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Study of Unsteady Behaviour of Dynamic Shock Systems in Supersonic Engine Intakes

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Abstract : An analytical investigation is performed to study the unsteady response of a one-dimensional, non-linear dynamic shock system to external downstream pressure perturbations in a supersonic flow in a varying area duct. For a given pressure ratio across a wind tunnel, the normal shock's location can be computed as per one-dimensional steady gas dynamics. Similarly, for some other pressure ratio, the location of the normal shock will change accordingly, again computed using one-dimensional gas dynamics. This investigation focuses on the small-time interval between the first steady shock location and the new steady shock location (corresponding to different pressure ratios). In essence, this study aims to shed light on the motion of the shock from one steady location to another steady location. Further, this study aims to create the foundation of the Unsteady Gas Dynamics field enabling further insight in future research work. According to the new pressure ratio, a pressure pulse, generated at the exit of the tunnel which travels and perturbs the shock from its original position, setting it into motion. During such activity, other numerous physical phenomena also happen at the same time. However, three broad phenomena have been focused on, in this study - Traversal of a Wave, Fluid Element Interactions and Wave Interactions. The above mentioned three phenomena create, alter and kill numerous waves for different conditions. The waves which are created by the above-mentioned phenomena eventually interact with the shock and set it into motion. Numerous such interactions with the shock will slowly make it settle into its final position owing to the new pressure ratio across the duct, as estimated by one-dimensional gas dynamics. This analysis will be extremely helpful in the prediction of inlet 'unstart' of the flow in a supersonic engine intake and its prominence with the incoming flow Mach number, incoming flow pressure and the external perturbation pressure is also studied to help design more efficient supersonic intakes for engines like ramjets and scramjets.

Keywords : analytical investigation, compression and expansion waves, fluid element interactions, shock trajectory, supersonic flow, unsteady gas dynamics, varying area duct, wave interactions
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