# Welding NASCAR's New Materials

**BY DENNIS KLINGMAN**

*The move to improve safety has also helped drive the use of newer materials and new welding technologies*

NASCAR® purists prefer that the sport remain focused on the skills of the drivers and less on the advancement of technology. In an effort to maintain a level playing field, many contend that emerging technologies be left to racing circuits that feature the cars.

Ironically, the move to further improve NASCAR's safety has ushered in a host of new technologies, many of which unintentionally also boost performance. Where to draw the line, however, is a debate likely to continue for years.

With that, NASCAR strictly regulates which materials can be used for each specific component. Balancing safety and performance, technology unavoidably advances, following closely in the footsteps of Formula One™ racing and the aerospace industry.

However, while the issue remains in dispute, race team fabricators nonetheless work to stay ahead of approaching technologies. On the forefront of the latest debate are materials such as Inconel® 625 and chrome-moly 4130. Both are finding their way onto more and more racing "stock cars" every day, as the sport's ruling body acknowledges the need and grants permission.

Over the past few years, the trend in materials has moved some NASCAR components from carbon steel to stainless steel. Today, that trend is shifting again from stainless steel to Inconel, and many race shop welders are trying their hand at titanium in anticipation that that, too, will be allowed on selected car components. Currently, titanium is limited to a handful of engine parts that are rarely welded, but race shop welders anticipate a widening use that could be only a few years away.

## New Materials

Inconel, a trademarked name for a family of high-strength nickel-based alloys, exhibits exceptional anticorrosion and heat-resistant properties. The nickel-based alloys are, in many ways, a vast improvement over stainless steel.

Inconel has been used in a variety of high-tech applications, such as military vehicle exhaust ducts, submarine propulsion motors, underwater cables, heat exchangers, and gas turbine shroud rings.

Inconel also has been used in Formula One and Champ Car exhaust systems for years. But, more recently, several Nextel Cup® racing teams have incorporated Inconel 625 for ultralight and highly durable exhaust systems and headers.

Race teams today continually push the limits of ground clearance restrictions in an effort to lower their cars' center of

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*A ropey overly convex appearance on high-alloy materials often signals too little heat input and the potential for weld failure.*

*Here, the appearance is improved over cold welds but an overly convex bead profile means too much weld metal may be present.*

*Note the flat bead face and smooth bead appearance with good wetting and wash-in at the weld edges.*

gravity to enhance aerodynamics and handling. In doing so, they often abuse the car's undercarriage exhaust systems, which can scrape along the track during hard turns and throw a plume of sparks behind the car.

Because of this, teams are sometimes forced to repair or even replace exhaust systems. Using Inconel can actually extend the life of exhausts and limit needed repairs.

As an added benefit, Inconel's higher strength and often thinner wall thickness has actually yielded increased horsepower for some Nextel Cup cars. Inconel, used in exhaust tubing, has also proven to resist vibration and withstand thermal

## Top Ten Facts about Gas Tungsten Arc Welding Chrome-Moly 4130

Yes, you can gas tungsten arc (GTA) weld 4130 tubing up to 0.120-in. wall thickness easily with the techniques and procedures described below. These procedures apply to typical sporting applications such as experimental airplanes, race car frames, roll cages, go-carts, bicycles, and motorcycle frames. The suitability of these techniques and procedures must be evaluated for your specific application.

**Q: Can I weld 4130 using the GTAW process?**

A: Yes, 4130 chrome-moly has been GTA welded in the aerospace and aircraft industries for years. As with all welding, proper procedures and techniques must be followed.

**Q: Do I need to preheat?**

A: Thin-wall tubing less than 0.120-in. does not typically require the normal 300°–400°F preheat to obtain acceptable results. However, tubing should be around 70° F or above before welding.

**Q: What filler material should I use?**

A: Although there are several good filler materials, ER80S-D2 is one you should consider. This material is capable of producing welds that approximate the strength of 4130. ER70S-2 is an acceptable alternative to ER80S-D2, as is ER70S-6, although weld strength will be slightly lower.

**Q: When I use ER70S-2 filler material, do I sacrifice strength for elongation?**

A: Yes. The filler material, when diluted with the base material, will typically undermatch the 4130. However, with the proper joint design, such as cluster or gusset, the cross-sectional area and linear inches of weld can compensate for the reduced weld deposit strength.

**Q: Why is 4130 filler metal not recommended?**

A: 4130 filler typically is used for applications where the weld will be heat treated. Due to its higher hardness and reduced elongation, it is not recommended for sporting applications such as experimental airplanes, race car frames, and roll cages.

**Q: Can I weld 4130 using any other filler materials?**

A: Some fabricators prefer austenitic stainless steel filler metals to weld 4130 tubing. This is acceptable provided 310 or 312 stainless steel filler metals are used. Other stainless steel filler metals can cause cracking. Stainless steel filler material is typically more expensive.

**Q: Do I need to heat treat (stress relieve) 4130 after welding?**

A: Thin wall tubing normally does not require stress relief. For parts thicker than 0.120 in., stress relieving is recommended. 1100°F is the optimum temperature for tubing applications. An oxyacetylene torch with neutral flame can be used. It should be oscillated to avoid hot spots.

**Q: Do I need to preclean 4130 material?**

A: Remove surface scale and oils with mild abrasives and acetone. Wipe to remove all oils and lubricants. All burrs should be removed with a hand scraper or deburring tool. Better welding results with clean materials.

**Q: Do I need to backpurge 4130 material?**

A: Backpurging is not normally necessary, although some fabricators do. It will not hurt the weld and may improve the root pass of some welds.

**Q: Should I quench the metal after I finish welding?**

A: Absolutely not. Rapid quenching of the metal will create problems such as cracking and lamellar tearing. Always allow the weld to slow cool.

*Fabricators at Chip Ganassi Racing use GTAW to repair and customize Nextel Cup exhaust components.*

cycle heating and cooling better than other materials.

Chrome-moly is an abbreviation for chromium-molybdenum steel. It comprises a range of low-alloy steels that have been used for things such as bicycle frames and race car roll cages.

Chrome-moly has the advantage of high tensile strength. It is easily welded, and is considerably stronger and more durable than standard 1020 steel tubing.

Chrome-moly has found its way onto some NASCAR suspension systems and chassis extensions, where heavier, lower tensile strength carbon steel was previously used. Its use in racing is growing each year.

Titanium is a strong, lustrous, and corrosion-resistant metal. It is most commonly alloyed with vanadium and aluminum. NASCAR currently allows titanium only for a limited number of engine parts, but race teams anticipate a wider use is not far off.

Titanium is noted for its high strength-to-weight ratio. It is a light, strong metal with low density, which when pure is quite ductile and relatively easy to work.

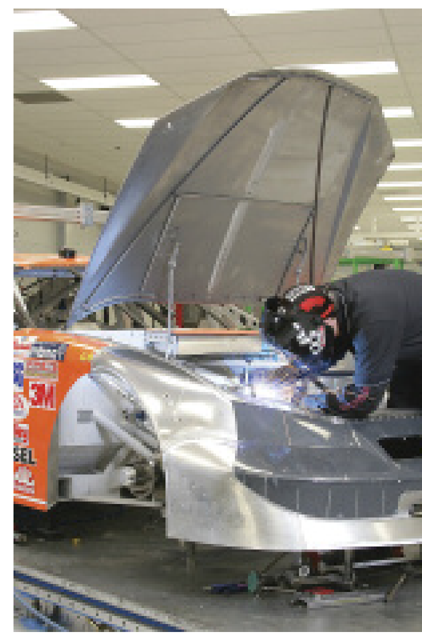
Titanium 6Al4V grade has a tensile strength equal to that of high-strength low-alloy steels, but weighs 33% less. When compared to 6061-T6 aluminum alloy, titanium exhibits a higher strength-to-weight ratio, making it ideal for a number of race car components.

*A welder uses an inverter-based gas tungsten arc welding machine on exhaust headers at Penske South Racing.*

## Welding Steel and Chrome-Moly Steel

The massive steel cage-like chassis structures of NASCAR cars are made of carbon steel and generally are welded using gas metal arc welding (GMAW). However, many of the cars' fabricated components are meticulously gas tungsten arc (GTA) welded.

Weight-to-strength ratios are a primary concern in race car welding. So the goal for both GMA and GTA welding is to create a strong, deeply penetrating weld. Top team fabricators pride themselves on being able to produce a proper slightly convex bead profile. Overly convex bead profiles are generally unacceptable and are considered to add unnecessary weight.



*Chrome-moly is now being used in some chassis extension components at Joe Gibbs Racing.*

Welding chrome-moly is very similar to welding carbon steel. Team fabricators have come to learn that the techniques, practices, and rules of thumb common in industrial welding on thicker chrome-moly material often do not apply to the thinner gauge welding typically performed on racing components.

Textbook guidelines often assume that the material is thicker than 0.120 in., and they recommend preheating chrome-moly from 300° to 400°F as well as postweld heat treatment. However, since racing components are typically fabricated from thinner material, preheating and postweld heat treatment is not typically necessary.

Some top race welders purge their tubing applications when welding on chrome-moly, in order to preserve or enhance the material's mechanical properties.

Inconel 625 is a more difficult material to weld than chrome-moly or standard steel. First, the Inconel pool does not reach the same level of fluidity as when welding on carbon steel. The pool is more difficult to manipulate. It is less forgiving of poor fitup, and it can be more difficult to maneuver across gaps.

Thus, certain precautions are recommended. Proper shielding on the front and back sides of the welds in any nickel-based alloy is very important to avoid porosity and reduced ductility. An Inconel tube must be purged of its inside air and replaced with argon before welding.

Tight fitup is essential. Gaps require more welding manipulation and present an increased chance for error. Because of this, team fabricators often lay an increased number of tack welds to improve fitup. Careful, thorough cleaning of the material avoids contamination, porosity, and subsequent cracking. Nextel Cup welders use 100% argon shielding and ERNiCrMo-3 filler metal (AWS specification A5.14) for Inconel 625.

Today, NASCAR teams either purchase prefabricated Inconel headers or build them themselves. Regardless of the arrangement, all teams that use Inconel headers are required to weld them in some way, whether to simply install them or to repair or modify them.

A set of Inconel headers can cost $5000 to $7000, so it is important that any welding work is done correctly the first time. However, the thinness of the material — generally about 0.035 in. or less — allows welders just one pass, and that weld must be carefully performed. There are no subsequent passes that can compensate for inferior workmanship on the first pass. Everything must be perfect. Poor welds would require cutting the section out and rewelding one or more welds to fit in a replacement section to complete the fabrication or repair.

Titanium and most titanium alloys can be welded using GMAW or GTAW. However, with the racing focus on code-quality welding on thin materials, GTAW is almost exclusively preferred. Operators will find that a titanium pool has good fluidity compared to Inconel 625.

Welding titanium requires thorough surface cleaning and the correct use of shielding gas surrounding the entire weld as molten titanium reacts readily with oxygen, nitrogen, and hydrogen. Exposure to these elements or surface contaminants can adversely affect the weld and lead to cracking. Heat-affected areas must be shielded until temperatures cool below 600°F. Shielding a titanium pool with 100% argon is preferred, but some helium or argon/helium mixtures are also effective. Auxiliary purging systems and very large gas cups are often used.


*Chip Ganassi Racing fabricators evaluating new gas metal arc welding machines.*

Note that titanium cannot be welded to most other metals because brittle metallic compounds will form that often lead to cracking.

## Welding Technology

Many NASCAR rules are designed to help race teams maintain relatively low operating costs while simultaneously maximizing driver safety. The average NASCAR car today costs roughly $185,000, which is about the same price for the transmission on a Formula One car.

With a NASCAR focus on controlling costs and maintaining a competitive environment for the team while continually increasing driver safety, the teams increasingly seek and benefit from advancements in technology.

Introducing new materials such as titanium and Inconel was often considered impractical in the past because welding such materials was difficult and required very skilled craftspeople, additional time,

*Elite NASCAR fabricators practice hands-on skills with instruction from specialized welding instructors at the Lincoln Electric Advanced Motorsports Seminar.*

and more money.

Today, however, welding these new materials has become considerably more commonplace with recent advancements in welding equipment, furthering NASCAR's likelihood to allow them on race cars.

## Inverter-Based Welding Power Sources

In particular, inverter-based welding power source technology has become prevalent, allowing operators to set software-driven welding parameters to a specific material and application. For example, welding waveform programs can be developed to control heat input, penetration, and other arc characteristics on Inconel or titanium on a specific thickness, with a particular shielding gas or a specific joint design.

Inverter-based welding power sources operate at frequencies above 20 kHz, as compared to traditional power sources, which operate at a line frequency of 50 or 60 Hz. Some inverter-based system advantages include smaller, therefore lighter, components such as chokes and transformers, a higher electrical efficiency, and a faster response to the welding arc.

Inverter power sources were first introduced to the industry in the early 1980s.

**The advantages of chrome-moly steel include high tensile strength, good weldability, and durability.**

The initial attraction was their small size and portability. Today, inverters are designed for many different arc welding processes, including shielded metal arc, gas tungsten arc, flux cored arc, and submerged arc welding.

Inverters today provide optimum arc characteristics for very specific applications, such as welding thin Inconel — important for race welders. Many inverter models are software programmable to allow operators to manipulate the welding output characteristics. Inverters from The Lincoln Electric Co. are programmed with Waveform Control Technology™, an embedded software program that allows the ability to customize the waveform output. Operators can choose from a predefined set of programs and manipulate the parameters of that program to best fit a given application.

## Winning Welds

NASCAR team fabricators frequently review new welding technology. Many relentlessly seek new ways to improve the quality of their work and deliver innovations in welding practices or techniques uniquely adapted to high-performance race car fabrication.

For the vast majority of NASCAR welders, safety is the No. 1 concern, knowing that their welds must hold up to 200 mph turns, high G-forces, and punishing collisions. Team fabricators work hard to build these machines by hand with the highest quality, because they know their driver's life is on the line every time they climb in to practice or race.

In NASCAR, the weld shops are as competitive as the drivers and the pit crews who run the races each Sunday. They, too, weld to win, and as safety drives the technological advancement of NASCAR, it is certain that performance will follow close behind.®