

Magnetism in Stainless Steel Fasteners

“The stainless steel fasteners I received stick to a magnet.” This is one of the more frequently heard complaints at FEDS HQ in Winona, MN. Stainless steel fasteners being nonmagnetic is also one of the largest misconceptions amongst fastener users. This document will explain why most stainless steel fasteners are at least slightly magnetic and why many are so magnetic they are attracted to even weak household magnets.

There are five classes of stainless steel (ferritic, austenitic, martensitic, duplex, and precipitate-hardened) and only one is nonmagnetic (austenitic). However, the austenitic class just happens to include the most widely and universally used types of stainless steels in the market. The first four classes are defined based on the microstructure of the metal with the last class, PH, based on its heat treatment. **Microstructure is important because this is what gives the stainless steel its magnetic properties.**

The table below provides a brief overview of the classes of stainless steel as well as some properties of the materials.

Details on the Five Classes of Stainless Steel			
Classes	Non/Magnetic	Crystal Structure	Common Examples
Ferritic	Magnetic	BCC	405, 430, 442
Austenitic	Nonmagnetic	FCC	201, 301, 302, 303, 304, 316
Martensitic	Magnetic	BCT	403, 410, 416
Duplex	Magnetic	Combination	2205, Alloy 255
Precipitate-Hardened	Magnetic	Combination	17-4PH, PH 17-7

How Does an Austenitic Stainless Steel Become Magnetic?

As stated before, the microstructure of the metal is what gives the steel its magnetic properties. If the stainless steel chosen was austenitic, e.g. type 316, and a portion of the microstructure were changed to any one of the other four classes then the material would have some magnetic permeability, i.e. magnetism, built into the steel.

The microstructure of austenitic stainless steel can be changed by a process called **martensitic stress induced transformation** (MSIT). This is a microstructural change from austenite to martensite and the transformation can occur due to **cold working** (the process by which many fasteners are made) as well as **slow cooling** from austenitizing temperatures. After cold working or slow cooling an austenitic stainless steel will have an appreciable level of martensitic microstructure. Due to martensite being magnetic, the once nonmagnetic austenitic stainless steel will now have a degree of magnetism.

Cold Working

Though it may not seem like it, all fasteners can go through quite a bit of cold working prior to seeing service in the field. Cold working fasteners occurs in the wire drawing, forming, and thread rolling processes. Each of these processes will, typically, create enough martensite to produce a measurable degree of magnetism.

Susceptible Alloys

Low alloy content stainless steel (particularly that of low nickel, carbon, and/or nitrogen) are more susceptible to MSIT than stainless steel with higher alloying elements. Type 304 is an example of a stainless steel that is quite susceptible to forming martensite after cold working but in fact MSIT affects all austenitic stainless steel to some degree or another. To help showcase these differences figure 1 & 2 have been provided to show **permeability (magnetism) vs. percent cold working** as well as **magnetism vs. tensile strength** of some common stainless steels.

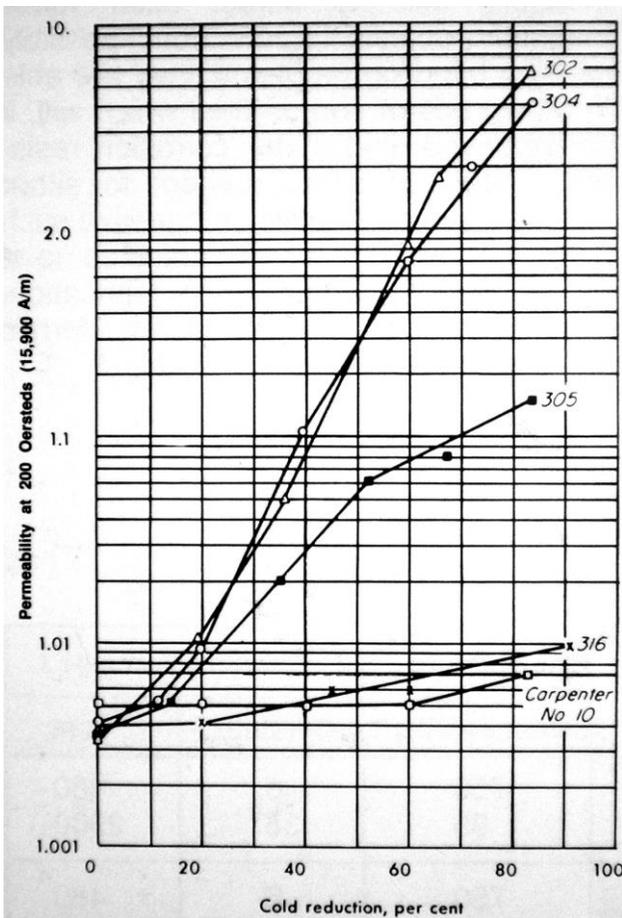


Figure 1: Notice the lower alloy steels yield a higher magnetism with the same amount of cold working.

Source: Carpenter Stainless Steel, *Selection Alloy Data Fabrication*, 1991, page 243.

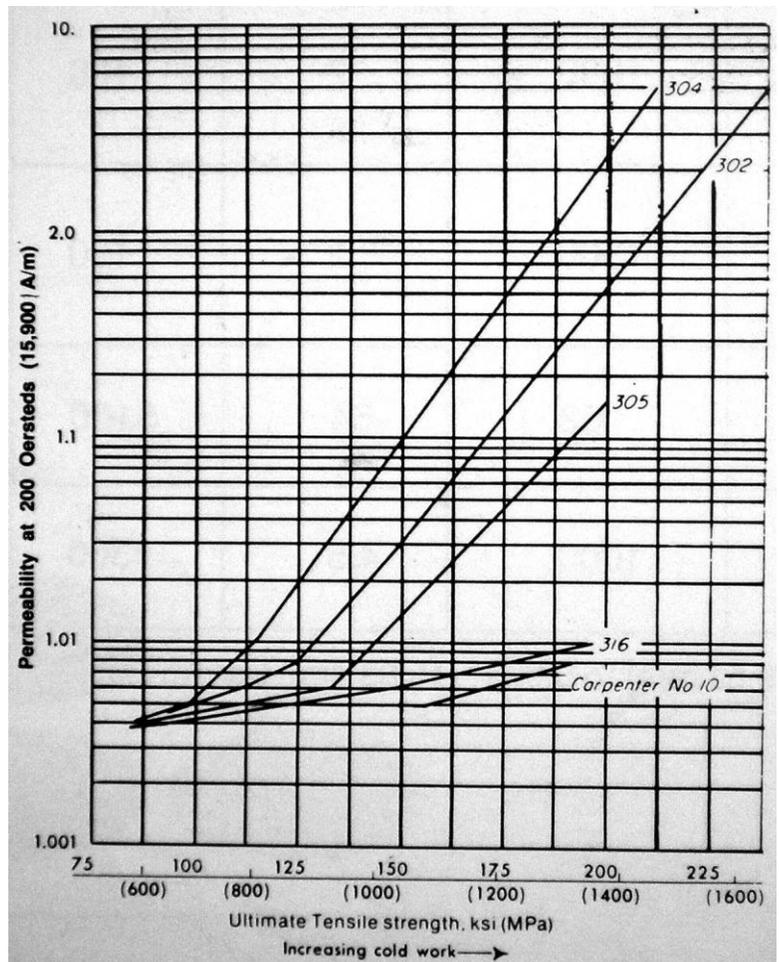


Figure 2: Magnetism of stainless steel (cold worked) vs. tensile strength.

A visual representation of the microstructural changes that a stainless steel has gone through some sort of cold working can be seen in figures 3 thru 6. The figures gradually increase the amount of cold working done to a sample starting with 100% austenite microstructure and ending with nearly 100% martensite. Note: figure 3 is of type 304 and the latter three figures (4-6) are type 301; however, the grain structure in figure 3 is typical of all austenitic stainless steels.

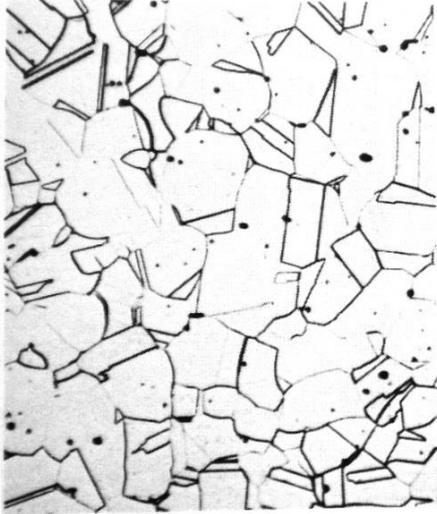


Figure 3: Type 304 stainless steel with austenite microstructure. 0% cold working. (250x)

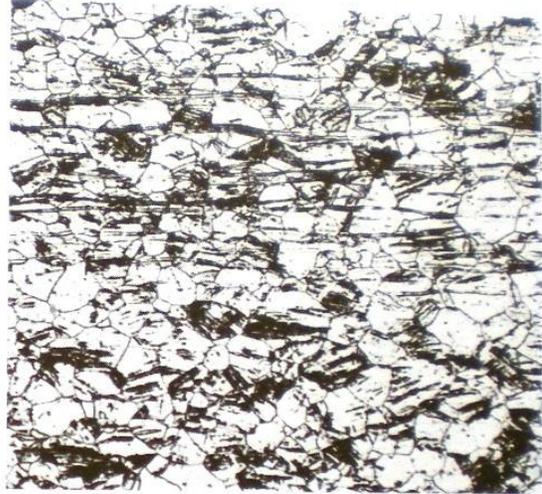


Figure 4: Type 301 stainless steel. This sample has been cold worked to form martensite (dark) within the austenite (light) matrix. (200x)



Figure 5: Type 301 stainless steel. Cold worked to 25% hard. Martensite has formed within the austenite grains. (250x)

Source: ASM Handbook, *Metallography and Microstructure*, Vol. 9, 1998, page 287.



Figure 6: Type 301 stainless steel. Cold rolled to ~100% hard. Austenite has converted to martensite in nearly all locations. (250x)

Controlling Magnetism in Stainless Steel

Magnetism is sometimes a factor in deciding which fastener to use. If a 100% nonmagnetic stainless steel fastener is required steps can be taken to reduce the amount of cold working done to a part, e.g. thread cutting vs. rolling, as well as possibly annealing the part after all cold working processes. Without a complete annealing treatment of the post cold worked part, it will never have zero magnetism. At times, an additional annealing process may not be possible due to material properties, economic reasons, and time constraints. A balance of allowable magnetism and economic requirements must be reached in accordance with the end user. Please contact a Fastenal Engineering and Design Support agent for more details.