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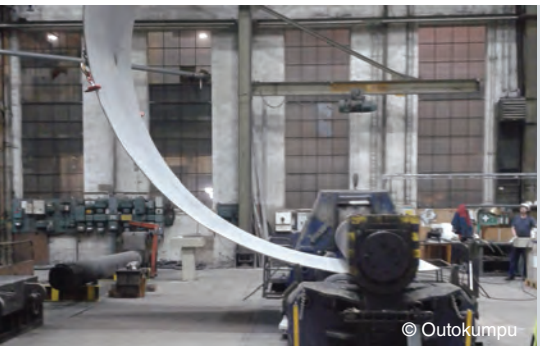
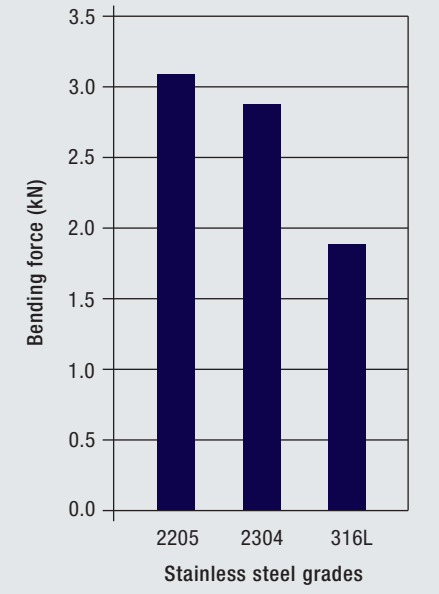


Bending, cold forming, and springback of duplex stainless steels

Duplex stainless steels have shown good formability in a variety of fabrications. Most applications of duplex stainless steels require relatively simple forming, such as the rolling of cylindrical sections, press forming, and vessel and tank head forming by pressing or rolling. In most of these applications, a primary concern is the high strength of duplex stainless steel and the power of the forming equipment. A typical first estimate is that a duplex stainless steel will respond to forming similar to a 300-series austenitic grade at twice the thickness. A comparison of the minimum force required to begin plastic deformation in bending is shown in **Figure 1** for several stainless steels.

The lower ductility of duplex stainless steels compared with austenitic stainless steels must also be taken into account. Duplex grades have a minimum required elongation of 15 to 30% in most specifications in comparison with the 40% minimum elongation required for the austenitic grades. The duplex grades require a more generous bend radius than austenitic grades or need intermediate solution annealing in severe or complex forming because of their lower ductility. Minimum solution annealing temperatures for duplex stainless steels are summarized in **Table 1**.



Source: Outokumpu

Figure 1: Minimum force required to begin plastic deformation in bending of 2304, 2205, and 316L test samples 50 mm (2 inch) wide and 2 mm (0.08 inch) thick.

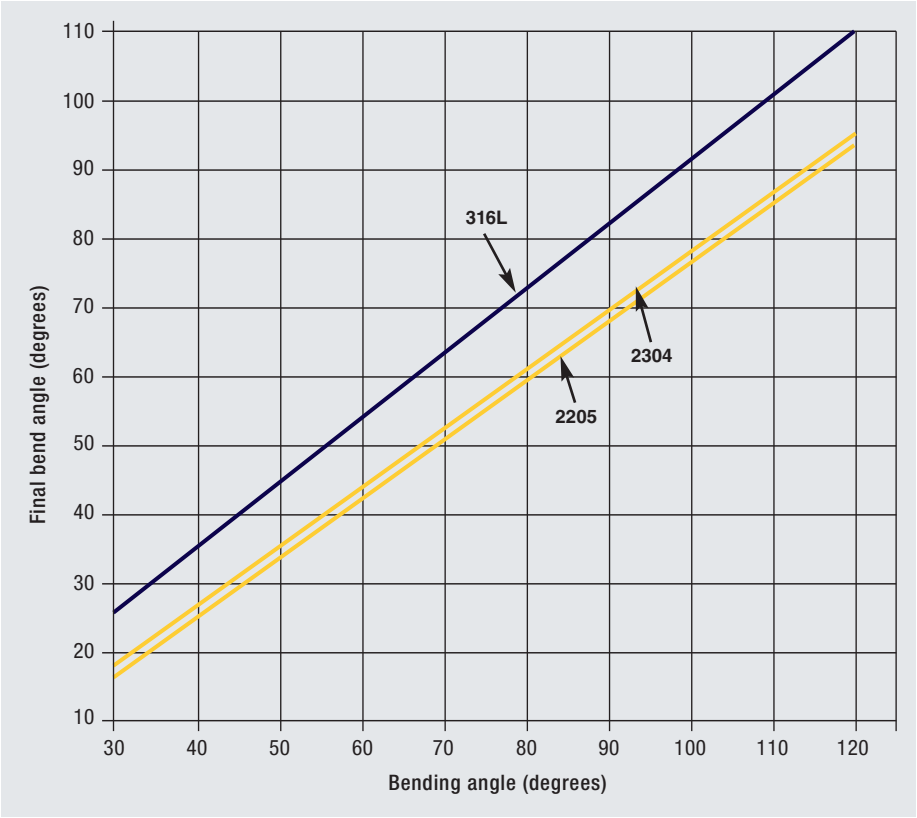
Table 1: Minimum solution annealing temperatures for duplex stainless steels

Grade	UNS No.	Minimum annealing temperature	
		°C	°F
2304	S32304	980	1800
	S32003	1010	1850
	S32001	1040	1900
	S32101	1020	1870
	S32202	980	1800
	S82011	1010	1850
2205	S32205	1040	1900
	S32506	1020–1120	1870–2050
	S32520	1080–1120	1975–2050
255	S32550	1040	1900
2507	S32750	1025–1125	1880–2060
	S32760	1100	2010
	S32707	1080–1120	1975–2050

Source: Producer data sheets and ASTM A 480

While the high yield strength of duplex stainless steel can allow down gauging, it can also pose challenges during fabrication. Because of their higher strength, plastic deformation requires higher forces. The springback in bending operations is larger than with austenitic stainless steels because of the higher bending forces required for duplex stainless steels. A springback comparison of two duplex stainless steels and Type 316L austenitic stainless steel is shown in **Figure 2**.

The use of stress relief treatments to reduce the cold work from forming or straightening operations is not advisable. The duplex stainless steels inherently have very good chloride stress corrosion cracking resistance and this can be only marginally improved by reducing residual cold work. There is no satisfactory temperature below the solution annealing temperature at which stress relief can be employed without the danger of formation of intermetallic phases, which will lower corrosion resistance and reduce toughness.



Source: Outokumpu

Figure 2: Comparison of springback of duplex stainless steels and Type 316L for 2 mm (0.08 inch) thick sheet.