Fabricating the Rosa Flowlines in Angola: How to Manufacture a World-Class Product in a Remote Location

E. de Franco,
Rosa flowlines fabrication manager, Saipem SA, Saint-Quentin en Yvelines, France
C. Geertsen,
Rosa Project Manager, ITP Interpipe, 11 quai Conti, 78430 Louveciennes, France.

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1. Introduction: the Total Rosa Project

The Rosa field is located in the Total-operated prolific Bloc 17. The project consisted in tying the wells of the reservoir back to the Girassol FPSO in waterdepths down to 1500m. Due to the extended step-outs of up to 20 km and a total flowline length of 66 km stringent thermal design requirements were imposed on the system, both to provide sufficient fluid arrival temperatures at the FPSO and sufficient preservation time to allow circulation and replacement of the live oil with dead oil in case of a prolonged shutdown. Saipem chose in 2004 the ITP technology for flowline insulation and offshore fieldjointing which had previously been deployed both in deepwater projects (Shell operated Bonga field in Nigeria) and shallow water (Total Tchibeli project in Congo). The technical step-outs from the Bonga project were challenging in themselves, but the real difficulty lay in the project requirement for a fabrication in Angola.

2. Project specific requirements

Design requirements

The main design drivers were the U-value (0.75 W/(m².K), based on the OD) and the depth of installation (down to -1470 m). An added difficulty derived from the very soft and silty seafloor which led to a high level of potential feed-in for thermal buckling over the long stretches between subsea manifolds and line end-points. Mechanical testing on a full-scale pipe section was required to prove that the Pipe-in-Pipe operated soundly with no buckling even when loaded to levels past yield stress. A particular development of the project was centred on the implementation of a semi-automatic welding process with an associated automatic UT system for the execution and inspection of the welds linking the inner and outer pipes.

Local content requirement

A primary requirement (and meant to gain in importance in the future) was to provide a high degree of local fabrication in Angola. These ‘local content’ requirements are increasingly seen in the large West African projects. Although in some instances it may lead to higher overall costs or more challenging schedules and logistics due to the complexity of transporting a large number of sub-elements, their rationale is to increase the value of the project for the host country and assist in the development of a local industry and expertise. Saipem, through its local subsidiary Petromar has already promoted the development of a local workforce for several years and has in particular established a welding school on the premises of the Soyo base.

While Petromar’s long-standing involvement as an Angolan operator therefore provided a natural base for hiring a local workforce, the Soyo location also had other additional advantages. In

particular, there are deep-draught berths in the Kwanda River estuary, allowing for a direct delivery of steel pipes from ocean-going vessels, and a large tract of flat ground that could be turned into an efficient fabrication space for the 1300 quadjoints (ca. 50 m each).

Description of the selected design

The ITP design is a particularly efficient implementation of a high performance insulation package specifically developed for pipeline insulation. The Izoflex™ insulation provides a thermal conductivity of less than 7mW/(m.K) against 14 mW/(m.K) for the best competing materials such as nanoporous products. This translates into a design requiring smaller outer pipes because less insulation material is needed.

Material	Thermal conductivity
Fibreglass	30-40 mW/(m.K)
PU foam	25 mW/(m.K)
Nanoporous material	14 mW/(m.K)
Izoflex™	7 mW/(m.K)

Table 1 : Insulation material comparison table.

The add-on effect is that handling and welding costs are also reduced – a significant item when multiplied by the 66 km of PiP. The system is optimised for offshore J-lay installation. Each quadjoint is fabricated as a single insulated unit and they are linked up offshore through a single buttweld on the inner pipe, thus providing offshore installation times of twice as rapid as other systems that require welding of both inner and outer pipes.

3. The fabrication process

The fabrication process has been designed to be easily implemented in all-purpose yards around the world. It is based on an assembly-line approach where the operators at each station only have to perform a limited number of operations so that high degree of standardization (with the entailing high quality) can be achieved. In particular, all tooling has been simplified so that it can be operated by workers who are trained on-site prior to fabrication start. Training can usually be achieved in less than a day, and the learning curve is short. Proficient work-teams will achieve maximum fabrication rates in one to two weeks. Only for the welding and NDT are skilled personnel required. This is a particular advantage for the large-scale projects in developing countries where the fabrication usually will last less than a year and where it is expected that workers with generalist skill sets will be available. Also the pipe logistics internal to the pipe-in-pipe assembly have been optimized to minimize handling. The importance of this cannot be understated as a Pipe-in-pipe fabrication like Rosa involves the assembly and handling of more than 10,000 individual pipes and their associated insulation materials, for a total weight of more than 12,000 tonnes. Transfer of pipes from work-station to work-station is performed locally, either by rolling the pipes sideways or moving it axially with rollers, with no need for overhead cranes. The use of cranes can be restricted to moving the bare pipes from stockpiles into the fabrication area, and the finished PiPs from the fabrication area to the temporary storage, awaiting load-out. The following particular challenges associated with fabricating the Rosa quadjoints in Angola were identified:

Achieving fabrication rates of 400m per day (8 quadjoints),

Performing the insertion over 48 m (previous experience was 24m),

Setting up an automated system for welding and inspection of the welds linking inner and outer pipes.

Previous references

There was a considerable body of previous experiences available in both companies, Petromar and ITP, that could be harnessed into making the fabrication a success. Petromar obviously had the experience of fabricating locally and managing large teams of operators on previous Angolan projects. ITP on the other hand, had implemented its fabrication process for both the deepwater Shell Bonga Project (1100m water depth, offshore Nigeria) and the Total Tchibeli Project offshore Congo. ITP also had an experience with organising the insulation process in a developing country with a fabrication of 12m joints for the Camisea LPG project, in Peru.

Fabrication process qualification programme

Welding processes

A specific welding process based on SAW was developed for the onshore welding. This provided a high quality of execution and a precise control of all welding parameters.

NDT's

A specific automated UT apparatus was developed for inspecting the Interpipe welds linking inner and outer pipes. This provided a 3D image of the weld flaw distribution inside the wled, which, coupled with ECA analyses, allowed setting a threshold for making a repair.

Insertion

Prior to setting up the fabrication in Angola an insertion test was run in Saipem's Sandouville France logistics base. This validated the design choice of pipe sizes and insertion gaps. During the fabrication in Angola itself, all insertions went flawlessly.

Annulus reduced pressure

An important feature of the PiP system is the reduced pressure in the annulus. Due to the particular structure of the Izoflex microporous material, the thermal performance improves by a factor of 3 to less than 7 mW/(m.K) when the pressure is drawn. This makes the Izoflex insulation material the most efficient used in offshore pipe-in-pipes. It is worth noting the performance is about a factor of two better than competing aerogel materials. It is worth noting, from a fabrication viewpoint, that the required pressures can be obtained with robust roughing pumps that are compatible with the harsh environment of sea-side yards in a tropical environment. Similar equipment are used for example in brickworks for drying out raw materials
A combined bending and thermal test was performed on a 24 m length Pipe-in-pipe with a field joint in the middle.

Figure 1: Rosa Pipe-in-pipe bent to a radius of 29 m. The test piece is instrumented with strain gauges.

The thermal test was performed on the pipe after having bent it to a radius of 29 m, well past yield stress for the most strained areas. It was noted that the pipe did not suffer any measurable buckling, and that the achieved thermal performance after the bend test was 0.6 W/(m².K), about 20% better than required by the specification. This provided a considerable degree of confidence in the robustness (mechanical and thermal) of the selected design.

4. Fabrication set-up

Production lay-out

Petromar prepared a work area by filling in part of the lagoon bordering the Kwanda base, and setting up a covered workspace for the insulation placement.
All other operations were to be performed in open air with only tent covering for certain operations such as the welding.

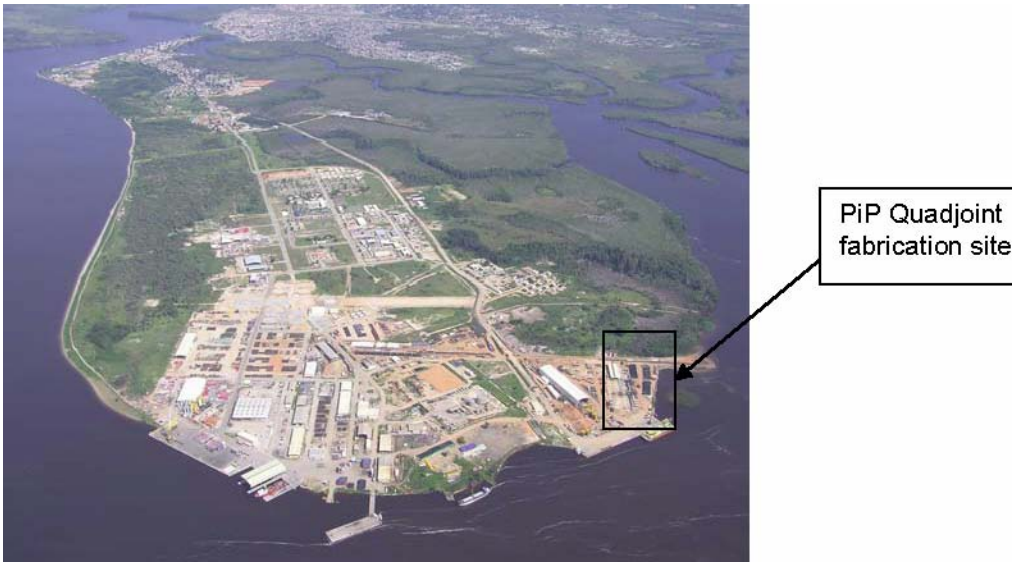

Figure 2: General view of Kwanda base. The three dark shapes are finished quad-joint

piles.

Figure 3: View of the PiP fabrication site :
bare pipe quadjoint firing line front right,
insulation placement in the white building,
PiP insertion, welding and pressure drawdown to the far right.

Tooling

The following tooling was provided by ITP;

Insulation placement tooling
Insertion tooling (quadjoint into quadjoints)
Swage tooling

• Pressure reduction tooling All tools were specially made for this project, with a particular care only to use well-known suppliers with good track-record. One of the main changes to the usual projects was that all the equipment, in particular all the electrical hardware were marinised and tropicalised to withstand the harsh conditions of Soyo, i.e. high temperatures, high ambient humidity and the occasional tropical rainshowers and flowing mud. As the logistics for the project were difficult with typical transit times of 6 to 8 weeks, it was not possible to consider sending out the equipment without their stock of spares and replacement elements. On the basis of previous projects' experience, the wear rate and likelihood of failure was evaluated conservatively for each piece of equipment, and spares were sent along, together with appropriate contingencies. These were sufficient to keep the material operating at 100% capacity over the duration of the project. All in all similar PIP fabrication rates were obtained in Angola as for a European fabrication.

Schedule

The schedule, although not overly aggressive in terms of pipe-in-pipe fabrication rates was challenging because of the logistics. It is worth noting that all fabrication tooling was fabricated, tested and approved for fabrication service in less than four months. Transportation and customs then typically lasted for about two months, and another month was required to set up and test all the tooling for fabrication start.

Production statistics

The initial fabrication rate was set at 8 quadjoints per day. After an initial period it was decided to improve the fabrication rate through a streamlining of the process and an incentive scheme for the operators. The fabrication rate then increased to close to 12 quadjoints per day. It is worth noting that this fabrication rate is identical the fabrication rates achieved on previous projects. (600 m per day).

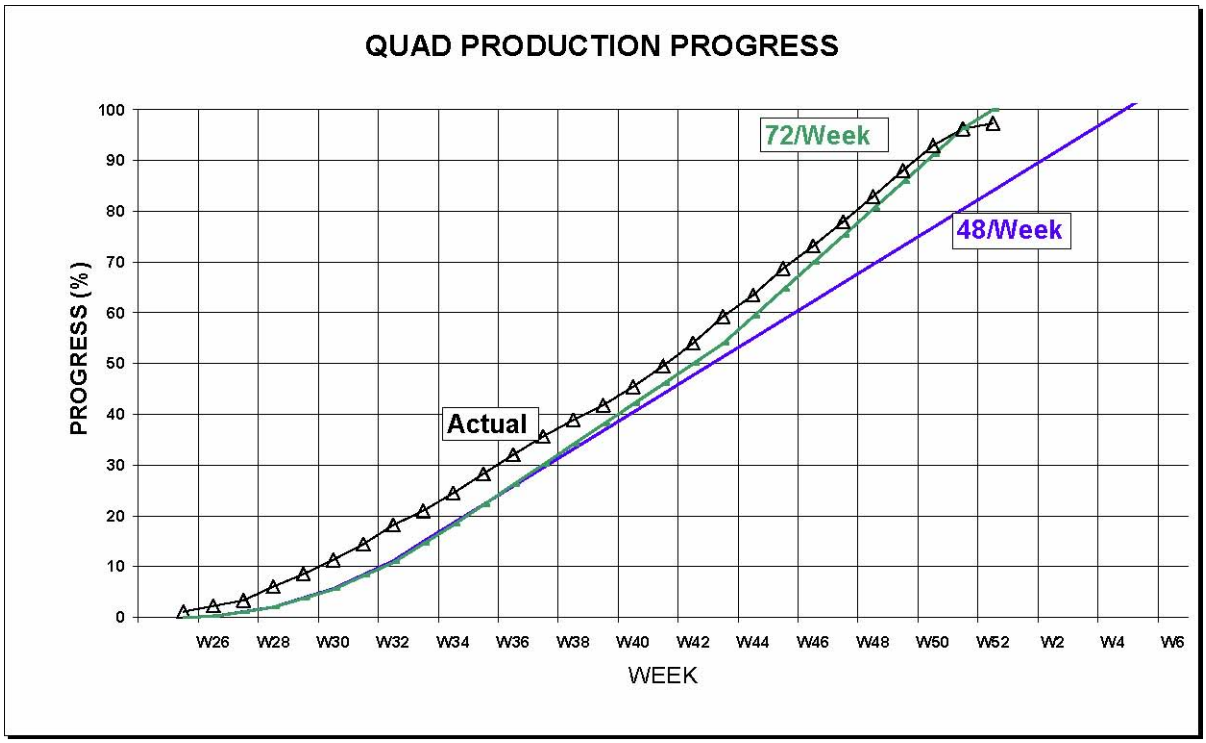

Figure 4: Production progress S-curve.
The initial fabrication rate was significantly improved about halfway through the project from 8 quadjoints/day to 12 quadjoints/day.

5. Conclusions & Final remarks

The keys to the success

The following elements were identified as keys to the successful onshore fabrication:

Use of a known and validated process
Fabricate with a locally well-known and experienced company
On-site training facility for welders
Only perform a limited number of innovations and only with a view to improve repeatability through automation of welding and NDT's
Careful planning of production process execution
Provide sufficient number of back-ups for all equipment sent to the Kwanda base

As an additional element, it is worth noting that the offshore installation campaign of the flowlines also went successfully with sustained installation rates of up to 2.5 km/day, which is a record for pipe-in-pipe in deepwaters.