Vacuum Chambers and Special Components

Design

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Vacuum Chambers and Special Components

Introduction

Vacuum mechanics is the strongest line of the VACOM product range. We see the greatest challenges in the manufacturing of special components.

The requirements of vacuum applications especially in the field of high-technology exceed the requirements of traditional mechanical engineering. A weld seam not only has to fulfill the requirements for mechanical stability but also needs to be gas tight. The used materials have to be characterized by low outgassing rates and low gas permeation. It is not sufficient that the electropolishing process results in a blank surface. In extreme high vacuum (XHV), every cm² of surface is a cm² too much. The difficulty lies in the creating of a chamber and component design as small as possible which, however, leads to new technological challenges because of the heat dissipation during the production process. Demanding on the one hand low outgassing rates and minimal gas permeation and on the other hand minimal particle generation and affinity further limits the possibilities.

Niche markets like vacuum technical applications require to find and define an interface between the mass products available on the market and the highly specialized unique components. Here, it is necessary to understand correlations, question basic physical processes and develop the ability to work interdisciplinary.

We take all these correlations and findings as a basis already at the design and thus, reach new efficiencies and qualities. We are pleased to help our customers and prospective customers with questions on design optimization. Mutually non-disclosure agreements (NDA) secure a respectful treatment of the intellectual efforts of all parties concerned.

We bring together knowledge and experience in vacuum technology and are therefore your contact for:

- Design
- Highly precise machining
- Joining technology
- Surface treatment, also under cleanroom conditions

All this is only possible if the processes are accompanied by a well-organized quality control, which is highly qualified and has modern measurement equipment at disposal.

We look forward to realizing your specific demands for your chamber and special components together with you.
Vacuum Chambers and Special Components

Design

Production Drawings and 3D Models

We create for you vacuum suitable designs from simple components (flanges, connectors etc.) to complex chambers.

We design technical drawings suitable for production according to your demand, sketch or specification (figure). We provide you the models as neutral format (STEP) for your further design and processing if required.

We also can directly import your 3D data, review it regarding the production-oriented design and adjust it if necessary.

Standard Components with Individual Dimensions

For standard components, such as connectors, with individual dimensions we established solutions (variant configurator) which allow us to create drawings and bills of materials in no time.

Other tube dimensions which are not included in the variant configurator can be processed by us as special component. The base material (tubes and corresponding flanges) are available in stock. Thus, these components are also ready for dispatch at short notice.

CAD Models for Standardized Cylindrical Chambers

We create standardized models and drawings for tube-based chambers based on cylindrical chambers. In doing so we use the functionalities of a modern CAD system to process your task in short time and as efficient as possible. Modifications are also practicable without great effort.

By using these standard models we can co-ordinate technical details with you on the 3D model within shortest time.
Vacuum Chambers and Special Components

Design

Adjustment of Focal Point

The alignment of ports and flanges to a defined focal point can be of essential importance for many specific applications in vacuum technology.

The figure on the left shows a component with numerous ports with the following technological requirements:

- Alignment of the ports to three focal points
- Many overlapping weld seams
- The chronological order of the different welding steps, so that the part is weldable and can be clamped on the milling machine in the intermediate steps
- Uniform weld seams in order to maintain the distances of the ports to each other by the complex geometry
- Constructive solution of the bottom, which has to be welded at the end of the production process while only a very low virtual leak was allowed

Our special competences include the linking of several joining processes of components with low dimensional and positional tolerances less than 0.1 mm.

Measurement of Semi-Finished Products

We developed a process by combining several modern measurement and machining methods in which the production-related variations of semi-finished products such as tubes, spheres, torispherical heads etc. are registered and compensated during design and manufacturing.

FEM Analysis

For many applications aberrations such as the deformation of chamber walls can be crucial for the accuracy of processes. To simulate a situation like this, VACOM uses the tool “Autodesk Simulation Mechanical”. Here, in-process dimensioning and new product developments are aimed for and strength tests are performed. The simulations include structural mechanic, transient, thermal, and harmonic analysis, and the coupling of the different types of analysis. This enables us to determine the size of vacuum chambers and components and, e.g., to simulate the components' deformation under the influence of atmospheric pressure and a temperature source. Existing products are optimized with this method. Newly developed products which are mechanically and/or thermally stressed can be tested in a suitable simulation. Thus, lean and accurately dimensioned products can be developed.
Mechanical Production

Precision Turning and Milling – Our Dimensions of Production

Machining is one of our main focuses of our mechanical production.

We have 3- and 5-axis precision milling centres available for the realization of your specific requirements. Thus, we are able to manufacture chambers with dimensions up to 1200 x 700 x 600 mm and chambers with diameters up to 500 mm. We realize larger dimensions for you after individual technical clarification.

Our clamping and setting concepts are designed and optimized for the economical production of small batches and custom-made items.

The realization of your orders is carried out with one of the most modern CAM systems. Hence, we can use the model data which you provide (*.step, *.iges) to process your orders.

We have established processes for the adaptive milling in the mechanical production which take into consideration the real geometry of mold components e. g. for spherical chambers. Based on these technologies which are unique on the market, we manufacture vacuum standard and special components of highest precision. We are able to realize distances of ports and exits to each other, the precise positioning of focal points and beam guidance within narrow tolerances.

We have technologies and processes at hand for the eccentric application of sealing surfaces and cutting edge geometry (CF components). With these technologies, we are able to manufacture chambers and special components for you which are optimized for your demanding usage, avoiding unnecessary joints e. g. for flanges, feedthroughs etc.

Furthermore, we are able to expand the fields of application of your existing chambers and vacuum components by inserting additional connecting possibilities as part of a repair.
Vacuum Chambers and Special Components

Welding Technology

Vacuum-Tight Welding

We mainly join tube-flange and tube-tube connections manually using several welding processes to produce weld seams of high quality. We are experienced in welding stainless steels of different qualities. Hereby particularly noteworthy are the materials 1.4301, 1.4307, 1.4404, 1.4435, 1.4429, 1.4541 and 1.4571.

The emergence of virtual leaks is prevented by welding the components on the vacuum side. If this is not possible, we weld vacuum-tight on atmosphere side (not full connection) or use full penetration welding (full connection). If there are custom-specific higher requirements on the strength of the welded components, we are able to attach additional weld seams for support.

With the used weld processes, we are able to manufacture very small but also massive components. Our specific knowledge focuses on highly complex vacuum chambers with a large number of exits and the intersection of several exits which have to be manufactured with low tolerances regarding angularity and a high fitting accuracy. We have a lot of experience in welding temperature-sensitive parts such as electrical and optical feedthroughs. Standardization of the processes and technologies allow us to ensure consistently high quality of all welding processes.

Our welding processes are certified according to ISO 3834-2:2006.

This includes the standardized welding by:
- Qualified welders
- Qualified welding supervision staff
- Certified and regularly calibrated equipment
- Ensuring the traceability of products, materials etc.
- Documented processes
- Permanent quality control
- Continuous training of welders
- Internal audits
- Qualification of welding processes
- Preparation of welding procedure specifications for reproducible weld seams
- Permanent monitoring before, during and after the welding process

According to the requirements and depending on the welding geometries and the thickness of the components we are able to apply the following welding processes:
- TIG welding
- Orbital welding
- Laser welding
- Micro plasma welding
We already manufacture vacuum components of various aluminum alloys. New is that vacuum parts made of hardenable aluminum alloy 6060 and 6082 can now be joined using TIG welding.

Aluminum offers numerous production-related advantages in contrast to the usually in vacuum technology used stainless steels 304, 316L and 316LN. For example, aluminum is easier to machine (higher chip thickness, higher feed rates).

Major advantages of aluminum are:

- Lower weight due to density 2.73 g/cm³
- Absolutely not magnetizable, which means a relative permeability \( \mu = 1 \) (magnetic neutrality, free of ferromagnetism)
- Higher thermal conductivity (160 to 190 W/mK for aluminium alloys of 6000 series in comparison to 50 W/mK for stainless steel 1.4429)
- Advantage of shorter bakeout time because of lower bakeout temperature of ca. 150 °C
- Low hydrogen concentration in the material

The natural oxide layer of aluminum functions as additional barrier and prevents diffusion and desorption processes.

The chosen alloys are technological suitable for extrusion moulding. This procedure enables the production of elaborate chamber profiles. Such complex profiles are used as vacuum chambers in research centres in accelerator facilities. Being absolutely not magnetizable is an indispensable prerequisite of undulators in particle accelerators. The reduced pumping time due to the lower hydrogen and carbon concentration in aluminium as well as the extremely low hydrogen permeation are highly advantageous for the operation of accelerators.

The properties mentioned above cause a considerable reduction of the operating costs for all applications in UHV.

- Low bakeout temperatures
- Short pump down times
- Low effort to sustain the UHV
Surface Treatment and Refinement of Components

Surface Treatment

We offer you as standard the following surface treatments:

- Mechanical and chemical untreated surfaces
- Mechanically polished
  - Mechanical treatment of the surfaces by polishing with stainless steel wire brush
- Pickling
  - Removal of annealing colors
- Glass bead blasting
  - Blasting of the component surfaces with glass beads to accomplish an optimal silk-matt gloss
- Electropolishing
  - Anodic removal of the component surface treatment in an electrochemical process

The surface treatment serves besides optical effects to deburr, reduce outgassing or minimize the number of particles. We have specified processes with defined results for the surface treatment. If required, we are able to modify our processes for you to meet your requirements.

If you require other surface treatments for your components differing from the here described methods, we can realise these in co-operation with our partners or with you.

Electropolishing

Electropolishing is a standard method which we use to refine the surface of components. It is carried out in the clean room area.

Well tested processes ensure that besides deburring, smoothing and polishing absolutely clean and passivated metal surfaces with low surface desorption are achieved.

At all times during the whole process chain of surface treatment and refinement of components the protection of sealing surfaces and cutting edges as well as the minimization of particle contamination is ensured.

Electropolished components are characterized by a better corrosion resistance and a low wear of highly stressed components.
UHV-Compatible Cleaning and Bakeout

Cleaning in Cleanroom Area

We have the knowledge and technical equipment for an economical cleaning of components with unique characteristics regarding material, complexity of surfaces as well as low outgassing and low particle generation. Our processes are optimized to fulfill requirements e.g. for optical industries and accelerator technology. The cleaning process and the applied cleaning agents are ideally adapted to the used materials and geometries.

The complete six-stage cleaning cascade is carried out in the cleanroom ISO class 7 which ensures a low particle generation. All components which are integrated into our cleanroom cleaning process are pre-cleaned. The “history” of the assembly has to be considered before a cleaning process is successfully started. It is of essential importance to avoid contaminations of sensitive materials and complex geometries already in the production process.

All cleaning stages are equipped with conductance and pH value control and the measurement results are permanently logged. The whole media supply is free of Zn, Sn, In, Pb and Si.

Bakeout in Vacuum Oven

Vacuum components can be baked out in vacuum ($10^{-5}$ mbar) up to a temperature of 300 °C to further reduce the outgassing values. This process reduces the outgassing values for example of stainless steel to $2 \times 10^{-10}$ mbar l/s·cm² for water, $2 \times 10^{-12}$ mbar l/s·cm² for volatile organic compounds and $1.5 \times 10^{-13}$ mbar l/s·cm² for heavy volatile organic compounds.

The bakeout process can be controlled and logged in situ using mass spectrometry.
Bakeout, Assembly and Packaging in Cleanroom

Bakeout of Vacuum Chambers

Furthermore, we have the opportunity to bakeout complete vacuum chambers up to 250 °C with a diameter up to 900 mm and a height up to 1400 mm. At the same time, we can specify the outgassing by means of mass spectrometry.

By default, the complete bakeout and outgassing process is recorded up to a atomic mass number of 200 amu. The residual gas spectrum can be offered as protocol on request.

You can find further information on bakeout in vacuum and residual gas analysis in the following chapter Service.

Assembly of Components in Cleanroom

VACOM offers the possibility to assemble units with high demands on a low particle emission under cleanroom conditions. Workstations of ISO class 5 are available in which even large assemblies can be fitted.

In addition, we have special workstations of ISO class 1 available which are used for processing and fitting assemblies up to a maximum weight of 25 kg.

The cleanroom quality is regularly checked and recorded using particle measurements.

Packaging in Cleanroom

All products are packed after the cleaning process to preserve the cleanliness achieved during cleaning. The packaging of the components is executed in a cleanroom of the appropriate ISO class – depending on the required particle specification. We use packaging material with low outgassing and particle generation. Components which need cleanroom suitable packaging are packed twice in special foil impermeable to moisture and afterwards PE foil applicable for cleanrooms. This allows the storage of the components for more than a year without any loss in the quality of purity.

Cleanroom primary packaging:
- Protection against particle contamination
- Protection against water and hydrocarbons
- Vacuum packaging or packaging flooded with nitrogen as standard possible
Vacuum Chambers and Special Components

Quality Control at VACOM

We are committed to the quality management system according to DIN EN ISO 9001:2008 since 1998 and involved the research and development department into the audit since 2011. Our subsidiary VACOM bvba is included since 2012.

Further certifications:
- Certification of our welding processes according to DIN EN ISO 3834-2 by the German Welding Society DVS (Deutscher Verband für Schweißen und verwandte Verfahren e. V.)
- Environmental Management System according to QuB by LGA Intercert
- GOST-R Certificates for selected product groups

The quality control is integrated into the whole production process and the commodity flow. At the beginning, the incoming goods control in accordance to the inspection plan and the documentation via ERP system takes place. Either a 100 %-control or a sample check is made for all goods receipts in accordance to specifications and depending on agreements with suppliers and sub-contractors as well as provided inspection protocols.

Integrated in all production stages of the production, the quality control is carried out according to the functionality of the component. After every single production stage a qualified worker self control is performed.

All welded components and assemblies are helium leak tested down to $1 \times 10^{-9}$ mbar l/s. For higher demands we offer to check to $< 1 \times 10^{-10}$ mbar l/s and $5 \times 10^{-11}$ mbar l/s. Hereby, the higher costs have to be considered. The measurement results are recorded and archived. We can generate a log for you on request.

The quality control checks all products in the final check according to the inspection plan.

The following testing equipment is available for the quality control:
- He leakage detector
- Foerster probe
- Geiger-Müller counter
- Measuring microscope
- Surface roughness measuring device
- 3D-coordinate measuring machine
- Hand-held measuring devices (calipers, outside micrometer, thread gauges, feeler gauge etc.)

All relevant measuring instruments are subject to a defined calibration cycle, the monitoring is carried out by an external certified calibration laboratory.

Test Certificates/Certificates - Marking

We can provide you the following certificates for components delivered by us:
- Acceptance test certificates 3.1 according to DIN EN 10204:2005 based on specific tests
- Factory certificates 2.2 according to DIN EN 10204:2005 based on non-specific tests
- Restamping certificates in accordance with technical rules
- Logs to proof passed He leak test according to customer specifications
- Marking of components using laser engraving according to VACOM standard or customer demands

![Certificate Image]

![Quality Control Images]
Quality Control

Qualified Residual Gas Analysis

We are able to verify the desired cleaning result and also quantify and document the outgassing behavior with our residual gas analysis systems.

We have our own RGA service area. We offer qualified outgassing measurement by means of quantitative and qualitative residual gas analysis. The residual gas analysis serves as standardized quality control of the produced low-outgassing vacuum components (small components up to complete vacuum chambers) as well as verification of provided products. The measurements are carried out with a partial pressure of up to $2 \times 10^{-14}$ mbar and a mass number up to 300 amu. The highly sensitive measurement setups allow the detection of smallest contaminations to serve highest demands on the cleanliness of vacuum components and chambers.

We offer the residual gas analysis also as service at the customer's site.

Particle Measurement

We can perform a particle measurement in order to classify the components into a particle class according to ISO 14644 after cleaning.

The measurement is based on ISO 14644 and the VDI-guideline 2083. We measure selected samples according to your specifications or VACOM standard on the surface or integral with flow-through components. The results are recorded and documented in a standardized log for particle sizes between 0.3 μm and 10 μm.