Vacuum Technology Division
Room 329 - Session VT-TuM

Molecular Drag Pumping

Moderator: J.C. Helmer, AVS Fellow

8:20am **VT-TuM1 Performance of Molecular Drag Pumping Stages in Hybrid Turbopumps***, **M.H. Hablanian**,* Varian Associates

Quantitative evaluation of molecular drag pumping action in turbopump channels allows an optimized placement of such channels among the stages of a high-compression hybrid turbine-type high-vacuum pumps. Although the drag action can be utilized in the entire range of pressures, the practical engineering considerations dictate the actual design (certain cross-section, length, parallel and series arrangement, and angular position) and placement of drag stages within the entire architecture of the pump which is to have a desired overall performance. The usual broad range of interest is between 0.1 and 100 torr but often can be more practical between 0.5 to 10 torr. Above 10 torr exit pressure, it is usually more effective to use other type of impellers. Theoretically, it may be desirable to have each stage of a hybrid turbopump of a different configuration but practical design (regarding size, ease of manufacture and assembly, and cost) necessitate some compromises. This is especially true of rotor design requirements. In addition, the choice of drag stage involves considerations of the wide range of pressure conditions in which a turbopump must function, the associated power requirements, and the crossing of various gas flow regimes. It is relatively simple to establish general guidelines for proper stage arrangements but actual design demands a complete knowledge of the performance of each individual impeller type.

8:40am **VT-TuM2 Turbodrag Pump Technologies***, **O. Ganschow**,* Schorch GmbH, Germany

Turbodrag pumps, i.e. molecular pumps with a bladed section followed by a drag section on a common shaft, have become the most popular high vacuum pump in the last 12 years, as they tolerate backing pressures approximately a hundred times larger than pure turbopumps. The paper reviews various technologies for turbodrag pumps in terms of the merits and limitations of their design principles. This covers rotor dynamics aspects, response to thermal loads, maximum rated backing pressure and throughputs, compression ration versus size as well as mechanical design considerations and potential future developments.

9:00am **VT-TuM3 Pumping Mechanism of Helical Grooved Molecular Drag Pumps***, **T. Sawada**, W. Sugiyama,* Akita University, Japan

The flow on a rotor of molecular drag pumps varies from viscous to slip to free molecule flow according to the decrease in pressure. As the first step, the flow through a groove facing a wall moving along the groove is analyzed. On the assumption that the flow in the groove is steady, isothermal, incompressible and laminar, the Navier-Stokes equations are simplified in the viscous and slip flow regimes and can be solved numerically with relative ease. In the free molecule flow regime, the drag (or friction) is caused by the momentum carried to a wall-piece by gas molecules colliding with the wall-piece, and the drag must be equated to the force exerted by the pressure on the two cross-sections sandwiching the wall-piece. The weighted linear combination of the two equations for slip and free molecule flows can describe the flow through the three flow regimes. The flow in ridges which leads a leak is treated in the similar way to the flow in grooves. Then, the flows in grooves and ridges hitherto treated separately are connected by the continuity condition of mass flow rate normal to the groove-ridge interface. The pressure gradient which is discontinuous at the groove-ridge interface is smoothed by Boon and Tal's "Narrow groove theory ". The pressure difference or the pressure ratio across the pump is obtained from the relationship between the smoothed pressure gradient and the axial mass flow rate derived above. The calculated results suggest that the radial clearance can be enlarged by factors of 20-100, compared with that of a conventional Holweck-type pump.

9:20am **VT-TuM4 Measurements Illustrating the Importance of Desorption and Molecular Residence Times on the Molecular Drag Process***, **A.D. Chew**, R.A. Abreu, I. Creaye,* BOC Edwards, United Kingdom

Knowledge of the molecular residence time is a fundamental factor in the understanding of molecule-surface interactions and has special relevance in the analysis of the molecular drag process. In this paper we describe experiments based on a technique originally devised by Holst and Clausing.@footnote 1@ In this technique molecules are beamed onto a variable high speed rotating disc and the point of desorption is measured. This in principle provides a means for the direct determination of the residence time. Preliminary results for various gas-surface combinations including nitrogen, helium, oxygen, krypton and perfluorocarbons on aluminium are presented. The method was further exploited to investigate the effect of surface speed on the desorption flux distribution, and to give insight into the mechanism of the molecular drag process for gases of different molecular mass. The possible application of this phenomenon to gas separation is discussed. @FootnoteText@ @footnote 1@G Holst and P Clausing, Physica 6, 48 (1926)

9:40am **VT-TuM5 Improved Design of a Multi-Groove Vacuum Pump Compressing Directly to the Air***, E.S. Valamontes, **S.E. Valamontes**, C.N. Panos,* Technological and Educational Institute of Athens, Greece

For a multi-groove vacuum pump the shortening of its length, during its function, is related to the increase of the velocity of molecules of the pumping gas. We are trying to achieve it without increasing the number of the turns, which leads to the increase of the velocity, but by using some new ideas. We study the exact behavior of the coefficient of internal viscosity by introducing a disc with blades in the pump which indirectly leads to the desirable shortening of its length and finally to have a pump compressing directly to air. The appropriate shape of the disk and its design are the main problems of the present work.

10:00am **VT-TuM6 Matching of Turbine Stages to a Drag Stage under Viscous Flow Conditions***, Ch. Beyer, H. Englaender, **P.J. Klingner**,* Leybold Vacuum GmbH, Germany

The design of the adapter part between the turbo molecular part and the drag stage of a compound pump is decisive for - the high vacuum performance (a) the fore vacuum pressure tolerances (b) the manufacturing costs and (c) the degree of compactness of this pump (d) especially in process applications under viscous or molecular-viscous transition flow conditions. The authors present approaches for the layout of turbo rotor stages at viscous flow (Leybold Advanced Technology). Operation diagrams illustrate the combination of turbo molecular and drag stages as part of pump optimization; measurement data give first informations about the influence of specially designed filling stages on the adapter efficiency.

10:20am **VT-TuM7 Flow Investigation of Siegbahn Pump by CFD Methodology***, **H.-P. Cheng**,* Precision Instrument & Development Center, Tawain. Read by J. Helmer, with historical figures by L. Westerberg.

The maximum flow through turbomolecular pumps or turbodrag pumps is limited by the maximum rotor temperature resulting from gas friction. Further, a variety of applications, especially in the semiconductor industry, require a high pumping speed in the 1 - 100 mtorr pressure range. Main subject of the presentation is the special design of the drag section of a turbodrag pump and the resulting improvements related to the features: maximum gas flow and high pumping speed in the 1 - 100 mtorr pressure range.

10:40am **VT-TuM8 Performance of a Peripheral Drag Pump***, **T. Ohbayashi**,* Osaka Vacuum, Ltd., Japan*; T. Sawada,* Akita University, Japan

This is a theoretical and experimental study of a peripheral drag pump. It has a peripheral pumping channel and a gas inlet and outlet which are separated by a "stripper", this is similar to a Gaede's drag pump. In that type of pump, a pumping channel comprises an annular groove and a chamber wall. In the pump in this study, two pumping channels which work in parallel comprise a rotating disk and two annular stators. This modification keeps the leak small with a relatively large clearance between the rotor and the stator. The performance of the peripheral drag pump is determined by the flow through the pumping channel, the "carry back", the leak in the "stripper" region, and the leak in the clearance between the rotor and the stator. In the theoretical calculations, the flow through the pumping channel is evaluated as Poiseuille flow and Couette flow through rectangular channels and the flow in the stripper region and in the clearance are evaluated as Poiseuille flow and Couette flow between parallel plates. Experiments were carried out on the peripheral drag pump of a single stage in a pressure range of 3 - 1300 Pa for air and 9 - 1200 Pa for hydrogen. The theoretical predictions agreed with the experimental results.

11:00am **VT-TuM9 Development of New Generation Turbo Molecular Pump*, Y. Maejima,*** *C. Urano,* Seiko Seiki, Japan

300mm wafer process requires extremely high process gas flow. Therefore, pumping requirements for vacuum pumps have increased up to 3,000 l/s. However, large pumps have disadvantages such as heavy weight, effect in case of failure. Our solution and concept for the new generation vacuum pump is to develop a 2,000 l/s dimension pump with higher performance than a 3,000 l/s pump at process pressure range. (from 1 Pa to 3 Pa) To accomplish this development, our target was to maintain pumping performance down to 5 Pa. We have simulated the influence of turbine blade parameter (blade length, dimension, shape) for maximum gas flow performance.

11:20am **VT-TuM10 Power Dissipation in Turbomoleculars Pumps at High Pressure*, R. Cerruti,*** *M. Spagnol, J.C. Helmer,* Varian VPT, Italy

The operating range of Turbopumps is being extended to higher pressures as a consequence of many demanding applications. Varian VPT has specialized in the design of Gaede stages for extending the operating pressure of the pump. In this paper, another important design aspect of a Gaede stage is identified and analyzed: the power consumption in viscous flow conditions Starting form the analysis of the pressure distribution into a single Gaede stage, already presented in a previous paper, a transitional power consumption model is derived. The model allows to predict the power consumption of a single Gaede stage as a function of the pumping channel dimensions and clearances, the rotational speed, the nature of the gas pumped and the operating pressure. The model is based on three main assumptions: 1. the pressure distribution along the channel satisfy a diffusion viscous model at zero net gas flow 2. the gas flow boundary layer across channel is derived from a simple viscous model 3. the gas viscosity obeys a transition expression valid for the pumping channel geometry Results are compared with the experimental data provided by different single Gaede stages, with different dimensions, at different speed and operating pressure. The behavior of the model with different pump stage clearances is analysed and results are compared with the experimental evidence. A useful use of the model is in the optimization of the design of multistage Gaede pumps.

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