Back to the Basic — Surfacing

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Apart from their common uses in fabrication, the various welding techniques can also be used to deposit metal as a coating or surface on a component. Coatings are sometimes employed in a reclamation procedure, but when utilised on new components can allow compromises to be made in terms of cost or mechanical properties which are not possible with a single material. A wide variety of coating techniques is currently employed in industry, but in this article only those related to welding processes will be discussed.

In order to determine an appropriate coating procedure, it is necessary to determine the type of wear the component will experience in service. Based on this, a coating material can be chosen, which is normally a compromise between the material cost and the expected life of the component. Only at this stage can the deposition technique be selected.

TYPES OF WEAR

Wear can be defined as the progressive loss of material by a component. The various types of coating material are resistant to different wear mechanisms, and in general, coating with a high wear resistance are more costly. Care must be taken to select a material adequate for the service conditions, without over-specification.

In many practical situations, component wear is brought about by a combination of mechanisms. For this reason it is advisable to monitor the performance of coated components in service, in order to provide data for a more informed assessment of service conditions when a subsequent application of cladding material is required.

Friction

Friction occurs when two or more components rub together. It can generally be described as the resistance to relative motion of the components involved, and its magnitude depends on a number of factor. Surface condition, the presence of lubricating substances, and the frictional characteristics of the material concerned (their mutual coefficient of friction) all affect friction levels.

Metal loss by friction largely occurs because minute areas on the interface weld together under the pressure generated by service loads. As movement continues, the weld is broken, tearing out a piece of material from one or other component. If this process is allowed to continue, material would be lost to the extent that the operation of the complete mechanical system could be affected.

To reduce the effects of wear by friction, it is necessary to provide running surfaces which have a low mutual coefficient of friction and are also hard enough to withstand the service loading.

Abrasion

Abrasion is the wearing of a component by contact with a material of higher hardness. This contact may take the form of hard particles sliding over the surface of the component, or the trapping of particles between two moving surfaces. This mechanism is sometimes subdivided into classes such as gouging, scoring, erosion, etc, but the basic abrasive wear mechanism is similar in all these cases.

To combat the effects of abrasion it is necessary to compromise between two properties. The surface must be strong enough to withstand the stresses generated by the wear mechanism but also tough enough not to fracture under the mechanical loadings which are frequently intermittent and sudden. For this reason, a range of coating materials is available, and care should be taken to select that most appropriate to the service conditions in the specific application.

Impact

Impact wear is frequently associated with the use of sharp tools in various forming processes. To be effective, such a tool must have a hard surface formed to a sharp edge, but must be tough enough to resist the stresses induced by impact. When such a tool is used the edge may be deformed by the impact forces, and if the surface is insufficiently tough the material will crack or spall, while if it is not sufficiently hard adhesive wear may occur. It should be noted that when material is lost by cracking or spalling, this may provoke abrasive wear elsewhere.

Corrosion

Corrosion can be defined as the loss of material by chemical change, either by solution into aggressive media such as acids, or the formation of compounds, normally oxides, on the component surface which are easily eroded. Corrosion is not, strictly, itself a form of wear, but its action is to render the surface of the component less resistant to other wear mechanisms.

Some coating materials have very high corrosion resistance, but these tend to be expensive. Lubricants may allow the use of a cheaper alternative under appropriate conditions as they may prevent the formation of oxide layers, carry away frictional heating, and may combine with the surface material of the component to form a more beneficial product.

Heat

The temperature of the bearing surface may have an important influence on the wear rate: The strength and hardness of metallic materials decreases with temperature, the effectiveness of lubricating materials is reduced, and the rate of chemical reactions such as oxidation may be increased. In general, wear rate increases with elevated temperature.

COATING MATERIALS

Because there is very wide range of surfacing materials, it is common practice to classify them into groups. The system used here is based on that established standards.

Steels

The softest of these are low alloy steels used for component reclamation and buffer deposits below more highly alloyed surface coatings. These have high toughness and impact resistance, but low abrasion, corrosion and temperature resistance.

Martensitic alloy steels are relatively cheap and available in a wide range of formulations, offering various combinations of abrasion and impact resistance. Some can be heat treated to vary their properties further. Martensitic chromium steels contain up to 12 % chromium to enhance their corrosion and temperature resistance.

Tool steels have relatively high hot strength, and are heat treatable. In general, higher levels of carbon enhance wear resistance at the expense of impact resistance.

Austenitic stainless steels have high corrosion and temperature resistance, and are characterised by a relatively low room temperature hardness (200 Hv approx) which increases to about 500 Hv if work hardened. This material is frequently used as a buttering layer between carbon and manganese steels.

Austenitic manganese steel is also soft but work hardness to about 600 Hv. It becomes embrittled above 400 deg C. Austenitic chromium- manganese steels, although more costly, can be applied directly over carbon or low alloy steels without the formation of a brittle interface.

Irons

Most iron surfacing alloys contain about 30% chromium, and the deposit consists of chromium carbides in a matrix which may be austenite, martensite, or a combination of both depending on the consumable formulation. They have high abrasion resistance, and their hot hardness and oxidation resistance is enhanced by high chromium levels.

Nickel Alloys

Pure nickel and its alloys with copper and iron are used to surface cast iron, and are soft and machinable. Nickel-molybdenum- chromium -tungsten alloys have good corrosion and heat resistance, combined with good erosion and impact resistance. Nickel alloys with chromium and boron have good hot hardness and high temperature oxidation resistance, while those with molybdenum and iron are resistant to salt spray and alkalis.

Cobalt Alloys

Cobalt is normally alloyed with chromium and tungsten to form the group of alloys developed under the trade name of Stellite. They have high hot hardness and excellent high temperature corrosion and abrasion resistance. Higher levels of alloying enhances these qualities at the expenses of toughness and impact resistance. They are relatively expensive.

Copper Alloys

Copper alloys, with aluminium, silicon, tin and zinc are principally selected for their corrosion resistance, but should not be used in high temperature applications. Copper aluminium alloys have good impact resistance, although this reduces with increasing levels of aluminium, and they have the lowest oxidation resistance. Copper silicon alloys have good impact and corrosion resistance, but do not produce good bearing surfaces. Alloys with tin have low impact strength, but excellent corrosion resistance, while those with zinc have low impact strength and poor corrosion resistance, but form excellent bearing surfaces. All copper based alloys are machinable.

Tungsten Carbide

These consumables are supplied as steel tubes containing tungsten carbide granules. These remain the final deposit, supported in a matrix of carbon steel, into which some tungsten and carbon dissolves. The coating has high abrasion resistance, and can stand low velocity impacts although it is some what brittle. As the tungsten carbide particles tend to protrude above the matrix as the surface is worn, this coating is not suitable for metal to metal contact applications.

Chromium Boron Paste

This is spread over a steel component and fused by the use of an arc welding process. Its main characteristic is extremely high abrasion resistance, with low impact resistance.

DEPOSITION TECHNIQUES

The deposition of wear resistant coatings is carried out using processes which are closely allied to welding techniques, and are normally referred to by the same name. When depositing those materials which do not contain iron onto a steel component, it is necessary to control the amount of inter-mixing (dilution) between the coating and the component in order to avoid impairing the properties of the resultant surface.

Oxyacetylene (OA)

This is carried out in a similar manner to OA welding, using a consumable in rod form. The torch flame is adjusted to be neutral for nickel based alloys, while most other materials utilise a flame with excess acetylene to reduce surface oxides. In the hands of a skilled operator this process can produce low dilution deposits of closely controlled shape, but the deposition rate is low and the amount of heat build up is high. This may give rise to distortion or cracking problems.

Powder Welding (PW)

This process uses a modified OA torch to which a power hopper has been added. The powder flows, at a rate controlled by a hand lever, into the combination gas stream and emerges with the torch flame. The technique is mainly used with the self fluxing nickel alloys. The interface must be heated to the bonding temperature of 1000 Deg C, or the material will not form a molecular bond. The rate of deposition is therefore low for the initial layer, although this can be increased by preheating. In general, the technique requires less skill than OA, but the range of suitable consumables is limited.

Shielded Metal Arc Welding (SMAW)

Also known as manual metal arc welding (MMA), this technique utilises lengths of electrode of between 1.6 and 8 mm diameter, with a flux coating which protects the arc and molten pool in a similar manner to normal SMAW. It is suitable for a wide range of consumables, is all positional, and is very suitable for one off or small batch work. It is, however, highly dependent on operator skill and low in duty cycle, and dilution levels tend to be high, with stub end loss.

Gas Tungsten Arc Welding (GTAW)

Also known as TIG or argon arc welding, an arc is maintained between a non consumable tungsten electrode and the workpiece, and shielded by an inert gas. The consumable is used in rod or wire form. This technique is capable of producing high quality deposits with low dilution levels (5 to 10%) and can be carried out manually or using mechanised welding equipment, in which case the deposition rate is normally higher. It is not suitable for open site work as the inert gas shield can be disrupted by cross draughts.

Plasma Transferred Arc Welding (PTA)

In plasma welding, the arc from tungsten to workpiece is constricted by a cooled copper orifice to create a parallel, stable plasma stream. Into this stream the coating material, in powder form, is introduced by means of a stream of carrier gas. The process is invariably mechanised, lends itself readily to automation, and can produce low dilution deposits of high quality. The deposition rate is higher than GTAW, and torches are available for internal bore surfacing. The equipment for PTA tends to be relatively complex and expensive.

Gas Metal Arc Welding (GMAW)

In GMA welding, the consumable, in the form of a solid or tubular wire, is fed through the centre of a torch which also provides an inert gas shield. An arc is struck between the workpiece and the consumable, which is melted off at a rate balanced by the consumable feed speed. The technique can be used manually or in a mechanised system, in any position, with deposition rates similar to, or slightly higher than, PTA. Controlled transfer pulse techniques can reduce spatter levels, and low dilution deposits are possible with correct choice of parameters, although bead shape can be unfavourable at very low dilution levels.

A range of tubular consumables is available in which the flux decomposes to form a shield for the molten pool, making the gas shield unnecessary. This technique is more convenient for site use, although the quality of the deposit may be lower than normal GMAW and known as FCAW process.

Submerged Arc Welding (SAW)

Submerged arc welding is similar to GMAW, in that a wire or strip consumable electrode is used, and an arc is stuck between this and the workpiece. No shielding gas is used, the arc being submerged below a layer of layer of powdered flux which is deposited from a hopper ahead of the weld pool. The arc melts the flux, which forms a protective layer over the weld pool. The process is always mechanised, and high deposition rates can be achieved, invariably in the downhand position. Dilution may be high unless operating parameters are carefully selected, or multilayer techniques used. It is most suitable for large components of simple geometry.

Electroslag Welding (ESW)

Electroslag welding is very similar to submerged arc welding, but the formulation of the flux is changed so that in the molten state it becomes electrically conductive. In this form, the passage of current through it provides sufficient heat to melt the electrode and raise the surface temperature of the component to a level suitable for bonding. It is claimed to provide higher deposition rates, lower defect levels and better control of dilution than SAW.

ECONOMICS

There are two areas in which the economics of hard facing becomes relevant. In the case of the process operator, the selection of process may very well be influenced by the price of the consumable to be used. In general, material purchased in the form of powder is cheaper than that in rod form, with tubular electrodes being the most expensive. For the high quantity user, this price differential will tend to dominate his costing structure, so that most economical choice may well be PTA, where the high initial equipment cost is offset by relatively low consumable costs. At the low consumption end of the market, the simplicity and flexibility of SMAW and GMAW are attractive, and the relatively high consumable cost is not significant.

In the case of the end user, the choices are rather different. The selection of a wear resistant coating is invariably a compromise between the replacement cost of a worn component and the additional cost of relatively expensive wear resistant coatings. The time required to replace components, and the cost of that down time carried through the rest of the manufacturing cycle, are also relevant considerations in the choice of coating. As is often the case in industrial situations, the optimum choice must be constantly reassessed, as it will be influenced by economic, application and technological factors.

REFERENCE

[1] Grainger, S. (Ed) "Engineering coatings - design and application", Abingdon Publishing, 1989. ISBN 1 85573 000 6.