A Verticality Adjustment Technology for AP1000 Refueling Machine Mast

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Abstract: The refueling machine is used to handle the nuclear fuel assembly in the nuclear island, and is used to transport fuel between the fuel upender basket and reactor vessel core. During Unit 1 of a nuclear power plant initial fuel loading, it was found that the inner mast operated with large friction, which caused frequent triggering of overload protection during fuel operation, and the refueling machine was difficult to be operated normally. According to the unique design characteristics of the inner mast of the AP1000 refueling machine, the verticality adjustment method of the mast of the AP1000 refueling machine is developed. By adjusting the verticality of the outer mast, the concentricity of the inner and the outer mast, the levelness of the equilibrium arm of the inner mast, and the gap between the guide roller of the outer mast and the inner mast, the problem of high friction in the operation of the inner mast is solved. At the same time, the verticality of the inner mast during operation is ensured. This method has been successfully applied in the first overhaul of a power plant. It can be used to guide the installation and adjustment of the refueling machine mast with similar structure.

Key words: Refueling machine; Mast; Verticality; Total station

1. Foreword

The AP1000 core consists of 157 fuel assemblies[1], and the theoretical minimum gap between adjacent fuel assemblies is only 1.02mm. This requires that the inner mast of the refueling machine has a very high running verticality when the fuel assembly is moved up and down. Otherwise, when the refueling machine is loaded and refueled in the on index position, it is easy to cause scratches between the operated fuel assembly and the adjacent ones, which will maybe damages the fuel assembly intermediate grid.

In order to prevent damage during the fuel assembly up and down movement, the AP1000 refueling machine[2][3] is designed with overload and underload protection control logic. If the parameters such as the verticality of the outer mast, the concentricity of the inner and outer mast, the levelness of the balance arm of the inner mast, the clearance between the guide roller of the outer mast and the inner mast are not adjusted properly, sometimes it can meet the verticality requirements of the inner mast. But the running friction of the inner mast will still be too large, which will affect the fuel loading and unloading efficiency and the life of the guide roller. During initial fuel loading of a nuclear power plant, it was found that the friction of the inner mast reached about 30kg at an operation altitude of 2800mm-3500mm, which was very close to the protection value of 68kg when the fuel assembly was loaded. The refueling machine can only run at reduced speed, seriously affect the loading speed.

2. Idea of adjusting the mast of AP1000 refueling machine

The AP1000 refueling machine does not rely on guide rollers to ensure vertical movement of the inner mast. The AP1000 refueling machine is designed to ensure that the inner mast maintains a vertical posture in a free hanging state. The guide roller is only used to limit the movement of the inner mast in the horizontal direction. Therefore, as long as the verticality of the outer mast is ensured, the guide roller is installed on a vertical line, and the gap between the guide roller and the inner mast meets the requirements of the drawing, the running verticality and friction of the inner mast will naturally meet the requirements. Therefore, the first step should be to adjust the verticality of the outer mast, the second step to adjust the horizontality of the balance arm of the inner mast, the third step to adjust the concentricity of the inner and outer masts, and the fourth step to adjust the gap between the inner mast and the guide roller.
As shown in Figure 1, the AP1000 mast is supported by the part 3 installed on the trolley, and the part 1 is installed on the part 3 via the part 2. Due to the existence of the part 2, the part 1 can rotate together with the part 6 for a certain amount angle. On the outer surface of the part 1, seven pairs of parts 5 are mounted from top to bottom. The verticality of part 1 can be adjusted by changing the thickness of part 4. The gap between parts 5 and 6 can be adjusted by changing the thickness of part 8.

### 2.1 Adjustment of verticality of outer mast

The machining of the outer mast adopts one-time clamping, one-time positioning, and one-time machining to complete all mechanical features, with high machining accuracy. Therefore, using certain machined features on the outer mast can reflect the verticality of the mast installation.

According to this idea, a part 3 with a thread at one end and a cone at the other end is produced, the part 3 is screwed into the threaded hole of the part 1, and the conical point of the part 3 reflects the center of the threaded hole of the part 1. Screw the part 3 into the threaded holes at the uppermost and lowermost positions on the same side of the part 1 and the part 2, and hang the plumb in the upper part 3, as shown in Figure 2. The difference in the distance between the plumb line and the machined flange surfaces of parts 1 and 2 reflects the verticality in this direction, and the distance between the plumb line and the lowermost tooling reflects the verticality in another orthogonal direction. According to the measurement results, adjust the thickness of part 4 in Figure 1 until the verticality of the outer mast reaches ±4.76mm.

### 2.2 Adjustment of inner mast balance arm

By adjusting the lengths of part 1 and part 3 as shown in Figure 3 to ensure that part 2 is kept horizontal, so as to ensure that part 4 remains concentric with the outer mast during the up and down movement, which can reduce the chance of the inner mast and the guide roller rubbing against each other, thereby reducing friction.
2.4 Adjustment of guide roller clearance

According to the design drawings, the theoretical gap between the inner mast and the guide roller is 1.6mm, which is converted into a gap of 1.13mm between the side of the inner sleeve and the side of the guide wheel. Lower the inner mast until the bottom of it is slightly lower than the position of the seventh pair of guide roller seats. Without gaskets, install the guide roller on one side, push the inner mast to make it stick to the guide roller, and plug the other side between the guide roller and the inner mast with a 2.3mm thick feeler gauge, measure the clearance between guide roller and its seat. Half of the measured value is the theoretical thickness of the shims added to the guide rollers on the north and south sides. Since the outer mast is not absolutely vertical, in order to ensure the uniform clearance between the inner mast and the guide roller, the thickness of the gaskets added on both sides should be adjusted based on the theoretical thickness and the verticality of the outer mast measured after adjustment per section 2.1 of this article, withdraw part of the gasket from one side of the outer mast and add it to the other side.

Using the tooling as shown in Figure 5, take the seventh pair of guide wheels as the benchmark to ensure that the distance between the outer surface of the guide roller seat and the vertical line is equal, and adjust the thickness of the gasket between the guide roller and its seat to make the seven guide rollers at the same side are installed on a vertical line, and the other side is installed in the same way.

3. Check and accept

After adjustment, stick the target reflector at the position of the inner mast close to the fuel assembly gripper, and use the total station to measure the running verticality of the inner mast. Since the positioning accuracy of the refueling machine is ±3.18mm, the inner mast running verticality shall not be greater than 3.18mm. It should be noted that, the coil spring of the reel wrapped with fuel gripper cylinder compressed air supply pipe, the underwater camera cable reel coil spring, and the gripper proximity switch cable reel coil spring apply eccentric force on the top of the inner mast. When the refueling machine is not loaded, the eccentric force has a great influence on the posture of the inner mast, which will cause the measured verticality of the inner mast to be large. It is necessary to untie the connection between the air supply pipe, the cable and the top of the inner mast to eliminate the influence of the eccentric force before measuring.

During commissioning, simulate the process of inserting fuel assemblies into the core with the inner mast loaded with dummy fuel assembly and measure the running verticality of the inner mast, the measured value is required to be within 1mm.

The running friction of the inner mast is also verified. It is divided into no-load acceptance test and load acceptance test. It is required that the mast can run smoothly at the highest speed without jamming, overload and underload. Friction is generally controlled within 10kg.

4. Conclusion

The inner mast maintains a vertical posture in the free hanging state, and the guide roller is only used to limit the movement range of the inner mast in the horizontal direction, which is the unique design concept of the AP1000 refueling machine. According to this, a method
for adjusting the verticality of the mast of the refueling machine was developed. During the first overhaul of a nuclear power plant, this method was applied to solve the problem of large running friction of the inner mast of the refueling machine, and at the same time ensured the inner mast verticality during operation.

References

