Fabrication yards across the globe struggle with the growing demand to improve efficiency and lower operational costs. According to on-site observations, any fabrication process in a multi-disciplinary environment needs a holistic approach to improve efficiency and maximise throughput.

In a joint collaboration project in Malaysia, Intergraph PP&M and NESTIX examined how an integrated production planning and execution system can help yards to more effectively manage their pipe spools workshop. This solution brings together multidisciplinary design, construction, material management, quality management, and process machines to automate shop fabrication and promote more efficient handling of pipe spools fabrication processes.

This article describes a case of a pipe spools workshop owned by the second largest fabricator in Malaysia, which provides a full range of construction and engineering services required for the oil and gas industry. The case study showcases the main benefits of an integrated approach, and how it can be applied in order to provide a complete solution addressing all of the challenges identified.

Overcoming industry challenges
Shop fabrication, an early stage in industrial construction projects, has a significant influence on the successful delivery of a construction project. Effective planning and scheduling of industrial fabrication activities become essential to reduce time and cost of construction projects during this stage. However, the fabrication process in marine, shipbuilding and the offshore industry is always complex and associated with a high degree of uncertainty. Such complexity makes it difficult for most manufacturers to produce reliable project estimations.

Fabrication yards are constantly facing various challenges in their business, including:
- Massive quantity of single parts and assemblies per project
- Continuous cost pressure from the market
- Shorter project delivery schedule
- Frequent design changes
- Shortcoming of traditional planning methods.

In order to improve efficiencies in production processes, especially pipe spools fabrication, many yards have tried to increase their workshop capacity by gravitating to more automated fabrication machines and processes, such as CNC machines and robotic fit-up and welding machines. However, yards that have invested in this equipment have found that their traditional planning and
routing procedures were insufficient to drive the highly linked process flows through the automated workstations.

We found the same problem in this yard. Typically, in their planning process, pipe spools orders are released for production based on their required dates without considering the shop level loading. On the contrary, there are also cases where orders are released to the shop way before the required dates in an attempt to achieve the level loading of the shop to match capacity with demand. The production workforce fabricates spools using whatever reachable materials are available on the shop floor.

In shipbuilding and the offshore industry, we learned that work station planning cannot be optimised according to the serial production approach, but must be performed by attribute-driven work content. Planning and routing decisions must take into consideration the variables of individual process times, work station capacities, emerging engineering design, schedule changes, and shop level loading. Traditional planning methods could not handle these variables effectively and are not sufficiently responsive to the dynamic nature of the shipbuilding and offshore environment. Therefore, implementation of an effective production planning and parts control and pipe spools fabrication in the ship hull and offshore structure, based on the principles of digital manufacturing, is needed.

**Holistic fabrication**

During the project, it became clear that in order to achieve the goals for on-time delivery, optimised resource and material allocation together with maximised throughput, the fabrication process in a multidisciplinary integrated environment needs to be covered holistically. This integrated system approach has been applied in:

**Spool design data interface**

Engineering design data is a key component for production planning. It involves macro-level planning that provides working instruction, information for pipe parts nesting, cutting, fabrication and assembly.

In this project, Intergraph Smart 3D (SSD) was used as a 3D CAD software for design, modelling and spooling activities. It produces isometric and spool drawings, the bill-of-material (BOM), and profile configuration file (PCF) files for the production department to execute their job. Pipe parts and assembly information are imported from SSD into production system by reading a PCF (Piping Component file) file.

The system interacts with project scheduling to schedule pipe spools fabrication according to the needs of pipe spool assembly or delivery date.

The yard uses SmartPlant Construction (SPC) to manage their construction activities based on work package (WP) concept. The spool fabrication work packages is read into production system, including pipe spools ID, work packages start and end date, work steps and attachments.

**Production planning**

Production planning aims to bridge design and production using 3D CAD data, production scheduling, and production-related information, i.e. material information, work queue and shop level loading.

Through the interface with the material management system (SmartPlant Materials - SPMat), the material catalogue is shared with the 3D CAD system, and, at the same time, the material information and inventory status is shared with the production system. An order will not be released by the system into production if the material required is unavailable. This prevents the issue where spools are fabricated half-way and staged in the middle of the production line.

Followed by order release, nesting on selected pipes and real geometry remnants are made automatically using different nesting strategies for the purpose of material optimisation.

During the work phase definition, the production times of different works for parts and assemblies in the workshops is calculated based on actual pipe cut-length, nesting and welding seams. Therefore, the required production capacity for all production orders work phases can be specified accurately. Production flow times are shortened when the load of workshops is balanced and optimised in advance, making the most of a finite capacity.

**Production execution**

Work queues are established during the production planning following the DBR (Drum-Buffer-Rope) principle. The machine queue is now the basis for material flow in the workshop. Production execution starts when material is released on to the shop floor, and it is important that the material is released just-in-time (JIT) to guarantee "LEAN" material flow in production. Material picking lists with detailed information of material location in stock, quality and dimensions, guides operators to pick the right material and bring it to their workstation at the right time.

**Production integration and feedback**

During the work phase's execution, traceability of production status, material
used, and location play a significant role as thousands of fabricated parts must find their way to the right assemblies and workshops at the right time. When material, part, or assembly related work has been completed, the status of the corresponding order will be updated accordingly, and at the same time, worker and machine operation times, quality, and material utilisation are followed up in real time.

Production feedback enables the construction team to further plan or make necessary adjustments to any activity that depends on the completeness of production, e.g. installation/erection. This information is further referred to as a benchmark for continuous improvement of the rules set in 3D CAD software.

Managing change
Changes of design and schedule are reflected in the production system through the interface with 3D CAD software (S3D) and construction management system (SPC). In the production system itself, via different menu options, it is possible to view the production events (disturbances, pauses, rejections and completed works), or to observe the inventory of the storage locations. This allows the contractor to halt production and take stock of the required changes quickly so that the most efficient measures can be taken to accommodate the changes.

Real-life project results
We faced difficult challenges during the initial implementation of the system, especially changing the way people work. The workforce showed resistance when they were requested to follow the process defined in the system; often, workers in the shop work on what they see in front of their machines. They are also instructed to work continuously to fill up the machine capacity as idle time is simply not allowed. Production people commonly interpret idle time as being non-productive.

Several brainstorming and training sessions were conducted throughout the system implementation and go-live period. After the system was stabilised, we could see that the implementation of Smart Production in integration with Smart Yard was bringing recognisable advantages in the following areas:

Reduced labour and duration for production planning
Through interface with the 3D CAD system and with automation in spool splitting and routing, pipe nesting, capacity calculation and load balancing, the duration for work preparation is shortened.

Reduced remnant and scrap
With detailed inventory management and auto-nesting capability, the integrated solution managed to reduce the remnant turnover time and scrap generation.

Reduced material-in-process on the shop floor
The excessive inventory that stays on the buffer rack in the workshop has greatly reduced. This is mainly because the work order is only released into production when all the required material is available in the warehouse. Furthermore, the operator picks material and sends it to the shop floor according to work queue, and parts are produced following the demand schedule (Just-In-Time).

Improved traceability and visibility of the real-time production status
The system follows each work step in every work phase through the production process in real time. Traceability is improved by having information on who did what to which raw material or part and when the action occurred. Real-time production reporting enhanced the management of change, and consequently helped to reduce the reworks and span times to fabricate the spools.

Increased accuracy of production data
Production receives design data via the interface with the 3D CAD system and turns dynamic engineering data into stable procurement data. As a result, information transfer is no longer via paper methods and the risk of transcription error is reduced – human error like miscounting materials or mistyping dimensions is eliminated.

It is clear that the integration of a production management system with 3D CAD software and PLM systems, such as Smart Yard, has the ability to optimise the spools fabrication process, which can be a bottleneck in most fabrication yards. By seamlessly integrating design, procurement, and site materials, the system improves communications and streamlines information exchange at all levels of the workforce, and more efficiently supports the planning and management of production. Duplication of effort and re-creation of information are greatly reduced because of greater visibility, providing more insight and allowing faster decision making that keeps schedules and deliveries on track. The resulting business advantages include shorter delivery times, more accurate task management, reduced risk and better control of the production process.

Figure 3: Integrated, consistent dashboard reporting at different level of process

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