Oil and gas companies continuously look at mitigating drilling risks and reducing total drilling costs. Higher rates of penetration (ROP) and lower non-productive time (NPT) are key parameters for improving the efficiency and performance of a drilling programme. In order to reach deeper, more remote hydrocarbon reservoirs, operators are designing drilling programmes that require equipment manufacturers, such as Vallourec, to push the limits of existing technologies to engineer new solutions that are able to keep pace with these industry advances.

However, in an industry that is becoming more competitive, the cost associated with the development of a drilling programme is now another essential parameter to be considered.
In response to these challenges, drill string elements have evolved, not only to provide improved mechanical and hydraulic performance but also to offer a lower cost of ownership. In this regard, drilling tubulars, which were traditionally measured through their mechanical, hydraulic and operational performance, are now required to be economically efficient.

Developed by Vallourec’s research and development team, VAM® X-Force™ was designed and qualified to address the most challenging drilling programmes while providing significant operational and economic benefits, covering the two main drivers of the oil and gas industry: performance and cost-efficiency.

**DRILLING CONNECTIONS**

API connections, introduced in 1927, are the oldest and most popular type of drilling connections available in the market. API connections rely on a primary external shoulder and a single start thread with a triangular shape to provide the required mechanical performance.

API threads are fairly robust and can be run without the use of stabbing guides. They are also valued because they usually have low repair rates and are easy to run. However, the ratio section versus torsional performance on these types of connections is limited and driven by the additional need for torque and hydraulic performance. As a result, premium drill pipe manufacturers developed a new type of drilling connection based on the API thread design during the second half of the 20th Century.

The thread design included a secondary internal shoulder that increased the torque generating surface. Just a slight modification in the design provided 50% more torsional strength compared to an API design. Moreover, while the torsional strength was significantly improved, tensile and fatigue performance remained intact. In addition to the extra strength, double shoulder connections feature a flush internal diameter that avoids turbulent flows, prevents downhole tools from getting stuck and cement from getting trapped in the space available between the pin and the box.

In terms of operational performance, API double shoulder connections inherited most of the features of their precursor, such as speed of use and robustness. However, to compensate for the increased mechanical performance, the repair rate of an API double shoulder is slightly higher than it is for an API.

Although API and API-based double shoulder connections remain a valid option for many of the current drilling operations, the increased complexity of new and existing wells required connections able to provide more torque and/or better hydraulic performance.

In response to demands for additional mechanical and operational performance, Vallourec developed VAM Express™, a high torque double shoulder connection designed to perform in most drilling environments.

In order to achieve increased torsional strength without degrading the tensile strength or the fatigue life of the connection, VAM Express was designed outside the API design rules. VAM Express provides up to twice the torsional strength of an API connection without degrading other mechanical performance (Figure 1).
THE NEXT GENERATION

During the last few years, due to the increased complexity of drilling programs and the environment, drilling tubulars are not only required to provide better mechanical performance but also to offer efficient operational results at a lower cost of ownership.

VAM Express has addressed the challenges of many onshore and offshore drilling programmes worldwide for over a decade, but there are some specific wells that required additional mechanical, and/or hydraulic performance and other operations required additional safety margins.

To address the challenges listed above, the company’s research and development team responded with the VAM X-Force, a connection designed and qualified to offer enhanced performance with three core focuses:

- **Mechanical**: by providing the highest torque available and the longest fatigue life without degrading the tensile strength of the connection.
- **Operational**: by increasing the speed of make-up, saving time on the rig, without degrading break-out torque.
- **Economic**: by maintaining the robust and easy to use characteristics of VAM Express, while making it easy and cost-efficient to repair.

The process followed to develop this connection is described in Figure 2.

Based on a specified market need, a functional analysis was conducted to define the requirements for this connection. This preparatory phase was key and served as the base of the design and qualification processes during the rest of the project.

### Product design

VAM X-Force was designed to provide enhanced torsional strength without degrading other performance, and was based on the existing VAM Express, maintaining the ‘easy to use’ aspect.

The key feature and source of most of the improvements provided by X-Force is the shape of the thread: the curved thread design provides the highest available torsional strength amongst rotary shouldered connections and a speed of make-up equivalent to an API thread.

The thread shape of the connection is characterised by a curved shape on the loading flanks that increases the surface available for torque generation and an enhanced elliptical thread root that reduces stress on the critical cross section of the connector, improving its fatigue life.

In addition to the mechanical and operational performance, economic considerations were also included during the final design, leading to a thread taper and height that optimises the re-cut length. Based on all the design considerations listed, the VAM X-Force final design comprised:

- **A primary external torque shoulder providing initial seal and pre-load during make-up.**
- **An innovative thread profile:**
  - A curved shape on the loading flanks able to generate more torque due to the increased available surface.
  - An enhanced thread form that reduces stress on the critical cross section of the connector, thus improving its fatigue life and providing deeper stabbing.
  - An engineered taper and shallow PIN nose for deeper stabbing.
- **A secondary internal torque shoulder providing high torque and internal flushness.**
Qualification process
A rigorous qualification process confirmed the outstanding performance of this new and user-friendly connection. The X-Force qualification programme was aimed to test that the connection can be safely used in the most critical conditions required by the specification (Figure 4).

The first step of the qualification process was to evaluate the design through finite element analysis (FEA). Then analytical calculations and FEA were validated through physical testing that demonstrated that:
- The torsional strength of the connection was more than twice the strength of an API connection and about 20% more than VAM Express.
- The connection could withstand at least 100 makes and breaks without galling or compromise of the seal ability of the connector, even when made up with the highest available torque.
- The connection was able to withstand at least the equivalent axial bending and pressure loads as VAM Express.
- The connection has a fatigue performance significantly better than previous generations of rotary connectors.

CONCLUSION
While other technologies have worked in the past, they do not stand up against today’s mechanical, operational and economic challenges. Because of this, Vallourec developed X-Force, a new connection designed to improve the operational and economic performance of drilling operations in the most challenging drilling environments.

The design provides the following advantages:
- The highest available torque amongst rotary shouldered connections without compromising other performance factors (such as tensile strength), which allows for deeper, further drilling.
- An enhanced fatigue life due to its curved thread design, which reduces the stress on the critical cross section.
- Faster trip times due to its engineered single start thread design.
- High break-out to make-up torque ratio, reducing the risk of the string backing out while drilling.
- Deeper stabbing and eliminates the need for stabbing guides with the use of the optimised taper and thread design.
- Reduces the pressure and hydraulic horsepower requirements for circulating drilling fluids, viscous pills and cement as it is able to design tool joints with a reduced OD and an enlarged ID.