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Forming guideline for Forta FDX 27

General characteristics

Ferritic-austenitic stainless steels, also referred to as duplex stainless steels, combine many of the beneficial properties of ferritic and austenitic stainless steels. Due to the relatively high content of chromium and nitrogen, these steels offer good resistance to localized and uniform corrosion. The new FDX product concept exhibits a unique combination of high strength and substantially improved formability compared to standard duplex stainless steel, utilizing Transformation Induced Plasticity (TRIP). The TRIP-effect means that while it is a duplex microstructure consisting of ferrite and austenite, the FDX grade is alloyed to give an optimal austenite stability leading to a controlled transformation of austenite to martensite during cold forming operations.

Forta FDX 27 aims to substitute Supra 316L/4404, thanks to similar corrosion resistance.

The industrial forming tests performed so far with Forta FDX 27 have shown that:

- Component design features and tooling set-up did, in many cases, not require any major adaptations/changes
- Lubrication systems applied for austenitic grades are also valid for Forta FDX 27
- No repeatability issue was identified during the stamping process
- Higher stamping force in comparison with the corresponding austenitic grades is needed due to higher strength
- An improvement of the final component strength properties of up to 40% is possible when using the same thickness as the baseline standard austenitic grade

Characteristic properties

- Increased formability compared to other duplex grades
- High mechanical strength
- Good resistance to uniform corrosion, pitting and crevice corrosion
- High resistance to stress corrosion cracking and corrosion fatigue
- Good abrasion and erosion resistance
- Good fatigue resistance
- High energy absorption
- Low thermal expansion
- Good weldability

Basic fabrication advice

Table 1

Advices for forming try-outs
Consider selecting a thinner gauge Forta FDX 27 grade than the baseline austenitic grade, if beneficial for the application
Keep in mind the difference in proof strength and spring back effect between Forta FDX 27 and the baseline grade
Adjust press force to accommodate the higher strength of Forta FDX 27. Some applications might require an increase of 40 – 50%
Start the tests with the usual lubrication procedure. Depending on the complexity of the design and results from initial try-outs, adjustments might be necessary

Applications

Forta FDX 27 provides a totally new stainless steel solution for applications where the formability of other duplex grades is not sufficient or limits the design efficiency. Examples of potential applications are:

- Forming intensive components
- Heat exchangers
- Flexible pipes
- Pump components
- Components for automotive industry
- Components for structural design
- Domestic heating piping

Chemical composition

The chemical composition of Forta FDX 27 is tailored to exhibit duplex properties in combination with the TRIP-effect which enables the improved formability. The chemical composition range of Forta FDX 27 and other duplex grades are shown in Table 1. The values are given according to Stahl Eisen Liste (Register of European Steels) and ASTM A240 for Forta FDX 27.

Chemical composition of selected stainless. Table 2

Outokumpu name	EN	ASTM/UNS	Chemical composition, by mass%. Typical values [1]					
			C	Cr	Ni	Mo	N	Others
Forta FDX 27	1.4637	S82031	≤0.04	19.0-22.0	2.0-4.0	0.6-1.4	0.14-0.24	≤2.5Mn
Forta LDX 2101	1.4162	S32101	0.03	21.5	1.5	0.3	0.22	5Mn
Forta DX 2304 [2]	1.4362	S32304	0.02	23.0	4.8	0.3	0.10	Cu
Core 304L/4307	1.4307	304L	0.02	18.1	8.1	–	–	–
Supra 316L/ 4404	1.4404	316L	0.02	17.2	10.1	2.1	–	–

[1] For Forta FDX 27 the range in chemical composition is given.
[2] Also available as Forta EDX 2304TM with modified composition for enhanced properties.

Mechanical properties

Table 2 shows the mechanical properties for flat rolled products. Minimum values according to ASTM A240 when applicable. The mechanical behavior of Forta FDX 27 can be illustrated by the stress strain curve obtained from tensile testing, seen in Figure 1.

Compared to the corresponding duplex grades it is seen that the mechanical strength is similar but that the elongation to fracture is much improved for the FDX grade, exhibiting a superior combination of strength and formability compared to the corresponding austenitic grades.

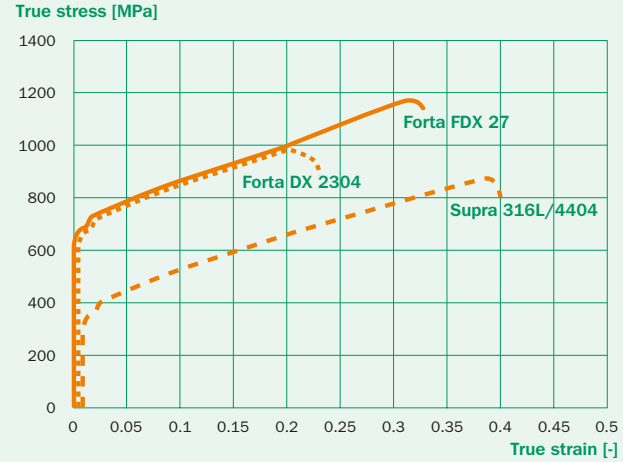

Fig. 1. Caption.

Mechanical properties for flat rolled products. Table 3

Outokumpu name	EN	ASTM/UNS	Typical values					Minimum values		
			$R_{p0.2}$ MPa	R_m MPa	A_{50} %	A_{80} %	A_g %	$R_{p0.2}$ MPa	R_m MPa	A_{50} %
Forta FDX 27	1.4637	S82031	650	850	40	36	34	500	700	35
Forta LDX 2101	1.4162	S32101	620	825	31	28	19	530	700	30
Forta DX 2304	1.4362	S32304	620	800	28	26	19	400	600	25
Core 304L/4307	1.4307	304L	280	630	62	58	52	170	485	40
Supra 316L/ 4404	1.4404	316L	285	610	60	56	47	170	485	40

Source: Outokumpu Sheet Metal Forming Handbook for 1 mm sheet thickness.

Forming Forta FDX 27

The high proof strength of duplex stainless steel compared to austenitic and ferritic stainless steel can impose some differences in forming behavior depending on chosen forming technique. The impact of the high strength varies for different forming techniques. Common for all is that the estimated forming forces will be higher than for the corresponding austenitic and ferritic stainless steel grades. This effect will usually be lower than expected from just the increase in strength since the choice of duplex stainless steel is often associated with down gauging. Forta FDX 27 has excellent formability properties in comparison to other duplex stainless steels such as Forta LDX 2101 and Forta DX 2304 and close to standard austenitic stainless steels such as Core 304L/4307 and Supra 316L/4404. The TRIP-effect offers a balanced work hardening rate resulting in an enhanced uniform elongation and higher work hardening ratio at large (plastic) deformations in comparison to other duplex grades. These remarkable mechanical properties make Forta FDX 27 more suitable for manufacturing of components with stretch forming as the primary forming operation. As for most of the duplex stainless steels, the Lankford values (r-values) are less than 1.0 in transversal direction but always larger than 0.4.

Figure 2 shows the elongation versus the proof strength for different types of stainless steels, illustrating that the FDX grade forms a type of group with a unique combination of properties.

The key advantage of Forta FDX 27 compared to other duplex grades is that it is more adaptable to various forming processes since it has far improved formability. For example, components to be formed predominantly by deep drawing can almost be designed as those made in standard austenitic stainless steels with good results. Moreover, physical try-outs verify that Forta FDX 27 is suitable for forming intensive component such as heat exchanger plates.

Figure 3 shows the relative formability for different types of stainless steels, illustrating the improved formability of Forta FDX 27 in comparison with other duplex grades such as Forta LDX 2101 and Forta DX 2304.

Welding

The advantageous formability of Forta FDX 27 comes from the TRIP-effect and it is important to realize that this effect largely disappears from the weldment because of the heating cycle and choice of filler material. In cases where the joint has been autogenously welded there can however still be a beneficial TRIP-effect in the weldment depending on the exact circumstances of the welding.

Any difficult forming operation should thus preferably take place before welding in order to take full advantage of the formability feature. It should however be pointed out that the weldment still has good formability in line with standard duplex grades. Outokumpu can support customers about the impact on the forming process of the FDX grade.

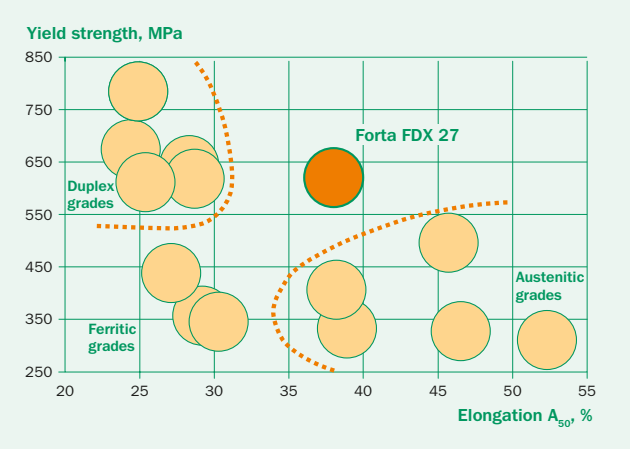

Fig. 2. Elongation versus proof strength for different types of stainless steels. Typical values for cold rolled coil and sheet.

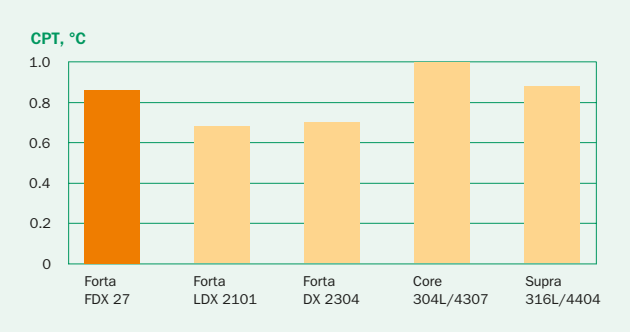

Fig. 3. Typical critical pitting corrosion temperatures (CPT) in 1M NaCl measured according to ASTM G150 by using the Avesta Cell. Test surfaces wet ground to P320 mesh. CPT varies with product form and surface finish.

Deep drawing

Figure 4 shows the FDX grade performance in deep drawing tests (Swift cup test) for different drawing ratios. The Limiting Drawing Ratio (LDR) is the ratio of the largest circular blank diameter to the punch diameter without any failure in the cup during forming. From the LDR testing, none of the samples suffer from delayed cracking 1000 hours after deep drawing up to a LDR of 2.0.

Fig. 4. Swift cup samples.

Temper rolled Forta FDX 27

Temper rolling is a technique used to increase the strength of a material through a precise cold rolling reduction, targeting a specific thickness and a proof strength or tensile strength at the same time. Due to higher elongation values on annealed condition than regular duplex, Forta FDX 27 can be temper rolled to reach higher proof and tensile strength and still keep an acceptable formability level. Figure 5 shows the tensile strength and elongation of the FDX grade after different levels of tensile deformation compared to standard duplex grades and ultra-high strength steel (UHSS).

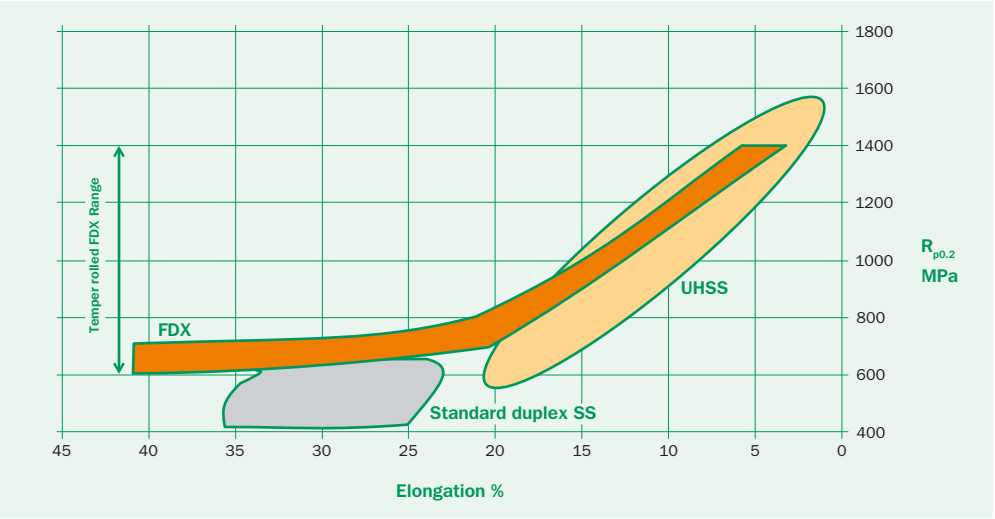

Fig. 5. Proof strength and elongation of the Forta FDX 27 after different levels of cold working compared to standard duplex stainless steels and ultra-high strength steels (UHSS).

Own notes

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outokumpu classic

Moda	Core	Supra
Mildly corrosive environments	Corrosive environments	Highly corrosive environments

outokumpu pro

Forta	Ultra	Dura	Therma	Prodec	Deco
Duplex & other high strength	Extremely corrosive environments	High hardness	High service temperatures	Improved machinability	Special surfaces

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