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Focusing of expansion waves

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Abstract – Focusing of Expansion Waves

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The flow field which results from an expansion wave entering a cavity, and the focusing effect which occurs was studied using both numerical and experimental methods. Previous research into cavity flows has looked at shock waves entering a cavity as well as shock wave focusing phenomenon; however no previous work on expansion wave cavity flows was found. The type of flow was analysed for different cavity geometries, different expansion wave pressure ratios and different expansion wave widths. The numerical work was done using the commercial CFD codes, Ansys Fluent and STAR CCM+. An inviscid solver was found to be sufficiently accurate to model the flow. The experimental work was performed using a unique shock tube with windows at the diaphragm and in the driver section. A number of sub-studies were done during the development of the shock tube. These included a short study on the use of different materials as a diaphragm in a shock tube in order to get the best possible expansion wave for the experiments. Hundred micron thick aluminium sheets were found to give the best burst as it responded well to scoring and once scored gave a consistent symmetrical burst. Another study was performed into the straightening of an initially curved expansion wave. This was done to try and improve the experimental results as a diaphragm will always have some curvature at burst resulting in an initially curved expansion wave. It was found that by curving the walls of a shock tube the leading edge of an expansion wave could be made to straighten faster, however this introduced additional undesirable two-dimensional waves behind the leading edge of the expansion which resulted in a simple straight walled shock tube being used in the experiments.

The numerical and experimental work showed that a focus region forms when an expansion wave enters a cavity, and this region has very low fluid property values, especially temperature and pressure. The basic focus region can be described as a region of flow enclosed by compression or shock waves in which two dimensional expansion waves repeatedly reflect to create very low pressures and temperatures. The effect of an initially curved expansion wave was considered and it was found that the flow is significantly affected by the shape of the expansion. For a plane expansion wave a focus region develops in the driver section of the tube and collapses towards the end of the driver. For a curved expansion wave the focus region develops at the centre of the curvature. The pressure ratio over the expansion wave was also studied by changing the initial diaphragm pressure ratio in the shock tube. It was found that as the wave strength was increased, the focusing happened later and was stronger until the pressure ratio was sufficiently high for supersonic flow to occur. At this point the focusing changed, most significantly for the cylindrical cavity where the flow pattern seen for subsonic flow disappeared completely, and was replaced by a different focusing pattern. The width and thus the gradient of the expansion wave was also found to be important as once the expansion wave starts to widen, the focusing becomes significantly weaker and may not even be noticeable.