ISBN: 978-3-95450-240-0 ISSN: 2673-5539 doi:10.18429/JACoW-RuPAC2021-WEPSC10

OPTIMIZATION OF ACCELERATORS VACUUM STRUCTURES PUMPING

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Abstract

The pumping features for the complex parts of the accelerator vacuum system are modelled to growth the efficiency of vacuum pumping. The vacuum system of a 7.5 MeV/nucleon proton and light ion (A/Z<3.2) accelerator-injector was considered. The Monte Carlo method is suitable for molecular flow modelling in high vacuum. The Molflow+ program was used for this aim. The pressure distribution simulation over the RFQ, IH resonators chambers volume, connecting vacuum pipes and extended vacuum tracts is carried out. The influence of parameters of individual structural elements changes was investigated to define the vacuum conditions inside the accelerators vacuum chambers. The vacuum system configuration and parameters are selected basing on these results to obtain the required vacuum level.

VACUUM SYSTEM FEATURES

Molflow+ software package is used to determine the parameters of the linear accelerator vacuum equipment. This is a Monte Carlo simulator intended to calculate pressure profiles and conductance in ultra-high vacuum [1].

To determine the characteristics of the vacuum it is necessary to specify the geometry of the internal vacuum surfaces, gas loads and the parameters of the pumping equipment in the simulation model.

The vacuum requirements are determined by the allowable degree of the beam destruction via capture and loss of electrons, nuclear reactions, Coulomb scattering due to the interaction with residual gas. Based on the loss evaluation the pressure along the channel, providing a stable ion beam passing through the structure should be of the order of 10^{-5} Pa. At this pressure the molecules will move independently of each other and the simulation of these conditions by the statistical tests method is possible.

In stationary conditions, the molecules desorption from the vacuum chambers walls is the main source of pumping gas loads. The value of thermal outgassing is chosen 10^{-6} Pa·m^3/s·m^2, which is typical for the initial level of vacuum constructional materials outgassing.

The sections of the linear accelerator structure are independent vacuum systems separated by insulating vacuum gates. This includes ion sources, RFQ section, beam transport sections at low energy LEBT, medium MEBT1, 2 and high HEBT, H-type resonator sections IH1, 2 (see Fig. 1).

Figure 1: Block diagram of linear accelerator sections.

VACUUM PORT

The vacuum pumps are connected to the resonator chambers using vacuum ports (see Fig. 2).

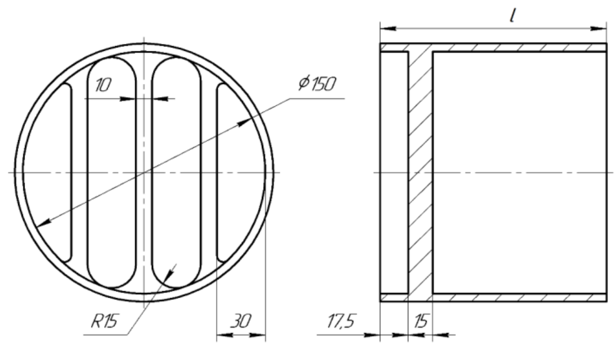

Figure 2: Vacuum port diagram.

Grilles are installed in ports to limit the penetration of microwave power outside the resonator chamber. Vacuum valves are also attached. These construction features affect the vacuum conductivity and reduce the efficient pumping speed. Their conductivity was modelled in the operating mode. The conductivity of the DN 150 port with RF grill according to the simulation results is shown in Table 1.

Table 1: Port conductivity Values

Port height *l*	Conductivity
55 mm	1050 l/s
75 mm	990 l/s
100 mm	911 l/s

RFQ CHAMBER

The model of the RFQ resonator vacuum chamber was used to calculate the pressure distribution along the beam axis and over the volume of the resonator chamber. Vacuum surface model for Molflow+ created from CAD 3D model of the resonator chamber with internal electrodes, plungers, vacuum and RF ports (see Fig. 3).

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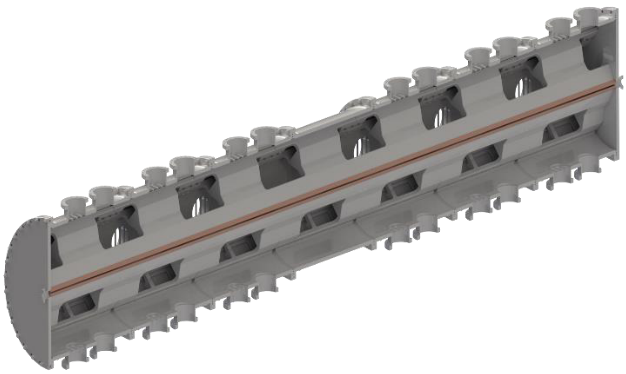

Figure 3: RFQ model.

The influence of the conductivity of internal cavities configuration in the electrode structure on the pressure distribution uniformity over the cavity volume was estimated. Situations with connection of pumps to the vacuum port in various quantities and configurations were simulated. Fig. 4 demonstrates the pressure distribution profile along the resonator axis with full pumping through all resonator ports with 300 l/s pumps. The inner surface of the resonator with a total area of about 34 m^2 is copper coated. The calculated pressure was up to $1.3 \cdot 10^{-5}$ Pa, while its relative fluctuations are insignificant.

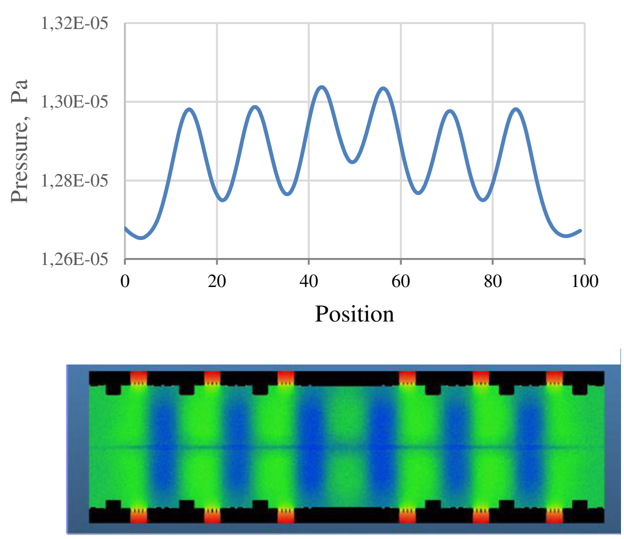

Figure 4: RFQ pressure profile.

When 6 pumps were turned off on one side of the resonator, the total pressure increased due to a decrease in the effective pumping speed, however, no significant disruption of the pressure uniformity in the resonator was observed. It can be seen that the slotted electrodes have good molecular conductivity. Various pump connection schemes can be used. For example, when using the combination of TMP and IP pumps (see Fig. 5). According to this scheme, the TMP provides pumping of significant dynamic gas loads and can be stopped in stationary pumping regime. IP pumps keep vacuum conditions at low thermal gas flows.

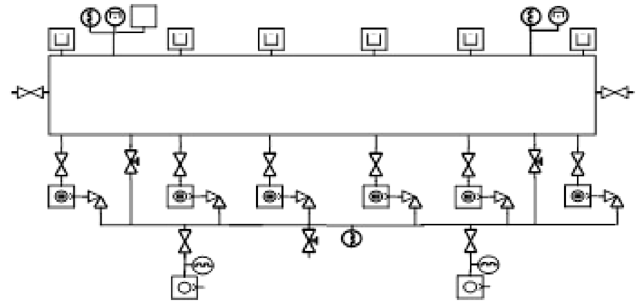

Figure 5: RFQ vacuum system.

H-TYPE RESONATOR SECTIONS

The design of the vacuum section with H-type resonators consists of several resonators and intermediate channels between them. Models of vacuum surfaces were also created from a CAD 3D model of the resonator chamber with internal equipment of electrodes, plungers, vacuum and RF ports (see Fig. 6).

Figure 6: H-type resonator model.

Using a model of a vacuum system of resonators the pressure distribution along the beam axis was calculated on the resonator chambers and intermediate pipelines. Based on the symmetry of the structure, a section with a resonator and adjacent channels was considered as a model. A resonator with two half-length sections of pipes on each side was taken (see Fig. 7).

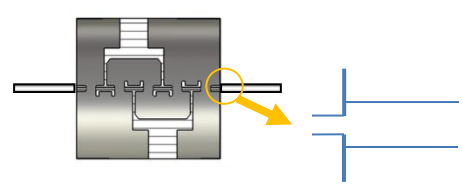

Figure 7: Output channel diagram.

There was an increase in pressure in the connecting pipeline between the resonators (see Fig. 8, a). This is explained by the design feature of the electrode at the inlet tract to the resonator. The channel in the inlet electrode has a very low conductivity (about 5 l/s). In aim to reduce this effect, the analysis of gas flows at the resonator inlet depending on the pumping speed was carried out on the calculation model. Various forms of the electrode that can increase its conductivity are considered. Models of channels with straight bore internal (see Fig. 8, b) diameter and cone bore (see Fig. 8, c) reduced the pressure in the pipeline.

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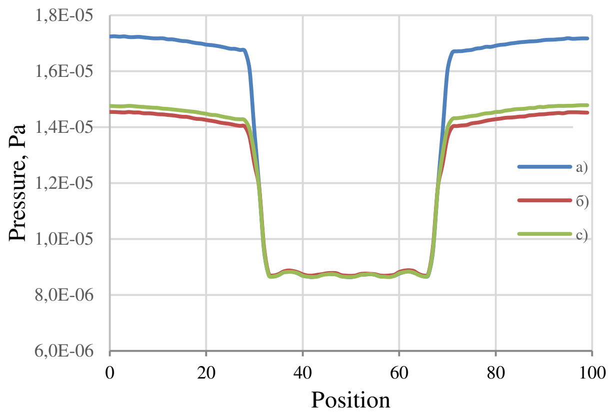

Figure 8: Pressure distribution along the axis of the resonator and pipelines.

In addition, the possibility of reducing outgassing flows by reducing the pipeline internal surface area was considered. The dependence of the pressure in the connecting pipeline on its diameter is investigated. Taking into account the considered factors, possible variants of the pumping scheme with a combination of high-vacuum pumps types were proposed. Pumping is modeled for each structure and pressure distribution profiles in the structures along the beam path are obtained (see Fig. 9).

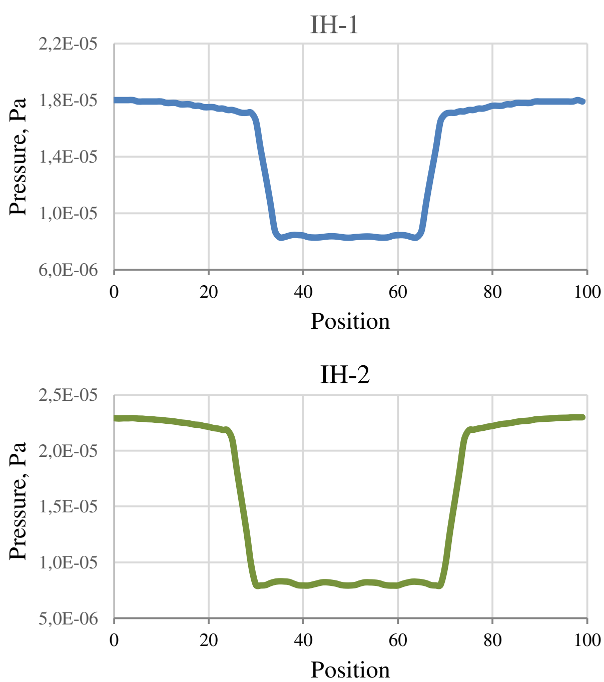

Figure 9: Pressure in H-type resonators and pipelines.

BEAM TRANSPORT CHANNELS

The conditions of pumping of bunchers vacuum chambers and extended beam transport channels were studied separately. For bunchers chambers pumping a system with local vacuum groups are proposed. The pipelines length of LEBT and MEBT channels is relatively small. This made it possible to pump them out through the diagnostic chambers and bunchers resonators.

Modelling has been used to optimize the connection period of IP pumps in HEBT channels. The modelled results were compared with the analytical calculation data. Taking into account the selected distance between the pumps of about 2 m, a model of the vacuum channel was compiled and the pressure distribution along all sections of the channel was obtained (see Fig. 10).

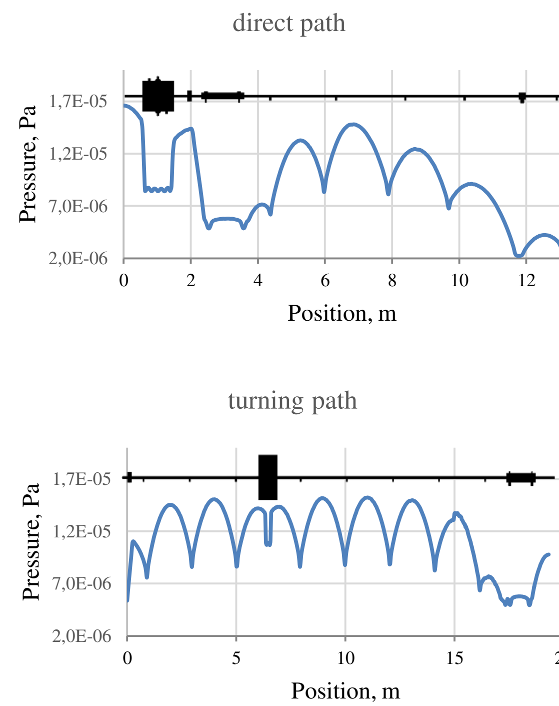

Figure 10: Pressure distribution in the HEBT channels.

CONCLUSION

Based on the results of pumping simulation in the Mollflow+ program, pressure distributions were obtained for different resonators structures, and the influence of the pumps location on the pressure profiles was investigated. The selected vacuum schemes and the efficiency of the pumping equipment allow us to provide the necessary vacuum conditions in all sections of the designed accelerator. The presence of local pressure increases is not critical, this small increase will not affect the beam passing.

REFERENCES

[1] Molflow+ A Monte-Carlo Simulator package, CERN. https://molflow.web.cern.ch/content/about-molflow