COUPLING OF BLOWING AND ROUGHNESS EFFECTS IN THE SPALART-ALLMARAS TURBULENCE MODEL

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INTRODUCTION

During a high speed atmospheric re-entry Thermal Protection System can ablative and develop roughness. A review of surface roughness and blowing influence on aerothermodynamics reveal these effects to be significant, and thus it is important to set up an extended model taking into account both of them. The model for a flow in a turbulent boundary layer on a rough surface was constructed earlier based on the extension of the Spalart–Allmaras turbulence model (Spalart, Aupoix). One of the main suggestions of the Spalart–Allmaras turbulence model is the logarithmic velocity profile in the boundary layer, which is shifted for a rough surface depending on the roughness height. In this study the possibility of taking into account both roughness and blowing in the Spalart–Allmaras model is analyzed. The approach is based on the modification of the variables and boundary conditions of the base Spalart–Allmaras model in the way similar to description of the roughness effects in the Spalart-Allmaras-Aupoix approach. Two ways of including the effect of roughness are considered which use two different velocity laws. The first one uses the formula of Ilegbusi for the velocity which describes the both effects of blowing and roughness. The second one uses the bilogarithmic law for the velocity which holds in case of blowing.

DESCRIPTION OF THE MODEL

1. BILOGARITHMIC LAW FOR THE VELOCITY IN CASE OF BLOWING

In the limit region (far from the wall):

\[ \vec{v} = \vec{v}_b + \vec{v}_f \approx \vec{v}_b + \vec{v}_f \]

Thus, the dependence is defined:

\[ \vec{v}_b = \phi \left[ \Delta \vec{v} \left( h^* \right) \right] \]

From the Spalart–Allmaras model:

\[ \tau_b = \phi \left( \Delta \vec{v} \left( h^* \right) \right) \]

2. THE VELOCITY LAW OF ILEGBUSI

The limit case:

\[ \vec{v} = u_s \vec{y} \]

Boundary conditions:

\[ \vec{v} = \vec{v}^*_b \] at the wall

\[ \vec{v} = \vec{v}^*_f \] \( \left( y^* \left( h^* \right) \right) \) in the limit region

REFERENCES


ACKNOWLEDGEMENTS