Research on Maritime Transport Technology for Large Spacecraft

Rui-zhao DU¹,²,*, Qian-ru WU³, Chen-chen JING³ and Xiao-dong ZHANG¹,²

¹Beijing Institute of Spacecraft Environment Engineering, 100094 Beijing, China
²Beijing Engineering Research Center of the Intelligent Assembly Technology and Equipment for Aerospace Product, 100094 Beijing, China
³Beijing Institute of Technology, 100081 Beijing, China

*Corresponding author

Keywords: Large, Spacecraft, Maritime technology.

Abstract. With the increasing dimension of spacecraft and the use of Wenchang launching site in Hainan province, maritime transportation for spacecraft has become a major form of transportation right after road transportation, railway transportation and air transportation. In this paper, the forms of transportation and the characteristics of maritime transportation for spacecraft are introduced, and maritime research of some typical domestic and international aerospace products is investigated. Finally, based on the maritime implementation experience of a certain type of spacecraft, the maritime technology for large spacecraft is summarized, providing a reference for the maritime transportation for spacecrafts in the future.

Introduction

Spacecrafts need to be transported to launching site by road, rail, ship or air to execute launching task [1], which is of great importance. In June 2016, Japan’s DSN-1 X-band military communications satellite was damaged during transportation from Japan to Europe’s Guiana Space Center spaceport in South America and will miss its planned summer launch aboard a European heavy-lift Ariane 5 rocket, also delaying its intended co-passenger, India’s GSAT-18 telecommunications satellite. The problems during the spacecraft transportation have drawn great attention of aerospace workers.

In terms of the layout of the spaceport, Jiuquan, Xichang and Taiyuan satellite launching sites are all in inland areas. Spacecrafts are usually first transported by road, then by rail or air. With Wenchang launching site put into use, maritime transport provides a new choice for spacecraft transport.

Transportation Forms of Spacecrafts

Transportation forms of spacecrafts generally include road transport, railway transport, air transport and maritime transport. Road transport, the basic transportation form, plays an irreplaceable role, which is often used in conjunction with other transportation forms. Road transportation is responsible for the transportation of spacecrafts from the assembly plant to airports, ports, railway stations and so on. This transportation form is restricted by road width, bridges, culverts, toll stations and road quality. It is not suitable for long-distance transport and requires long transportation period under severe environment.

Trains with special equipment are adopted in the railway transport, consisting of flatbed train, closed car and metal containers. Railway transport is strictly restrained by tracks, bridges and tunnels, and needs high requirements for the dimensions of spacecraft packing boxes, which cannot meet the demand for the transportation of large-scale spacecraft. Basically, the environmental conditions of railway transport is the same with that of road transport.
Air transport becomes more and more popular due to its fast speed and no restricts on the launching site (inland or coastal). However, there is still no super air conveyance in China, and it’s hard to realize the transportation of large spacecrafts in the near future. Air transport includes transporting cargo inside and outside the airplane. The spacecrafts transported are usually loaded inside the plane in the domestic. Although air transport has an obvious advantage in transport time, it’s restricted by the size of the conveyance’s cargo and cargo capacity. Meanwhile, air transport is easily affected by rain, snow, fog and some other weather conditions. The impact during take-off and landing process and air turbulence during the flight will bring a little impact to the spacecrafts as well.

Compared to air transport, maritime transport is not restricted by the dimension and weight of transporting goods, and transporting environment and weather conditions nearly have no effect on it. It is of high reliability, and requires relatively low developing cost and technology. Nonetheless, it generally takes long time for maritime transport because of the low speed. Spacecrafts are susceptible to salt fog and the location of launching site is limited by the harbor position [2]. With dimension of spacecrafts increasing, maritime transport is becoming the most fundamental transportation form.

At this stage, spacecrafts are usually transported by road, then by rail, air or marine in the domestic. Many factors should be taken into consideration in the selection of the transportation form for spacecrafts, including the location of launching site, dimension of the packing box of spacecrafts, weight of transporting goods, transporting environment and so on.

Characteristics of Maritime Transport of Spacecrafts

Dynamic Characteristic of Maritime Transport of Spacecrafts

High requirements for the transporting mechanical environment are needed because of the high reliability and precision of spacecrafts. The requirements for overload in forward, transverse and vertical directions (excluding gravity) should be less than 0.9g.

The movement of boats in waves is complicated. According to wave resistance theory, the complicated movement of boats in waves can be decomposed into six simple movements, including...
rolling, pitching, yawing, swaying, heaving and surging when the ship acts a rigid body. Under normal circumstances, there is little chance that yawing exists with large longitudinal stabilizing torque. Rolling and pitching usually create large force on spacecrafts [3].

There are another two impact excitations in the moving process of the boats. One occasion is that impact happens at the bottom of stem in the process of discharge and inhalation of water. This is a sudden impact of loads, which can cause vibration of partial or even the whole ship. Another occasion is that impact happens when big waves (over six-meter height) slap wave-ward side of the boats [1].

Based on the mechanical environment of maritime transport of spacecrafts, high requirements of loading position on the boats and lashing method are needed. Spacecrafts should be loaded in the metacenter of boats, and the lashing method is designed by the distribution and number of the fixed points for packing boxes of spacecrafts and loading capability.

Table 1. Vibration acceleration peak values of a type of spacecraft in road and maritime transport.

<table>
<thead>
<tr>
<th>Testing direction</th>
<th>Road transport</th>
<th>Maritime transport</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forward direction</td>
<td>-0.827</td>
<td>0.109</td>
</tr>
<tr>
<td>Transverse direction</td>
<td>0.86</td>
<td>0.009</td>
</tr>
<tr>
<td>Vertical direction</td>
<td>0.561</td>
<td>0.011</td>
</tr>
</tbody>
</table>

Comparing the monitoring mechanical environmental data of a type of spacecraft between road transport and maritime transport, although vibration amplitude is vulnerable to sea condition in maritime transport, the vibration is of low frequency with low impact load to spacecrafts. In road transport, impact acceleration increases rapidly due to the fluctuating road conditions and the sudden acceleration and deceleration of transport vehicle. Consequently, the mechanical environment of maritime transport is better than that of other transportation forms.

Salt Fog Proofing Design of Spacecrafts’ Fixture in Maritime Transport

It generally takes long time in maritime transport because of the restriction on the speed of boats. Taking a type of spacecraft transported from Tianjin cruise port to Qinglan port of Hainan as an example, the one-way transporting time takes about a week. Salt fog corrosion on the spacecrafts and other outfits cannot be avoided in maritime transport. When ambient air is filled with salt, the air will have conductivity, making the insulating property of the electronic equipment, instruments and cables decrease [4] and reducing working reliability, which can even lead to electric leakage and short circuit. Salt fog can contribute to the corrosion of the equipment, especially for metals [5]. The corrosion of metals is conducted electrochemically and the corrosion mechanism is based on galvanic corrosion [6].

Spacecrafts are placed in the packing boxes during transportation. The packing boxes are filled with purity nitrogen, which is 2KPa higher than outside, providing a clean and safe storing environment. However, the developed ground process equipment cannot be packed in the packing boxes due to the large dimension. Considering the transporting cost, it is not economic to develop a specialized box for the ground process equipment. As consequence, salt fog proofing should be taken into consideration in the initial design of ground process equipment.

The salt fog proofing design of ground process equipment should consider many factors, including the selection of electronic components, metal materials, machining process and surface treatment of the product. In the premise of meeting the requirement of function and performance, smooth transition is adopted in the determination of the shape and dimension to avoid stress corrosion and enhance the technology of coating in the design and processing of the tooling. In addition, devices of moisture proofing, mildew proofing and salt fog proofing are required in the design of internal electronic equipment and seal design also needs to be included.

According to the current implementation experience, painting is the easiest and most effective way of all the salt fog proofing designs of ground process equipment, requiring that surface paint should be
inspected before transporting the ground process equipment. Furthermore, equipment with electromechanical function will take performance tests after maritime transport to launching site to make sure that the tooling can meet the application requirement.

Maritime Transport Introduction of Space Products at Home and Abroad

Maritime Transport Introduction of China’s Long March 7 Carrier Rocket

In June 2016, the Long March 7 rocket was transported from Tianjin cruise port to Qinglan port of Hainan by Yuanwang 21 transport ship, the distance of which is about 2000 nautical miles. Yuanwang 21 is the first carrier-rocket transport ship, with innovative design of safeguard measures in maritime environment and roll stabilization and shock absorption measures of rocket containers, which maintain the temperature, humidity and salt fog in the rocket cargo to a certain level.

Figure 3. Maritime transport of CZ-7 rocket.

Maritime Transport Introduction of Japan’s HTV Cargo Ship

Japan’s HTV cargo ship is assembled and tested in Tsukuba Space Center in construction stage. Afterwards, it is carried to Tsukuba port in road transport, and then carried to Tanegashima Space Center by maritime transport to complete the assembly of launching stage, test and ultimate launch.

Figure 4. HTV loading process in maritime transport.

Summary

A type of spacecraft has completed the first maritime transport tasks. Different from the maritime transport of carrier rocket, higher demand of transporting environment is required for the maritime transport of spacecrafts. Summary on the maritime transport of this type of spacecraft can provide a reference for the maritime transportation for other type of spacecrafts in the future.
Selection of Transporting Routes

The selection of transporting routes is restricted by developing location of spacecrafts and the launching site, following nearby principle. The spacecraft developed in Beijing will choose the Tianjin cruise port as the starting point of transport, while the spacecraft prepared to launch in Wenchang launching site in Hainan will choose Qinglan port as the endpoint of transport. It should be confirmed that harbor crane (shore crane or truck crane) can meet the load and speed requirements of lifting. Transport port needs to realize in or outbound harbor of the ship and docking requirement of transport ships, avoiding the occurrence of ship grounding because of shallow water in the port. Offshore transport is preferred in transportation, and offshore hydrological condition and sea conditions are relatively good, contributing to break and supply of goods and materials in storm conditions.

Selection of Transport Ship

Transport ship is the main carrier of spacecrafts in maritime transport. Load and space should be considered in the selection of transport ship. Spacecrafts should be loaded in the metacenter of the transport ship, and ground process equipment and container are placed in the sealed cargo. Transport ship should be able to provide the corresponding mechatronics interface with the transport device, including the power supply mode, gross electric capacity and connectors’ type. Transport ship are supposed to provide enough fixed points to ensure the adhesion. Currently, the traditional fixed style is that the equipment should be first put into place, then fixed by wall or lashing eyes. Transport ship should provide grounding contact as well and transport ship should realize in or outbound harbor and docking requirement.

Cargo Load Principle in Maritime Transport

Container is the main carrier of cargo in maritime transport. Spacecraft is required to carry a lot of supplies during the factory transport. There are many types of the supplies and all of them are of different shapes and sizes. As a result, the supplies should be put into containers in maritime transport. Using the container to transport supplies can not only provide a relatively closed transport environment, but also facilitate road transport of supplies, loading and unloading of supplies, and fixing of supplies in truck or boat. Meanwhile, the supplies prepared to transport should be allocated rationally to reduce the amount of transporting goods and increase the load and unload efficiency. Packing boxes for spacecraft should be located in better transport environment to meet the requirement of ‘last loading and first unloading’ principle.

Conclusion

From the developing process of spacecrafts in China, spacecrafts are developed in the tendency of large scale in the future. In addition, air transport and railway transport are restricted by the transport envelope. With the use of Wenchang launching site in Hainan province, maritime transport is playing a more and more important role in spacecraft transportation. As a new transport form, although maritime transport has long transport cycle and harsh environment of salt spray corrosion, it has the advantage of superior mechanical environment and high transport envelope compatibility. Further research should be carried out to ensure the smooth implementation of maritime transport of spacecrafts.

References


