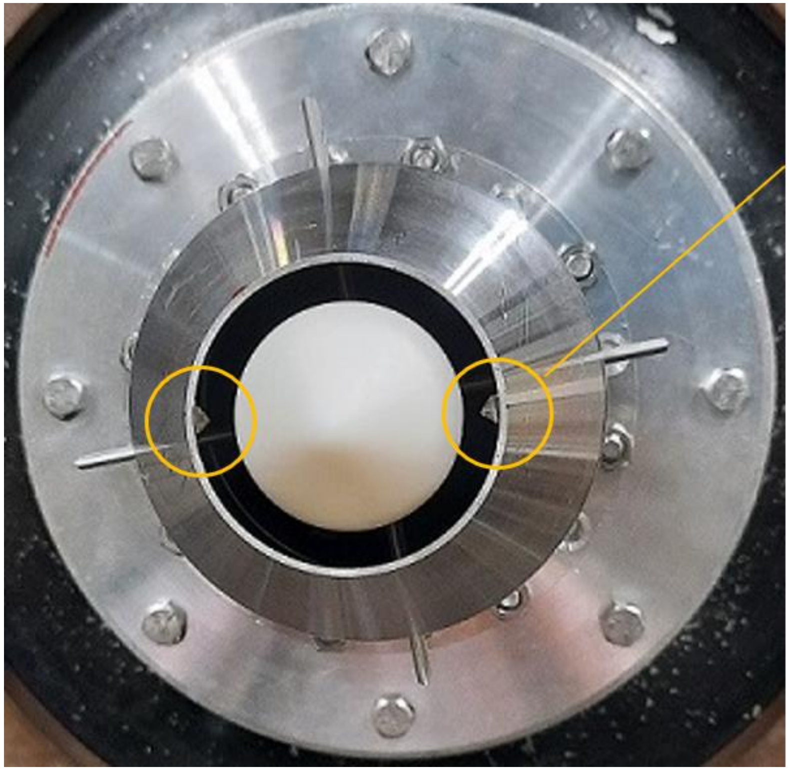




At low M_J,
All conic cases quieter

At supersonic condition all cases have screech and comparisons are difficult

Use tabs to suppress screech

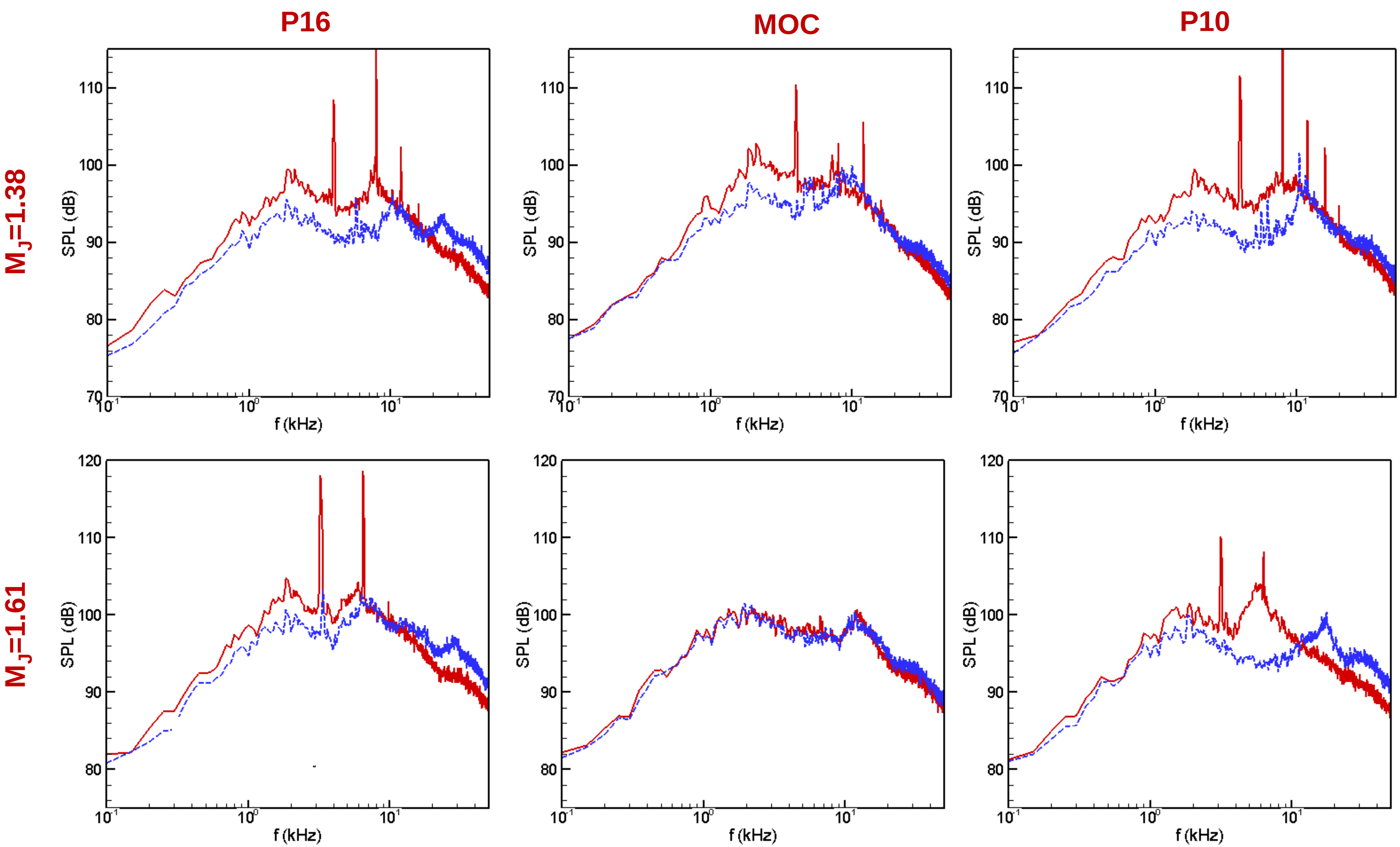


(2) Tabs

Blockage
< 0.9%

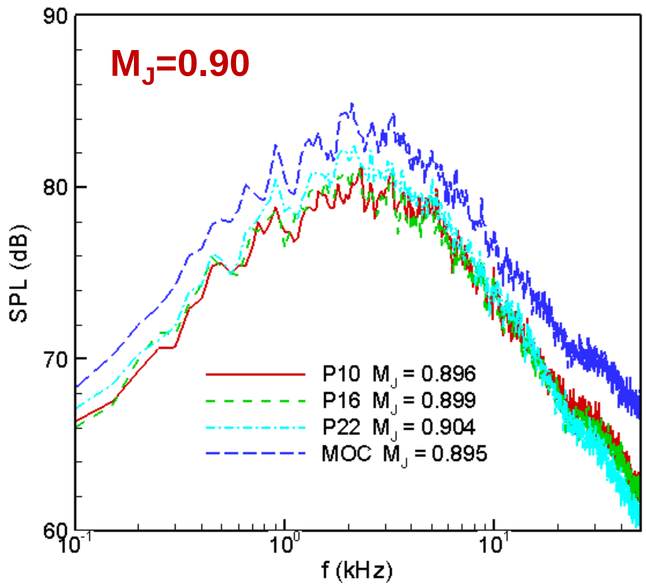
Screech suppressed by Tabs

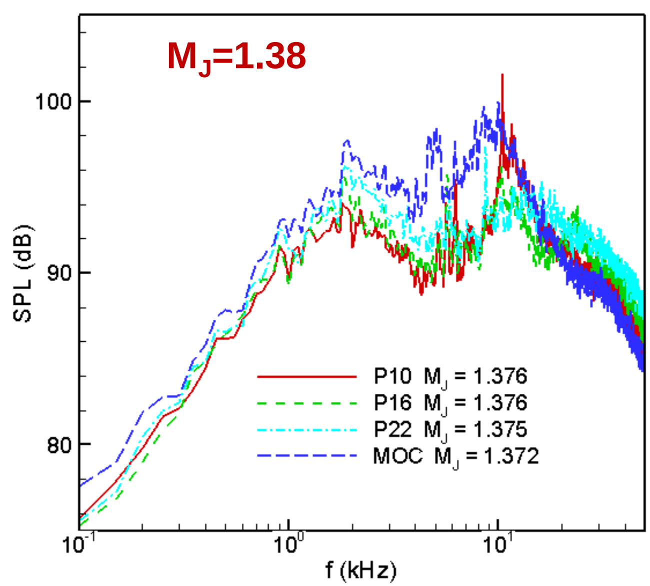
Red = No-Tab   Blue = Tab

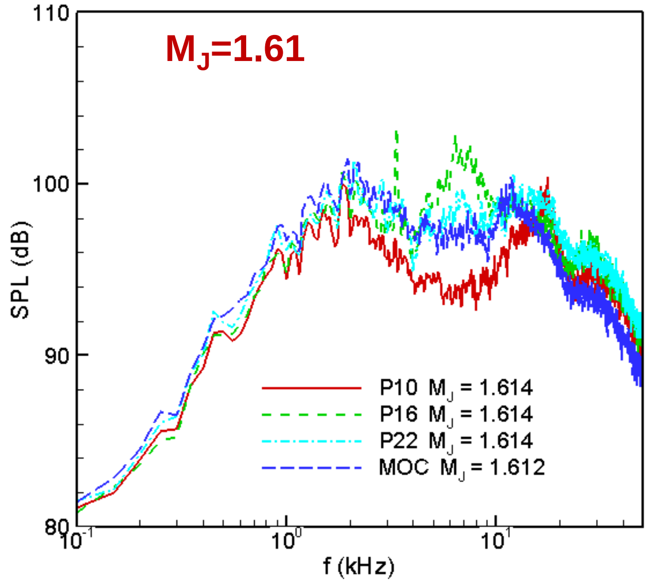


Effect of various plug shapes Tab

Crown location: -0.18 P10 P16 P22 MOC







At low M_J, trends same as seen with no Tab.

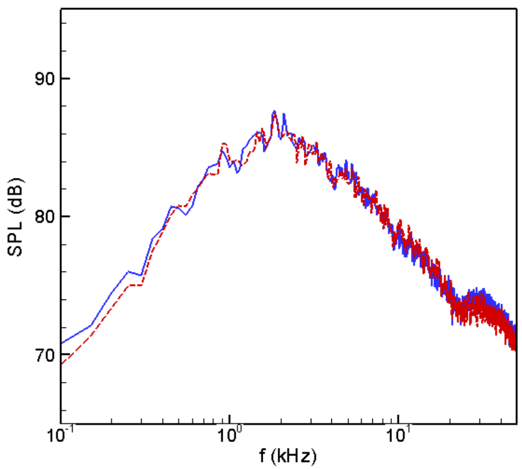
Overall, P10 is less noisy.

Porous plug data PRS2 vs P16 Tab

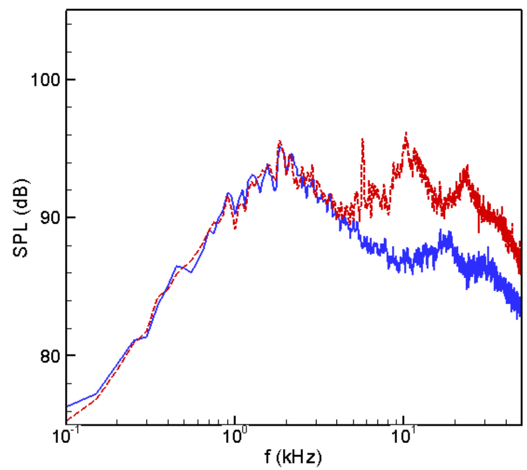
PRS2 = P16 with 0.037 holes 6% open

Red = Solid plug   Blue = Porous plug

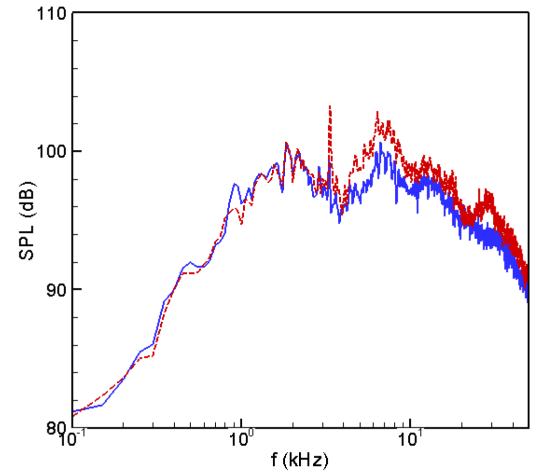
M_J=1.10

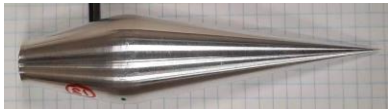


M_J=1.38



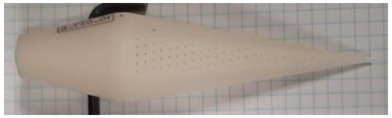
M_J=1.61

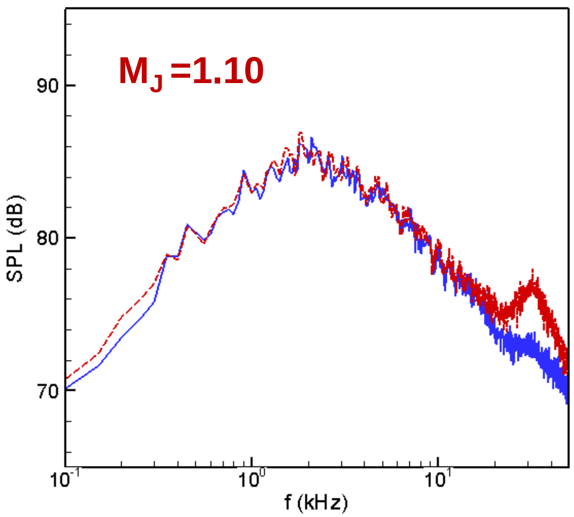


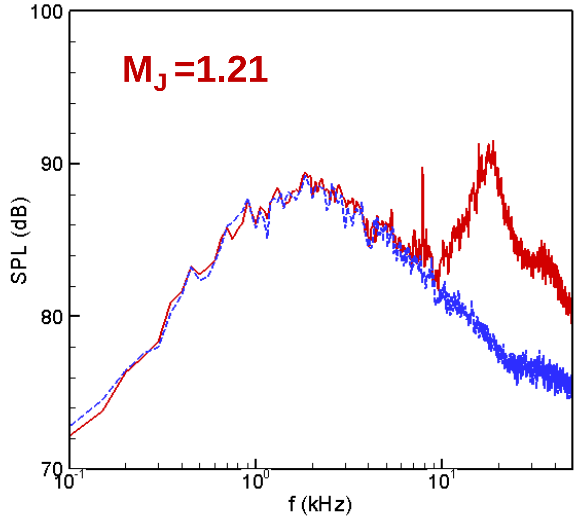


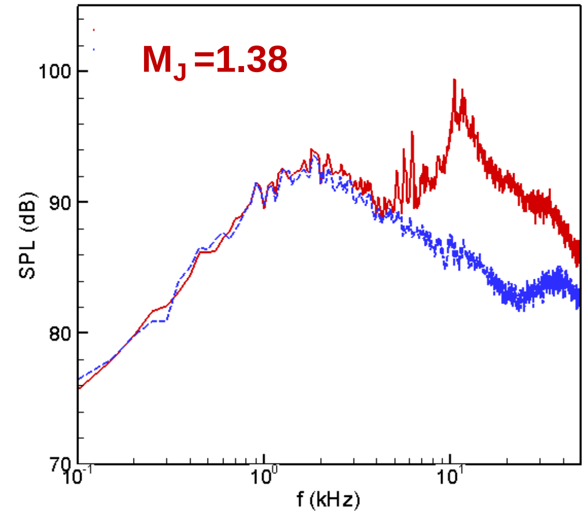
Porous plug data PRS6 vs P10 Tab

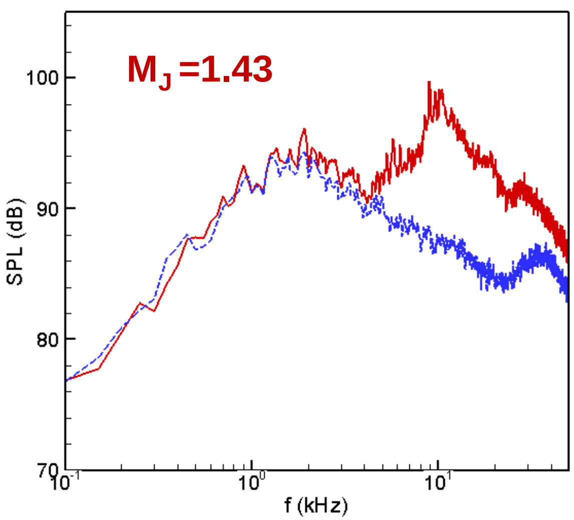
PRS6 = P10 with 0.037 holes 6% open

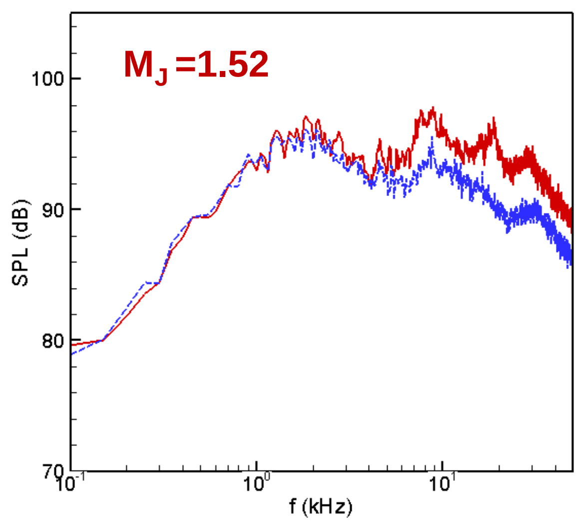


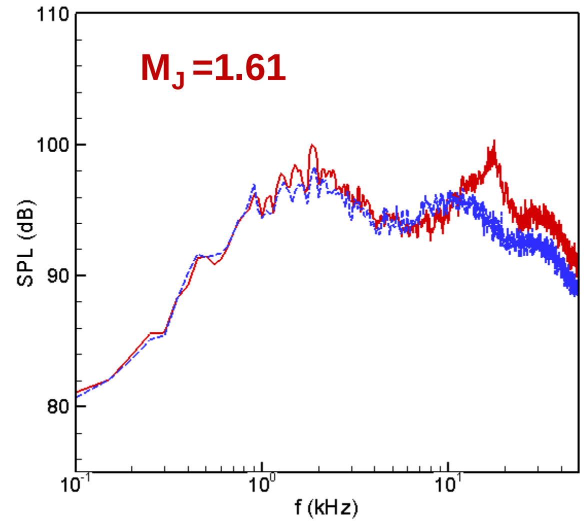




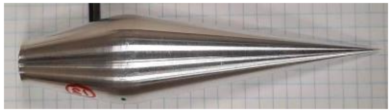








Most pronounced effect of porosity seen so far. Note: at M_J=0.90 no effect.



Schlieren PRS6 vs P10 Tab

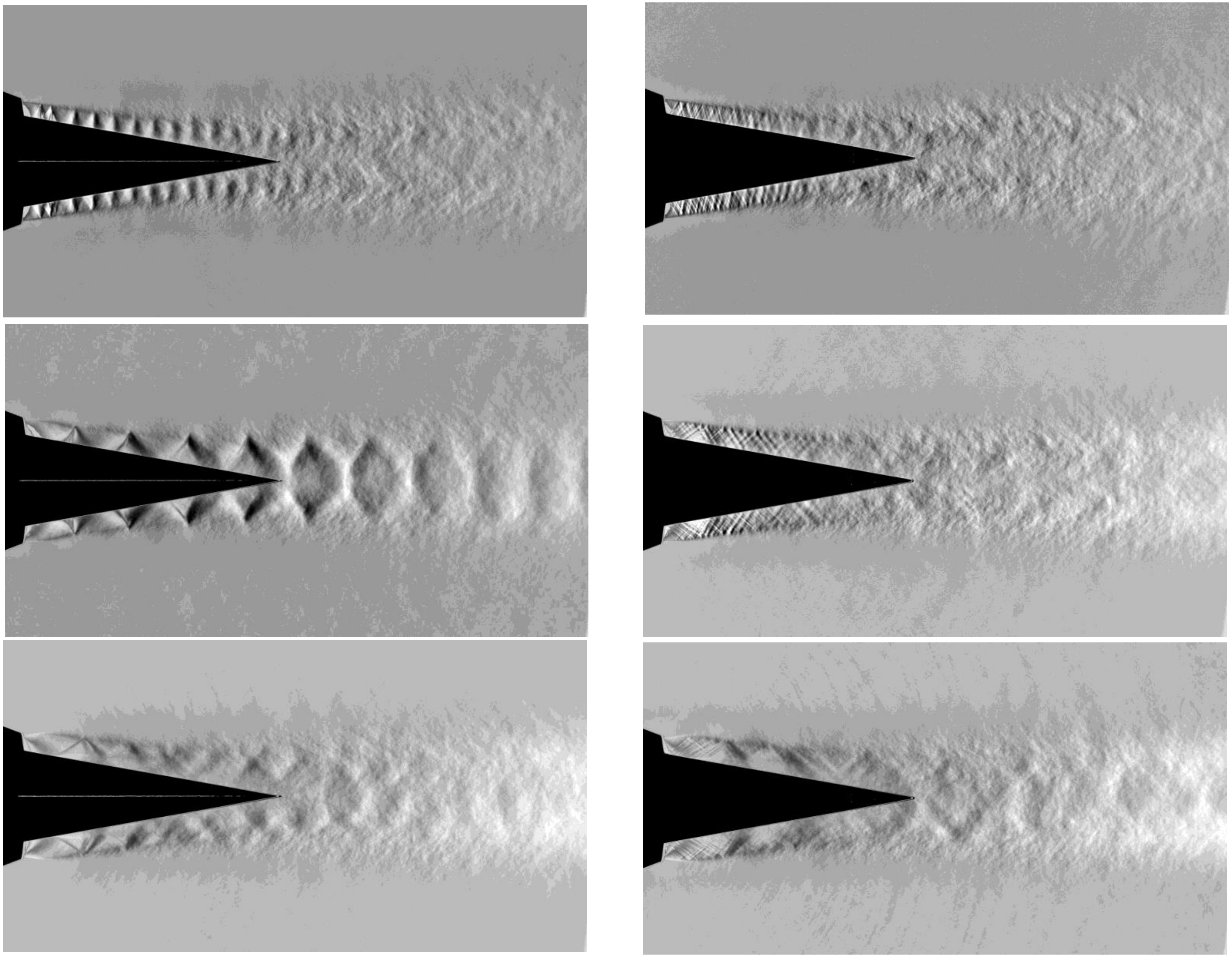
PRS6 = P10 with 0.037 holes 6% open

P10 | **PRS6**

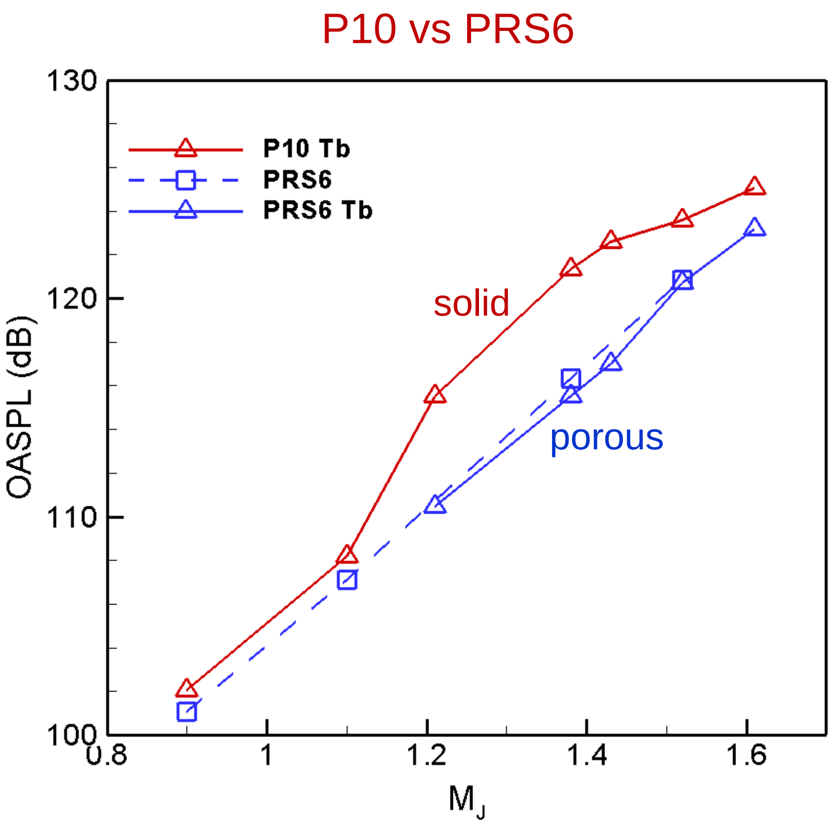
M_J=1.10

M_J=1.38

M_J=1.61

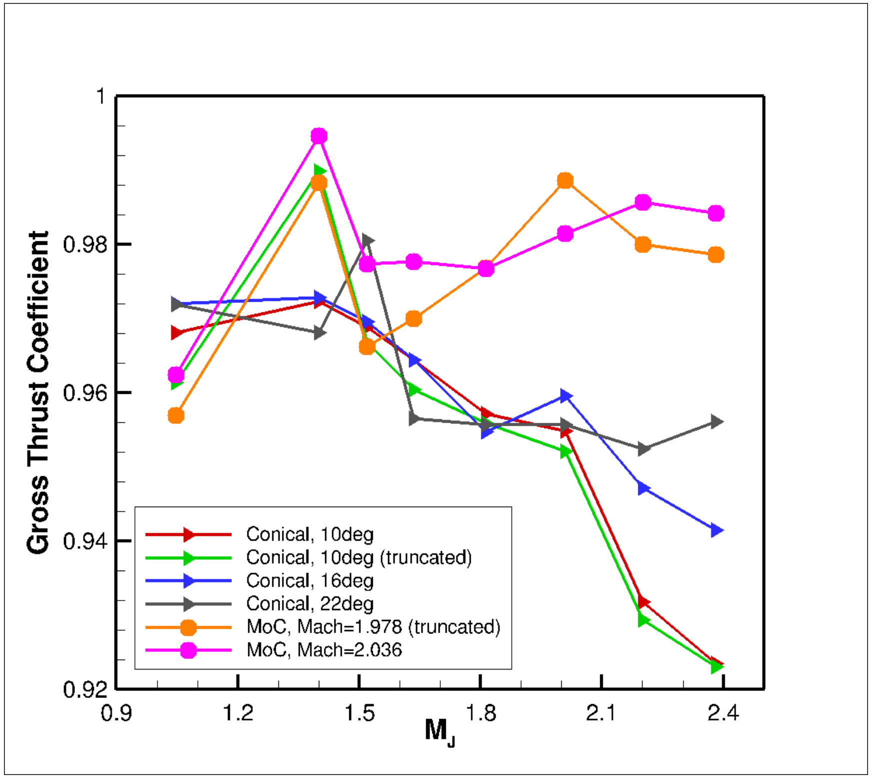


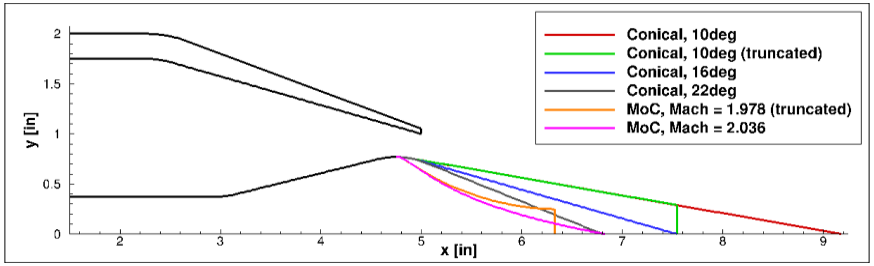
Effect of porosity on OASPL P10 case



OASPL reduction by 5 dB or so. Reduction occurs mostly by reduction in shocks and resultant elimination of BBSN.

CFD Results (Aviation 2021-2304)





CFD by Heberling using 'FUN3D'

Overall trend checked by Bridges using 'Solidworks'

Also spot checked by Jonathan Burt

Thrust of MOC and MCT are superior.

Conclusions

A long conic plug (P10) is good for noise at LTO but has bad overall thrust performance.

MOC with M_D=2 has good overall thrust performance but is bad for noise at LTO.

May need plug with changeable shape.

Porosity has prospect for additional noise attenuation.

Effect of various porosity on P10, M_J=1.38 Tb