Front. Eng. Manag. 2022, 9(2): 349–353
https://doi.org/10.1007/s42524-022-0187-3

SUPER ENGINEERING

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Management innovation and construction integration technology in Brazil's superlarge deep-water offshore oil and gas unit project (FPSO P67/P70)

Keywords Brazil FPSO P67/P70, superlarge, dry towing operation, construction integration, risk control management

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Construction Integrator: Offshore Oil Engineering Co., Ltd., China

1 Background and characteristics of Brazil FPSO P67/P70 project

Floating Production Storage and Offloading (FPSO) is a comprehensive large-scale offshore oil and gas production unit that integrates oil and gas processing, oil storage and unloading, daily life, and power supply. Approximately 210 FPSO units are in service currently, distributed in various offshore oil and gas fields in the world, accounting for approximately 72% of the total number of floating platforms. FPSO includes three major systems: Hull, topside facilities, and mooring system, among which the construction and integration of the hull and topside facilities are considered core activities.

- Hull (mainly used for temporary storage and export of crude oil extracted from the sea);
- Topside facilities (offshore oil and gas plants, including oil and gas processing facilities, and public utilities such as power/thermal stations);
- Mooring system (a facility to anchor FPSO in offshore oil and gas fields).

Received December 3, 2021

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Brazil's FPSO P67/P70 project is located in Santos Basin, approximately 300 km away from São Paulo. The Santos Basin is the largest sedimentary basin in Brazil with a water depth of approximately 2188 m. Offshore Oil Engineering Co., Ltd., China (COOEC) is responsible for the construction of two integrated FPSOs — P67/P70, which will be used to develop the oil field in the basin.

In 2014, the original Engineering Procurement Construction (EPC) general contractor of the two FPSOs P67/P70 was unable to complete the project due to the bankruptcy of its parent company. COOEC is the only domestic offshore engineering company with experience and ability to execute FPSOs independently from design, procurement, and construction to integration and commissioning. It became the only choice globally when other contractors withdrew due to the huge complexity and difficulty of the project. In May 2015, COOEC signed the project contract with the owner and its subcontractors. The main work included the remaining detailed design of P70, the construction of 6 new modules and M00 (an appellation for FPSO's loose items), the integration of all modules in the 2 FPSOs (18 modules per FPSO), the commissioning of the whole ship, the towing of the 2 FPSOs, etc.

2 Key technologies applied in FPSO P67/P70 construction integration

FPSO P67/P70 is one of the most advanced, complex, and huge FPSOs in the world. Its technical characteristics are mainly reflected in the following aspects:

- Large-scale and modularization (highly integrated giant offshore floating plant for the production, storage and export of oil and gas);
- Deep-water type (water depth of nearly 2200 m, FPSO + underwater wellhead / multipoint mooring);

- Complex / High-pressure processing system (desulfurization / decarbonization / dehydration based on membrane / dry-wet pressurization reinjection and output);
- Energy-saving, environmental protection, and safety requirements with highest standards (zero emission / zero triethylene glycol / non-combustion support / all waste heat recovery / active and passive fire prevention).

This project is the first FPSO project with a water depth of 2200 m undertaken by COOEC. Through joint design and independent technical research, a series of major technological breakthroughs and innovations has been achieved, covering many leading technologies from design to module construction, integration and dry towing transportation, including technologies for superlarge FPSO process design and floating body design, superlarge FPSO module construction and integration, superlarge FPSO dry tow loading and unloading and long-distance ocean transportation, etc., along with the application of new processes and new materials.

2.1 Superlarge FPSO topside modules integration

Modular construction has gradually become the mainstream technology for oil and gas engineering construction in the world. However, for deep-water FPSOs, due to the complex process system and compact structure, the difficulty of the integration increases geometrically. Study on the technology and procedures of the integration process matters a lot — reasonable planning of the work platform for land installation and integration, as well as module installation priority, construction technology, and fabrication design, was considered to be a key link affecting the integration. Before module integration started, the matching of module size and sling size should be given to full consideration, and the integration scheme and plan should be continuously optimized. Under proper integration sequence, modules with similar specifications were arranged together for continuous lifting (see Fig. 1), reducing the time for replacing slings; at the same time, the hoisting cycle has been declined from 93 to 64 days.

2.2 Deep-water regional high-pressure tightness test technology for FPSO

The gas tightness pressure of P67/P70 could be up to 574 bar, and the water pressure is up to 906 bar. With the multiple increase of pressure, the risk coefficient goes up exponentially. During the implementation of the project, through the design of operation procedures and testing units suitable for ultrahigh pressure, including a set of remote control cabinets and a set of remote control panels, double remote control of pressure suppression was realized, which, with detachable features, could simplify operation processes, and be conducive to the rapid maintenance of equipment, as well as be more safe and reliable.

2.3 Overall performance evaluation technology for the key connecting structures of the riser suspension system

A set of performance evaluation technologies for the key connecting structures of the riser suspension system was independently developed, and a fatigue life assessment method for the key structures based on simplified algorithm was established. The checking and evaluation of member structures were accomplished using the SESAM software. A set of welding treatment methods to improve fatigue life of the structures was formed and applied, and U-shaped brackets were also used to improve structural strength as well as fatigue life.

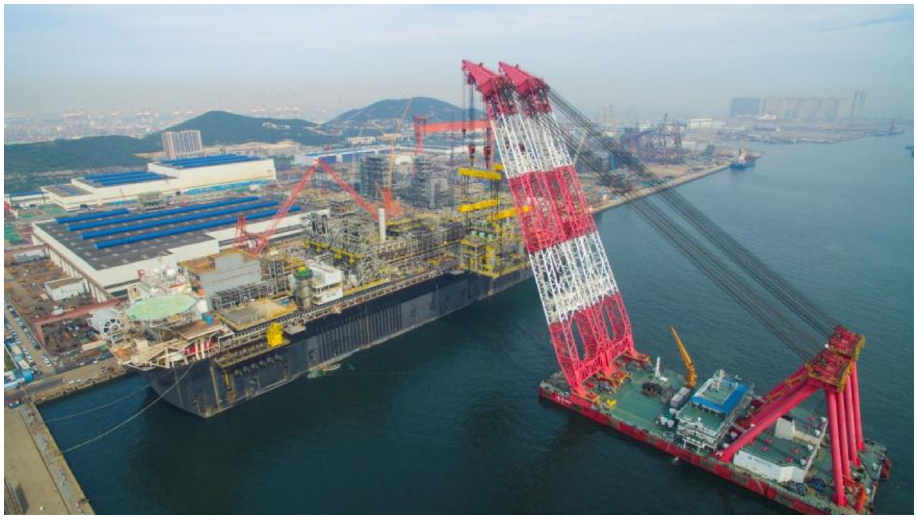

Fig. 1 Module lifting and integration for FPSO P67.

2.4 Innovative application of spherical bearing buffer device

A spherical bearing was applied to the installation connection between the module and the hull. The bottom of the columns of 16 main modules and 7 sub-modules were all connected to the hull buttress using spherical bearings. Hence, the connection between the column and the buttress could be regarded as hinged connection, which could effectively reduce the impact of hull deformation. Without bending moment transfer, the strengthening structure of the hull buttress was relatively simple. The reaction force interface between the module and the hull was simple and clear, and the reaction force value was relatively accurate. The friction noise at the module bottom during hull movement was eliminated.

2.5 Dry towing loading and unloading and long-distance transportation of superlarge FPSO

FPSO P67/P70 has a total length of more than 300 m, a total width of 74 m, a dry weight of nearly 80000 tons, and a displacement of 350000 tons, equivalent to five times the displacement of the Liaoning aircraft carrier. P67 is the first dry towing ocean transportation project of 350000-ton FPSO carried out by China. It was loaded on Boka Vanguard, a semisubmersible transport ship with the largest bearing capacity in the world. "Dry towing" transportation was conducted in the way of "ship on board" (see Fig. 2), passing through the Pacific Ocean, Indian Ocean, and Atlantic Ocean, sailing 12000 nautical miles, crossing half of the earth, and finally reaching Brazil. The difficulty of dry-towed transportation of such a maritime "Big Mac" to Brazil on the other side of the earth is considered the most in the world. Compared with wet towing, dry towing saved at least 50 days for transportation, effectively reducing potential safety risk in the process of long-distance towing, and greatly shortening the project implementation period.

3 Innovation and application of superlarge deep-water offshore oil and gas installation project management

3.1 Module/Equipment transportation

COOEC was responsible for organizing the customs clearance, shipment, and transportation of P67/P70 hull, all modules, and equipment (see Fig. 3). The modules and equipment were mainly distributed in seven different sites in Brazil and China. COOEC mobilized global resources for the first time to transport these modules and equipment in 11 ships. All the design, customs clearance, shipment, and transportation were oriented by COOEC. Through more than one year, COOEC had transported nearly 50000 tons of P67/P70 modules and equipment to its Qingdao site in China.

3.2 Project schedule management

On December 4, 2019, FPSO P70 was successfully delivered in Qingdao, approximately 3 months ahead of the contract date and the integration period of which is nearly 8 months shorter than that of the P67, with the integration efficiency improved by approximately 30%, creating a new speed record for the delivery of international superlarge FPSO. Problems were found and solved in time through daily, weekly, dedicated, and high-level coordination meetings. Daily plan preparation, daily

Fig. 2 FPSO P70 dry tow loading.

progress tracking control, and refined management were example of measures adopted by COOEC to improve the efficiency of management. In the FPSO P70 onshore construction stage, the test, cleaning and recovery of 807 pressure test packages, the tightness test of 212 tightness packages, the certification of 738 mechanical completions, the performance acceptance test and commissioning of 703 subsystems, and the transference and acceptance signature of 610 subsystems which state the successful accomplishment of previous performance test were accomplished to maximize the completion state of onshore construction. Some offshore commissioning work was also completed. Finally, FPSO P70 was put into operation 70 days in advance.

3.3 Project risk management

With the goal of building a comprehensive risk prevention and control system for the project, COOEC established a three-level (management, functional, and project level) risk management and control mechanism (see Fig. 4), expounding the general goal and basic approaches of its

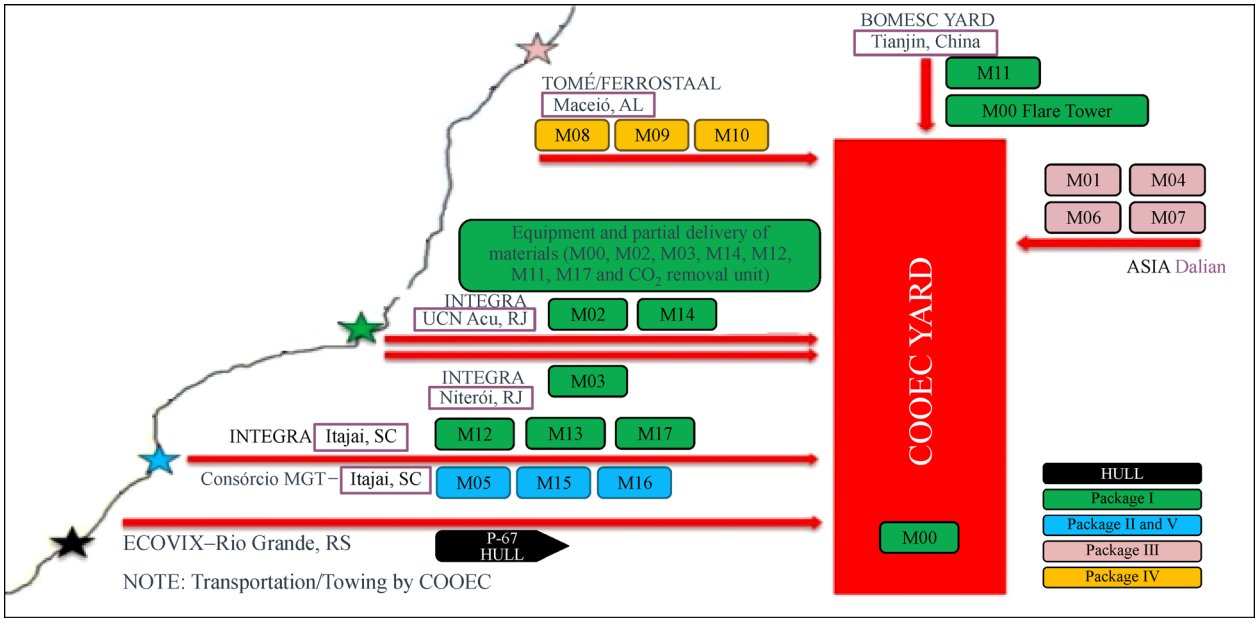

Fig. 3 Schematic of FPSO P67 hull and topside modules transportation.

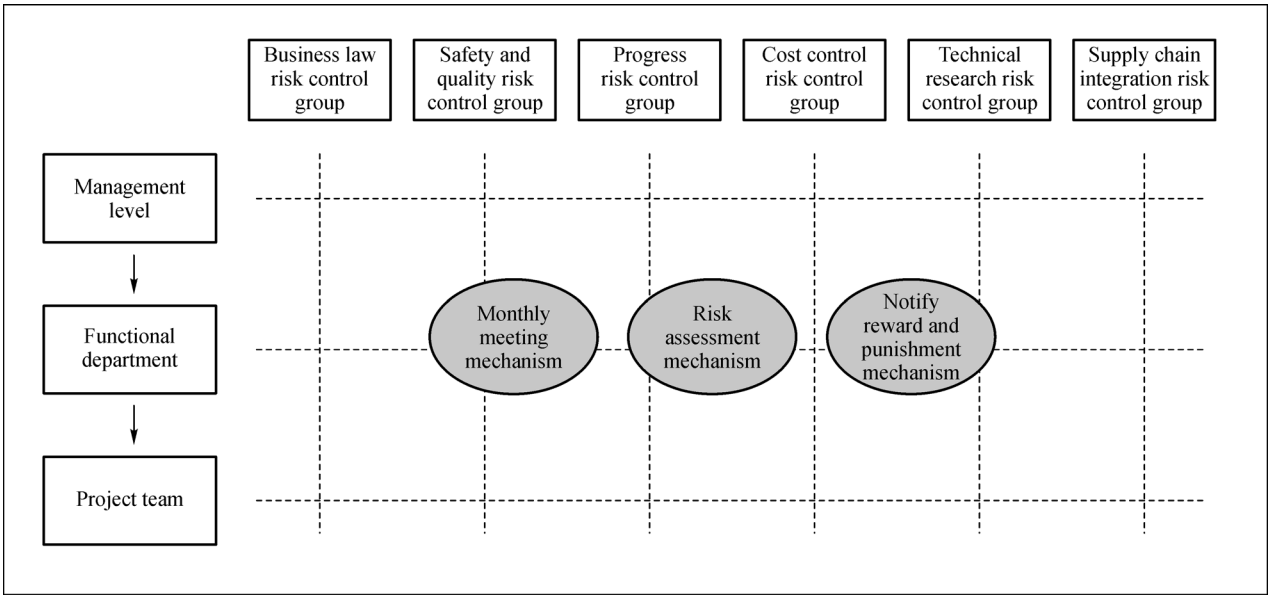

Fig. 4 Project risk management and control mechanism based on matrix analysis.

risk management system. This system improved risk identification, assessment and disposal at both company and project levels, as well as whole-process control mechanism. With six risk control groups established, the overall objectives, working principles and handling procedures for emergency response plan were defined, as well as corresponding plans. Through a series of management mode innovations, the capability and level of comprehensive risk management and control have been improved.

4 Construction effect and impact of Brazil FPSO P67/P70 project

COOEC successfully delivered two FPSOs through effective project management and control measures after the failure of the original contractor. Specifically, FPSO P70 was put into operation 70 days in advance, creating a new speed record for superlarge world-class FPSO delivery in China. The successful implementation of the project has enabled COOEC to achieve a leap forward in the general contracting capacity of superlarge deep-water FPSOs.

The implementation of comprehensive risk management and control for offshore oil engineering projects has solved management weaknesses and prominent problems that have restricted the company's international development and built a risk "firewall" for the entire process from bidding to final completion of international offshore oil engineering project, achieving closed-loop risk management and control. With a high standard and strict control at the implementation level, this risk management and control system provides reference and guidance for China's offshore oil engineering enterprises to implement international projects.