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DEVELOPMENT OF A VACUUM CHAMBER DISASSEMBLY AND ASSEMBLY HANDCART

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Abstract

This paper developed a dedicated disassembly and assembly handcart for CSNS magnetic alloy cavity vacuum chamber. The optimal supporting section structure was determined by the use of ANSYS to analyze the strength of different sections. The stress situation of the handcart was improved by adding an extension rod at the end of the handcart. The installation position of the handcart was determined by the center position of the associated equipment. The development of the disassembly and assembly handcart structure was completed through structural optimization, disassembly and assembly process analysis, and positioning scheme design. The development of a handcart can improve the positioning accuracy of the vacuum chamber and prevent damage to the vacuum chamber during disassembly and assembly process.

INSTRUCTIONS

Magnetic alloy cavity is an important device for CSNS power increase. The length of its vacuum chamber is about 1.8 m with the weight of 75 kg. The vacuum chamber needs to pass through several cavities during the assembly-disassembly of it. And it is necessary to protect the insulating ceramics in the middle of the vacuum chamber. Meanwhile, just one small gap was left between the vacuum chamber and cavity to ensure the performance of the cavity. The smallest gap was only 3.5 mm. These factors make disassembly and assembly of the vacuum chamber very difficult and challenging. So, a dedicated handcart was developed for the disassembly and assembly of vacuum chamber.

OVERALL STRUCTURE DESIGN

The overall structure of the handcart is determined by the functions it is intended to achieve and working conditions [1]. First, the handcart is used to support the vacuum chamber steadily. And then it is required to smoothly move to the installation position of the vacuum chamber. To achieve the above functions, the overall handcart structure is designed as the following picture, which is composed of a base, support part, and guide part. The structure of the handcart is shown in Figure 1.

SUPPORT STRUCTURE DESIGN

The support beam is extended into the interior of the vacuum chamber during disassembly and assembly, supporting the weight of the vacuum chamber. Its strength and deformation need to be within a reasonable range. Based on the working condition of the support beam, it is determined that the force acting on the support beam is a cantilever structure. Several different cross-sectional shapes of support beams were selected for comparison. And the one with the best stress conditions was determined as the support beam. I-beams, rectangular tubes, and circular tubes were selected for comparison in usual materials. One end of the support beam was fixed and the load of the vacuum chamber was uniformly acted on the supporting surface [2]. The calculation results were shown in Table 1.

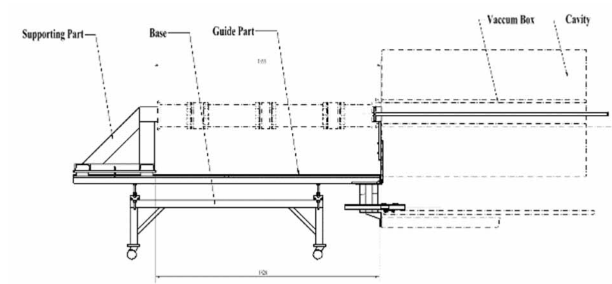

Figure 1: Overall structure of the handcart.

Table 1: Stress and Deformation for Support Beams with Different Cross-sectional Shapes

Cross-sectional shapes	Maximal stress [MPa]	Maximal deformation [mm]
I-beam	17.6	0.67
Rectangular	21.0	0.97
Circular	26.6	1.12

The distribution of stress and deformation on the supporting beams of each section is shown in Figure 2.

From above results, it can be concluded that under the same load, I-beam has the best stress state. And it can also be found that there is still significant deformation under cantilever structure for I-beam. If the cantilever structure can be eliminated, the stiffness of the support beam can be greatly improved. Figure 3 shows the stress and deformation distributions of the support beam under two fixed ends. The maximum deformation is only 0.02 mm, and the maximum stress is only 4.9 MPa.

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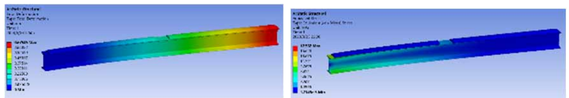
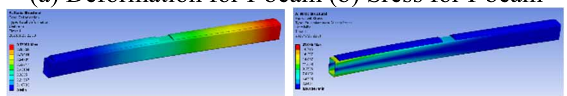

(a) Deformation for I-beam (b) Sress for I-beam


(c) Deformation for rectangular (d) Sress for rectangular

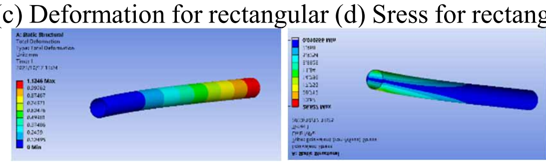

(e) Deformation for circular (f) Sress for circular

Figure 2: Distribution of deformation and stress for different sections.

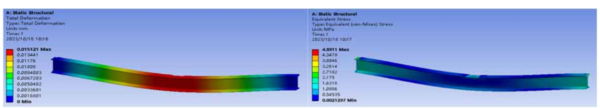

(a) Deformation (b) Sress

Figure 3: Distribution of deformation and stress for two fixed ends I-beam.

But it is quite difficult to fix the two ends of the support beam under actual working conditions. To improve the stress condition, two expansion rods are added to the side of the I-beam, which are extended during operation and supported by auxiliary support at the other end. And it is necessary to connect the support structure with other parts to form a complete handcart. Therefore, the final support structure was consisted of installation seat, support beam, and expansion rods, which was shown in Figure 4.

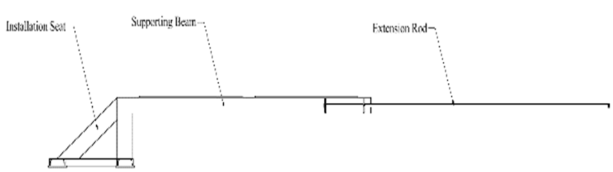


Figure 4: General drawing of support structure.

DESIGN OF POSITIONING AND GUIDING MECHANISM

When disassembling and assembling the vacuum chamber, the inner cylinder of the cavity has been aligned and adjusted in place, so it can be used as a reference to locate the handcart [3]. According to the structure of the cavity, a positioning mechanism is set up on the support surface of the cavity, and a circular sleeve is used for positioning. Since the position of the cavity has been adjusted, the center of the positioning sleeve is naturally parallel to the center of the cavity. To adjust the center of the positioning sleeve to the same vertical plane of the cavity, this positioning sleeve can be used to guide the direction of the handcart. To achieve directional guidance of the handcart, a positioning sleeve and two guide rails are set at the handcart end, and the handcart position is adjusted to be concentric with the positioning sleeve at the cavity end to achieve directional guidance of movement. The positioning guide mechanism is shown in Figure 5.

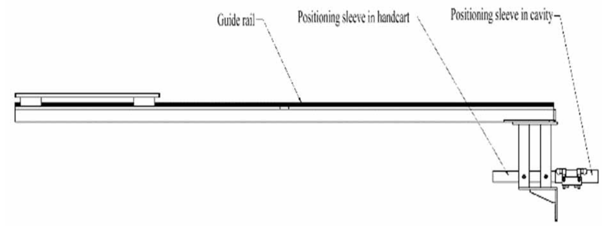


Figure 5: General drawing of positioning and guiding mechanism.

To ensure smooth installation, a gap fit is used between the two sleeves. Assuming the gap between the sleeves is Δ, the guiding length is L, and the movement distance is L_1, then the offset t generated from the entire movement can be calculated using Eq. (1).

$$t = L_1 \times \tan\left(\arctan\frac{\Delta}{L}\right) = \frac{L_1}{L}\Delta \tag{1}$$

If the gap is designed as 0.5 mm and the guide length is 300 mm, the offset produced within the 1.8-meter range of motion is only 3 mm, which is less than the minimum gap between the cavity and the vacuum chamber. So, the positioning and guiding mechanism can meet the requirements.

BASE DESIGN

The base is directly placed on the ground to support, adjust and transport the handcart. The base is welded by profiles, which is easy to process with low cost and good strength. Four universal wheels are installed at the bottom of the base for easy transportation, and an adjustment mechanism is fixed at the top to adjust the position of the handcart. The overall structure of the base is shown in Figure 6.

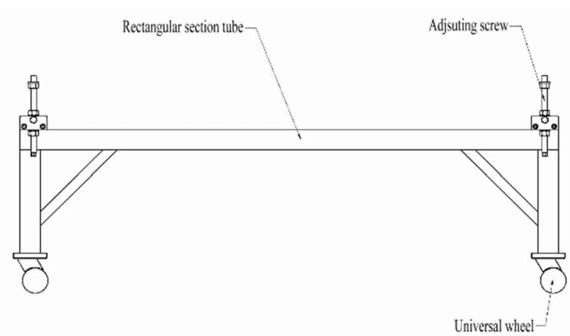


Figure 6: Overall drawing of the base.

SUMMARY

By analysing the disassembly and assembly conditions of the cavity vacuum chamber, the overall structure of the handcart was achieved. And ANSYS was used to analyse and compare the stress situation of support beams with different cross-sectional shapes, and the cross-sectional shape with the best stress conditions was selected as the support

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beam. A positioning and guiding mechanism was designed for the handcart using the center of the cavity. An adjust and movable base has been designed for the handcart. The handcart can meet the disassembly and assembly requirements of the vacuum chamber in a long distance and small gap in the magnetic alloy cavity.

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