Magnetic arc blow - causes and remedies

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Magnetic arc blow, although not encountered very frequently by most fabricators, can cause disruption of the welding and increase welding time and cost. In this article the author describes magnetic arc blow and the origins of magnetism in steel, and looks at methods of reducing magnetic problems.

Magnetic arc blow is not an uncommon problem if the entire welding industry is considered, but it is rare enough for individual fabricators to operate for years without any serious difficulties an then be caught by surprise when it does occur. The confusion felt by the welding team in often increased when similar materials have previously been welded with well developed procedures, presenting little or no trouble. Then a new batch of material arrives which is magnetised to such an extent that welding is greatly disrupted due to arc blow.

Most cases of magnetic arc blow are dealt with on the shop floor by the welder who, despite the unstable conditions, manages to produce acceptable welds. News of the magnetism therefore does not often pass beyond the welding foreman. Nevertheless, increased welding time will be required when incorrectly deposited weld metal needs to be ground out and re-welded. There is also the associated risk of introducing defects such as slag inclusions, porosity and lack of side wall fusion. The net result is increased welding time and cost.

What is magnetic arc blow ?

All welding processes which use either an arc or a beam of electrons are subject to disruption in a magnetic field. This is caused by the electrons which make up the arc being forced to follow a curved path when they pass through a magnetic field, FIg 1. When this occurs, the

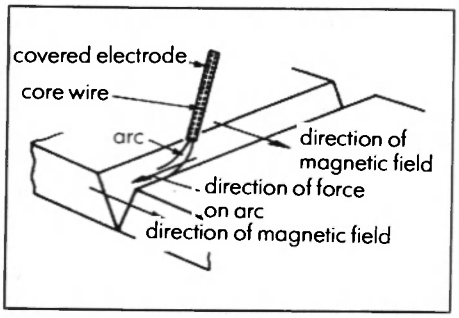

Fig. 1. : Force on an arc caused by a magnetic field

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Units and Nomenclature

Coercive force, coercivity

The magnetic field required to reduce remanent flux density to zero, A/m.

Ferromagnetic

Materials with relative permeability >>1, usually between 100 and 1000.

Magnetic field strength

H, the intensity of the magnetic field irrespective of physical properties of the environment, A/m.

Note: 1A/m= $4\pi\times10^{-3}$ oersted.

Magnetic flux density

B, the intensity of the magnetic field taking into account the medium in which the field exists. This is the quantity measured by Hall probes and search coils, weber/m^2, or tesla.

Note: 1T=10^4 gauss.

Permeability of free space

A constant, $\mu_0=4\pi\times10^{-7}$H/m. Relates B and H in a vacuum, B= μ_0H.

Relative permeability

A constant, μ_rWhich relates the ratio of magnetic flux density in a particular material with the flux density which would be measured in a vacuum. Thus if 1mT were measured in a vacuum, a material with relative permeability 200 would contain 200×1mT=200mT.

Remanence

The magnetic flux density B_r which resides in a specimen after a saturating magnetic field is withdrawn.

Saturation magnetic flux density

Saturation flux density B_s in a specimen is achieved when further increase in magnetic field strength causes the same increase in flux density in the specimen as would occur if the medium was a vacuum, ie, the material ceases to amplify the magnetic flux density at saturation and μ_r=1. This typically occurs at 1.9T for steel.

arc is deflected, usually along the direction of the weld preparation. The welding arc also creates its own magnetic field which interacts with the magnetism in the steel. causing the arc to behave erratically and in severe conditions to be extinguished completely.

The strength of the magnetic field in the weld preparation determines the degree of severity of any resulting arc blow. In addition, the influence of magnetism also depends on the shape and depth of the weld preparation and the particular pass being made. In general, the effects of magnetism are more pronounced in deep and narrow preparations, Fig 2. Since the magnetic flux tends to be concentrated at the root of a preparation, the root pass in often most susceptible to arc blow. On subsequent passes, magnetic flux is generally shunted away from the welding arc by metal already deposited and arc disturbance is less common.

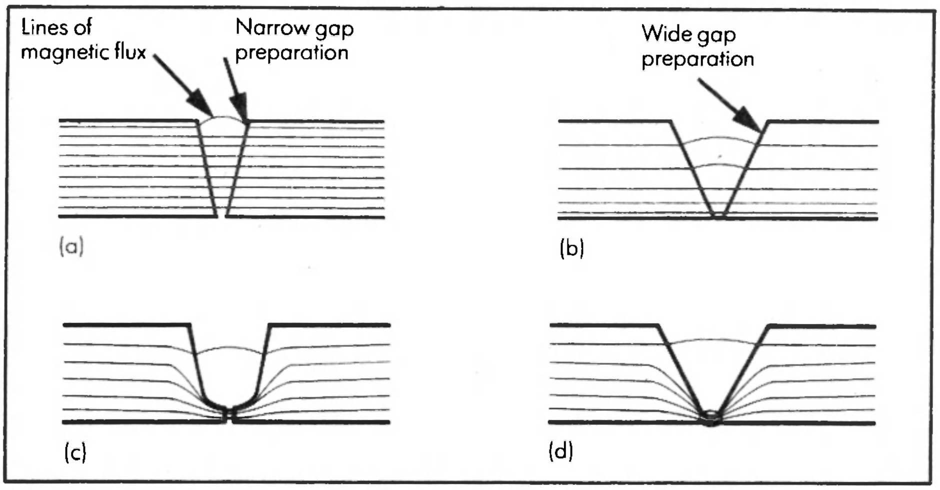

Fig 2. The effect of weld preparation on magnetic field strength, which is proportional to concentration of magnetic flux lines: (a) Narrow gap. Field in gap is relatively strong and distributed throughout the preparation. (b) Wide gap. Field is weaker than narrow gap and is concentrated near the root.(c) J is of no concern. (d) Wide gap after root pass has been made. Most magnetic flux is channelled harmlessly through the weld metal.

The level of magnetism at which arc blow becomes a problem depends on the welding process employed. As a rough guide, welding usually proceeds normally in the presence of magnetic fields up to 2mT (20 gauss). In the range 2-4mT (20 to 40 gauss) arc instability can be expected, and over 4mT (40 gauss) arc blow can be expected. It should be noted that the magnetic field in a weld preparation is always significantly higher than that measured at the open end of a steel sample. For example, if 1mT (10 gauss) is measured at the end of a length of steel, when two steel section are assembled to form a weld preparation the flux density can rise tenfold to 10mT (100 gauss).

This should be borne in mind when checking steel samples for remanent magnetism.

The sensitivity of different welding processes

Some welding process are more sensitive to arc blow than others, and it may be possible to reduce the effect of magnetism by modifying or changing the welding technique.

The effects of arc blow are reduced by welding at higher current which requires a higher arc voltage and produces a stiffer arc. A higher voltage causes electrons in the arc to travel faster so that they turn less in a given magnetic field.

Welding carried out in hyperbaric conditions is more prone to arc blow because electrons in the arc are slowed down and scattered by the extra gas molecules in the high pressure atmosphere, allowing them to turn more in a magnetic field.

Arc blow encountered using DC welding techniques is usually not found when AC power supplies are used. TIG welding tends to be more sensitive than MIG or MMA methods because of the lower arc voltages used. Additional difficulty is sometimes found when two or more welding heads are used at the same time on the same joint. This is because the magnetic field produced by the weld current at one head can interfere with the arc at another head.

Origins of magnetism in steel

Significant magnetism occurs only in ferromagnetic metals or alloys, ie, iron, cobalt and nickel, and most ferritic steels. Some materials are more difficult to demagnetise than others, and it is usual to distinguish between magnetically hard and soft materials. Magnetically soft materials magnetise relatively easily but tend not to retain magnetism, whereas magnetically ☞

Table 1.					
Magnetic properties of common ferromagnetic materials					
Material	Condition	Saturation magnetic induction, B_s T	Relative Permeability μ_r	Coercive force H_c A/m	Remanence B_r T
Soft iron	Annealed	2.00	1000	100	0.15
Mild Steel	As-cast	2.10	850	159	—
BS 4360 : 50D	As-cast	2.10	700	600	1.03
Carbon steel,	Annealed	1.92	216	136	0.80
0.1C, 0.33Si, 0.67Mn	Normalised	1.96	248	168	0.85
	As-cast	1.95	208	128	0.66
Carbon steel,	Annealed	1.88	224	156	0.87
0.19C, 0.30Si, 0.48Mn	Normalised	1.91	360	216	0.90
	As-cast	1.89	232	168	0.73
Carbon steel,	Annealed	1.85	400	296	1.05
0.34C, 0.44Si, 0.55Mn	Normalised	1.87	575	440	1.05
	As-cast	1.87	480	440	0.85
Manganese steel,					
0.19C, 0.48Si., 1.14Mn	Annealed	1.86	400	—	—
0.29C, 0.29Si, 1.40Mn	Annealed	1.78	960	—	—

hard materials remain magnetised. There is a fairly close correlation between metallurgical and magnetic hardness in ferrous steels. Most weldable steels used in engineering are categorised as magnetically soft and retain only fairly low levels of magnetic flux.

Magnetic hardness of steel is quantified by referring to a property known as remanence; the higher the remanence, the greater is the magnetic flux retained, table 1. The coercive force is a measure of the resistance a steel type has to demagnetisation. The higher the coercive force, the more difficult it is to magnetise or demagnetise the material. It has been found in practice that the higher the carbon content and/or the nickel content of steel, the more prone it is to retain magnetism.

The origin of magnetism in steel components can be divided into three main areas, which are summarised below.

Magnetism due to manufacture, inspection and handling

Steel can be magnetised by the Earth's magnetic field or another local magnetic field as it cools down from red heat. Magnetism which is localised closed to welds in fabricated items probably arose from the welding current used in the fabrication process. An example is the magnetism often associated with the longitudinal seam weld used in some pipes.

Localised magnetic fields can be produced by using magnetic clamps or magnetic lifting gear. Magnetic fields can remain in steels after magnetic particle inspection has been carried out. Most specifications do, however, insist on the component being demagnetised after inspection.

Steel stored near cables carrying DC currents can become magnetised, although AC currents would have little or no effect.

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Magnetism due to machining and assembly

Machining and assembly of components does not introduce magnetism into the material but can cause it to be magnified; two weakly magnetised pieces of steel assembled to form a joint preparation will result in a magnetic field about 10 times greater than that when the components are apart. Bevelling the end of a steel plate or pipe can cause the magnetic field present in the material to be concentrated in the root of a joint preparation, Fig 2.

The fabrication of large steel structures such as bridges or pipelines can result in increased levels of magnetic flux as each joint is made. This is further increased if the structure lies north-south.

Alignment clamps, tack welded supports and other items used to jig components for welding can introduce localised magnetic fields.

Magnetism introduced by welding processes

DC welding currents can introduce magnetism, although usually this is not a problem since deposited material shunts the magnetic flux away from the weld preparation, Fig 2. Repair welds can suffer from arc blow due to magnetism introduced by the original welding process or by arc gouging, which uses very high currents.

Multi-head welding can suffer from arc instability when the magnetic field from one head interferes with other head(s). This can be particularly problematic when the heads are in close proximity and when pulsed power supplies are used. AC welding does not normally introduce fields into the workpiece.

There is must debate as to whether the position of the earth return clamp can influence the occurrence of arc blow.

There is a wide range of individual preference, but on balance there seems to be little correlation between the location of the clamp and its effect on arc blow. However, both the welding cable and the earth return cable should be routed as far away from the joint preparation as is practicable.

Reducing magnetic problems

Some unorthodox techniques have been tried in attempts to minimise problems of arc blow, and much time can be lost investigating these. They have included using leather socks filled with iron filings placed in the weld preparation in an attempt to shunt the field across the gap, and sacking the entire team of welders and employing new workers. Neither of these methods proved helpful.

Very large power supplies providing up to 20,000 amps have been used in attempts to demagnetise large structures. This approach is extremely expensive to attempt and does not usually achieve the required result, since it is difficult to remove the relatively weak magnetic fields which cause arc blow. On other occasions, the welding supply cable has been wrapped around the component in the hope that this will demagnetise the preparation. This latter technique could achieve the desired effect but unless it is carefully implemented, it could just as easily cause an increase in the magnetic approach to dealing with arc blow would be preferable to folk-lore and in the end will save time and money. The recommended steps are outlined below.

First, it is necessary to know how strong the magnetic field is in the weld preparation. Fields of 4mT (40 gauss) will exert a noticeable pull on a welding rod (except an austenitic rod). A magnetic field meter or gaussmeter will give a quantitative reading and show if the magnetic field is uniform or along the joint.

If the field is relatively low, up to 4mT (40 gauss), it may be possible to reduce the problem to manageable levels by adjusting the welding parameters. Choosing a larger diameter electrode or wire will allow higher currents to be used, in turn stiffening the arc. A wider weld preparation will also reduce the strength of the magnetic field, and the use of a J type preparation also tends to keep the magnetic flux away from the arc (Fig 2).

Small components can be demagnetised by passing them through a demagnetising coil powered from the mains and therefore operating at mains frequency. This is a very common and routine operation. A demagnetising coil operating at 50 or 60 Hz will demagnetise the surface of a steel component to a depth of approximately 2mm. To demagnetise thick walled components using this technique requires a lower frequency demagnetising current. If the component is large, such as a pipeline or tubular structure, then there is so mush stored magnetic energy that complete demagnetisation is virtually impossible to achieve, and localised techniques have to be used as described below.

Remanent magnetism in the parent material can be ☞

reduced using a spare welding set, providing it is a smooth DC supply and has a continuously controllable current which can be adjusted down to about 10 amps. About 10 turns of cable connected to the welding supply should be would around the component is such a way that each of the turns lies parallel to the joint which is to be welded, Fig 3. the welding supply is adjusted so that the current in the cable creates a magnetic field which cancels out the field in the joint. Since the cable can be connected to the supply two different ways, when current is supplied the magnetic field can increase of decrease in the component. If an increase is detected, the cable connections should be reversed. The reduction of the magnetic field in the preparation can be detected crudely, by the reduction of pull felt in a welding rod, or more accurately, by the use of a magnetic field meter.

Conclusions

Magnetic arc blow sometimes arises unexpectedly even in well established applications. Welders generally attempt to cope with the situation, but there is an associated risk of introducing weld defects leading to an overrun in the welding time. Choice of weld procedure and joint geometry play important roles in modifying the sensitivity to inherent magnetism. Some pracautions may be taken in an attempt to avoid or limit the effect of magnetism, but many of the so called remedies risk making matters worse. Any method adopted to deal with the problem should be reliable and systematic in order to ensure that it meets quality assurance requirements.

Since the ultimate result of magnetic arc blow, even in its milder forms, is a reduction in quality and an increase in cost, it is appropriate for welding companies to assess their capabilities for dealing with it. Proprietary equipment is available which removes magnetism from the weld preparation quickly and efficiently, freeing welders to do the job they do best and enable the fabricator to complete the work within budget. ■

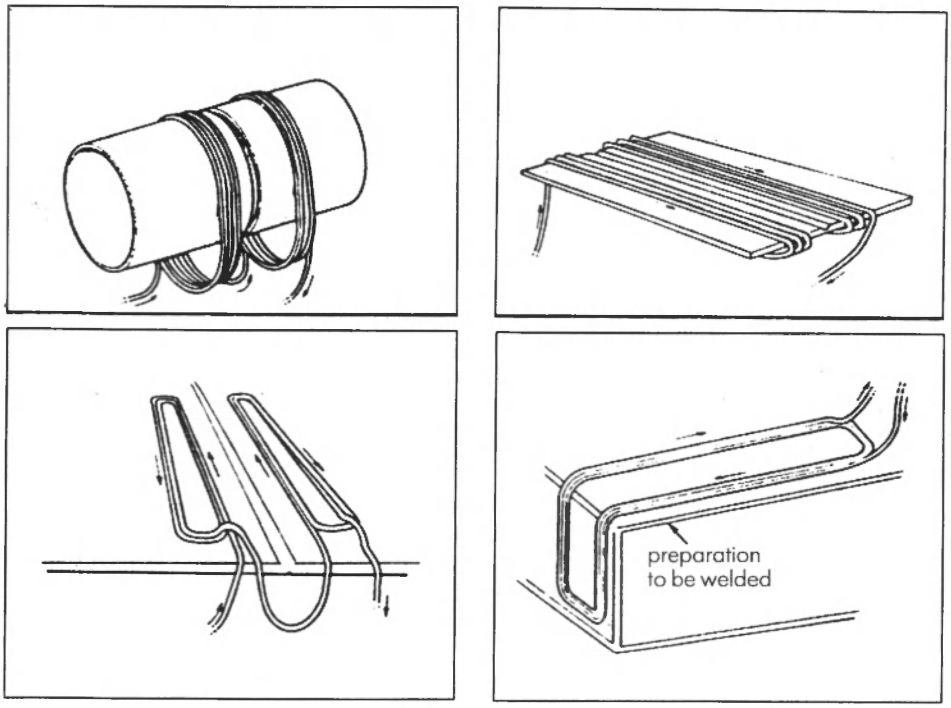

Fig. 3. : Demagnetising Cable configurations. Arrows indicate current directions, which should always be parallel to weld preparation

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