Determination of critical distributed roughness height inducing transition on AEDC cone at transonic/supersonic speed in CIRA PT-1 Wind Tunnel

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Abstract

1. Analysis of scenario

The present work fits in the aerodynamic investigation of thermal protection system (TPS) of re-entry vehicles subjected to extremely high convective heat causing severely increase of wall surface temperature of the vehicle. Since the action of the turbulent boundary layer on the vehicle surface makes the convective thermal loads five times higher than a laminar flow, an inaccurate estimation of transition causes two disadvantages: the use of excessive thermal protection, with consequent increase of weight and reduction of payload, and the employment of expensive material able to support high thermal load.

This work improves the understanding of the transition mechanisms in transonic/hypersonic flow analyzing the effects of Mach number, Reynolds number, roughness height and transition trip position on laminar-turbulent transition induction on AEDC cone.

With this purpose an appropriate experiment is designed and performed in CIRA PT-1 wind tunnel, in transonic/hypersonic flow.

2. Statement of the problem

Within this context, a special test activity has been developed with two main purposes: to develop experience, software and techniques for transition detection ,that will be used during the future test campaign, and to determine the minimum transition trip height inducing transition on a 3D model reducing drag increase caused by friction resistance due to trip transition presence; this rise, in fact, involves less accuracy in extrapolation from Wind Tunnel to flight.

3. Adopted methodology

The experimental facility is the closed-circuit pressurized PT-1 Transonic Research Tunnel.

A Modern Design Of Experiment (MDOE) approach has been adopted; this formal method of empirical investigation allows to save costs and time.

Transition detection has been performed with infrared technique by means of ThermoVision A230G infrared camera, ThermaCAM Reserchер Professional software and a MATLAB code, able to correlate 2D images and 3D cone model, generated by the candidate for the purpose.

4. Main results

Transition position has been detected for each of 108 infrared images acquired.

The effects of Reynolds number, roughness size, transition trip position and Mach number on transition induction and location have been evaluated and found in agreement with literature data.

Moreover the trend of minimum roughness size inducing transition has been evaluated obtaining useful response: rise in Mach number and forward transition trip positions involve a reduction of roughness height necessary to induce transition. This result seems to be very important because it allows to reduce drag increase caused by friction resistance due to trip transition presence As a consequence, much accuracy in extrapolation from PT-1 Wind Tunnel to flight will be possible.

For the next future analogous full scale experiments are planned in the Perdue Mach-6 Quiet-Flow Ludwieg Tube with the aim to compare the results in order to estimate the effects of wind tunnel turbulence.