Magnetism - A Blow to Welding

The origins of magnetic arc blow are examined by Philip Blakeley and Joszef Takacs, who go on to discuss practical remedies which minimise any delays in the welding schedule. Solving problems associated with high levels of magnetism at a Hungarian site is used as a practical example. ***(Published in Welding & Metal Fabrication, May 1999)***

Tubular structures and pipelines are commonly fabricated by using one of several different arc welding processes. This type of work is routine, takes place everyday, and proceeds in a reliable and predictable manner. Yet once in a while, sufficient magnetism arises within the components being fabricated that welding becomes seriously disrupted, threatening to cause expensive delays in the programme of work.

This article examines the origins of magnetic arc blow and discusses practical remedies which allow fabricators to minimise any subsequent delays in the welding schedule. A practical example in solving problems associated with high levels of magnetism at a work site in Hungary is also described.

Introduction

Welding arcs consist of a stream of electrons travelling from the welding electrode to the workpiece which heat up the joint preparation and melt filler metal to form a molten weld pool which is directed along the joint to form a weld. If, however, significant levels of magnetism are present in the material being welded, then the interaction between the magnetic field and the welding arc causes the arc to be deflected sideways with subsequent disturbance of the weld pool, see figure 1. This deflection is called magnetic arc blow and can lead to the possible introduction of defects in the weld, an increase in the time required to complete the work, and a frustrated team of welders.

Often the interference with the welding arc is small and welders can make the necessary adjustments required to complete the job . Occasionally, however, the arc becomes unstable or is completely blown out causing defective welds and greatly increased welding times. The cost implications of increased welding times or late delivery can be significant.

Fig 1

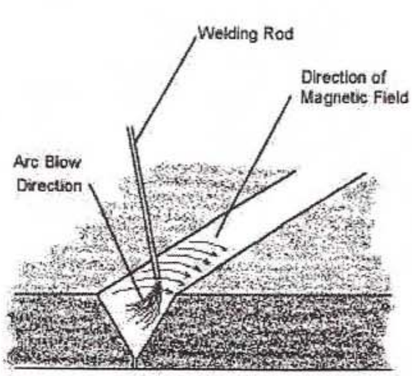


Fig.1 Arc Blow along joint prepearation caused by magnetic field

Fig 2

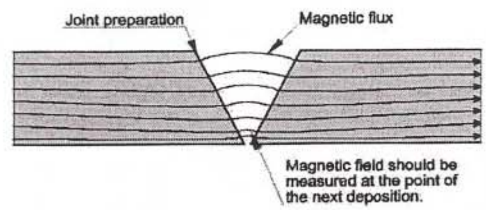


Fig. 2. Magnetic field distribution around a weld preparation.

The solution to the problem is to demagnetise the weld preparation to enable welding to proceed. To do this properly requires a means of measuring the magnetic field in order to assess the magnitude of the problem, and then to confirm that successful demagnetisation has taken place. Measurement of the residual magnetic field in the joint preparation is important to ensure that demagnetising procedures reduce rather than increase the value. Since the magnetism in the steel can arise, in part, from the welding current itself, demagnetisation has to take this into account and a suitable procedure is described below.

Some level of magnetism is normally present within steel (except stainless steel.) The key factor in determining whether or not this will cause problems is the strength of the magnetic field at the point of welding. This should be measured as shown in figure 2. In general, where the magnetism in a joint preparation is found to be above 20 gauss (2mT) , then disruption of the welding arc can be expected. When the value is over 40 gauss (4mT) then arc blow will be a problem. Demagnetisation techniques should aim to reduce the magnetic field in the joint preparation to below 10 gauss (1mT). It is not unknown to find magnetic fields of several thousand gauss which completely prevents any welding from taking place.

Once magnetic arc blow has begun to disrupt the welding arc, it is important to deal correctly with the problem to avoid unnecessary delays in the fabrication programme; it is important not to waste time with attempted remedies which cannot remove the high levels of magnetisation. By applying the correct demagnetisation procedures, welding can usually proceed at the normal production rate.

Magnetism - A Blow to Welding

Welding technique and parameters

Almost all the joints of the vessel were welded in the flat position including the circumferential joints which were rotated during welding. The nozzle-shell welds were also made as horizontal joints

The Longitudinal joints of the vessel were "V" beveled, back ground and rewelded from the other side. Two supporting layers were welded by GMAW process, all other layers by the SAW process.

The Circumferential joints had symmetrical "X" bevels with double side welding. As before two supporting layers were welded by GMAW process and all other layers by SAW.

For the nozzle-shell joints, the shell opening was "half V" bevelled, and the welding performed by back grinding and rewelding from the other side using the SMAW process. The nozzle circumferential welds were "V" beveled with welding taking place from one side. The GTAW process was used for the root pass welding, the filling and covering layers arc welded using the SMAW process.

The welding material used for all processes was the austenite-ferrite type high alloyed material ensuring compliance with the high impact test requirements.

Magnetic build up in weld prep

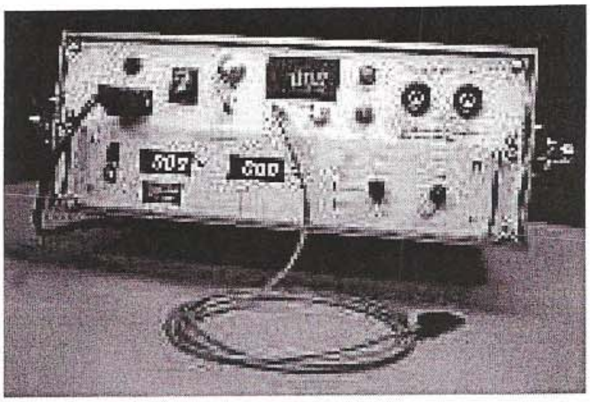
Manufacturing of pressure vessels started with cutting and bevelling of the steel plates and rolling the shell sections. It appeared that the above procedures resulted in an increase in the magnetic field found in the material. However, the magnetism was of a low level and did not interfere with the longitudinal welding.

It was only after the longitudinally welded sections were subsequently rolled and assembled in preparation for circumferential welding, that a serious increase in the magnetic field was detected. Measurements showed that the magnetic field strength was about 10 times greater in the weld preparation than at the components' bevelled edges . This caused arc blow which at some locations was sufficient to prevent arc striking.

Attempts were made to solve the problem, using AC welding processes or to demagnetise the material prior to welding, but did not prove successful. At some locations where the magnetism was lower, it was possible to weld successfully only by stiffening the arc through the use of larger diameter electrodes and higher arc voltages. With such high levels of magnetism in the joint, it was necessary to reduce the magnetic field strength to acceptable levels during the welding process.

Demagnetising procedure during welding

Smaller components can be demagnetised easily and routinely by passing them through a demagnetising coil powered from the mains. For bigger components such as the above vessel, the only way was to use a localised demagnetising technique during the welding process. To accurately monitor the magnetic flux, it was essential to use a magnetic field meter capable of measuring the magnetism in the root of the weld preparation. This enabled the magnetic field in the vicinity of the joint preparation to be cancelled out and the manufacturing of the column was completed.



Zeromag ZM100A De-Magnetiser

1. The magnetic field around the circumferential butt joints was not constant and varied significantly, particularly near the longitudinal joints. This necessitated continual monitoring of the magnetic field strength and continual adjustment of the demagnetising current to cancel out the residual field. Of course, after finishing welding and switching off the demagnetising equipment, the magnetic field returned to the components but was of no further concern. Figure 4 shows a circumferential joint being welded whilst demagnetisation is taking place.

Conclusions

1 Low levels of magnetism caused by the Earth's field or the welding current can result in much higher magnetic fields when tubes are assembled for the welding of circumferential butt joints.
2 It is worthwhile being prepared for the possibility of magnetic arc blow since there are some simple changes to the welding process which can be made to relieve the problem.
3 Demagnetisation whilst welding is taking place is the most reliable method of ensuring that welding can proceed with the minimum time delay.
4 Propriety equipment is available which reduces magnetism in weld preparations to the low levels required by arc welding.

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Further information on Zeromag

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Magnetism - A Blow to Welding

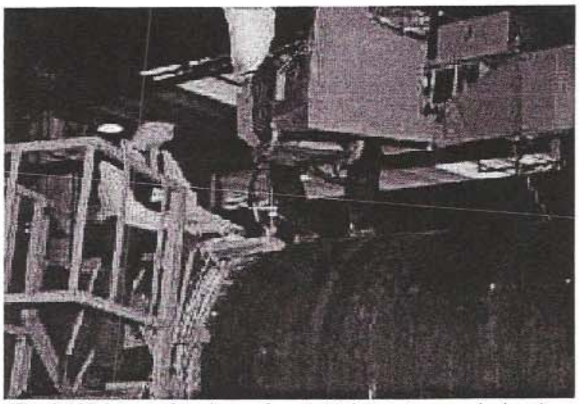


Fig 4. Welding of a circumfrential joint being carried out while demagnetisation is in process

REMEDIES FOR MAGNETIC ARC BLOW

Several techniques can be used to reduce or remove the problem of arc blow.

Consider the joint design

Make the weld preparation wider if possible. A J preparation is better than a V.

Check the assembly procedure

When making several circumferential welds to fabricate a tube assembly, it is better to carry out the central weld first, and work towards the ends. If welding proceeds by making the outer joints first, the final closing weld in the centre of the assembly involves welding two large structures together. A closing weld near the centre of a structure can result in arc blow problems.

Select the welding process

If possible, an A.C. welding process should be used. This avoids the welding current from significantly magnetising the steel. If a D.C. process has to be used, then the susceptibility to arc blow can be reduced by using the highest arc voltage possible.

Demagnetisation prior to welding

It is possible to reduce the magnetism within a steel tube by carrying out a demagnetisation procedure. This requires the tube to be passed through a coil which is carrying an alternating electric current. The coil length should be at least equal to the diameter of the pipe. The peak value of the current multiplied by the number of turns should be 10,000 ampere turns per metre length of coil. The frequency of the alternating current used depends on the wall thickness and material of the tubes . Typical values for the demagnetisation of steel pipes are 0.3 Hz for ½ inch wall thickness and 0.1 Hz for 1 inch.

Although this demagnetisation procedure is sometimes carried out, it is time consuming and requires expensive hardware and power supplies. Moreover, demagnetising prior to welding may not solve the problem of arc blow. Firstly, this is because it may not be possible to demagnetise tubes with linear seams which possess residual magnetism with both north and south polarity. Secondly, individual tubes may be successfully demagnetised to an acceptable level but once ends are butted together to form a weld preparation, the magnetic field can increase by a factor of 10. Thirdly, the magnetism which causes arc blow, may be caused by the welding current, rendering any prior demagnetisation useless.

Demagnetising During Welding

The most reliable method of demagnetising is to carry this out whilst welding is taking place. This is the only way to take account of variations in the level and polarity of the magnetic field which occur during welding.

The Zeromag system available from Diverse Technologies carries out this demagnetising process automatically. A sensor is positioned near the welding electrode and the Zeromag unit ensures that the magnetic field in the joint preparation remains below 1 mT enabling welding to proceed as normal. The Zeromag technique removes the magnetic field within seconds and maintains the field close to zero throughout the weld. Any changes in the polarity of the magnetic field which occur as the weld proceeds are detected by the Zeromag sensor which immediately makes the necessary adjustments to the demagnetising current.

Diverse also operates an on-site demagnetisation service to enable fabricators to deal with occurrences of arc blow.

REMOVAL OF MAGNETISM IN NI STEEL TUBES

Manufacturing of welded tubular structure from Ni alloyed steel.

A de-ethaniser column was ordered from DKG-EAST RT (Hungarian pressure vessel manufacturer) in the second half of 1998. Due to the low working temperature (-110°C) , 12Ni19 (WNr. 1.5680, DIN 17280) material was chosen for the vessel base metal. The material belongs to the 5% Ni alloyed carbon steel category.

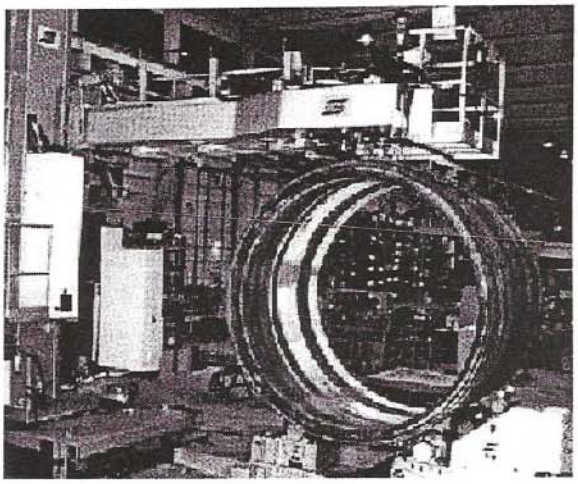
It has been found in practice that the higher the carbon and/or the Ni content of the steel, the more it tends to retain magnetism. These types of steels are categorised as magnetically hard materials and it is suggested that any order placed on a plate manufacturer specifies the maximum permitted magnetic field strength.

Details of the pressure vessel

The vessel is a vertically installed pressure vessel supported by a conical skirt. Vessel ends are closed by elliptical heads. The shell diameter is ID 1500 mm and ID 2500 mm, while wall thickness varies from 16 to 20mm for the ID 1500 mm part and 25 mm for the ID 2500 mm part. The transition cone between the two parts also has 25 mm wall thickness. The column's overall height is 35.4 m (See figure 3 for column details).

Due to the column dimensions, the vessel body was manufactured from 16 shell sections. Shell sections were welded by longitudinal joints (having 1800 to 2200 mm length) and the entire shell is fabricated by assembling and welding the circumferential joints between the sections.

Magnetism - A Blow to Welding



Factors affecting arc blow

A range of factors are responsible for the presence and strength of magnetism within materials. The most significant are listed as follows.

1. The Earth's Magnetic Field

This becomes particularly important when pipelines or structures are laid in a North/South direction rather than East/West. The effect can also be greater as the length of the pipeline increases. Although the Earth's magnetic field is less than 0.1mT, this can become concentrated to a much greater value by steel alloys.

2. Material

Magnetism can become a problem in materials with a ferrite crystal structure. This microstructure produces ferromagnetism which is found mainly in alloys with iron, nickel, or cobalt including steels but excluding most stainless steels. Arc blow is frequently encountered when welding steels with a high nickel content.

3. Weld preparation

The magnetic field in a weld preparation is higher where the two butting faces are close together. Therefore, magnetic arc blow tends to be worse at the root of a weld where the gap between the faces is at its smallest. It is also more of a problem in deeper , narrower V preps where the arc has to travel farther in the proximity of the faces of the preparation .

4. Presence of longitudinal seams

Where tubes have been manufactured using longitudinal welds, there can be a high magnetic field associated with the seams. Often, magnetism which is directed North on one side of the seam becomes strongly South on the other side. The location of these seams therefore causes particular difficulties when circumferential butt welds are attempted, since the welding arc will be deflected in one direction as the welder approaches the seam and will be abruptly deflected in the opposite direction as soon as the seam is passed by.

5. D.C. Welding current

D.C. welding current tends to cause or intensify magnetic fields within steel whereas A.C. welding currents are much less prone to this. Where the magnetism in steel is produced entirely by the effect of the welding current, then switching to A.C. should be considered if that is possible.

6. Assembly of components

When the magnetic field is measured at the end of a stand-alone tube or other components, this will be much lower than when tube ends are butted together. The strength of the magnetism normally increases, often by a factor of 10, when the pipes are assembled for welding.

7. Welding process.

Magnetic arc blow is more likely to occur with lower voltage arcs. Therefore TIG welding which uses a low voltage arc, and which is often used for the root pass of multi-pass welds, is particularly susceptible to arc blow. Manual metal arc welding using small diameter electrodes also calls for low currents and voltages resulting in a tendency to arc blow. Where possible, it is advisable to "stiffen" the welding arc by increasing the current and hence the welding voltage.

8. Magnetic particle inspection

Tubes which have been subjected to magnetic particle inspection can retain magnetism which subsequently contributes to the problems of arc blow.

9. Magnetic clamps

These can be used to lift steel components, or to attach items to a steel surface. They tend to leave magnetic patches in the steel which may contribute towards the residual magnetism in the joint region.

10. Large structures

Large structures such as those where pipes are used to link large vessels as frequently found in a refinery or chemical reactor are prone to becoming magnetic, particularly where the pipes are linking structures on the north of a site to those on the south. This occurs because large steel structures pull in the Earth's magnetic field and this becomes concentrated in the pipes which link the main parts together. Magnetic fields of several thousand gauss have been measured in pipes in these locations. Pipework being assembled or repaired under these conditions is very susceptible to magnetic arc blow.

11. Hyperbaric welding

Hyperbaric welding carried out with high ambient gas pressures is more prone to arc blow than welding at atmospheric pressure. This is because the electrons which make up the welding arc are slowed down by the high gas pressure allowing the arc more time to be deflected by any magnetic field which may be present.

Prevent Arc Blow When Welding

Arc blow can cause a number of welding problems including excessive spatter, incomplete fusion and porosity. What is arc blow and how can it be prevented?

Arc blow, also called arc wander, occurs in DC arc welding when the arc stream does not follow the shortest path between the electrode and the workpiece and deflects forward or backward from the direction of travel or, less frequently, to one side.

Back blow occurs when welding toward the workpiece connection, the end of a joint or into a corner. Forward blow occurs when welding away from the workpiece connection, or at the starting end of the joint. It is especially troublesome when shielded-metal-arc (SMA) welding with electrodes that tend to produce large slag coverings. In these cases, forward blow drags the slag or the crater forward and under the arc, disrupting the weld.

The direction of arc blow can be observed during open-arc welding, but not during submerged-arc welding. In this case, direction is determined by the type of weld defect produced.

Back blow is indicated by spatter; undercut, either continuous or intermittent; a narrow, high bead, usually with undercut; an increase in penetration; or surface porosity at the finish end of welds on sheetmetal.

Forward blow is indicated by a wide bead, irregular in width; a wavy bead; undercut, usually intermittent; or a decrease in penetration.

Arc blow can be one of two types: magnetic or thermal.

Magnetic Arc Blow

Magnetic arc blow, responsible for more welding problems than thermal arc blow, results from an unbalanced condition in the magnetic field surrounding the arc. This unbalanced condition usually occurs because the arc is located farther from one end of the weld joint than the other end and at varying distances from the workpiece connection. Imbalance also exists due to the change in direction of weld current as it flows through the arc and into and through the workpiece.

Fig. 1 shows a DC current passing through a conductor—either the welding electrode or the plasma stream between an electrode and a weld joint. A magnetic field surrounds the conductor; its lines of magnetic force, or flux, are represented by concentric circles at right angles to the direction of the current. These lines of force diminish in intensity in direct proportion to their distances from the electrical conductor.

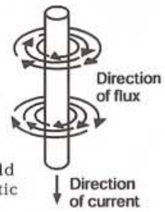


Fig. 1—Current passing through a conductor sets up a magnetic field, represented by planes of concentric circles known as flux lines.

The lines of force remain circular in a medium large enough to contain them until they diminish to essentially nothing. But if the medium changes, from steel plate to air, for example, the circular lines become distorted and tend to concentrate in the steel where they encounter less resistance. At a boundary between the edges of a steel plate and air, the lines squeeze and deform. This results in a heavy flux concentration behind or ahead of the welding arc. The arc then tends to move in a direction to relieve squeezing and restore the magnetic-field balance, veering away from the side of flux concentration. This veering is observed as arc blow.

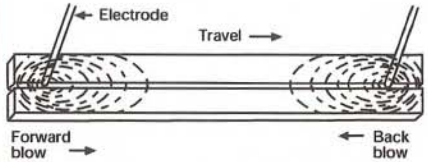


Fig. 2—Flux concentration behind the welding arc at the start of joint forces the arc forward while flux concentration ahead of the arc at the end of the joint forces the arc backward.

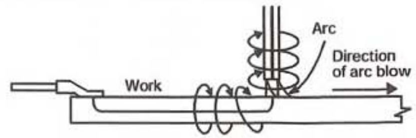


Fig. 3—Here, arc blow is caused by the welding current returning to the workpiece connection. The resulting magnetic flux combines with the flux around the electrode, causing a high-flux concentration at (x) that blows the arc away from the workpiece connection.

Arc-Blow Direction and Joint Location

Fig. 2 illustrates flux squeezing and distortion at the start and finish of a weld joint. At the start, flux lines concentrate behind the electrode. The arc tries to compensate for this imbalance by moving forward, creating forward arc blow. As the electrode approaches the end of the joint, the lines squeeze ahead of the arc. Again, the arc moves in a direction to relieve squeezing, in this case backward and observed as back blow. At the middle of a joint in two plates of the same width, the magnetic field is symmetrical, so no arc blow occurs. But, if one plate is wider than the other, side blow could occur at the midpoint of the weld due to flux squeezing.

Another squeezing phenomenon results from the welding current returning back toward the workpiece connection within the workpiece. As shown in Fig. 3, electrical current passing through the workpiece to the workpiece lead may create a flux. The heavy line represents the path of the welding current while the light lines represent the flux created by the current. As the current changes direction or turns the corner from the arc to the work, a flux concentrates at x, causing arc blow away from the workpiece connection.

Arc movement due to this effect combines with movement resulting from the flux concentration previously described to give the observed arc blow. The effect of the returning current may diminish or increase the arc blow caused by the arc flux. In fact, controlling the direction of returning current is one way to control arc blow.

In Fig. 4a, the workpiece cable connects to the starting end of the joint, and the flux created by the returning welding current in the work forms behind the arc. The resulting arc movement is forward. Near the end of the joint, however, forward arc movement diminishes the total arc blow by canceling some back blow created by flux concentration from the arc at the end of the workpiece (Fig. 5a).

In Fig. 4b, the work cable connects to the finish end of the seam, resulting in back blow, increasing in intensity at the finish of the weld. Fig. 5b illustrates the combination of squeezed fluxes. A workpiece connection at the finish of the weld, however, may be needed to reduce excessive forward blow at the start of the weld. But workpiece-connection positioning is only moderately effective in controlling arc blow. Other measures should be used to reduce arc blow when welding.

Fixtures Contribute to Arc Blow

Be aware of the relationship of arc blow to weldment fixturing. Steel fixtures may effect the magnetic field around the arc, and may become magnetized over time. Usually, fixturing won't cause problems when SMA-welding if weld current does not exceed 250 amps. Fixtures used with higher currents and mechanized welding should be designed to minimize arc-blow-promoting situations.

Here are some fixture-design tips:

- Design fixtures for welding the longitudinal seam of cylinders with a minimum of 1-in. clearance between the supporting beam and the work. Use nonmagnetic clamping fingers or workholding bars. Do not attach the workpiece cable to the copper backup bar—make the work connection directly to the workpiece.
- Fabricate the fixture from low-carbon steel to prevent buildup of permanent magnetism in the fixture.
- Weld toward the closed end of horn-type fixtures to reduce back blow.
- Design the fixture long enough so that end tabs can be used.
- Do not use a copper strip inserted in a steel bar for a backing. The steel part of the backup bar will increase arc blow.
- Provide for continuous or close clamping of parts to be seam welded. Wide, intermittent clamping may cause seams to gap between clamping points, causing arc blow over the gaps.
- Do not build into the fixture large masses of steel on one side of the seam only; counterbalance with a similar mass on the opposite side of the fixture.

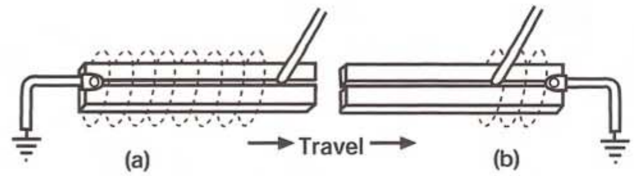


Fig. 4—Flux due to the welding current returning to the workpiece connection is behind the arc in (a) and ahead of the arc in (b).

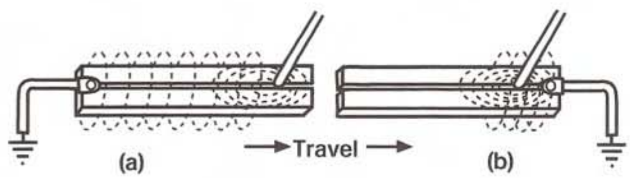


Fig. 5—In (a), magnetic blow at the finished end of a joint is reduced because the two flux fields tend to offset each other. In (b), the two fields combine to cause a strong back blow.

Problem Areas

Arc blow is especially problematic in the corners of fillet welds and in weld joints that use deep weld preparations. Here, the cause of arc blow is the same as when welding a straight seam—flux concentration and the movement of the arc to relieve it. Figs. 6 and 7 illustrate where arc blow, when using DC current, is problematic.

Using low welding current produces less arc blow than using high current because a higher current causes a more intense magnetic field. Usually, serious arc-blow problems do not occur when SMA-welding with DC under 250 amps, although joint fitup and geometry play a role.

The use of AC current markedly reduces the likelihood of arc blow. The rapid reversal of the AC current induces eddy currents in the base metal, and the fields created by the eddy currents greatly reduce the strength of the magnetic fields that cause arc blow.

Some materials, such as nine-percent nickel steels, are easily magnetized by external magnetic fields, such as those from power lines. These materials are difficult to weld due to arc blow produced by magnetic fields in the material. Hand-held Gauss meters easily detect and measure these fields. Fields higher than 20 Gauss can cause arc blow in these nickel steels.

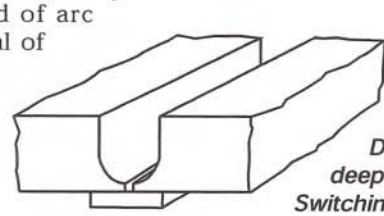


Fig. 6—Arc-blow difficulties abound when high-amp DC welding in deep-groove joints. Switching to AC current can alleviate this.

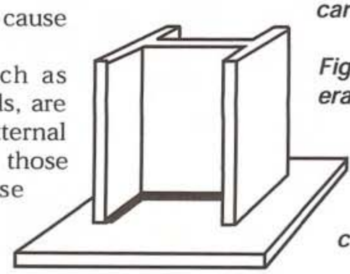


Fig. 7—Expect considerable arc blow when placing the inside fillet using DC current. Again, switching to AC current can help.

Thermal Arc Blow

Thermal arc blow occurs because an electric arc requires hot zones on the electrode and workpiece plate to maintain a continuous flow of current in the arc stream. As the electrode advances along the work, the arc tends to lag behind, caused by reluctance of the arc to move to the colder plate. The ionized space between the end of the electrode and the hot surface of the molten crater creates a more conductive path than from the electrode to the colder

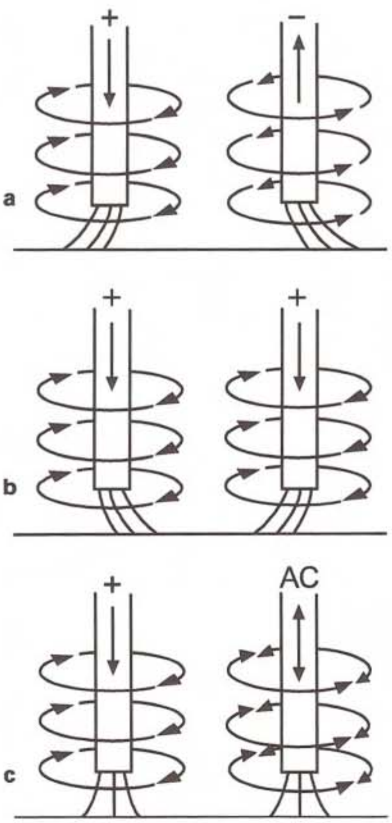


Fig. 8—Multiple-arc welding, when the two arcs are located close together, may cause magnetic arc blow. When the arcs are of different polarity (a), the magnetic fields combine to blow arcs outward. If the arcs are of the same polarity (b), magnetic fields oppose each other and the arcs blow inward. With one arc powered by DC current and the other by AC current (c), little or no arc blow occurs.

plate. During manual welding, a small amount of thermal back blow due to arc lag is not detrimental, but becomes problematic at higher welding speeds, as occurring in automatic welding. Thermal arc blow sometimes may combine with magnetic back blow, leading to quality problems.

Arc Blow with Multiple-Arc Welding

Welding with multiple arcs, for high speed and increased productivity, can cause arc-blow problems, especially when two arcs are located close together.

If these two arcs have opposite polarities (Fig. 8a), magnetic fields between the arcs cause the arcs to deflect away from each other. If polarity is identical (Fig. 8b), magnetic fields between the arcs oppose each other, resulting in a weaker field between the arcs and causing the arcs to deflect toward each other.

When using two arcs, one may be DC, the other AC (Fig. 8c). Here, the AC-arc flux field completely reverses for each cycle, which barely affects the DC field and results in very little arc blow.

When using two AC arcs, a common arrangement, arc-blow interference is avoided mainly by phase-shifting the current of one arc 80 to 90 deg. from the other arc. With a phase shift, the current and magnetic fields of one arc reach a maximum when the current and magnetic fields of the other arc are at or near minimum, resulting in very little, if any, arc blow.

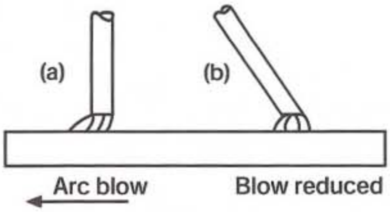


Fig. 9—Arc blow (a) may be corrected by angling the electrode (b).

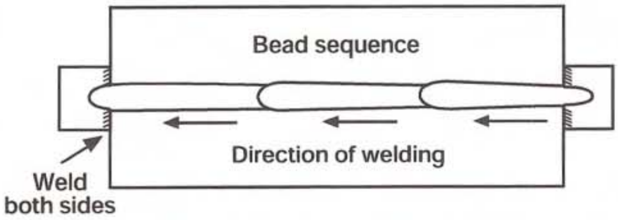


Fig. 10—The direction of welding and the sequence of beads is illustrated for the back-step technique. Note the tabs on each end of the seam—they should be of the same thickness as the workpiece.

How to Reduce Arc Blow

Not all arc blow is detrimental. In fact, a small amount helps form the bead shape, control molten slag and control penetration. But arc blow must be controlled when it contributes to defects such as undercut, inconsistent penetration, crooked beads, beads of irregular width, porosity, wavy beads and excessive spatter. Possible corrective measures include the following:

- If DC current is being used with the SMAW process—especially at welding current greater than 250 amps—change to AC current.
- Hold as short an arc as possible to help arc force counteract arc blow.
- Reduce the welding current. This may require an arc-speed reduction.
- Angle the electrode with the work opposite to the direction of arc blow (Fig. 9).
- Make a heavy tack weld on both ends of the seam; apply frequent tack welds along the seam, especially if fitup is loose.
- Weld toward a heavy tack weld or toward a previously made weld.
- Use a backstep welding technique (Fig. 10).
- Weld away from the workpiece connection to reduce back blow, and weld toward the workpiece connection to reduce forward blow.
- If welding produces heavy slag, a small amount of back blow is desirable, and is attained by welding toward the workpiece connection.
- Wrap the work cable around the workpiece so that the current returning to the power supply passes through it in such a direction that the magnetic field setup neutralizes the magnetic field causing the arc blow. **MF**

Information for this article was supplied by The Lincoln Electric Co., Cleveland, OH; tel. 216/481-8100; www.lincolnelectric.com.