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How can a new type of stainless steel boost the performance of plate heat exchangers?

Forta

Duplex & other high strength

Thanks to their compact, flexible design and efficiency, plate heat exchangers (PHEs) are often the preferred choice for heat exchanger applications. However, when operating under high pressures, leakage can be a problem, especially for gasket-sealed (GPHE) designs.

Several new welded and brazed designs have been developed to overcome this limitation. But no matter the type – welded, brazed or gasket – all PHEs could benefit from using a higher strength material to reduce the risk of the plate collapse that ultimately causes leakage.

The challenge with high strength materials is their limited formability, as that makes it difficult to create the detailed plate patterns required. The usual answer is to modify the plate design to accept a lower surface area – and consequently lower heat transfer efficiency. But Outokumpu is now able to offer an alternative with its formable duplex stainless steel grade known as Forta FDX 27.

Forta FDX 27 overcomes the formability limitations of duplex stainless steels

The typical materials used in GPHE applications are standard austenitic stainless steels. Alternative stainless steels are the duplex stainless steel grades, consisting of a balanced combination of a ferritic and austenitic microstructure. In addition to higher strength, they also offer higher fatigue strength, erosion resistance and an increased resistance to stress corrosion cracking. But although standard duplex grades have a relatively good formability, it is not sufficient for the complex patterns necessary for high performance GPHE products.

This situation has now changed with Outokumpu's newly developed Forta FDX 27 duplex concept that exhibits a unique combination of high strength and high elongation. It also offers price stability due to the relatively low content of alloying elements such as nickel and molybdenum that can fluctuate considerably in price over time.

With Forta FDX 27 it is possible to manufacture high strength GPHE plates with the same (or close to the same) surface area as traditional austenitic stainless steel and it is often possible to use the existing stamping tools. The unique formability properties of Forta FDX 27 compared to other stainless steel grades is illustrated in Figure 1.

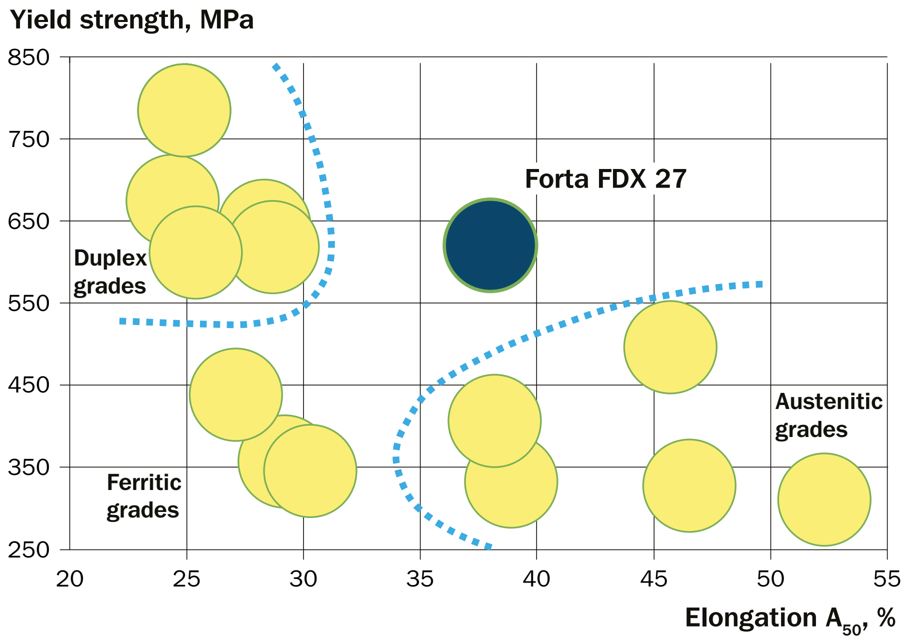


Figure 1 – Forta FDX 27 combines high strength and high formability.

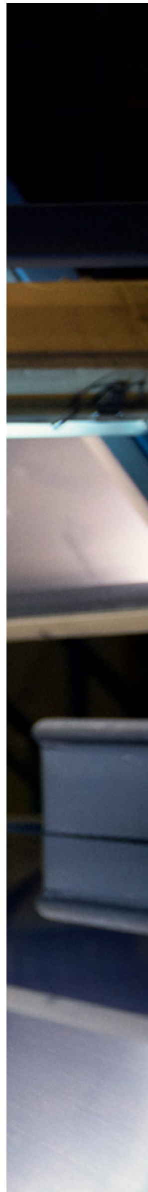
> This enhances the strength and formability of the steel with no detrimental effect on its corrosion resistance.

The TRIP effect

Forta FDX 27 achieves its excellent formability properties due to a phenomenon known as the Transformation Induced Plasticity (TRIP) – effect. The TRIP effect is achieved by the controlled transformation of some of the austenitic microstructure into martensite during plastic deformation. This enhances the strength and formability of the steel with no detrimental effect on its corrosion resistance.

Before the development of Forta FDX 27, the TRIP effect had only been known to work effectively with austenitic steel grades and it had never been successfully realized in duplex grades.

These mechanical properties make Forta FDX 27 suitable for the manufacturing of components with stretch forming as the primary forming operation, which is the case for GPHE plates. Forta FDX 27 can offer similar benefits for other heat exchanger designs, such as shell and tube, by enabling a reduction in wall thickness and bend radii.



	EN	ASTM UNS	$R_{p0.2}$ [MPa]	R_m [MPa]	A_g [%]
Supra 316L/4404	1.4404	S31603	270	288	47
Forta FDX 27	1.4637	S82031	648	852	37
Forta DX 2304	1.4362	S32304	450	650-850	20

Table 1. Selected mechanical properties (transversal direction) for the investigated materials, 0.6 mm thickness.

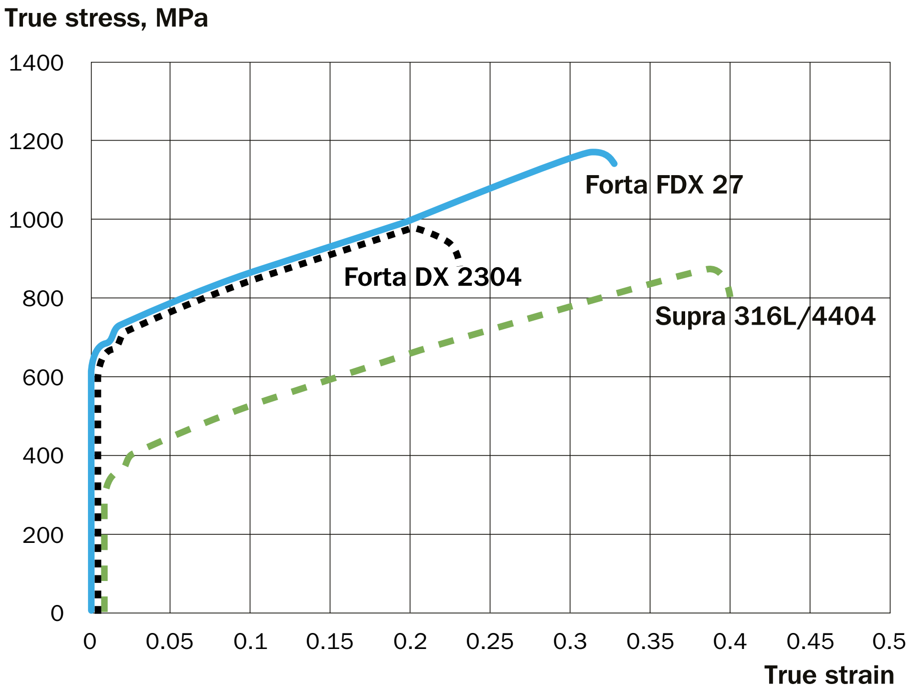


Figure 2 - Comparison of the true stress-strain curves for the two materials investigated.

Test program confirms the performance advantages of Forta FDX 27

To confirm the suitability of Forta FDX 27 for this application, tests were carried out to use it as a replacement for the traditional grade Supra 316L/4404 to improve the high pressure capacity of an existing GPHE design. The reason for comparing Forta FDX 27 to Supra 316L/4404 is the need for similar corrosion resistance. The materials used in the comparison were Forta FDX 27 and Supra 316L/4404 with a thickness of 0.6 mm.

An overview of the selected material properties is shown in Table 1. True stress strain curves for the materials are compared in Figure 2. The higher strength of Forta FDX 27 compared to austenitic Supra 316L/4404 is clearly shown - while still having good formability.

Forming evaluation of Forta FDX 27 for GPHE plates

Forta FDX 27 was formed into GPHE plates using the same tools as for Supra 316L/4404, with a sheet metal thickness of 0.6 mm. This enabled a direct comparison between the two materials. Figure 3. (left) shows the heat exchanger part design after forming, with the same configuration for the Finite Element Analysis (FEA) setup shown in Figure 3. (right).

From the FEA process it was possible to estimate the increase in strength of the final formed part. The overall strength was approximately 30 % higher for Forta FDX 27 compared to Supra 316L/4404. This increase in strength is beneficial for the final GPHE product performance in a high pressure application. An illustration of the strength increase is shown in Figure 4, where the strength has been normalized and compared between Forta FDX 27 and Supra 316L/4404.

Figure 3. Formed GPHE plate and final configuration from Finite Element Analysis.

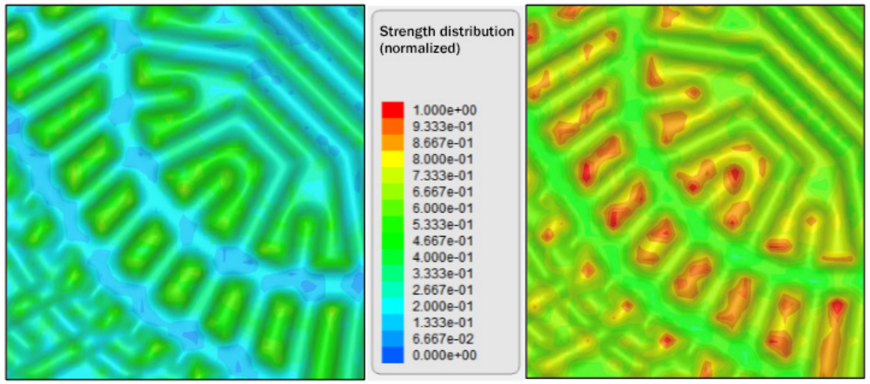


Figure 4. Strength distribution (normalized) after forming - Supra 316L/4404 (left), Forta FDX 27 (right).

Tooling setup

The Forta FDX 27 test program was conducted using the same tools as the Supra 316L/4404 material. No modifications were made to the tool design and the same lubrication was used as in normal production.

Since the GPHE sheets were formed successfully with both materials this shows that Forta FDX 27 offers the same functional surface area as Supra 316L/4404 for this particular GPHE design.

Conclusions – Forta FDX 27 offers a new approach to heat exchanger design

- GPHE plates can be formed successfully with Forta FDX 27 using the same design and material thickness as Supra 316L/4404 with no cracking occurring.
- FEA shows an estimated strength increase of 30% in the formed part when using Forta FDX 27 instead of Supra 316L/4404.
- Similar benefits can be obtained with other heat exchanger designs, such as shell and tube, where it is possible to reduce the tube wall thickness and bending radii, as well as reducing the shell wall thickness. Or it is possible to maintain the same dimensions while using Forta FDX 27 to increase the operating pressure for improved performance.

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