Sonic Boom reduction of supersonic aircraft

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1 Introduction

The concept of supersonic aircrafts and jet engines come from the age after the second world war and pushed the speed limits of aircrafts forward. Supersonic flight has always been a topic of great interest due to the potential to reduce inter-continental travel time. However a long row of problems arose and hampered the development of the supersonic aircraft and in the end only two civilian aircraft ever became operational, the Concorde and the Tupolev Tu-144. One of the problems that severely limited the use of supersonic aircrafts was the Sonic Boom. When breaking the sound barrier a high energy shock wave is created trailing the aircraft. Although not heard by anyone in the plane it's a big nuisance on the ground. It is heard as a loud explosion or boom, can shatter windows and makes animals panic. Therefore Supersonic flight is banned over most countries, limiting the possible supersonic flight routes of the Concorde (when it was still flying) just above water. Removing or reducing the Sonic boom is therefore of great interest if it could lead to supersonic flight above land.

This article will not discuss the change in properties when an airplane travels from subsonic to supersonic flight, but rather try to explain the different solutions for reducing the sonic boom that exist to be able to fly above land.

2 Reduction of sonic boom

There are several ways to reduce the sonic boom, all of the solutions aim to achieve a desirable shape of the aircraft. A critical part is the installation of the engines. By installing them on top of the wings the sonic boom can be diffused upwards instead of towards the ground, however, this will cause some performance penalties. The engine can instead be placed on the centerline above the wing to avoid this problem. The most common way to install the engines are below the wings, in which case the wings need to be tailored to different types of delta shaped wings or a highly swept wings. [1] It is not only the placement of the engines that affect the sonic boom it is also the nozzle. The contribution from the nozzle can be reduced by installing a convergent-divergent nozzle on the exit of the engine [2].This installation increases the area of affect that the pressure is distributed over when the shock wave reaches the ground.The same effect can be observed at higher altitudes.[3] Another way to reduce the sonic boom is to make the fuselage sleeker, many design are focusing on the nose of the aircraft, such as the project Quiet Spike that Gulfstream Aerospace and NASA developed[4]. There is some research about minimising the turbulent flow over the wing, that produces the shock waves. This should be done with special airfoils that are constructed to induce laminar flow control, this would mean that the leading edge of the wing will remain in subsonic state when the plane flying at supersonic speeds.[5]

3 Quiet Spike

Quiet Spike: The name that Gulfstream gave to the telescoping nose-boom concept, which it began developing in 2001. Quiet spike is a telescoping forward fuselage extension that alters the bow shock of the classic N-wave pressure signature generated by aircraft traveling at supersonic speeds[6]. This Quiet Spike shows a significant potential for reducing the sonic boom by creating just a mild nose shock. This is done by producing weak shock from its narrow tip followed by cross-section transition between the adjacent telescoping section. Thereby developing an asymmetrically shaped, less powerful pressure wave, that propagates parallel to the ground. [4]

4 Quiet Supersonic Technology

Since the Quiet Spike project, NASA has shifted their focus towards a low boom flight demonstration (LBFD) aircraft. Together with Lockheed Martin, NASA is working on the Quiet Supersonic Technology Experiment Aircraft, that aims to reduce the sonic boom. Their main goal with this project is to "Beat the Boom" and improve the experience of those on the ground, that deal with a supersonic aircraft flying

over them. As described by NASA, the QueSST is a preliminary design concept of the unique X-plane. Currently the design is based on computer models in order to confirm that all the pieces of the aircraft will come together properly, for a future real aircraft. The X-plane has a long nose with highly swept wings and a sleek fuselage.[7]
One of the milestones for the NASA-Lockheed team was to verify the aerodynamic performance predictions for the fuselage, control surfaces, and the nacelle diameter. To investigate these predictions the team built a scale model of the QueSST X-plane for wind tunnel testing, at the NASA Glenn Research Center. As of 4th September 2017, NASA claimed to have successfully accomplish their milestone of fulfilling the LBFD for the QueSST X-plane. Which was to reduce the sonic boom created to a softer "thump" instead, while flying at supersonic speeds. The next step for the NASA-Lockheed team is to initiate proposal acceptance procedures in order start awarding contracts for the construction of the X-plane. NASA claims this process will start as early as next year and during this process, the data for the preliminary design review will also be made available to successful bidders. This is a huge step forward in the field of supersonic flight and test flights can be expected as early as 2021. [8]

5 Conclusion

The interest in supersonic flight has picked up in recent years [9]. NASA has been working for a long time on reducing the sonic boom with different methods and has recently awarded Lockheed Martin with a contract to design a supersonic experimental aircraft, the QueSST X-plane [10].

Physics tells us that we can never get rid of the sonic boom altogether but these experiments show that it can be reduced and that the sound can be made softer for the human ear. Whether this is enough to make supersonic flight over land possible remains to be seen. If that is the case, there might just be a market for supersonic airliners again.

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REFERENCES

[1] Frank Jennings Jr K L R. Nasa centers team up to tackle sonic boom.
URL https://www.nasa.gov/aero/centers_tackle_sonic_boom.html

[2] Raymond Castner T L. Exhaust plume effects on sonic boom for a delta wing and a swept wing-body model.
URL https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20120009202.pdf

[3] Seebass R. Sonic boom theory. *Journal of Aircraft*, vol. 6, no. 3, pp. 177–184, 1969.

[4] Donald C Howe D F Frank Simmons. Development of the gulfstream quiet spike™ for sonic boom minimization.
URL http://highorder.berkeley.edu/proceedings/aiaa-annual-2008/paper0357.pdf

[5] Gonzalez C. Supersonic flight: Overcoming the sonic boom.
URL http://www.machinedesign.com/defense/supersonic-flight-overcoming-sonic-boom

[6] Donald Howe G A C D F G A C Gulfstream Aerospace Corporation; Frank Simmons III. Development of the gulfstream quiet spike tm for sonic boom minimization.
URL https://arc.aiaa.org/doi/pdf/10.2514/6.2008-124

[7] Harrington J. Nasa completes milestone toward quieter supersonic x-plane.
URL https://www.nasa.gov/press-release/nasa-completes-milestone-toward-quieter-supersonic-x-pl

[8] Russell J. The quesst for quiet.
URL https://www.nasa.gov/feature/the-quesst-for-quiet

[9] Paur J. Taking the sonic boom out of sonic flight.
URL https://www.wired.com/2010/07/aerospace-giants-design-supersonic-jets-with-a-silent-b
,keywords=

[10] Harrington J. Nasa begins work to build a quieter supersonic passenger je.
URL https://www.nasa.gov/press-release/nasa-begins-work-to-build-a-quieter-supersonic-passenge