Welding for Our Old Outboards

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There are many different welding process's, each with different attributes that make them more or less suitable to different welding applications. Of the four most common and well known welding process's, Oxy-Acetylene welding, Stick welding (SMAW - Shielded Metal Arc Welding), Tig welding (GTAW - Gas Tungsten Arc Welding), and Mig welding (GMAW - Gas Metal Arc Welding) only Mig and Tig are suitable for welding aluminum. The thing that makes aluminum difficult to weld is the oxide layer that forms as soon as it is bared to the atmosphere. You need to pay attention to this oxide layer when painting aluminum by using a self etching primer. This same oxide layer is also what gives aluminum much better corrosion resistance than iron based metals (steel). Aluminum oxide occupies the same volume as aluminum. Iron oxide, "rust" occupies a larger volume than the original metal. So when iron based metals corrode the oxide expands and flakes off exposing new metal to oxidation. The oxide offers no protection from the atmosphere. Since aluminum oxide does not expand it's volume, the oxide layer protects the metal beneath it from further oxidation. Aluminum oxide is also one of the hardest materials we know of. That is why most sandpaper is covered with it.

The difficulty it causes in welding has to do with melting points. Aluminum melts at about 1200 degrees F. Aluminum oxide melts at about 3600 Degrees F.

If you simply apply heat to the metal, by the time you have enough heat to melt the oxide, the core has long since melted and a large chunk just falls away leaving a mess.

If I recall my welding history correctly Tig welding was developed around the time of the second world war to weld the new exotic metals like aluminum and magnesium, that the existing welding process's could not get satisfactory results with. Tig welding uses a non-consumable tungsten electrode to channel the arc between it and the work piece. The tungsten is held in a Tig "torch". Filler metal is added via a separate rod. This gives the operator the greatest control over the entire process. The amount of heat applied by the arc and the rate of filler metal addition are completely independent. Tig is a constant current process, the operator selects the current on the machine and can even adjust it as he goes via a foot pedal or a thumbwheel on the torch. Tig welding can weld any type of metal capable of being welded and can weld at lower currents than any other process, allowing it to be used on thinner sections of material.

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Left:
Broken skeg and new cast piece. I had this done at a local foundry. I brought him a good condition original and had him do several pieces for me.

Right:
I placed the cast piece under the broken one and marked the cut line.

The down side is that it has the lowest rate of deposition of all the welding process's making it the most expensive, when you consider the operators time and how many inches per hour can be welded with any particular process. An inert gas, usually Argon is pumped through the nozzle of the torch to shield the molten pool of metal from the atmosphere. The inventor used helium as the shielding gas and so you will see some of the older machines called "Heliarc", but they are Tig machines. Helium is not used very often any more. It costs 3 times as much as Argon and you have to set the flow rate to twice that of Argon so it ends up costing 6 times as much. Some welders working on larger size materials will use a mixture of helium and argon because the helium gives better weld penetration for an equivalent amperage.

Mig welding uses filler metal on a spool. A motor advances the wire out of the nozzle of the Mig "gun" and the arc goes between the wire and the work piece. Mig welding is a constant voltage process. The operator selects the voltage and wire speed in inches per minute. In production welding shops Mig will almost always be chosen over Tig when possible because it is a much faster process.

Aluminum is welded with alternating current. In one part of the cycle when the electrons are going from the work piece to the torch or gun, it is called "cleaning mode" as this motion of electrons breaks up the oxide layer on the aluminum, and the shielding gas prevents the oxide from reforming. The other part of the cycle when the electrons are going from the torch or gun to the work piece, is when the actual welding is done. The heat in the circuit always follows the electrons. In cleaning mode the electrode in the torch or gun receives most of the heat. In the welding half of the cycle the work piece receives most of the heat. Older transformer welders are stuck with a 50/50 cleaning mode, welding mode cycle because of the 60hz sine wave supplied by hydro. Time wise the cycle spends equal time in the negative and positive halves of the cycle. Modern "Inverter" welders are basically creating an artificial waveform on the output that is not tied in to the 50/50 sine wave from the supply in any way. This way you can specify what time you want the wave to be in either cleaning or welding mode and you only get as much cleaning as you need. You can also have the output be a sine wave, triangular wave or a square wave.

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New piece, cut to size and held in place ready to tack weld.

View of "Third Hand" I made to hold parts for welding.

The thermal conductivity of a metal is directly related to it's electrical conductivity, and this has a direct effect on how much current is required to weld a given thickness of any particular metal. The more electrically and thermally conductive a metal is, the more current is required to weld it. This is because the rest of the metal on the work piece acts like a heat sink drawing heat away from the welding zone. A 1/4" piece of aluminum requires more current than a 1/4" piece of steel. A 1/4" piece of copper based metal like brass or bronze requires more current than that required for aluminum. Since silver is the most electrically conductive of all metals and therefore also the most thermally conductive it would require the most current of all to weld. Although I doubt anyone is welding 1/4" sheets of silver.

Tig and Mig can both weld aluminum, but Tig is the choice for welding castings on our old outboards because it has independent control of heat and filler metal. Recently I had to weld the block on a 35hp Johnson. The tab for the starter motor mount had broken off. Someone had repaired it with epoxy but it had broken off again. By setting the arc to a fairly high current and holding it in position without adding any filler you can raise the temperature of the local area high enough to let the base metal melt and then begin to add filler.

Melting the base metal is the definition of welding. In brazing or soldering the base metal does not melt. You heat it up enough to allow the filler metal to bond to it. Usually some kind of bronze alloy in brazing and a lead-tin alloy for soldering, though modern soldering alloys have done away with the lead because it is so poisonous. In Mig welding the only way to weld a large casting like that is to use pre heat. Using an oxy-acetylene torch the casting has to be heated to the 500 degree range and then welding can be done with a Mig machine.

Another advantage of the Tig machine is the foot pedal control for amperage. When welding highly conductive metals like aluminum, whatever current you started out welding with, by the time you get to the end of the weld and the entire piece is now much hotter, you need less current to melt the base metal. If you cannot change the setting you will have too much heat and will over melt the piece. With no amperage adjustment you have to stop the weld, let the piece cool and then start again. With the foot pedal control you can back off the current to the correct level so you don't have to don't have to stop and start. I bought a Tig machine. It was more expensive than an equivalent Mig machine but this way I don't have to invest in an oxy-acetylene setup, and I also don't have any space left in my shop for it.

Above: Replacement skeg welded in place.
Right: Excess metal ground away close to final size.

Far Right: Sanded to final size, good as new!