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Experimental set up for the study of plasma parameters in seeded arc plasma using Langmuir Probes inside low-cost vacuum chamber

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Abstract

In this piece of study, the design and development of a low cost vacuum chamber with different ports are mentioned. I-V characteristic of Langmuir Probe is obtained using the primary data of the experimental set up for 'single probe method' in nitrogen seeded arc plasma at atmospheric pressure The floating potential was found to be 36V and the electron density to be 1.24×10^4 K. Variation in electron density of the arc plasma with probe potential is also studied at low pressure range from 10 Nm^{-2} (0.10 mbar) to 20 Nm^{-2}.

Keywords: Arc plasma; vacuum chamber; plasma parameters; operational constraints; Langmuir Probe; floating Potential; electron density.

1. Introduction

The mechanical design of a vacuum chamber requires defining the boundary conditions. The conceptual design is followed by a detailed design, which is actually associated with the development of the device. Methodology & methods [1] of development of the device are given in this study together with a schematic diagram of a low cost vacuum chamber. In the cold plasma, unlike in low density Plasma [2], plasma parameters such as floating potential and electron density are calculated. *I-V* characteristic for Langmuir Probe [3-5] is obtained using 'single probe method' from the experimental set up. Variation in electron density of the arc plasma due to variation in pressure is also also observed using 'double probe method' for low pressure range from 0.1mbar to 0.2mbar.

2. Boundary conditions

Environment

Determination of the environment in which the vacuum chamber is to be operated is the first step in its design and development. The sub-sections are given below deals with the important points of environment.

The situation should not be very difficult when it is located inside a large building if the external envelope is simply the volume where the chamber is situated at adequate space for supports simplifies the design of the chamber. In addition, space and access to the pumping ports.

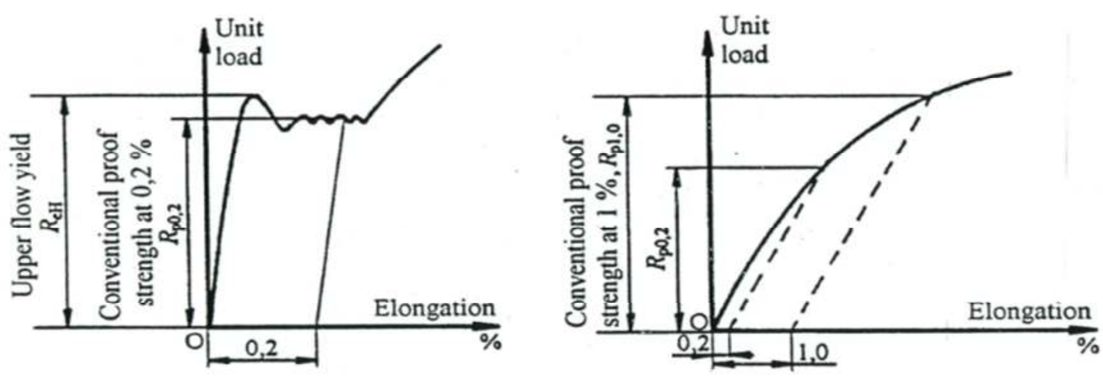
The envelope is the main parameter for the vacuum chamber of an accelerator, but the conductance is another one in case of lumped pumps; the pressure distribution between two pumping ports is parabolic, and the maximum value of this parabola defines the operating pressure. The inner piping and its insulation layers define the inner envelope, but an extra space is included to allow for the movements resulting from pressure and temperature variations.

Operating temperature is room temperature, bake-out temperature between 150ºC and 300ºC. The different effects of temperature include dilatations, stresses and changes of material properties, which have destructive effects if nod mastered properly.

Electrical impedance is reduced with a good electrical conductivity, but on the other hand, non-conducting material is required for electric insulation. The parameters such as the radiation length (X_0), and the collision length are considered.

Materials

The material parameters for the design of a vacuum chamber in terms of mechanics could be many, but there are only three main parameters. They are Young's modulus (E), the elastic limit ($\sigma_{0.2}$) and rupture limit (σ_r). These parameters are usually easily available for materials. Figure 1 shows a typical shape of traction curves [1] of materials. It shows how to define the yield or elastic limit. The modulus of rigidity is obtained through the value of the slope of the quasilinear part of the curve.



(i) Steel except austenitic stainless steel (ii) Austenitic stainless steel, Aluminium alloys

Fig. 1: Traction curves of metals [1].

Selecting materials for specific cases is a multi-parameter problem. It is eased by the use of non-dimensional parameters [6]. These have been used for the specific types of vacuum chambers such as the beam pipes, for the experiments installed in colliders [7]. They should be transparent to particles. The material selection is based on the non-dimensional parameter ($X_0E^{1/3}$) that gives a figure of merit for the materials (Table - 1) and, for this specific case of beam pipes, beryllium and carbon fibre composite outrun by a large factor aluminium, titanium, and steel.

Table 1: Figures of merit of materials.

	Be	*CFC*	*Al-Be*	*Al*	*Ti*	*Fe*
E(GPa)	290	200	193	70	110	210
X_0 (m)	0.353	0.271	0,253	0.089	0.036	0.018
$X_0E^{1/3}$	2.34	1.58	1.46	0.37	0.17	0.11

Leak tightness of a vacuum chamber is a must, but is difficult to obtain if the weldability of the material is poor. Cost is the final criterion behind it. The most common materials are austenitic stainless steel.

Design

Stresses generated by the loads enumerated before should usually remain in the elastic range. This means that the equivalent stress should not exceed the elastic limit ($\sigma_{0.2}$) anywhere in the structure. The membrane strain energy can be converted to bending strain energy, leading to instability and a bifurcation point on the behavioral curve, a potential buckling (Figure 2). Buckling is a non-linear phenomenon, and is strongly influenced by the defects inherent in the manufacturing.

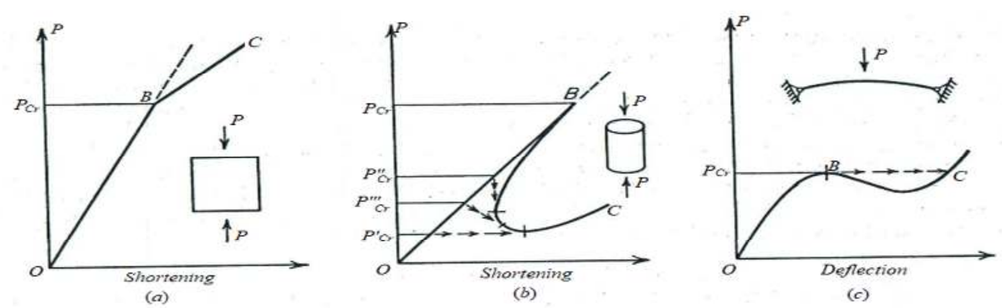


Fig. 2: Buckling behaviours [1].

The use of structural analysis, usually based on the Finite-Element Method, is necessary for the detailed design of vacuum vessels. In the shell elements [Figure 3], the through thickness stresses are assumed linear and integrated in membrane (constant term) and bending (linear term).

Bellows are either mechanically formed from thin tubes, or assembled by welding a series of individual annular rings. Bellows are designed to withstand a given number of cycles of axial expansion/compression over the expected life of the system.

Assembly

Materials for manufacturing are available in various states; raw products like blanks or sheets, or semi-finished products like extruded elements (aluminium, copper), moulded, forged, or sintered. The choice is usually based on cost but the final quality in terms of vacuum may be disturbed by the manufacturing techniques. Defects due to impurities internal to the material should not provoke a leak-through, and elaboration techniques properly handled is of help in this connection.

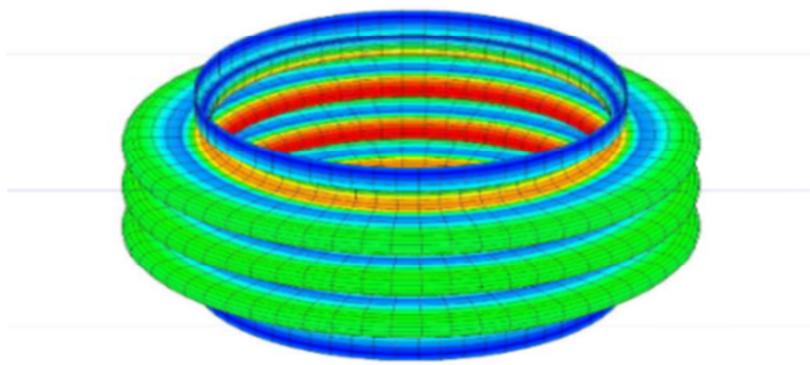


Fig. 3: Shell element: a bellow [1].

The main parameters for their design are the strength of the material to withstand high forces for bolting or clamping, and the quality and hardness of the surface where the seal is positioned. The first point is the weldability of the material. To fulfill their role of mechanical resistance, the welds are designed. Grooves help minimize heat propagation along the walls and can be useful in case of subsequent cutting and re-welding. The surfaces are etched before the brazing, and also a high-quality cleaning after brazing is important to increase the lifespan [8] of the vacuum Chamber.

3. Results and Discussion

Figure 4 Shows the Schematic diagram of the vacuum chamber with quartz windows Figure 5 shows the variation of probe current(*ln* I) with probe voltage(V) for single probe method, using the data obtained from the experimental set up. From the figure, the floating potential is 36V, and electron temperature is calculated to be 1.24×10^4 K. Variation of electron density at different pressure is shown in Figure 6. Figure 6 shows that the low cost vacuum chamber is suitable for the measurement of Plasma Parameters in a seeded arc plasma.

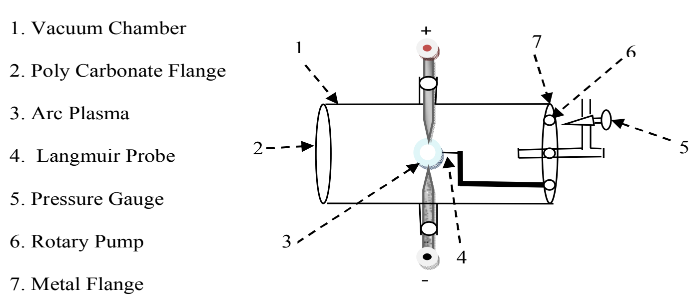


Fig. 4: A Schematic diagram for vacuum chamber.

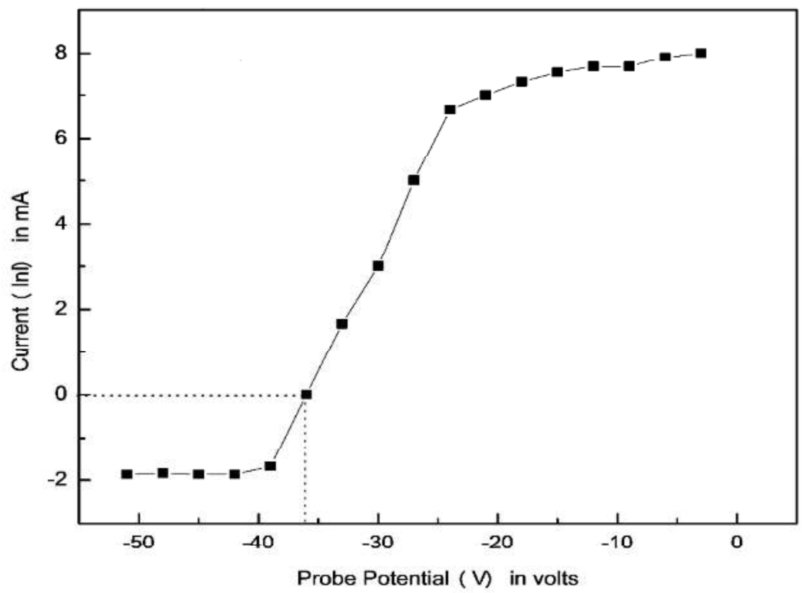


Fig. 5: I-V Characteristics of Langmuir Probe (single Probe Method) from data obtained from experimental set up.

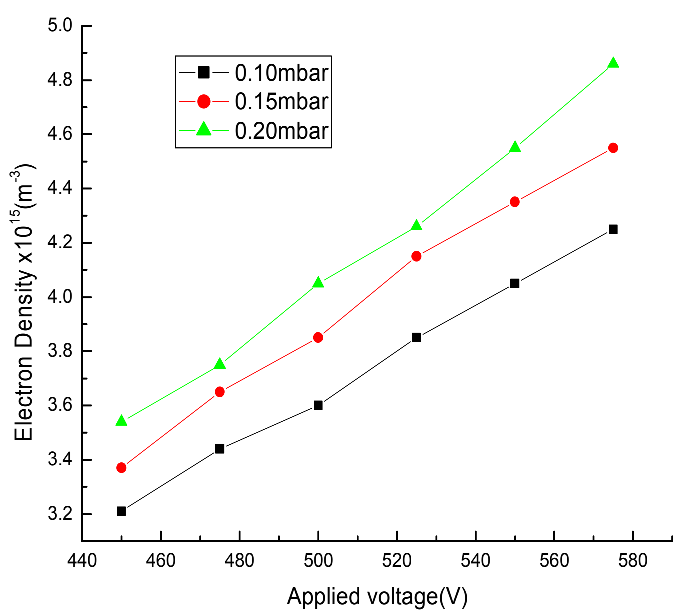


Fig. 6: Variation of electron density in arc plasma at low pressure.

4. Conclusions

A low-cost vacuum chamber of stainless steel has been developed in the laboratory by adopting a systematic approach for the study of Plasma parameters in seeded arc plasma. The nature of I-V characteristic plotted using data obtained from the single probe method. The results are in good agreement with the characteristics of the Langmuir Probe obtained by other researchers [9]. The electron density of the low pressure plasma increases as pressure increases. Results show that the experimental set up is suitable for measuring plasma parameters.

Acknowledgement

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References

[1] C. Hauviller, Design of vacuum chambers, CERN, Geneva, Switzerland (2007).

[2] V. K. Jha, Study on Compression of ICF Fuel in Rocket Model, American Journal of Physics and Applications, 5 (2017) 95-98. doi.org/10.11648/j.ajpa.20170506.

[3] A. Brockhaus, C. Borchardt and J. Engemann, Langmuir probe measurements in plasma Sources Sci. Technol., 3 (1994) 539-544.

[4] B. L. Robert and E. B. Brian, Recommended Practice for Use of Langmuir Probes in Electric Propulsion Testing, Journal of Propulsion and Power, 33 (2017) 566-581. doi.org/10.2514/1.B35531.

[5] T. H. Chung, Y. M. Shin & D. C. Seo, Comparision of two methods of interpretation of Langmuir probe data for an inductively coupled oxygen plasma, Contrib. Plasma Phys, 46 (2006) 348-353. doi.org/ 10.1002/ctpp. 200610013.

[6] M. F. Ashby, Materials Selection and Process in Mechanical Design, Butterworth Heinemann, Oxford, (1999).

[7] C. Hauviller, Design of vacuum chambers for experimental regions of colliding beam machines, IEEE Particle Accelerator Conference (1993).

[8] H. Fujimoto, T. Suekane, K. Imanishi, S. Yukiwaki, H. Wei, K. Nagayoshi, M. Yahiro, and C. Adachi, Impurities on OLED Degradation, SID Symposium Digest of Technical Papers, 48 (2017) 9-12.

[9] R.P. Sinha, B.M.K. Prasaad, M. Bhagat and B. Narayan, A Study of Cu Arc Plasma using a Moving Langmuir Probe, Indian Journal of Pure & Applied Physics, 26 (1988) 720-721.