

WELDING WITH MACHINING IN MIND

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This section provides information about bore buildup with subsequent machining in mind. There are several factors that can contribute to difficulty in machining the buildup produced by the Bortech 306-P BoreWelder. These include:

- Unevenness of the buildup.
- Slag or “glass” inclusions.
- Hardness of the weld.

During the buildup process, there are procedures that, if followed, may make the subsequent machining of the deposit more easily done. This section provides information about each. In addition, this section discusses:

- Step
- Tungsten Carbide Tools
- Cutting Speeds

UNEVENNESS OF BUILDUP

The machining of the deposits should be done, almost without exception, with tungsten carbide cutting tools (discussed in “Machining the Buildup With Tungsten Carbide Tools” on page 81). Due to this material’s sensitivity to impact, a smoothly applied deposit reduces machining problems. It is best to take the time during the buildup stage to create smooth and even deposits. Slower welding speeds, lower currents, and smaller steps all contribute to smoother beads.

Try to make the buildup smooth enough so the weld will “clean up” with a light first cut. In this way, during machining, the tool will never leave the work and the impact effect (also discussed in “Machining the Buildup With Tungsten Carbide Tools” on page 81) is thus minimized. If a bore buildup is done using axially applied beads, the use of carbide tools would be extremely difficult because of the rapid changes in tool loading that would be experienced.

SLAG OR “GLASS” INCLUSIONS

The slag produced by MIG welding generally consists of a glass (silicon dioxide) that forms on the surface of the weld. Wires with high silicon contents (E-70S-6 is one such wire) produce more of this glass slag. The slag tends to congregate into small solidified pools. Under normal circumstances, these pools are harmless. If there is too much step, the overlap between beads will be marginal and glass might be trapped between the beads as an inclusion. On the other hand, if the step is too small and the overlap too great, the solidified pools of slag from the previous bead might remelt and mix with the currently melted slag. This may produce an excessively large pool of glass that freezes on the surface of the weld.

Glass is an effective electrical insulator and it is difficult for the welding arc to penetrate through these large glass deposits to the previous bead. Instead, the arc may be diverted

around the glass and an inclusion may occur. This type of inclusion may or may not be of consequence to the finished part; but, it affects the machinability of the bore. Smoothly operating wires with less silicon (such as E-70S-2) produce less glass and may better suit your needs if inclusions become a problem. Closer attention to the size of the step also may be in order.

HARDNESS OF THE WELD

In order to harden steel, the steel must:

- Contain enough carbon or other alloys.
- Be heated to above its critical temperature (approximately 1350°F) long enough for the steel to transform into a new structure.¹
- Then be cooled rapidly enough (quenched) so that the carbon does not have time to migrate back before the steel transforms back again.

The amount of alloys determine the rate of quenching necessary for hardening. The carbon content determines the degree of hardening possible. After the steel has been hardened, it can be “drawn” or “tempered” (heated to a temperature less than the critical temperature) to reduce both the hardness and the locked in stresses induced by the rapid and uneven cooling. The higher the temper temperature (below critical) the lower the hardness will be.

The welding consumables generally used by the BoreWelder cannot be hardened. They will not respond to heating and quenching to produce hardness. However, some of the materials to which these wires might be applied contain enough alloys and/or carbon to enable them to be hardened. When a weld bead is deposited on materials that can be hardened, there also is admixture and the weld deposit will pick up some of the base metal alloys, making it possible to harden the deposit to some degree.

In addition, some of the base metal is heated above critical and then quenched, hardening it as well, in what is termed the Heat Affected Zone (HAZ). It is possible that portions of this zone might harden to such a degree that a crack might occur in this region because the material is unable to yield when the shrinkage stresses accumulate on cooling.²

So, to minimize hardening:

- The alloying through admixture with the base metal should be kept to a minimum.
- The quench effect produced by the relatively cold base metal should be as little as practical.

1. At room temperature, most steel has a Body Centered Cubic structure and carbon is usually in the form of Iron Carbide. Above critical temperature, the steel transforms into a Face Centered Cubic structure called Austenite. In this state, the carbon is in solid solution. When this steel cools, it must transform back to Body Centered Cubic and the carbon is forced out of solution. If insufficient time is allowed, a hard material, Martensite, is formed.

2. It is possible during borewelding to have this crack spread throughout the entire weld/bore surface interface and have the weld become a loose “bushing” in the bore. On inspection, it will be found that the “bore surface” is now larger than it was originally due to metal that has been pulled away, indicating that fusion occurred. This probably indicates that a preheat was desired.

Preheating the part before welding and/or slow rotational travel speeds will slow the cooling rate and help to control both the hardness and the shrinkage stresses. To soften a hardened bead, the weld bead can be reheated to temper it.

The previous information “sets the stage.” If the part being built up is large and cool and it has a high carbon/alloy content, weld hardening will occur. However, the amount of hardness almost always can be controlled to within acceptable limits. To control the hardness of the weld deposit:

- Use a low welding current and a low voltage to obtain a less violent arc with a resulting lower admixture. This will not lessen the hardness of the base material—only the weld. (The base material HAZ will become narrower but harder.)
- A slower rotational travel speed lets the arc play more on the already deposited weld pool, producing less penetration (less admixture) and more buildup of welding wire that cannot be hardened to dilute the alloy effect. More important, the slower travel also reduces the rate of quench imposed on the weld because heat from the welding has time to spread out into the base metal. This will cause the temperature to fall more slowly after the arc has passed. This decreases the hardness of the underbead material but increases the thickness of the HAZ. (Decreasing the hardness is usually a good trade for deepening the HAZ because thickening the HAZ makes for a more gradual transition.)
- A smaller step size causes the welding arc to play more on the previously deposited weld bead instead of on the alloyed base metal. Less admixture results and the wire that cannot be hardened dilutes the deposit. A smaller step size also has another effect. It tends to temper the previous bead more thoroughly. And, unless the bore is very large, heat tends to build up in the part after several revolutions because the buildup progresses more slowly up the bore. This latent heat reduces the quench effect on the weld bead.
- Preheating the part helps a lot. Even a preheat of 130°F or 150°F reduces the quench noticeably.
- During the beginning of a buildup operation, the part generally is cooler. Therefore, the first several beads may be harder than the rest due to the increased quench. In addition, there is no lower-alloy previous bead for the first bead to fuse with and, therefore, there will be a greater alloy pickup taking place in the weld because all fusion will occur with the alloy base metal. To make these beginning beads softer, return to the beginning portion after completion of the bore buildup and deposit another layer on top of the one just applied for 4 or 5 revolutions. This tends to temper the underlying beads. Also, the quench probably will be less than when the underlying beads were applied due to the fact that the part is probably warmer than at the start. This second pass is often surprisingly effective. On smaller bores, it even may be practical to buildup the entire bore with two passes solely for the purpose of tempering.

A NOTE ABOUT STEP

Step is the axial travel of the BoreWelder per revolution. You must be cautious when setting the step of the BoreWelder. If the step is too great, there is the obvious possibility that the beads will not fuse to each other. They will fuse only to the base metal.

On the other hand, if the step is too small, the welding arc may expend too much of its energy on heating the previous bead and not enough on heating the base metal. In such cases, you run the risk of lack of fusion to the base metal. There have been cases in which the step was so small, the deposit was actually a cylinder cast against the bore surface but not fused to it.

It is important to note that the size of the step is contingent on other parameters such as the wire speed and the rotation speed. Therefore, it is of great importance to be able to adjust the step increment precisely.

MACHINING THE BUILDUP WITH TUNGSTEN CARBIDE TOOLS

To machine the buildup as deposited by the BoreWelder, it is strongly advised that the cutting tool is of tungsten carbide. Tungsten carbide tools allow the higher cutting speeds necessary for a good surface finish and they get the job done more quickly. Most important, tungsten carbide will hold its edge when it must cut through the silicon dioxide glass slag formed by most MIG welding wires. High speed steel tools will not tolerate glass. They lose their edge and it becomes impossible to perform accurate work. Even if no glass inclusions are present in the weld, high speed steel tools will not last long because the weld, even if soft, is of an abrasive nature.

Tungsten carbide works well and will last a long time provided several of its properties are kept in mind. Tungsten carbide is very hard, giving rise to its excellent resistance to abrasion as well as its ability to cut harder materials. It also will withstand higher cutting edge temperatures and, thus, higher cutting speeds. However, it has weaknesses that must be kept in mind when machining weld buildup.

Tungsten carbide is a relatively brittle material. It is not very ductile and will not hold up well against shock loads whether they are pressure or thermal shock.

Because of the thermal shock weakness inherent to tungsten carbide, it is generally advisable that *no* coolant is used. This is because when boring a hole it is very difficult to keep the tool evenly immersed in the coolant at all times. If the cutting edge is allowed to heat momentarily due to lack of coolant coverage and is then quenched as the coolant returns (as caused by a chip momentarily diverting the coolant), the edge is likely to suffer micro-cracking that will rapidly propagate and cause catastrophic tool failure.

Do not use a coolant.

Low impact resistance of tungsten carbide makes it prone to failure in what is known as interrupted cuts. An interrupted cut is when the cutting tool must leave the cut and re-enter again. A milling cutter must withstand interrupted cuts. The severity of the impact during the interruption (how gradually the tool leaves and reenters the cut) is a factor in determining the shape of the cutter. A milling cutter generally enters and exits the cut gradually in a well designed milling operation. In cutting the bore buildup deposit, the surface quality will determine the severity of the interruptions. If the bore is very smooth there will be low impact on the tool even if the boring is not central so that the tool only cuts on one side of the bore. (If cutting is not central, the tool load will cyclically increase and decrease gradually as the depth of cut evenly varies—low impact.) On the other

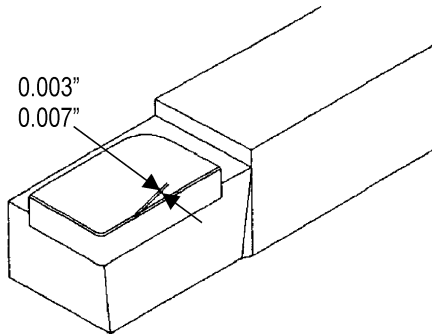
hand, there will be more impact if the bore buildup contains inclusions, “grapes,” keyways, or other rapid changes in depth of cut.

If cutting tool impact will be present, try to keep the tool buried in the cut at all times. If the tool leaves the work completely and is suddenly unloaded, it tends to spring ahead, probably worsening its reentry conditions because the unloaded tool will slam into the cut with no power behind it until backlash is taken up in the gearing. This condition is hard on tools.

SHARPENING TUNGSTEN CARBIDE TOOLS

If the tool must leave the work or if tools tend to chip in use, you should heavily hone the cutting edge using a silicon carbide hand honing block. Tungsten carbide has great compressive strength but a lower tensile strength. In its cutting configuration, the edge is stronger if it has good support beneath it. Remove the abrupt overhang of the edge to provide this support. Hone the cutting edges of the tool to a 45° chamfer of .003” to .007”. That is, make the tool appear dull, hone its edge away so that a 45° flat exists. During actual cutting, the real chip load is actually back from the edge on the top “rake” surface. The chamfer will not adversely affect the cutting as you might suspect. In fact, on all but light finish cuts, a honed tool probably will improve the cutting by lowering the critical speed—the speed over which cutting improves. If this is done, the edge will last through these interruptions.

FIGURE 30: HONE THE CUTTING EDGES OF THE TOOL



The rake of the tool (the angle of the top surface of the tool, the part that the chip slides across) plays a part also. A positive rake (top surface sloping away from the cutting edge, making the tool more like a knife) requires less force to cut but the edge is weak. A negative rake (top surface sloping into the cut—a tool more like a scraper) is stronger but requires more power to operate. A negative rake should be considered for heavy roughing cuts with high feed rates. Light roughing cuts can be done with a positive rake. Hone either tool as described above.

A larger nose radius on the tool results in a stronger edge. While not the only cause, large nose radii also increase the risk of chatter. Chatter severely strains tungsten carbide. A nose radius of .030” is normal. Also, you should not allow the relief angle under the cutting edge to get larger than 5° to 7°. Larger relief angles do not support the edge ade-

quately and they promote chatter. If more clearance is needed, create a secondary relief below the first. A chip breaker is good, but should not unduly weaken the edge.

CUTTING SPEEDS

While using tungsten carbide, the cutting speed should be high enough to obtain smooth cutting. This speed changes with the hardness of the deposit and with the depth of cut and/or feed rate.

There is a critical speed at which the chips begin to glide over the top of the tool, glazing the underside of the chip. This speed is over the operating range of high speed steel tools. For a cut depth of .050" and feed rate of .010" in soft steel, the speed might be 150 to 250 sfm (Surface Feet per Minute).³ For a light finish cut, a speed of 300 to 400 sfm might be more appropriate. Harder materials require lower speeds to keep from overheating and destroying the cutting edge. But, keep the speed high enough to prevent the rough gray colored tearing associated with low surface speeds.

NOTE: A good source for additional information regarding cutting tools is the "Machinery's Handbook" published by the Industrial Press, Inc.

³. For a 4" diameter bore, the RPM is approximately equal to the sfm (200 sfm equals approximately 200 rpm). For a 2" diameter bore, 200 sfm equals approximately 400 rpm, etc.