DIRECT SIMULATION OF FREE MOLECULAR FLOW IN FULLY 3-D AXIAL ROTOR

A. Amoli, M. Hoseinalipour

Department of Mechanical Engineering, Iran Univ. of Science and Tech., Tehran, Iran

R. Ebrahimi

Department of Mechanical Engineering, K.N. Toosi Univ. of Tech., Tehran, Iran

E-mail*: ali_amoli@hotmail.com*

ABSTRACTS

Free molecular flow within fully 3-D single rotor is simulated using Monte Carlo method. The real topology of the rotor including blade-casing clearance and blade thickness is addressed in this simulation. Good agreement between numerical results and known experimental data confirms the validation of presented algorithm. The parametric study for numerous sets of blade geometries yields designing curve that suggests optimum compression ratio or pumping speed for desired conditions. The designing curve shows that for maximum pumping speed, the prior stages of turbomolecular pump should have large number of blades with high height and large angel, while the later stages must be designed with short height, small angle and great spacing for high compression.

INTRODUCTION

The methods employed in vacuum technology for the compression of gases are generally different from those used in other branches of engineering. Special pumps are necessary in order to vacuum an enclosure by capturing the gas inside it and transmitting it from the enclosure to the high-pressure side. In the high (10^{-3} to 10^{-7} mbar) and ultra-high vacuum range (below 10^{-8} mbar) the turbomolecular pump (TMP) is widely used for provision of cleaner and higher vacuum environment comparing with oil-diffusion pumps.

The TMP consists of two main parts namely, rotor and stator. The rotor consists of a couple of blade rows which establishes a density difference by acting as a barrier of different permeability to the molecules incident from its high- and low -density sides. With appropriate blade geometry, molecules incident upon the blades from upstream side have greater probability of being transmitted through the blade row than molecules incident from the downstream side.

The pumping performance of TMP in free molecular flow has been investigated experimentally and theoretically by Kruger.[1] His study was based on parallel flat-plate blades with infinite height, and calculations were made on single-row and multi-row blades by numerical and Monte Carlo methods. Sawada et al.[2] studied flat blades with finite height for a single rotor using integration method. This method was based on some geometrical calculations for the transmission of molecule from elements of the blade, and integrating of these elements on the blade boundary. However a closed form solution for integral equations could not be found due to compl-ication of multiple reflection between blades and solution was obtained using numerical approach. Chu and Hua[3] evaluated the modified velocity of molecules passing through an infinite blade height by statistical mechanics method. Their results are expressed in analytical forms, which are easier to be applied to the design of the TMPs.

Katsimichas et al.[4] simulated free molecular flow within a single rotor machine with a 3-D flat plate blade using Monte Carlo method. Their calculations were done in the rotational reference frame where the molecular paths are not straight lines. Also they neglected effects of clearance between tip of the blade and pump casing. The maximum compression ratio was found higher than that calculation by 2-D simulation especially at high rotational speed and when pumping heavy gases. Skovorodko[5] considered the effect of clearance between the blade tip and pump casing. Neglecting the blade thickness, he simulated the free molecular flow in a couple of rotor-stator stages using the inertial reference of frame and Monte Carlo Method. In an inertial frame the moving path of a molecule is a straight line and following this path is done both in rotor and stator in a similar system of coordinates. This is actually one of the main advantages of using inertial frame in such simulations.