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ADVANCED CONSIDERATIONS ON USING THE VACUUM AS A 'MATERIAL' IN AEROACOUSTICS

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INTRODUCTION

- VACUUM IS A ‘MATERIAL’ WHICH IS NOT YET USED IN AEROACOUSTICS
- NEVERTEHLESS, VACUUM BEGAN TO BE CONSIDERED FOR GROUND APPLICATIONS AT VARIOUS VACUUM INSULATION PANELS (VIP)
- IN 2017, AT THE CEAS-ASC AEROACOUSTICS WORKSHOP FROM DUBLIN WE PRESENTED A FIRST SOLUTION FOR USING THE VACUUM FOR NOISE REDUCTION IN FAN DUCT AND IN AIRCRAFT CABIN
- IN THIS PRESENTATION, A REVIEW OF THE FIRST SOLUTION IS DONE AND IN ADDITION, A SECOND SOLUTION ON USING THE VACUUM FOR REDUCTION OF NOISE GENERATED BY THE HELICOPTER MAIN GEARBOX AND REDUCER OF GEARED TURBOFANS IS PRESENTED.

OUTLINE

1. SOLUTIONS WHICH USE VACUUM IN AEROACOUSTICS
2. SITUATIONS WHERE VACUUM SOLUTION CAN BE APPLIED FOR NOISE REDUCTION ON AIRCRAFT
3. A CHIP TECHNOLOGY FOR GENERATING OF VACUUM ON AIRCRAFT
4. CONCLUSIONS

1. SOLUTIONS WHICH USE VACUUM IN AEROACOUSTICS

WE IDENTIFIED TWO SOLUTIONS OF USING THE VACUUM IN AEROACOUSTICS:

A. THE FIRST SOLUTION:

'SUCTION' OF INCIDENT NOISE ON A SURFACE

B. THE SECOND SOLUTION:

REDUCTION OF PROPAGATED NOISE POWER FROM A SURFACE TO ANOTHER SURFACE BY USING OF VACUUMED SPACE

1. SOLUTIONS WHICH USE VACUUM IN AEROACOUSTICS

A. THE FIRST SOLUTION: 'SUCTION' OF INCIDENT NOISE ON A SURFACE

- Preliminary idea was presented at the ASC-CEAS Workshop from Dublin (2017)
- At this solution, noise is sucked by very fine vacuumed holes. The holes have sharp edges (fig.1)
- Theoretically, on a surface with multiple micro-perforations, noise 'suction' should reduce the noise reflection coefficient R (fig.2).
- Simulations done in ACTRAN shown that for porosities of 25…50% and vacuum density $\rho_v = 0.001$ kg/m^3, transmission loss in a cylinder as presented in fig.3 is about 80%.
- In fig.4 acoustic velocities and pressures distribution is presented. It can be seen that using of vacuumed cavity (D=40mm) around the acoustic liner (Φ28 mm) leads practically to disappearing of the acoustic wave inside the liner.

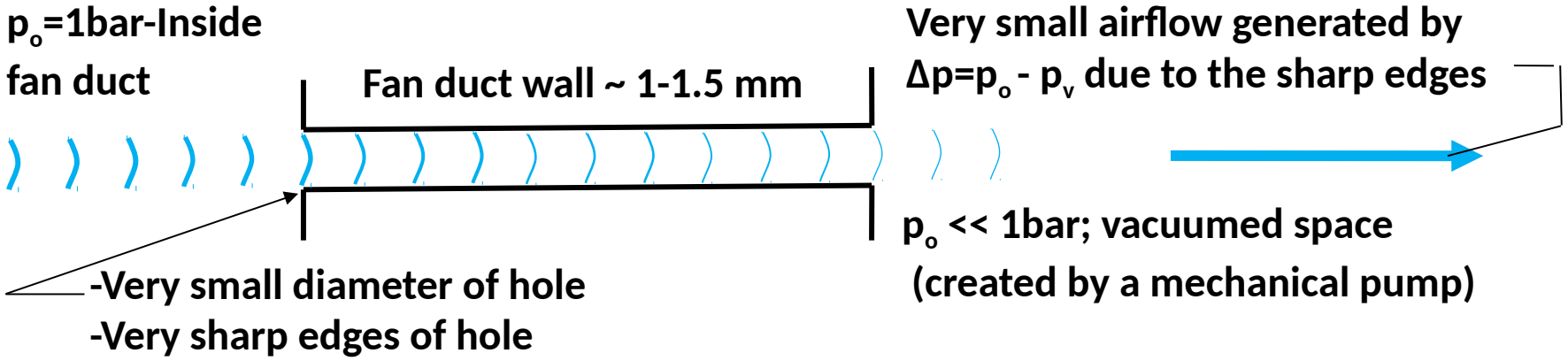


Fig.1- Scheme for understanding of 'suction' of noise by vacuum

1. SOLUTIONS WHICH USE VACUUM IN AEROACOUSTICS

A. THE FIRST SOLUTION: 'SUCTION' OF INCIDENT NOISE ON A SURFACE

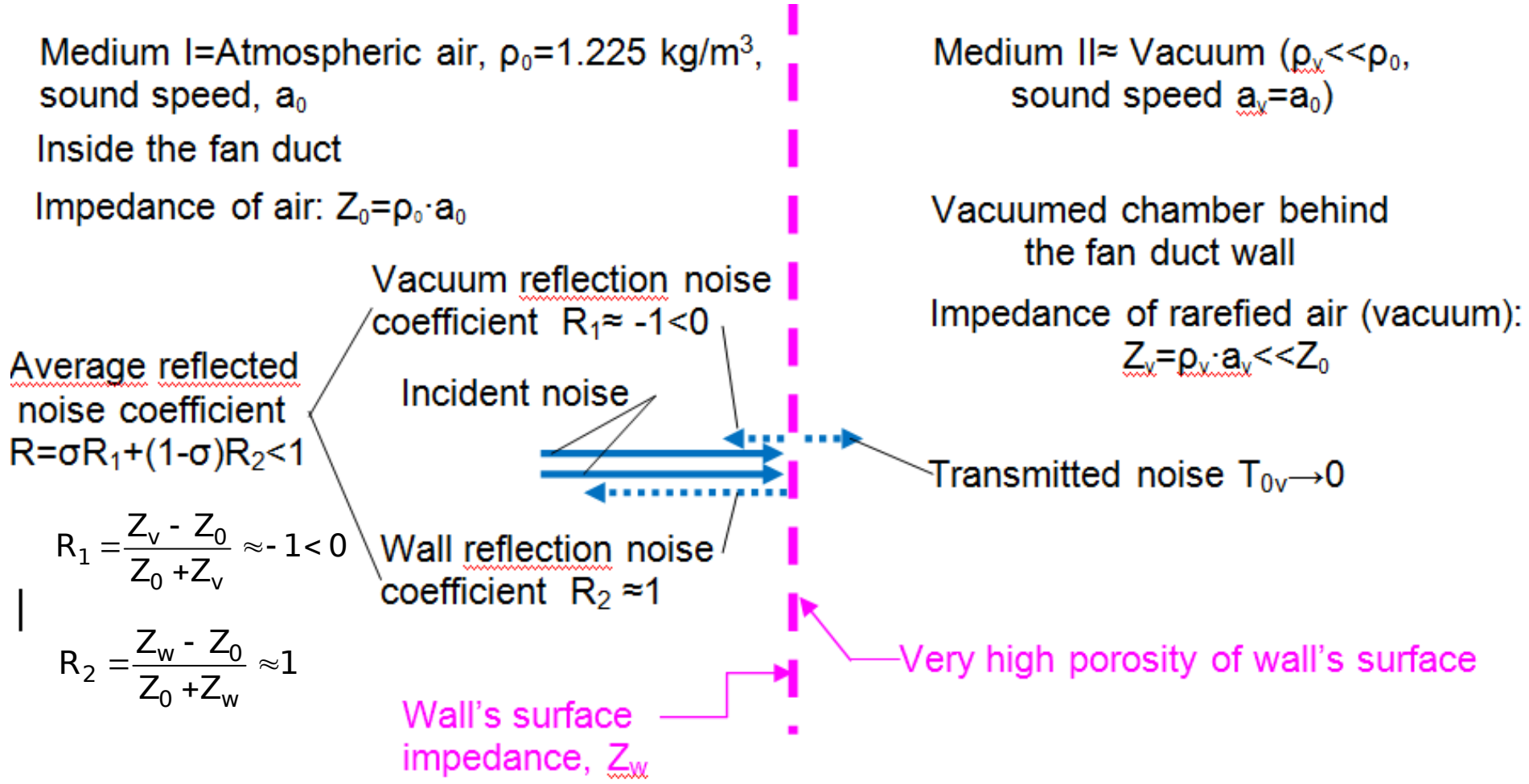
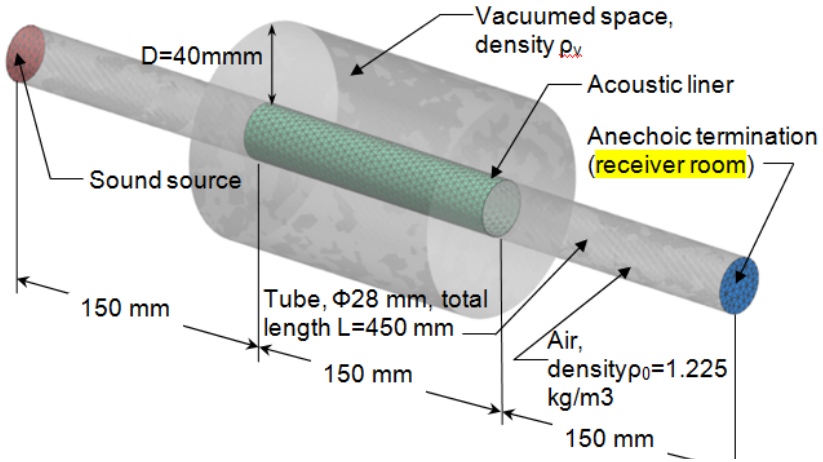


Fig.2- Scheme for understanding of reduction of reflection coefficient of fan wall duct

1. SOLUTIONS WHICH USE VACUUM IN AEROACOUSTICS

A. THE FIRST SOLUTION: 'SUCTION' OF INCIDENT NOISE ON A SURFACE



Transmission loss is ~80%

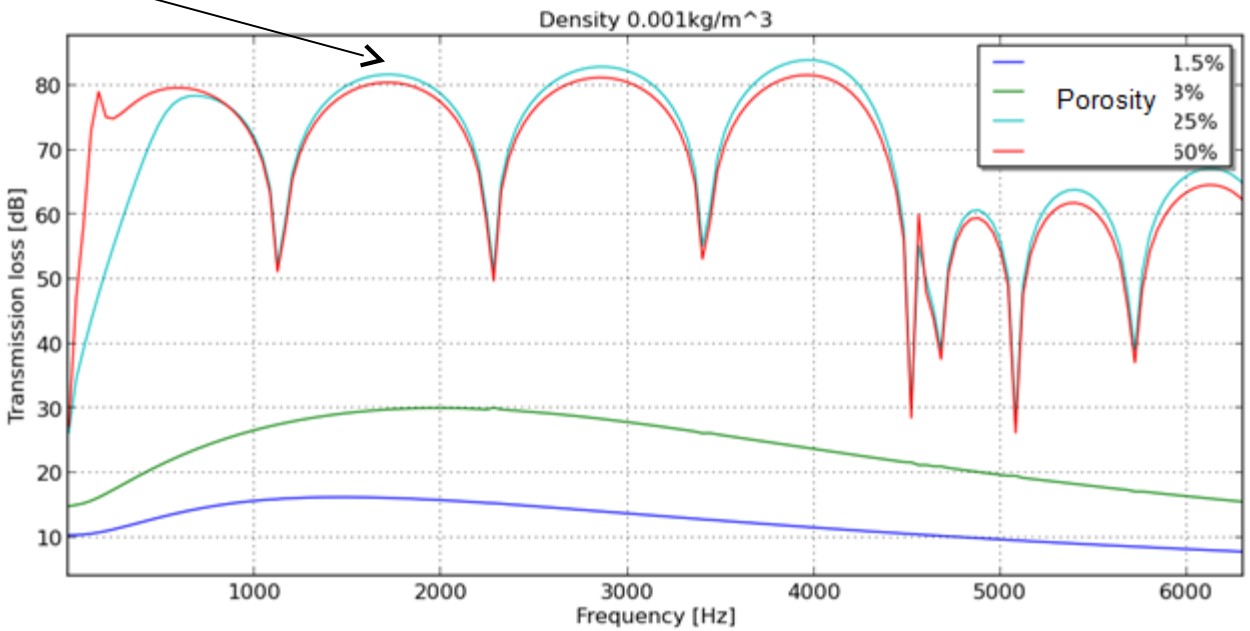


Fig.3-Simulations in ACTRAN: Transmission loss is ~80% in the case of a vacuumed acoustic liner with porosity 25%...50%

1. SOLUTIONS WHICH USE VACUUM IN AEROACOUSTICS

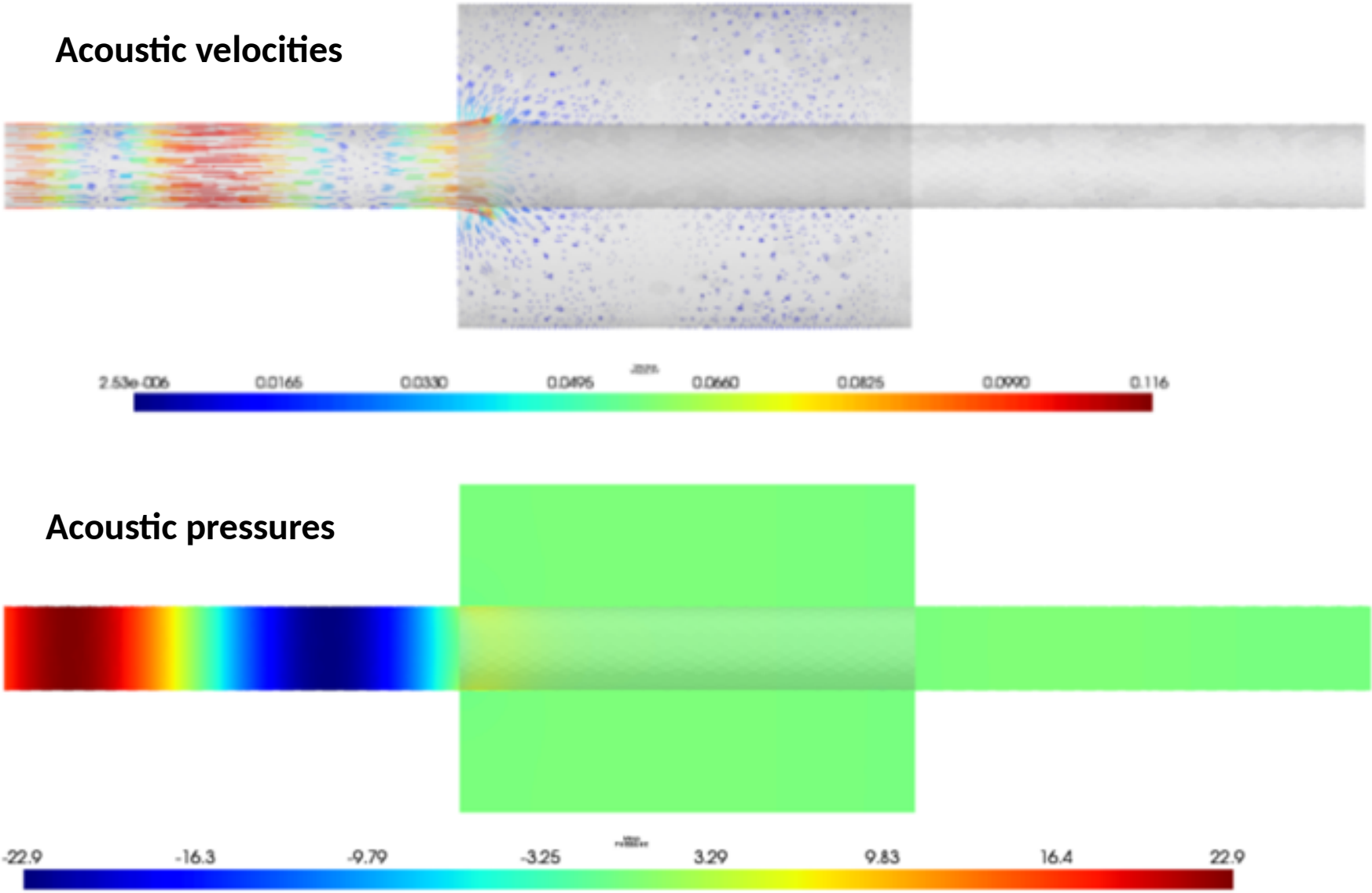


Fig.4-Simulations: Acoustic velocities and pressures in the case of previous vacuumed liner

1. SOLUTIONS WHICH USE VACUUM IN AEROACOUSTICS

B. THE SECOND SOLUTION: REDUCTION OF PROPAGATED NOISE POWER FROM A SURFACE TO ANOTHER SURFACE BY USING OF VACUUMED SPACE

- THIS SOLUTION IS APPLIED IN SOME GROUND APPLICATIONS (VACUUM INSULATION PANELS ('VIP') AND MODIFIED ATMOSPHERE INSULATION (MAI)- FIG.5, 6 ESPECIALLY FOR THERMAL INSULATION [1, 2].
- AT 'VIP', VACUUM IS CREATED BY SUCKING ALL THE AIR OF PANELS AND SEALING THEM TIGHTLY (SUBSTRATE IS A MICROPOROUS MATERIAL, GLASS FIBER ETC.)
- AT 'MAI', A POROUS SILICA CORE IS FILLED WITH STEAM, WHICH AS IT COOLES AND CONDENSES LEAVES A VACUUM.

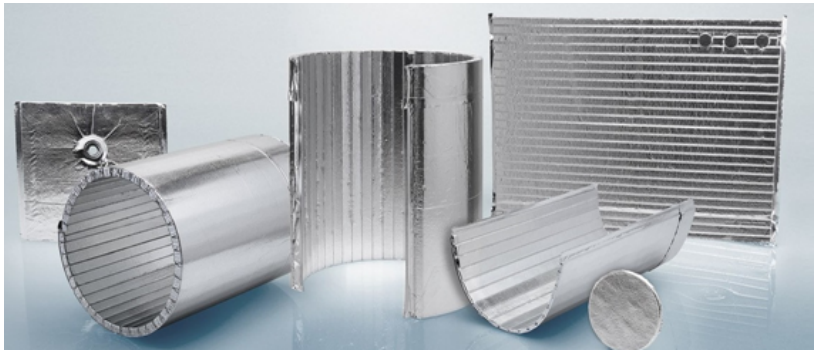


Fig. 5-Vacuum insulation panels (Microtherm), with a microporous substrate covered with an impermeable aluminum

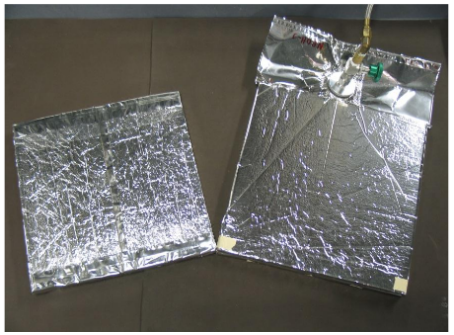
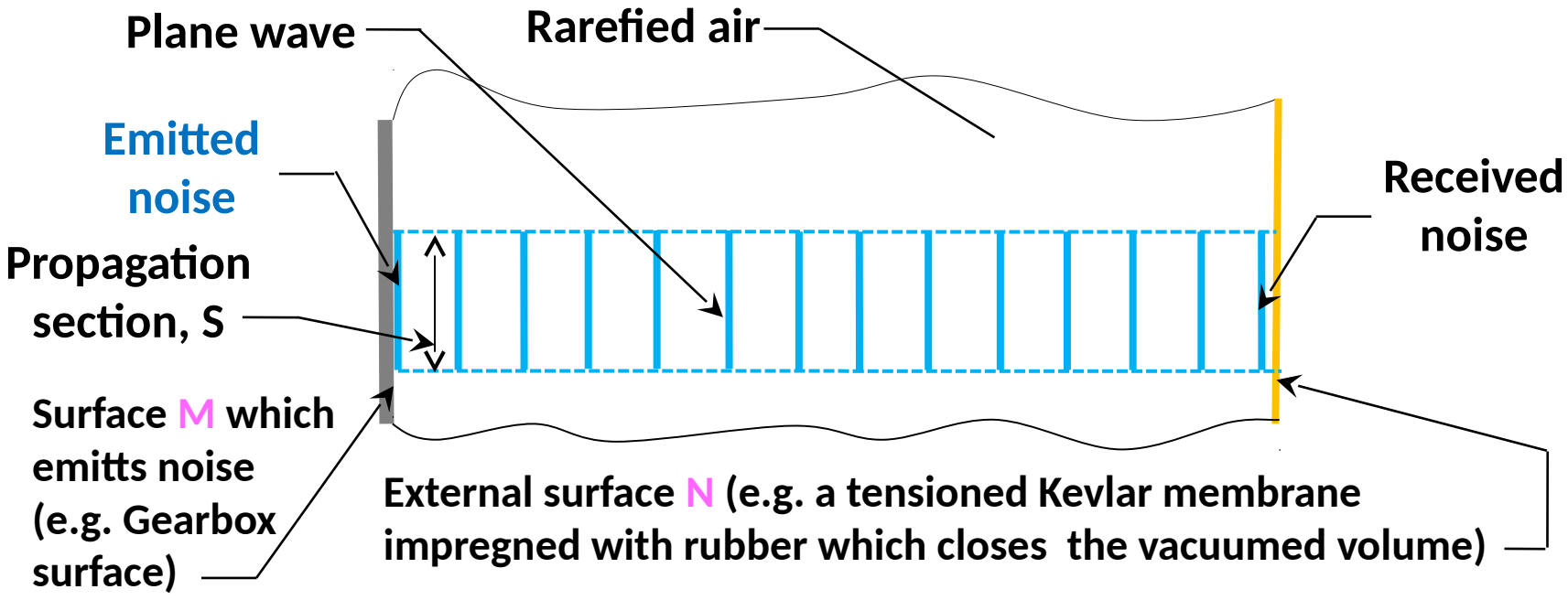


Fig. 6-Modified Atmosphere Insulation panels (MAI)

1. Sheldon WALTERS, Stephen DANCE, Noise Control Potential of Vacuum Isolation Panels, Inter. noise 2014, Melbourne, Australia, 16-19 November
2. https://www.buildinggreen.com/newsbrief/new-cost-effective-take-vacuum-insulation

1. SOLUTIONS WHICH USE VACUUM IN AEROACOUSTICS

B. THE SECOND SOLUTION: REDUCTION OF PROPAGATED NOISE POWER FROM A SURFACE TO ANOTHER SURFACE BY USING OF VACUUMED SPACE



The transmitted noise power depends directly by air density, ρ :

$$P=2\pi^2 \cdot S \cdot \rho \cdot A^2 \cdot \nu^2 \cdot a$$

Where,

P = Noise power transmitted by wave, W

S = Area of propagation section, m^2

ρ = Air density, kg/m^3

ν = Wave frequency, s^{-1}

A = Wave amplitude, m

a =Speed of sound

2. SITUATIONS WHERE VACUUM SOLUTION CAN BE APPLIED FOR NOISE REDUCTION ON AIRCRAFT

A. THE FIRST SOLUTION: 'SUCTION' OF INCIDENT NOISE ON A SURFACE. EXAMPLE: APPLICATION AT FAN NOISE REDUCTION

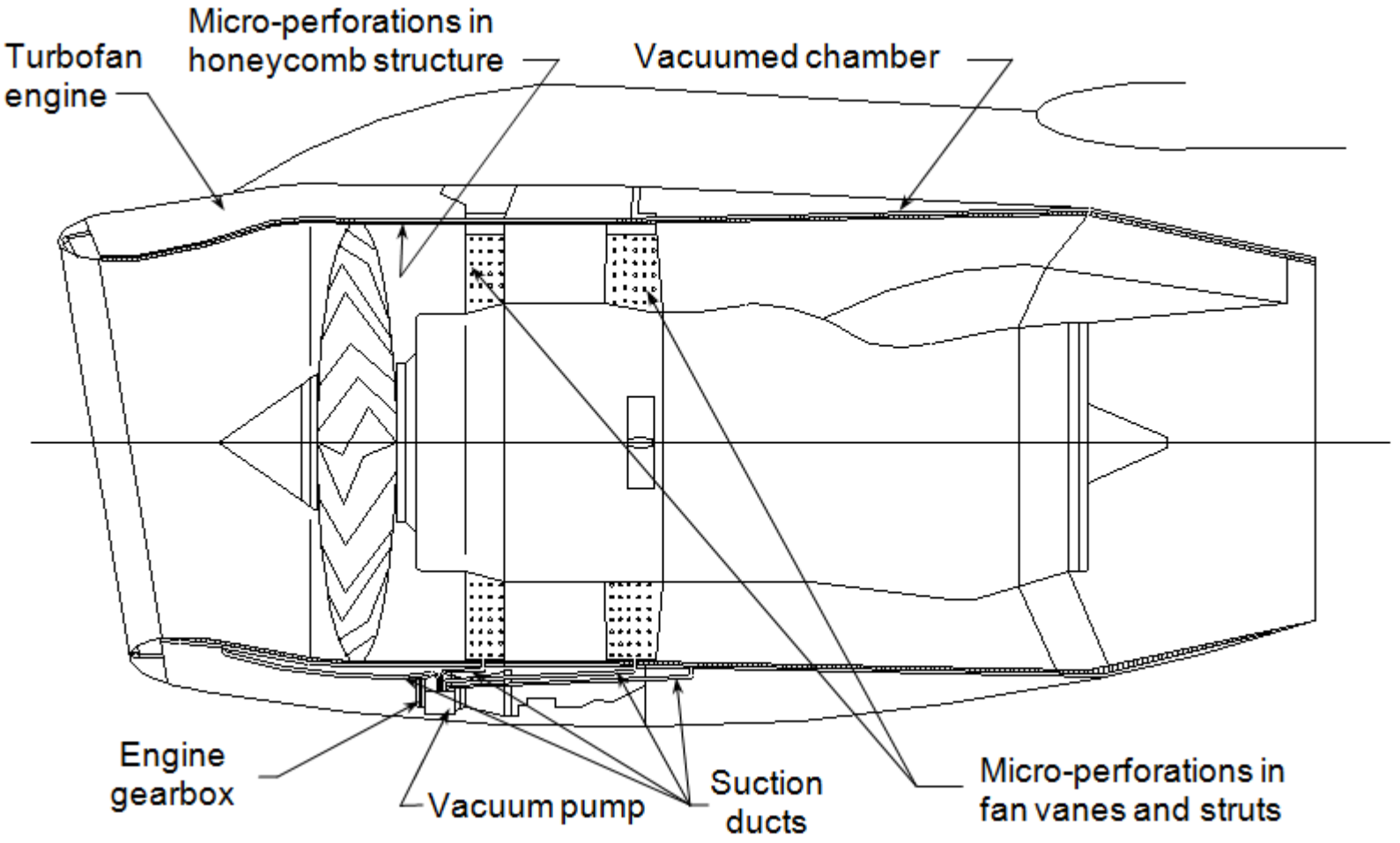


Fig.7-Vacuuming of micro-perforated areas of fan duct and fan vanes

2. SITUATIONS WHERE VACUUM SOLUTION CAN BE APPLIED FOR NOISE REDUCTION ON AIRCRAFT

B. THE SECOND SOLUTION: REDUCTION OF PROPAGATED NOISE POWER FROM A SURFACE M TO ANOTHER SURFACE N BY USING A VACUUMED SPACE.

EXAMPLE: BLOCKING OF NOISE RADIATED BY MAIN HELICOPTER GEARBOX

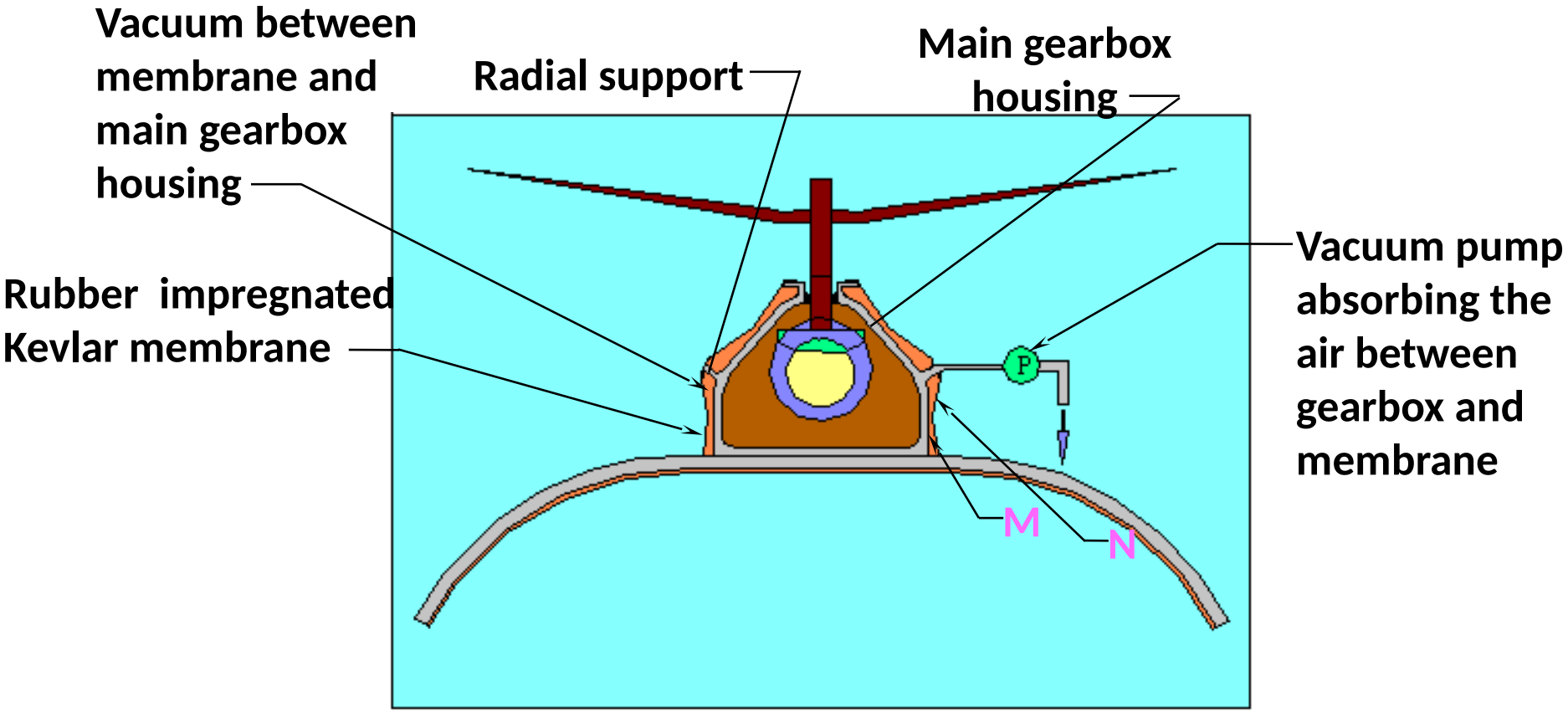


Fig.8-Vacuuming of space between the rubber impregned Kevlar membrane and the main gearbox of a helicopter

2. SITUATIONS WHERE VACUUM SOLUTION CAN BE APPLIED FOR NOISE REDUCTION ON AIRCRAFT

B. SECOND SOLUTION: REDUCTION OF PROPAGATED NOISE POWER FROM A SURFACE TO ANOTHER SURFACE BY USING OF VACUUMED SPACE-BLOCKING OF NOISE RADIATED BY FAN GEARBOX

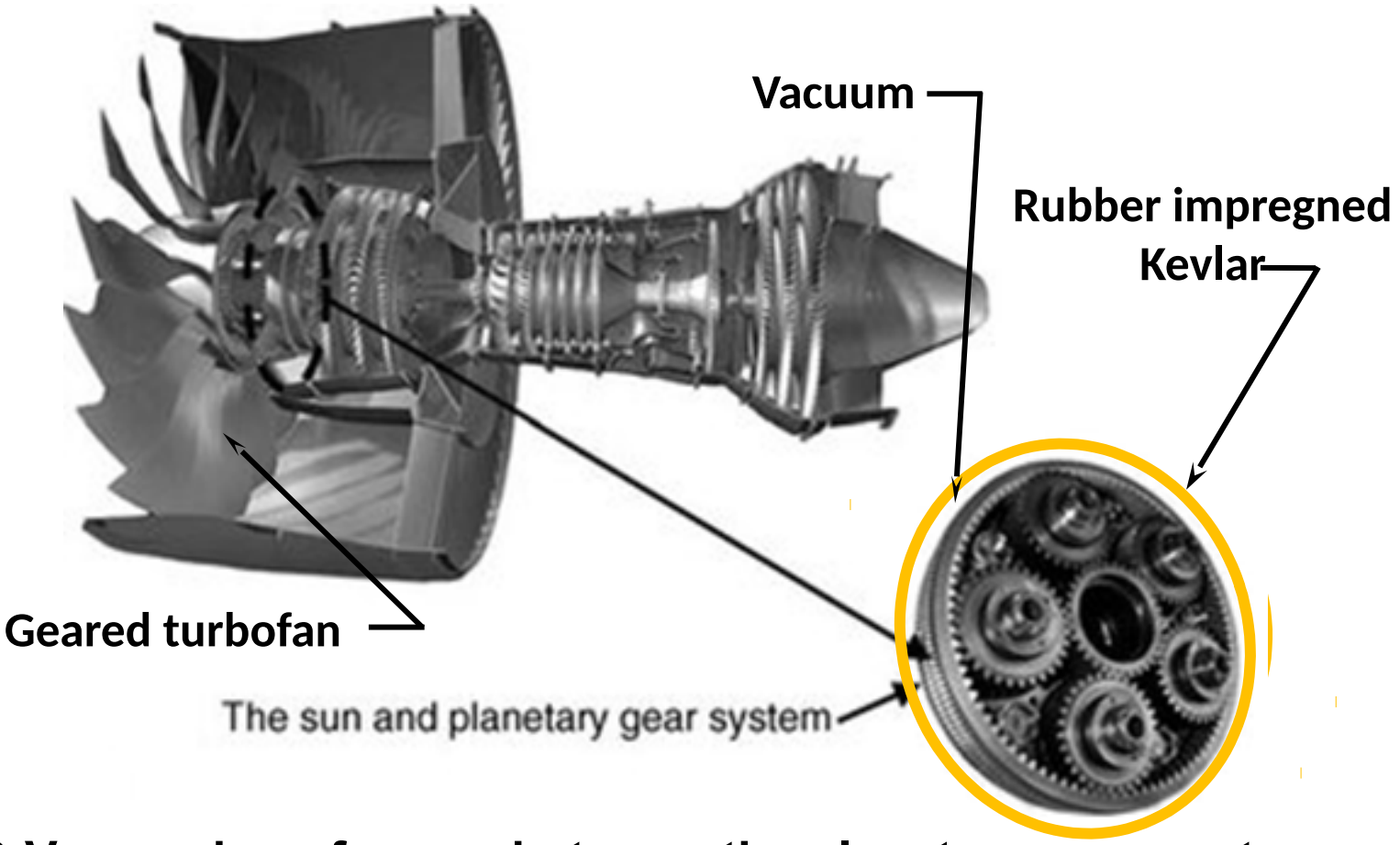


Fig.9-Vacuuming of space between the planetary gear system and the surrounding rubber impregnated Kevlar membrane

3. A CHIP TECHNOLOGY FOR GENERATING OF VACUUM ON AIRCRAFT

- VACUUM IS EASILY CREATED ON AIRCRAFT BY A MECHANICAL PUMP DRIVEN BY ENGINE (SEE FIG. 10 FOR VACUUMING THE FAN DUCT AND FAN VANES)
- THE MICROPERFORATIONS HAVE VERY SMALL DIAMETER (~Φ0.02 MM) AND VERY SHARP EDGES FOR REDUCTION OF ABSORBED AIR FLOW AND POWER CONSUMED BY THE VACUUM PUMP.

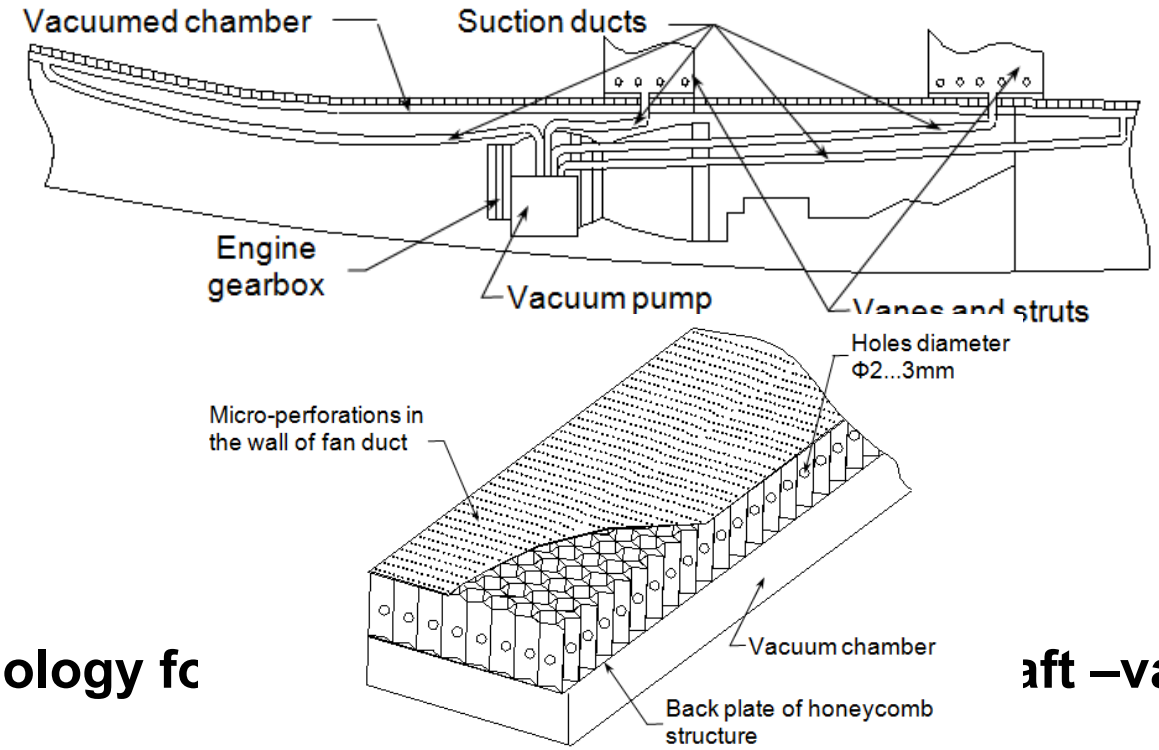


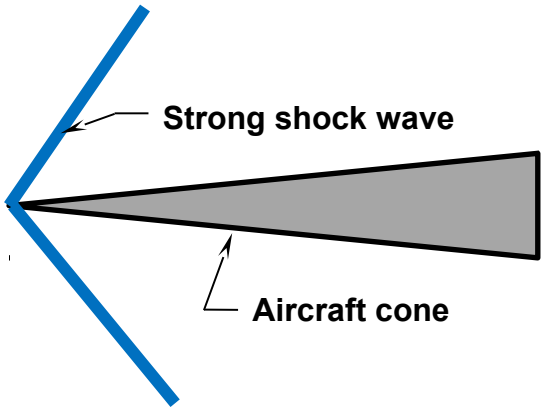
Fig.10-Technology fc aft –vacuum pump

4. CONCLUSIONS

- VACUUM SOLUTION IS ALREADY USED IN SOME GROUND APPLICATIONS
- SIMILAR SOLUTIONS WITH A SPECIFIC DESIGN SHOULD BE USED IN AVIATION, TOO
- TWO DIRECTIONS WERE IDENTIFIED FOT VACUUM APPLYING IN AVIATION:
  - -A. 'SUCTION' OF INCIDENT NOISE ON A SURFACE
  - - B. REDUCTION OF PROPAGATED NOISE POWER FROM A SURFACE TO ANOTHER SURFACE BY USING OF VACUUMED SPACE
- THE TWO SOLUTIONS CAN BE APPLIED FOR FAN NOISE REDUCTION, COMPRESSOR NOISE REDUCTION, CABIN NOISE REDUCTION, **SHOCK WAVE INTENSITY REDUCTION***, HELICOPTER GEARBOX NOISE REDUCTION ETC.

***A NEW SOLUTION FOR SONIC BOOM MITIGATION AT THE EUROPEAN SUPERSONIC BUSINESS JET**

The normal case ⊔ Strong shock wave ⊔ Strong sonic boom



The new solution ⊔ Vacuumed laser micro-holes on cone and wing surface ⊔ weak shock wave ⊔ weak sonic boom

Weak shock wave generated due to the low reflection coefficient R_w caused by vacuumed micro-holes on surface W