FILLER FIX

Tips for successfully welding 4130 heat-treatable low-alloy steel

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As one of the most common of the heat-treatable low-alloy steels, 4130 steel can be found in a number of industries and applications. It is also among the most likely to cause confusion when it comes to welding.

Its high hardenability is the key to 4130 steel responding to heat treatment. The material's varying mechanical properties, however, can make it challenging to select a filler metal for welding that matches its strength in a given condition.

For that reason, there are many different ways to weld 4130 steel, depending on the application and the desired outcome. Fabricating thin wall tubing for a race car frame with 4130 steel, for example, has different requirements than using the material to fabricate heavy-duty, multi-inch valves for petrochemical applications.

This article provides some best practices for selecting the proper filler metal for welding 4130 heat-treatable low-alloy steel, along with recommendations for pre- and post-weld heating.

Welding 4130

The 4130 steel alloy relies on the addition of carbon as well as molybdenum and chromium as agents that increase hardenability – the ability to increase hardness and strength through heat treatment. The strength of the material can change greatly depending on its condition: annealed, normalized, or quenched and tempered. For instance, the approximate tensile strength for annealed 4130 steel is 90 ksi while the material tensile strength in a normalized condition is around 100 ksi; quenched and tempered 4130 steel is stronger, offering tensile strength up to 200 ksi.

In addition, several types of filler metals can be used to successfully weld 4130 steel. While welding operators may assume they need ›

Because of its high hardenability, 4130 steel responds well to heat treatment, but it can also vary in mechanical properties, making it challenging to select a filler metal that matches its strength in a given condition.

a filler metal that matches or overmatches the mechanical properties, that is not always the case.

Consider these three options for selecting the appropriate filler metal based on the condition of the 4130 steel and the demands of the application.

Strength undermatch: When a part design or the application requirements do not require the weld deposit to match the strength of the 4130 steel, it is possible to use a lower strength filler metal, such as mild steel wire or stick electrode offering a tensile strength of approximately 70 ksi. Mild steel filler metals offer the advantage of additional crack resistance due to their ductility, but the resulting weld will not be as strong as the base material. As long as the part design allows for this undermatch, that lower strength weld should not pose problems. See Figure 1 for mild steel filler metals often used for strength undermatch when welding 4130 steel.

Matching annealed strength: If the 4130 steel is in the annealed condition (the recommended condition for welding to avoid cracking) and will not be post-weld heat treated to increase material strength, using a filler metal with comparable strength properties is common and acceptable. For an approximate match to annealed strength 4130 steel, low-alloy filler metals offering 80 ksi to 90 ksi tensile strength are appropriate. These filler metals provide the advantage of a strength match in the weld deposit without the crack sensitivity of a chemistry match. See Figure 2 for filler metals that can be used for this option.

Chemistry match: For 4130 steel that will be post-weld quenched and tempered or hardened, it is necessary to have a filler metal (and resulting weld deposit) that responds to the treatment in the same way the material does. In other words, match the 4130 steel with a 4130 filler metal providing the same strength and chemistry. ›

Preheat, slow cooling and stress relief are all precautions that can – individually or combined – reduce the risk of cracking when welding 4130 steel.

Common Mild Steel Filler Metals for Strength Undermatch				
Solid Wire	*Metal-Cored Wire*	*TIG Cut-Lengths*	*Stick Electrodes*	*Flux-Cored Wires*
ER70S-X	E70C-6M	ER70S-X	E7018	E7XT-X

↑ Figure 1. Recommendations for mild steel filler metals for strength undermatch when welding 4130 steel per American Welding Society classifications.

Filler Metals for Matching Annealed Strength				
Solid Wire	*Metal-Cored Wire*	*TIG Cut-Lengths*	*Stick Electrodes*	*Flux-Cored Wires*
ER80S-X, ER90S-X	E80C-X, E90C-X	ER80S-X, ER90S-X	E8018, E9018	E8XT-X, E9XT-X

↑ Figure 2. Recommendations for filler metals for matching annealed strength in the weld deposit per American Welding Society classifications.

Preheat and Interpass Temperature °F				
AISI Steel 4130	<1/8"	1/8"-1/2"	1/2"-1"	1"-2"
	RT or Higher	300-400	400-500	450-550

↑ Figure 3. Preheat recommendations to slow the cooling rate and minimize the development of crack-susceptible microstructures within a weld.

Debunking chrome-moly myths

A brief history: 4130 steel was developed in the 1920s as a better replacement for the 1025 plain-carbon steel tubing that aircraft builders were beginning to use for frames. The 4130 steel was about twice as strong as 1025, it was easy to weld and it had good elongation and ductility for such a strong steel. It was a natural for aircraft space frames, which were just coming into vogue, replacing wood.

The same virtues make it a top choice for bicycle frames, motorcycles and race cars. Throughout the 1950s and 1960s, it was the material of choice for race car builders. Fabric-covered light planes had 4130 frames into the late 1960s. Today, one-off specials made with space frames and custom bicycles are usually made with 4130 tube. In sheets and plates, it found a variety of uses where strength and ductility are required.

It's from the amateurs that 4130 acquired its myths. Myth No. 1: First, they said, you can't braze it because brazing opens up the "grain" and weakens it. It's not so. Myth No. 2: You can't MIG weld it because of the cold starts resulting with MIG and their severe weak spots. The fact is, many kit airplanes have MIG-welded 4130 frames, and they don't break. Myth No. 3: Oxyacetylene is the preferred welding method because the heat-affected zone is too abrupt with TIG (although it's less abrupt than with MIG). It will crack, they say. The fact is, TIG is used in the large majority of ground vehicle and air frames, with no problems. Myth No. 4: You have to "stress relieve" welded joints with an oxyfuel torch or rosebud. As the article explains, that's only true in thicker sections. Most welding of 4130 is performed on thin-walled tubes, and they don't require stress relieving.

FAB Shop's scientific testing apparatus, a big freaking hammer, was applied to this TIG butt-weld in 0.065-in.-wall (16 ga.) 4130. The filler metal is 4130. After strenuous application of the testing instrument, we almost gave up trying to get it to crack. Finally, after folding it over 180 deg. and pounding on it some more, we produced a barely noticeable crack in the extreme edge. Fears of failure in 4130 welds are overblown – at least, if you're going to hammer your weld.

The origins of these myths are not easy to track down, but they stem from one important characteristic of the material: it's slow quenching. In thin-walled tubes, under 0.65 in. or so, it's right on the verge of being air hardened. That produces some complex heat-affected zones. Next to the weld, the parent metal can actually harden. At a further distance away, it's annealed, to varying degrees.

This does produce stresses. Again, though, 4130 is a moderately ductile and forgiving material. If you're welding life-dependent joints on a vehicle, of course you should run tests to be sure they're safe. But for most uses, follow what the major welding equipment suppliers tell you. It's not difficult and it's not mysterious. It just carries a lot of mythological baggage.

|| by Ed Huntress, editor ||

It is important to note, however, that there are high carbon levels in 4130 steel (which is what makes it heat treatable); as a result, it is more sensitive to cracking. Therefore, if the application does not require post-weld heat treatment, there is no advantage to using a chemistry match with 4130 filler metal.

Other filler metal options can be used to weld 4130 steel, such as a 309 austenitic stainless steel product. This type of filler metal offers good strength, is good for joining dissimilar materials and provides additional crack resistance. Be aware, this filler metal typically is also more expensive, and many jobs can be successfully completed with less costly, more readily available filler metals.

Additional tips

Preheat, slow cooling and stress relief are all precautions that can – individually or combined – reduce the risk of cracking when welding 4130 steel.›

- Preheat can be used to slow the cooling rate and minimize the development of crack-susceptible microstructures within the weld. The more heat that is in the base material before welding begins, the slower it will cool down. See Figure 3 on page 9, for preheat recommendations.

- Slow cooling of welded parts can be controlled with blankets, ovens or other methods. This practice offers the same advantages of preheat – to reduce the chance of unwanted microstructures forming, which helps the part resist hardening or cracking.

- Post-weld stress relief is another method to help prevent cracking and defects in the finished weld. Thin materials, less than 1/8 in., typically do not require stress relief because cracking is less of a concern. Thicker materials are commonly stress-relieved at 1,100 to 1,250-degrees F for approximately one hour per inch of base material thickness.

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Keys to success

As with the welding of any material, knowing the basics about filler metal selection and material properties can help make welding 4130 steel a success. The key is to know what condition the material is in and what requirements are necessary for the finished weld.

In many cases, there are fewer, less complicated considerations for the application than initially thought. As always, when questions arise about the best approach to a welding application, consult with a trusted filler metal manufacturer or welding distributor for assistance. ■

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