Structural Analysis of Extended Plasma Focus Chamber

Analisis Stuktur bagi Perlanjutan Kebuk Plasma Fokus

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ABSTRACT

Accelerator Development Centre (ADC) of Nuclear Malaysia intends to upgrade the plasma focus device. It involves the extension part placed on top of the existing plasma focus vacuum chamber. This extended vacuum chamber purposely to give an extra space in conducting experiments on the existing plasma focus chamber. The aim of upgrading the plasma focus device is to solve the limitation in research and analysis of sample due to its done in an open system that cause analysis of samples is limited and less optimal. This extended chamber was design in considering the ease of fabrication as well as durability of its structural. Thus, this paper discusses the structural analysis in term of pressure loading effect in extended chamber.

ABSTRAK

Pusat Pembangunan Akselerator Nuklear Malaysia bercadang untuk menaik taraf alatan fokus plasma. Ia melibatkan perlanjutan kebuk (extended chamber) di atas alatan plasma fokus sedia ada dengan tujuan untuk menjalankan aktiviti penyelidikan dan pengujian terhadap sampel didalam ruang tertutup berbekalkan gas yang dikehendaki. Pada masa kini, ujian terhadap sample hanya dilakukan pada persekitaran terbuka yang menyebabkan analisa terhadap sampel adalah terbatas dan kurang optimum. Oleh itu, rekabentuk rekaan yang baru telah dibincangkan dengan mengambil kira kemudahan fabrikasi dan juga kesesuaian rekaan. Kertas ini akan membincangkan keputusan analisa struktur terhadap rekabentuk perlanjutan kebuk yang akan di naiktaraf yang melibatkan analisis terhadap takanan.

Keywords: Plasma focus; Structural analysis; CATIA V5

Introduction

Plasma focus in Malaysian Nuclear Agency has been developing since 2005. Since then a full set of plasma focus device has been completed in 2007. This plasma focus device is from a Mather type design. Figure 1 shows of the Mather-type plasma focus device.

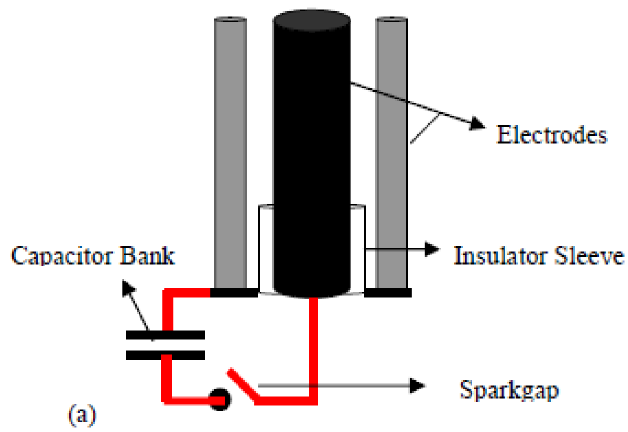


Figure 1: Sketch of Mather-type Plasma Focus

The Plasma Focus is a compact and simple device. The plasma focus occurs at the open end of coaxial electrodes when an intense electrical discharge between them is induced by external means. The coaxial electrodes are located inside a vacuum chamber which is filled with argon or deuterium gas. A charged capacitor bank is connected to the closed end of the electrodes through a switch. After closing the switch, a gas discharge starts in the gap between the electrodes forming an umbrella-like plasma layer. The azimuthal magnetic field produces a force that pushes the sheath toward the open end of the electrodes. Finally, the sheath clashes on the axis in the form of a small dense plasma focus which the lifetime of the focus is about 300 ns. Figure 2 shows the existing plasma focus device located at Nuclear Malaysia Agency.

Figure 2: Plasma focus device at Nuclear Malaysia Agency

ADC group intends to upgrade the plasma focus device which involves the extension part placed on top of the existing plasma focus vacuum chamber. The reason is purposely to give an extra space to conduct any experiment on the existing plasma focus chamber. In addition, the aim of upgrading the plasma focus device is to solve the limitation in research and analysis of sample due to its done in an open system that cause analysis of samples is limited and less optimal. This extended chamber was design in considering the realistic as well as durability of its structural. Thus, this paper discusses the structural analysis in term of pressure loading effect in extended chamber.

In this paper, a stress analysis is performed to ensure that the structural of the new extended chamber can withstand the high and low pressure. This extended chamber made from Stainless Steel AISI 304 and it properties is presented in Table 1.

Table 1: The properties of Stainless Steel from Catia Stress analysis software is shown below

Material	Stainless Steel AISI 304
Young's modulus	1.93e+011N_m2
Poisson's ratio	0.3
Density	7900kg_m3
Yield strength	2.05e+008N_m2
Coefficient of thermal expansion	17.28_Kdeg

The conceptual drawing of this extended chamber had been discussed with the group of plasma focus and engineering considered with the suitability of size and fabrication process. In term ease of fabrication, the dimension of design followed the standard sizing of the cylindrical pipe in market. Drawing of the extended chamber of plasma focus is shown in Figure 3.

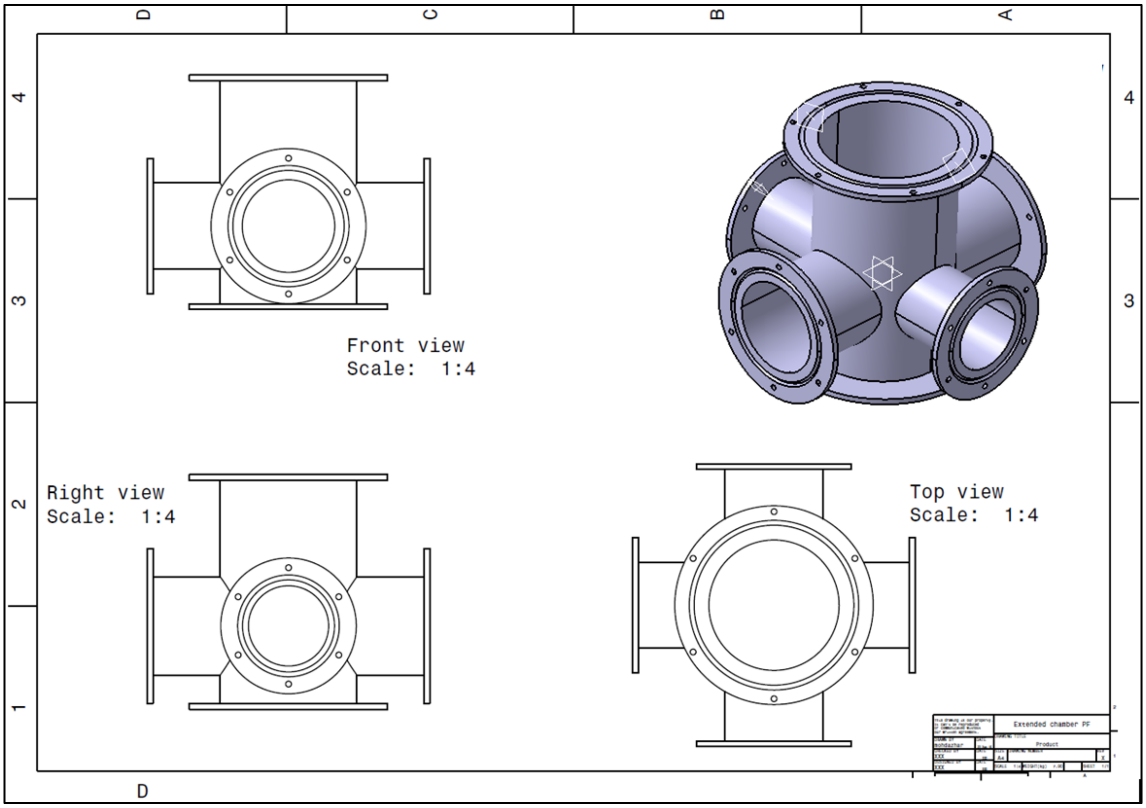


Figure 3: Drawing of Extended Chamber

Methodology

The internal pressure from the gas is the major concern for this extended chamber design. The equation for estimating the hoop stress created by an internal pressure on a thin-wall structure is presented in the following formula:

$$\sigma_\theta = \frac{Pr}{t} \quad \text{(for a cylinder)}$$

where

P is the internal pressure

t is the wall thickness

r is the mean radius of the cylinder

σ_θ is the hoop stress

The yield strength of the material gives important parameters for the structural strength analysis. The calculation and analysis are based on strength of material and mechanics of deformable bodies. The principal objective of mechanics material is to determine the stress and deformation of the structure due to load acting on it. Table 2 shows the loading pressure inside the structure.

Table 2: Loading pressure inside the structure

Pressure (N/m^2)
100
200
300
400
500
600

In this analysis, the result from Von Mises stress and displacement of structure were used to check whether their design will withstand a given load condition. In this case, a material is said to start yielding when its Von Mises stress reaches a critical value known as the yield strength. The Von Mises stress is used to predict yielding of materials under any loading condition from results of simple uniaxial tensile tests.

Result and discussion

By using the software CATIA V5R20, the maximum Von Mises Stress and displacement (deflection) of structure can be calculated automatically. Basic static analysis is used in this structural analysis. Figure 4 (a) and (b) shows the result of Von Mises and maximum displacement of the structure at gas pressure 500 Pa.

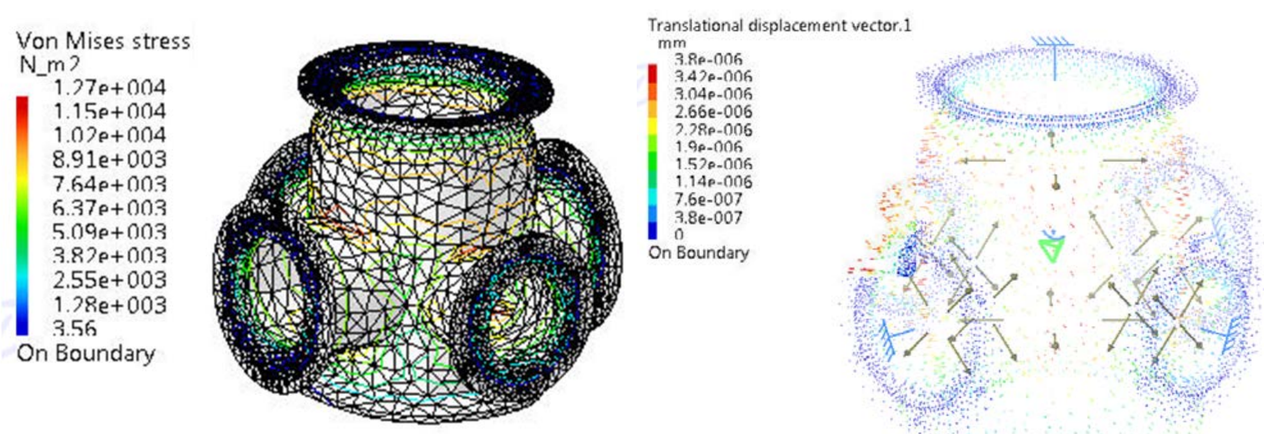
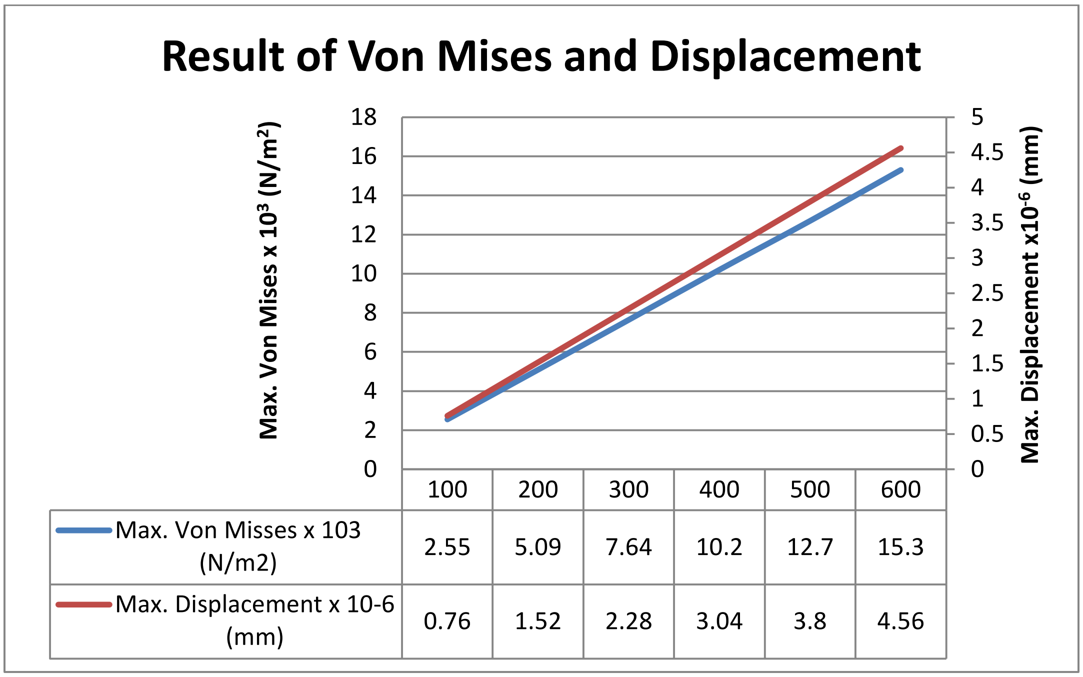


Figure 4: (a) Maximum Von Mises Stress (b) Maximum displacement

Figure 5 shows the result of Von Mises and displacement of the structure after being subjected to a certain pressure. From it, pressure of 600 Pa give the value of maximum Von Mises 0.0153 MPa and the maximum displacement of the structure is 4.56 x 10^{-6} mm. The result shows much lower of the maximum Von Mises as well as maximum displacement of the structure which is the value of yield strength of Stainless Steel is 205 MPa. Both values of Von Misew and displacement are in allowable criteria.



	100	200	300	400	500	600
Max. Von Misses x 103 (N/m2)	2.55	5.09	7.64	10.2	12.7	15.3
Max. Displacement x 10-6 (mm)	0.76	1.52	2.28	3.04	3.8	4.56

Figure 5: Result of Von Mises and displacement of the structure

Conclusion and recommendation

The stress analysis performed shows that the Von Mises Stress and displacement of the structure are under allowable criteria. Furthermore, it is important to analyze all the structures of extended chamber to ensure that the safety requirement in operation of plasma focus device is fulfilled.

Von Mises stress is considered to be a safe haven for design engineers. Using this information an engineer can say his design will fail, if the maximum value of Von Mises stress induced in the material is more than strength of the material. It works well for most cases, especially when the material is ductile in nature.

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