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Pipe technology and installation equipment for frontier deep water projects

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ABSTRACT

Project perspectives in new offshore districts are targeting water depths of 3000–4500 m in open ocean. Field development is often located in the proximity, not far from the toe of the continental slopes. In many circumstances the preferred option for exporting the products is the subsea pipeline, routed across the complex features of the continental slopes. Export pipelines from such fields are therefore large diameter pipes with thick walls to meet deep water strength criteria. Current projects show that material and linepipe technology are at the upper bound of what can be produced within the stringent criteria imposed by the application. Installation implies heavy lay spans that require large vessels as well as high capacity handling and pipe lay equipment. Specific upgrading of existing lay vessels cannot exceed certain limits and proven technology as high strength steel wire cables cannot implicitly provide adequate answers to the needs. Further, in case of huge fields, the development is progressive and the early pipelines include In-Line Structures that allow to accomodate future links to adjacent fields. The challenge is to lay along routes where features and bottom roughness require careful procedures to meet the established targets e.g. specific location of subsea structures in relation to pipeline alignment and their verticality.

In this paper new solutions backed by advanced engineering tools are presented and discussed. Attention is paid to the installation of pipelines and heavy structures in ultra-deep water.

1. Introduction

The offshore pipeline technology has been rapidly progressing during the last three decades, developing technical capabilities to enable construction and operation into increasingly deep waters and harsh environments. In particular, trunkline (Bruschi, 2002, 2003, 2012; Bianchi and Bruschi, 2008) and subsea field development (Offshore Magazine, 2014) projects are getting more and more strategic and complex. This fact deeply impacts on the offshore construction market: during the last decade a number of new pipelay vessels were built, 172 with respect to the 65 built during the early ‘80ies. These are purpose conceived for deep and ultra-deep water (DW and UDW) projects, where dynamic positioning (DP) technology is unique option for new pipelay vessels, rather than mooring. Further, even for shallow to medium water depth projects, environmental issues and safe operations in sensitive or brown fields led pipeline and field operators to prefer DP vessels (Dash, 2014), causing the decline of working opportunities for traditional and ‘skillfull’ moored vessels. The latter were mainly semi-submersible, the former are commonly mono-hull or ship shaped. The use of DP in pipelay vessels date back more than two decades; initially station keeping management was from DW

Abbreviations: AFD, accumulated fatigue damage; CRA, corrosion resistance alloy; DEH, direct electrical heating; DP, dynamic positioning; DPS, double pipe solution; DW, deep water; ETH, electrical traced heating; ECA, engineering criticality assessment; FDS, Field Development Ship; FEM, finite element model; FL, firing line; GoM, Gulf of Mexico; HC, holding capacity; HD, holding demand; H_s, significant wave height; i-DBB, inverse Double Block and Bled; i-HIPPS, inverse High Integrity Pressure Protection System; ILV, In-Line Valve; ILS, In-Line Structure; ISB, in-service buckling; JIP, joint industry project; MBL, minimum breaking load; MWTR, minimum wall thickness requirement; MHCR, minimum holding capacity requirement; OGOI, oil & gas offshore industry; OD, outer diameter; OSCV, offshore subsea construction vessel; PiP, pipe in pipe; PLET, pipeline end termination; PLEM, pipeline end manifold; RTFDA, real time accumulated fatigue damage assessment; RTM, real time monitoring; SAGE, South Asia Gas Enterprise; SCR, steel catenary riser; SAWL, submerged arc-welding longitudinal; SMLS, seam lessteel catenary riser; SNB, strain based design; SS, semi-submersible; SURF, structures; umbilicals, risers and flowlines; SWL, safe working load; UDW, ultra-deep water; TDP, touch down point; T_p, peak period; WD, water depth; WT, wall thickness

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drilling vessels. Plenty of experience was obtained in shallow to medium waters pipelay (actually more challenging operation than in deep waters). Recently, new skills have been developed in careful move up of heavy and long pipe strings even including In-Line Structures (ILS) in deep water projects worldwide. As for lay equipment, large diameter and thicker pipes move to a request for high holding capacity, so the selected holding equipment – track tensioner vs padded clamp – is commonly set over 10,000 kN up to 25,000 kN. Currently, there are 78 pipelay vessels, out of which only 28 having dynamic positioning, capable of operating in water depth over 600 m. Current utilization of deepwater pipelay vessels is at 100%, compared to shallow water anchored vessels with 44% utilization. There are 22 vessels under construction, all equipped with dynamic positioning system targeted for UDW, out of which 16 vessels built for operation offshore Brazil. This outstands the keenness of Oil & Gas Offshore Industry (OGOI) at the Pre-Salt development program in South Atlantic Ocean, in progress by Petrobras in Brazil and next by Sonangol in Angola (Dash, 2014).

Submarine pipelines between continents that cross the oceanic depths can be now conceived e.g. to transport the natural gas from Middle East to India (now named MEtI) in more than 3400 m water depth, as being proposed by SAGE (South Asia Gas Enterprise) over the last decade (Nash and Parry, 2014). A series of new projects of long distance gas transportation infrastructures are currently on the desk, regarding the Eastern Mediterranean and Black Seas (from Cyprus, Russia, Azerbaijan and South Caspian Regions through Turkey to Central Europe), that at the moment unexpectedly makes Turkey as the junction or even hub for the permanent links between Middle East regions and Central Europe. As reference, in the recent past the Mediterranean basin provided a relevant development framework for strategic submarine crossings to supply South Europe from North Africa with natural gas (O.M.E., 2001), landing in Southern Italy and Spain.

Development plans are now considering fields in ultra-deep waters: OGOI differentiates the upper bound limitation in depth, from what is defined as DW (maybe less than 1500 m) and UDW (up to 3000 m). Now frontier projects are targeting water depths greater than 3000 m likely to 4500 m. Plenty of field data, e.g. meteo-ocean, seabed morphology and soil properties, production and transport conditions vs export and storage requirements etc., are currently processed to qualify the potential of new concepts under development for the frontier depths. OGOI is deeply engaged to solve demanding requirements for new materials and line pipe technology upgrading. There are examples of new – likely only in term of capacity – and reliable installation technology for increasingly deep, harsh and remote sea districts. There is consensus, much more than in the early days, or confidence on the use of sophisticated engineering tools to predict the performance of the production and transport infrastructure during installation and specifically in-service over the expected life span; OGOI is increasingly moving to super-computers for numerical simulation of new environments. A significant effort is paid on the technological measures that allow to safely tackle new environmental hazards in ultra-deep waters (mass flows, mud volcano, strong currents etc.), to develop advanced hardware, likely autonomous, for monitoring and inspecting the status of well-being (integrity management technology) and intervening timely. There is presently a gap to be filled on what remoteness and increasing depths may create on the integrity management of complex items.

The new ships FDS2 and CastorONE are Saipem's replies to the forthcoming challenges in deep/ultra-deep water field development and pipe laying (Bruschi et al., 2010; Chiesa and Faldini, 2012; Faldini et al., 2014; Chiesa et al., 2013). The new vessels operate by using new welding, NDT and field joint coating technologies, including innovative installation equipment able to generate added value for the implemented solutions. The name of the vessel "Field Development Ship" (FDS) came more than ten years ago from the needs identified by the Operators, in relation with the architecture of deepwater projects. As basically field development projects include complex systems so the new fleet is designed to offer reliable solutions for the future configurations. Subsea is designed to route the oil and gas fluids to the floating treatment units. It includes flowlines and riser system, subsea structures as manifold or riser base, umbilicals, mooring lines of the floater, offloading and finally export lines. The requirement for a vessel able to conduct the installation of most of these components, with a significant level of versatility, appeared as a must. The success of the vessel has confirmed this assumption and, more recently, the needs increased in a similar way but with a trend to heavier and deeper pipelines, larger In-lines items and subsea structures. Then the concept of FDS has been duplicated with stronger capacities to give the appropriate answer to the market.

Trunk-line projects will be addressed to transportation of large gas volumes over long distances across harsh environments and Saipem vessel CastorONE (C1) is presented by showing off her capabilities for the UDW installation. Nowadays, onboard a typical S-lay barge or vessel, single or double joints, either pre-assembled onboard or onshore, are welded together in the main firing line and then laid onto the seabed along the relevant route. C1 is the first ever built-S-lay vessel which welds triple joints along the main firing line for subsequent move-ups. Two triple joint prefabrication plants feed the main firing line with triple joints. The single pipes are transferred through the vessel via conveyors and elevator, specifically designed and able to move gently the string within the giant vessel workshop. A special segment of the lay equipment is the stinger; it includes the integration of advanced mechanical devices, instrumentation and software to allow for a safe management of the pipeline in steep laying and during modification of settings. The stinger is considered 'smart' due to the automation and monitoring technology, which allows for backing the software based pipelay guidance with the outcome of instrumentation, suitably validated as local and global.

New project frontiers enhancing the technology response, also calling for greater responsibilities, are the leading factor in the offshore industry. The market is expecting firm and convincing response from all contractors. Issues, such as risk mitigation and cost-effectiveness, are the paths to be held with constant strength. The future project challenges shall also be driven by the level of vessel operation capabilities shown off by the contractors. New vessels are designed to play the right cards in the right moment, offering the level of flexibility, state of art technology and a mixture of skilled personnel and equipment, coupling the safety issues in front line, associated with the effective productivity requested by the market.

In this paper the new generation of deep and UDW pipelay vessels and equipment are presented. Material, line-pipe technology from recent pipeline projects and new pipe concepts are introduced and technology update commented. The lesson learnt from installation of heavy pipe in S or J, where meeting subsea targets while coping with the bottom roughness and established route alignment was demanding, is reported. Minimum requirements that the installation equipment must comply with are referred to the outcome of recent experiences in ultra-deep subsea projects, assumed as playground for near to come frontier deep water projects.

2. DW pipelay and subsea in 50 years R&D

The successful outcome of the engineering tools and procedures/equipment conceived and developed in the late 70's and in the 80's, for the design and construction of strategic pipeline links (Bianchi and Bruschi, 2008; Bruschi 2012), can support the trust