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Concept of a new turbomolecular pump with central opening for free axial access—The Ring turbomolecular pump

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Abstract

For conventional (single-flow) turbomolecular pumps (TPs) the central disc area of the inlet side of the compressor turbine is blind for pumping and may be utilized otherwise. The design feature of the new Ring TP displays a central opening of the TP all along the axis, where care is taken to prevent coupling between the vacuum areas on both sides of the compressor turbine. The axial opening can be used independently, e.g. for free central access to the high vacuum side through the TP.

Keywords: Turbomolecular pump; Central access through turbomolecular pump; New design concept for turbomolecular pumps; Ring turbomolecular pump; Differential pumping

1. Introduction

In modern vacuum technology, turbomolecular pumps (TPs) [1] are the standard devices for producing and maintaining high or even ultra-high vacuum conditions. For a brief review of the field see e.g. [2] or the recent edition of "Wutz Handbuch Vakuumtechnik" [3] and the references cited therein. TPs show (in the single-flow design) typically a rotational symmetric arrangement with an annular gas intake area to the turbo-compressor stage. In order to use all the possible pumping power of a TP it has to be coupled directly to the vacuum tank at a proper sized port. Then, this flange cannot be used for any other purposes, see left side of Fig. 1. If the pumping port has to be used additionally for further applications as, e.g. feed throughs or manipulators, large crosses or T pieces have to be mounted between TP and vacuum vessel, reducing considerably the pumping speed at the port flange, see right part in Fig. 1.

A conventional TP has an active annular-shaped pumping area defined by the ring area opened by the vanes at the intake of the turbo-compressor. The central circular disc part of the compressor turbine is blocked by the inner part of the rotor body and blind for pumping purposes. In principle, this central part of the rotor body is not essential and hence can be used for other purposes. However, in this case care has to be taken not to couple the high- and low-vacuum sides of the compressor turbine. A concept of a new type of a TP with an opening all along the central axis, the "Ring TP"—first proposed in Ref. [4], is presented here giving completely free access to the vacuum vessel through the central part of the TP without reducing the pumping speed at the port of the vacuum tank. Means will be described to decouple the high- and low-vacuum ends of the turbo-compressor stage.

2. Principle of the Ring TP

A conventional TP consists of the turbo-compressor stage with closely spaced and alternating rings of rotor and stator vanes. Stator vane rings stand on the outer body tube of the TP just fitting in between rotor vanes fixed on a rotor body. The rotor body is totally closed towards the center part on the high-vacuum gas-inlet side; thus separating completely the high-vacuum intake area from

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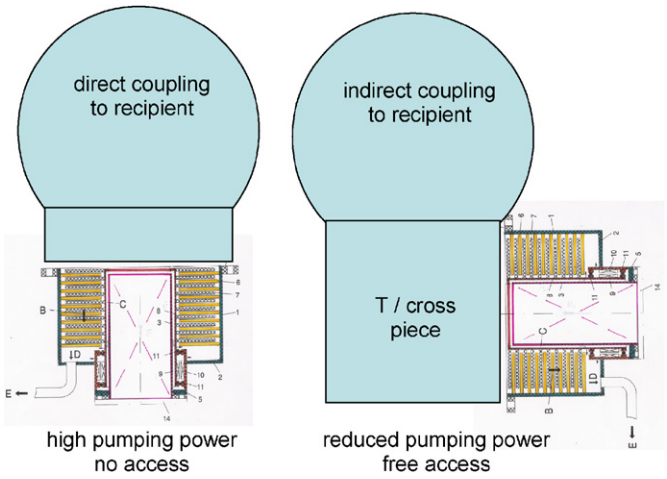

Fig. 1. Typical arrangements for a conventional turbomolecular pump (TP) at a vacuum device (direct coupling—left side/indirect one—right side).

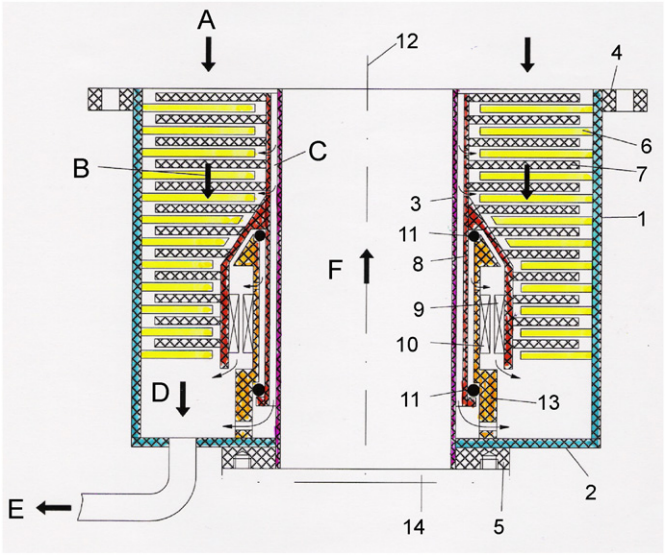

Fig. 2. A possible Ring TP design with central opening is sketched. Pressure/vacuum regions: (A) annular induction area, (B) compressor chamber, (C) annular gap region, (D) prevacuum chamber, (E) gas discharge line, (F) open center. Part assignments: (1) stator housing, (2) base plate, (3) inner stator cylinder, (4) port main flange, (5) base plate port, (6) stator vane ring, (7) rotor vane ring, (8) rotor body tube, (9, 10) motor drive, (11) bearing units, (12) central axis, (13) ring saddle support, (14) base plate closure.

the lower-vacuum side at the compressor outlet. The rotor body usually encloses along the axis towards the low-vacuum side support bearings and drive motor. The TP base body carries the corresponding non-rotating parts of motor and bearing supports and separates the low-vacuum side of the pump against the surrounding air pressure. In order to have direct access to the vacuum vessel through the TP, all the central parts of the TP can be mechanically opened along the axis by a central hole without influencing the mechanical principles of the TP—except that at first high-vacuum side and low-vacuum side of the compressor stage (as well as to some extent the surrounding outside high-pressure region) are coupled by this central bore. The task is now to decouple these different pressure regions.

The central opening in the base plate of the TP can be closed easily against the surroundings by a proper central flange mounted on the new base plate port of the pump. Alternatively this base plate port can be connected to other high-vacuum devices. In particular flanges with high-vacuum feed throughs of all different kinds can be attached here for central access through the TP into the high-vacuum vessel. This feature is the true reason for the central opening of the TP. The essential task for a design after the central opening of the TP is to separate high- and low-vacuum side of the compressor stage. There are different passive or active means to provide an efficient separation of both vacuum regions.

In Fig. 2 a possible design solution for such a hollow TP, called (single-flow or mono) "Ring TP", is sketched. The displayed example consists mainly of stator (1) and rotor (8) body with the corresponding blades (6, 7) forming the compressor turbine (B), and the static support (13) for the rotor body with bearings (11) and drive motor (9, 10). The parts of these units are listed in the figure caption. (For a more detailed design proposal see Ref. [4]—a final technical design has obviously to consider the stability of all the rotating parts as well as a realistic bearing and support concept, cf. e.g. Ref. [3].)

The crucial parts of a (single-flow) Ring TP are the two co-axial hollow cylinders—the inner stator cylinder (3) and the inner rotor cylinder (8) facing each other with a very narrow gap (C) between both surfaces. The inner stator cylinder stands vacuum tight on the TP base plate (2, 5) reaching axially up to the head of the TP, i.e. to the inlet region (A) of the turbo-compressor (B); the rotor cylinder (8)—just fitting into the inner stator cylinder (3)—builds the innermost part of the rotor body. The gap (C) between rotor and stator cylinders has to be very narrow in order to reduce by its low conductance, a gas backflow from the low- to the high-vacuum side of the turbine below a tolerable level. Moreover, active pumping of the gap can be provided by different means as e.g. a differential pumping by bypass holes into some of the compressor stages (indicated by small arrows in the figure) and/or by introducing molecular pumping structures into the gap-facing surfaces of at least one of the cylinders, e.g. structures like in a Holweck pumping stage or similar [5]. Either of these active pumping possibilities can be incorporated in the same design.

3. Design of a Duo-Ring TP

It is obvious that there are a lot of different technical solutions to reduce, in the Ring TP, the backflow through the gap between the two cylinder surfaces or—even better—to pump actively the gap between rotor cylinder and inner stator cylinder. The means range from passive