A Literature Review On Hardfacing And Its Welding Allies

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Abstract- *Wear is the main revealing factor that controls the life of any component. Metal parts often fail their intended use not because they fracture, but because they wear out, causing them to lose dimension and functionality. Different types of wear exist, but the most common modes are abrasion, impact, metallic heat (metal to metal), corrosion, etc. continue over the years to reduce wear either by using a new wear resistant material or by improving the wear resistance of the existing material by adding any wear resistant alloying element, etc. . In recent years, many methods have been an issue of intense development linked to wear-resistant applications. In this article an attempt has been made to review some hardfacing methods and materials used therein as well as the purposes and applications and ongoing research.*

Keywords- hardfacing, welding, welding consumables, wear resistance, purposes and applications

I. INTRODUCTION

Theprocess of making the surface hard to resist wear and tear of the component, preserve them before failure,Wear is a common problem in all industries such as sugar cane industry, cement industry, crushers, etc., and all engineers and researchers are concerned about improving the wear resistance of components that are exposed to wear. In this paper a coating technique is used to deposit the weld metal on the substrate to improve its wear resistance. A study was conducted to reduce the abrasion of the bucket nails caused by the soil and abrasive particles.

1.1 HARDFACING

"Hardfacing" is the deposition of a surface layer by welding, which is harder than the base material. Its purpose is to give wear resistance. Hardfaced layers may also be characterized by the following properties: l Soundness (cracks are acceptable in some cases). Toughness, depending on the need to resist impacts.Resistance to environmental stresses such as corrosion and high temperatures.Hardfacing may involve depositing one or several layers of weld metal. Some types are designed to be applied in one layer only, while others can be applied without limit. "Preventive hardfacing" is the application of hardfacing techniques to the production of a brand new component. In this case, the nature of the base metal may be less relevant, apart from cost considerations. "Remedial hardfacing" involves reconstitution of an already worn part, so compatibility with the material of the part needs to be considered

1.2 BENEFITS OF HARDFACING

By hardfacing your equipment, you will obtain the following benefits:

- Reduced maintenance
- Reduced operation costs
- Lower repair costs
- Extended equipment lifetime

1.3 HARDFACING DEPOSITION TECHNIQUES

- Thermal Spraying
- Cladding
- Welding

1.3.1 Thermal spraying processes are preferred for applications requiring thin, hard coatings applied with minimal thermal distortion of the work piece and with good process control. These processes are most commonly use the coating material in the powder form, and almost any material capable of being melted without decomposition, vaporization, sublimation, or dissociation can be thermally sprayed.

1.3.2 Cladding processes are used to bond bulk materials in foil, sheet or plate form to the substrate to provide triboligical properties. The cladding processes are used either where coatings by thermal spraying and welding cannot be applied or for applications which require surfaces with bulk like properties. Since relatively thick sheets can be readily clad to substrate, increased wear protection may be possible compared to thermal spraying and welding. If the coating material is available in sheet form, then cladding maybe cheaper alternative to surface protection. It is difficult to clad parts having complex shapes and extremely large sizes.

1.3.3 Welding on the other hand, are preferred for applications requiring dense relatively thick coatings (due to extremely deposition rates) with high bond strength. Welding coatings can be applied to substrate which can withstand high temperatures. Welding processes most commonly use the coating material in the rod or wire form. Thus materials that can be easily cast in rods or drawn into wire are commonly deposited. In Arc Welding the substrate and the coating material must be electrically conductive. Welding processes are most commonly used to deposit primarily various metals and alloys on metallic substrates. Hardfacing by arc welding is performed using all of the common processes and equipment. Of the arc welding group, Shield Metal Arc Welding (SMAW), or stick welding, is the most common and versatile process, although it does not provide the highest deposition rate. The rate of dilution depends on materials and on the welder's skill. Submerged Arc Welding can provide a much higher deposition rate if the conditions are correct for uninterrupted alloy deposition of hardfacing filler wire. The limitations are that dilution tends to be higher unless speed is kept as high as possible, and that the process is not readily adapted to field conditions. GMAW, or MIG, where shielding is provided only by inert gas, is readily applicable but only for those fillers supplied in wire form, and usefully complements the range of applications of the preceding process

1.4HARDFACING ARC WELDING PROCESSES

1.4.1 GAS TUNGSTEN ARC WELDING PROCESS

In the TIG process, an electric arc is produced between a refractory tungsten electrode and the part. A metallic filler wire may or may not be used.

The weld pool is protected from oxidation by an inert atmosphere (often argon).

1.4.2 SHIELDED METAL ARC WELDING PROCESS

The consumable electrode is composed of a solid core wire and a flux covering. An electric arc creates a weld pool between the electrode core and the part. The slag produced by the fusion of the coating protects the molten metal against oxidation, and can contribute to the deposit's chemical analysis.

1.4.3 Tubular electrode

A tubular electrode consists of a thin steel tube filled with a powder mixture. This type of electrode is only used for hardfacing applications. A uniform electric arc is formed between the tube wall and the part. This results in lower dilution and wider deposits compared with a conventional coated electrode. This type of electrode is less susceptible to moisture pickup than standard electrodes.

1.4.4 Gas Shielded Metal Arc Welding Process

The molten metal is obtained by creating an electric arc between a wire electrode (solid or tubular cored) and the base metal.
Flux cored wires:

- Improve fusion characteristics,
- Protect the molten metal against excessive oxidation.
- Offer a wider range of alloys that can be deposited.

Depending on the protective gas used, the terms Metal Inert Gas (MIG) and Metal Active Gas (MAG) are often used. This procedure is easy to automate.

Self shielded process / open arc process Process identical to MIG/MAG. It has the advantage of not requiring the use of a protective gas. It is usually used in the following cases,Working conditions unsuitable for other welding procedures (outdoor welding, draughts etc.). Exposure to the atmosphere has no negative effect on deposit performance. Also known as "Open arc", this procedure is particularly used for hardfacing solutions (excellent hardness and wear-resistance characteristics).

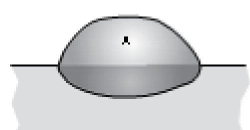
1.4.5 SUBMERGED ARC WELDING PROCESS

The molten metal is generated by an electric arc between a wire and the part, beneath a "blanket" of powdered flux. The electric arc is not visible and the welding flames are mostly absorbed by the flux layer. The procedure's configuration and the use of powder flux restricts its application to flat welding positions on plates and rolls. The submerged arc welding procedure provides very high deposit rates

1.5 DILUTIONS

Control of dilution is essential when surfacing. Dilution affects the chemical composition of the deposit, hardness and quality. During welding, some of the base metal dissolves into the weld pool, diluting it.

Dilution is calculated as follows: % dilution = $\frac{B}{A+B} \times 100$

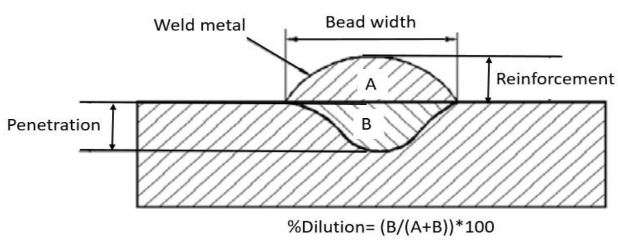


During surfacing operations, dilution should be limited to optimise deposit characteristics, whilst ensuring a good fusion with the substrate.

How can dilution be controlled?

- Select the right welding procedure, particularly heat input.
- Welding sequence: An overlap between weld passes, of about 50%, provides good dilution control. Multi-pass surfacing results in lower dilution than single-pass surfacing.

- Choose the correct polarity: DC+; DC-; AC Changing the polarity can influence the dilution rate.
- Welding technique The heat input is directly related to the welding technique: straight or weave bead technique.
- Welding position: The horizontal-vertical position (PC) should be used if possible as it produces less dilution than flat welding (PA). For hardfacing applications, several factors influence the choice of welding procedure: l Productivity and deposit rate.



1.6SURFACING THICKNESS.

- Working environment: workshop or outdoors.
- Option of automation.
- Repetitiveness of the work.

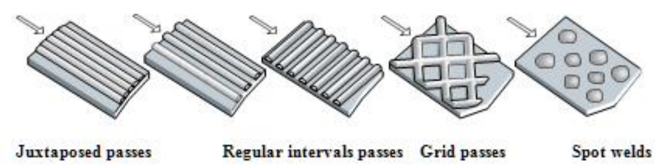
1.7 BONDING QUALITY.

“Bonding quality”, is directly related to the penetration of the bead in the substrate. Where there are impact stresses, a surfacing with high bonding strength will perform better over time. Bonding quality is important in resisting impact stresses. A poorly bonded coating will tend to spall off under impact. This can be mitigated by avoiding too sharp a change in composition at the fusion line, thus avoiding a large change in mechanical properties. One way of ensuring this is to adjust the welding conditions to give high penetration and thus high dilution in the first layer. Subsequent layers will reach the target composition. In extreme cases, a first layer of intermediate composition may be needed.

1.8BEAD PATTERNS

In some cases, geometric weld beads provide better wear resistance than a smooth hardfaced surface. This type of deposit is an economical solution to wear caused by low or moderate abrasion, under low impact. For these applications, the type of geometry to use depends directly on the size and properties of the abrasive

The principle of this type of surfacing is to restrict the relative movement of abrasive materials on the parts and to create an anti-wear barrier by capturing the material in the hollow areas.



1.8.1 JUXTAPOSED PASSES WITH CONTINUOUS OVERLAP

To counter severe abrasion, the hardfacing is continuous across the whole of the surface concerned. Thisensures that there is no contact between the external element and thebase metal.

Thebeadsarejuxtaposedwitha50%interpassoverlaptog uaranteeoptimalsurfacing characteristics (by restricting dilution). In most cases, the weld beads are oriented in the same direction as the flow, thus allowing continuous passage ofmaterial.

1.8.2 PASSES DEPOSITED AT REGULAR INTERVALS

In case of low or moderate abrasion (without impact), surfacing may be limited to separated parallel beads. Spacing of the beads is a key factor that depends directly on the size of the abrasive. In case of high abrasion, the space between the beads is reduced.

Bead direction relative to the operating flow:

- Larger abrasives: the beads are deposited parallel to the flow
- Mediumorfineabrasives,sandorsoil:theweldbeadsareo rientedatright anglestotheflowwithacrack-freedeposit.Spacingofthebeadswilldepend onthenatureoftheabrasiveandwhetheritiswetordry.

Inawetenvironment,anagglomerationofparticlesformst hatlodgesmore readily between the beads. In this case, the space between the beads may be increased. However, to guarantee proper protection, it is advisable to limit thisdistance.

1.8.3 GRIDPASSES

Cross beads can be used to create a grid pattern. The beads are oriented at angles of between 30° and 90°.

This type of pattern is widely used to combat abrasion involving large and small abrasives(e.g.sandwithgravelandrock).Thebeadpatterncausesth efineabrasive to lodge in the interstices, thus protecting the base metal from the larger abrasives (self- protection byclogging).

The smaller the non-surfaced area, the greater the protection given to the abrasion surfaces by the fineparticles.

1.8.4SPOT WELDS

Forlowormoderateabrasion,thishardfacingisusedwhen thebasemetalissensitive to the heat input generated by the welding (e.g. manganesesteels).

Theweldingprocessimpliesstartingthesurfacinginthece ntreandworkingoutwards.

Thiswillrestricttheweldingstressesanddistributethema roundthepartinquestion.

The interval between the spots depends on the size of the abrasive. The finer the abrasive, the smaller the distance between spots.

1.9 SHRINKAGE CRACKS

Weld deposits containing hard phases (carbides, borides etc.) are especially sensitivetoshrinkageoncoolingwhichgeneratescracks.Thesearet heresultofthe natural relaxation of stresses in the deposit. They avoid the risk of severe spalling in use, without adversely affecting the deposit’s resistance towear.

These shrinkage cracks run across the welding bead and are regularly spaced. Where shock/impact loads occur, it is important to ensure that these cracks do not spreadtothebasemetal.Therefore,itisnecessarytoapplyaspecialb ufferlayeras a barrier to cracking.

Shrinkage cracks” should be differentiated from “embrittlement cracks”. The latter appearintheformofcrazingandmayleadtomaterialspallingoff,wit haconsequent loss of protection. Similarly, longitudinal cracks are a bad sign. They are often evidence of contamination in theweld.

If need be, the cracking of some filler metals can be eliminated. To do so, the part must be preheated adequately and the correct cooling rates must be observed.

This is the case with cobalt base alloys (e.g. STELLOY 6). As they are required to guarantee good anti-corrosion protection, cracks cannot be tolerated.

1.10 BASE METALS

Base metals for hardfacing are chosen to provide weldability, metallurgical compatibility with the hardfacing alloy, and adequate compressive strength and toughness to support the hardfacing alloy under load. Carbon steels and low-alloy steels are by far the most common base metals for hardfacing. They are metallurgically compatible with the iron, cobalt, nickel, and copper hardfacing alloys. When applying copper alloys to steels, it is important to limit dilution to prevent hot cracking.

Many tools and equipment that require hardfacing were originally made of highly wear-resistant castings such as Ni-Hard™ or other high-chromium cast irons. Hardfacing these components must be performed with extreme care as they have very poor ductility and will crack when subjected to thermal shock. In some instances, the surfacing of cast irons, which is very difficult, also has been attempted. It is somewhat less difficult to surface the nodular irons. The grey cast irons are very sensitive to cracking, thus, hardfacing on gray cast iron should be applied only by persons with significant experience with hardfacing consumables and procedures. Personnel in welding shops or repair facilities usually are qualified for these applications.

1.10.1 The iron hardfacing alloys containing extensive carbides (tendency to spall off carbon-steel and low-alloy steel substrates. Austenitic steels (usually Hadfield manganese steel, but also chromium-nickel stainless steels) can provide a better base than carbon steels or lowalloy steels for these brittle alloys. An austenitic base (generally 2% carbon or more) avoids the brittle, cracksensitive interface that results from the deposition of high-carbon weld metals on carbon steel or low-alloy steel. For the same reason, the deposition by welding of an austenitic buffer layer before applying high-carbon chromium iron hardfacing weld metal is commonly performed to minimize spalling problems.

1.10.2 Cobalt and nickel hardfacing alloys are often applied over iron alloys, including stainless steels. Cobalt and nickel hardfacing alloys also can be applied over nickelalloy base metals. This combination is often used in aircraft and gas turbine engines.

1.11 Objectives Of The Hardfacing Process:

To extend the service life of critical (new) parts and assemblies in machines and mechanisms by depositing on them such metals/ alloys that will impart to them resistance to corrosion, abrasion, wear, impact, heat, galling, erosion, cavitations, hammering, scratching and indentations.

- To rebuilt worn-out or incorrectly cast or forged parts.
- To repair a component.

1.12 Application

- Hardfacing is used in the automobile industries for surfacing the IC Engine components like cylinder, cylinder head and piston etc.
- Hardfacing is used in the surfacing of the earth moving equipments like cranes crushers etc.
- Hardfacing is used in the surfacing of various machine components, which are subjected to wear and abrasion etc.

II. LITERATURE REVIEW

Some Studies Related to Hardfacing

Jha et al.,examined the abrasive wear behavior of two iron-base hard facing materials with different combinations of carbon and chromium after deposition on a steel substrate [10]. Effects of applied load and sliding distance on the wear behavior of the specimens were studied. Scanning electron microscopy (SEM) examination was also done. A significant improvement in the wear resistance of the hard faced layers over that of the substrate was found. The specimens with low carbon and high chromium contents attained better wear resistance than the one consisting of more carbon but less chromium.

Kumar et al.,discussed hard facing materials available and the factors to be considered for their proper choice like the alloy chemistry, area of application and the cost factor [11]. The economic success of the process depends on selective application of hard facing material and its chemical composition for a particular application. Hard facing materials of three different compositions have been deposited on the soil engaging part of agricultural implements made of mild steel. Hard facing was performed by the open arc welding techniques. Abrasive test and micro structure under SEM was studied. It was found that the wear rate of hard facing alloys was lower than that of mild steel and the hard facing alloys having the highest chromium content exhibited the lowest wear rate.

Fernández et al., tested the abrasive wear resistance of cast iron alloyed with different elements. Laboratory tests were compared to field tests of excavator teeth in mines [9]. Hard alloys are normally used as materials for excavator teeth in mining industry and they do not have enough anti-wear properties and coatings are employed as a good alternative. Acceptable correspondence had been found in laboratory and field tests. Hardness and micro hardness measurements and optical micrographs were performed to identify the mechanism of wear. Cast irons with low carbon content are not the best choice as abrasion resistance materials. Coatings based on Cr–Nb do not perform very well and show a high dispersion. Alloys on the basis of Cr–Nb–V and Boron have low wear ratios.

Arulmani et al.,discussed that surfacing has proved to be the most economical way of increasing the service life of the components. Various applications of surface engineering in industries, agriculture and public works etc. have been discussed [1]. Material loss due to wear in industries is significantly high. All these components face the problem of wear, before put into service, are given a surface hardening treatment or a protective coating with wear resistant materials of various types, depending upon its service conditions. Surfacing is a cost effective and proven method of depositing protective coating.

Chatterjee et al., investigated the weld procedural effects i.e. preheat & without preheat, single & double hard facing layer as well as buffer or without buffer layer. Two commercial & four iron based high Cr high C type hard facing electrodes were deposited on the grey cast iron plate in flat position using MMAW [6]. Buffer layers were employed between substrate & the hardfacing deposits in order to minimize dilution & contraction strain. Maximum bond strength was obtained in specimen deposited with high nickel buffer electrodes & specimen deposited without buffer resulted in minimum bond strength.

Bayhanenhanced the wear resistance of the chisel ploughshare made of lowalloy steel with three different hard facing electrodes. Wear tests on a regular share & three types of hardfaced share were conducted in the field & laboratory [2]. These hard facing electrodes are designated as EH-600, EH-350 & EH-14Mn. The wear rate in the laboratory & in field tests was found to be significantly different. The hard facing process with electrodes was effective in reducing the wear. When the cost is taken into consideration EH-600 & EH350 electrodes can be recommended for hard facing. Mainly, carbon and manganese proportions of the steels are effective on the wear rate.

Buchman et al., interpreted the abrasive wear behavior of hypereutectic & hypoeutectic based Fe-Cr-C hardfacings in terms of the microstructures [3]. The coatings were deposited onto a grey cast iron substrate by SMAW process using two commercial hard facing electrodes. The mass loss of the hard facings increased linearly with sliding distance in both dry & slurry conditions. The wear rate was not always directly proportional to load. The hardness of the hypereutectic coating was significantly higher than the hypoeutectic coating. There was no significance difference in the wear resistance of the hardfacings at the higher loads & there was contrasting wear behavior in the dry & slurry conditions.

Choteborsky et al., (2008) reported that high Cr content in Fe-Cr-C hardfacing alloys can be used in harsh abrasive conditions [7]. Cr rich electrodes are widely used due to their low cost and availability. Four different hard facing alloys reinforced with primary chromium carbides & complex carbides were used. The overlay material was deposited on the low carbon steel using GMAW process. Pin on disc machine was used for wear testing. A significant effect of primary carbides on the abrasive wear resistance of weld deposits was found. The results showed that the two layer complex carbide deposits gave the best abrasive wear resistance.

Selvi et al., (2008) studied the influence of C & Cr on wear resistance, hardness and effect on microstructure. The influence of Cr is studied by conducting tests using E410, E430 and modified E430 electrode [13]. The hard facing of valve seat ring used in boiler fed water circuit made of low C steel was done by MMAW process. It was found that C & Cr supports the improvement of wear resistance, hardness & refined microstructure on the weld overlays. The wear rate increases with increase in sliding velocity and applied load. As a result of increase in Cr, the hardness increases due to the formation of Cr carbide at the grain boundaries and there was also a progressive refinement in the grains of the welded layer.

Buchman et al., (2008) compared the abrasive wear behavior of two hardfaced deposits with that of Fe-C-B based alloy deposited by electric arc spraying onto a grey cast iron substrate [4]. The abrasive wear behavior of hardfaced Fe–Cr–C deposits by SMAW process had been compared with an experimental arc-sprayed Fe–Cr–B coating. The aim was to identify an alternative process that performed equally or better than SMAW process. Electric arc spraying was selected due to its cost effectiveness & deposition rate. The study showed that the arc-sprayed coating exhibited comparable wear resistance to that of the SMAW overlays, although it had higher porosity & its micro hardness was lower than the welded deposits.

Balsubramanian et al., (2009) compared five different welding processes including SMAW, MIG, TIG, SAW and PTAW and determined the best welding process to hard face boiler grade steels [5]. Comparison was made based on quantitative factors like measuring percentage dilution and qualitative factors like base metal properties, welding parameters, weld joint dimensions and initial preparation required, welder skill, operator fatigue, post weld cleaning, availability of consumables, ease of automation, positional weld capability. The PTAW process was found to be the best method to hard face boiler grade steel. Coronado et al., (2009) evaluated the effect of four different hard facing electrodes deposited by two different welding processes: FCAW & SMAW process [8]. The hard facing was deposited on ASTM A36 carbon steel plates. The wear test & SEM was used for the characterization of the microstructure of surfaces & worn surface of deposits. It was found that hard facing using FCAW process presented higher abrasive wear resistance than SMAW process. The Ti rich carbides gave highest abrasive resistance. The main abrasive wear mechanisms, found on the worn surfaces were micro cutting, micro-ploughing& wedge formation.

Pradeep et al., (2010) reviewed few hardfacing processes & materials used to reduce the wear either in the form of using a new wear resistant material or by improving the wear resistance of the existing material [12]. Different modes of wear exist – abrasion, impact, metallic, heat, corrosion etc.

Most worn parts don't fail from a single mode of wear, but from a combination of modes. It was concluded that hardfacing is the most versatile process to improve the life of the worn out component and is the best chosen process these days for reducing the cost of replacement. Hardfacing reduces downtime because parts last longer and fewer shutdowns are required to replace them. It can be done on any steel material using wide variety of welding processes. Different alloying elements can be introduced in to the base metal in the form of weld consumables to achieve any desired property

III. RESULT AND DISCUSSION

Hardfacing can be done on approximately any metal using wide variety of welding processes. Different alloying elements can be introduced in to the base metal in the form of weld consumables to achieve any desired property like hardness, porosity, wear and corrosion resistance etc. Surfacing is economical tool which can be used to increase the service life of the components used in various types of industries. Previously this was used to restore the worn parts but now days this technique is also used to make new parts. The success of hardfacing application depends upon the optimized composition of alloying elements and the welding process used for a particular application. Effort should be made for the right selection of surfacing materials and the process to achieve the full advantage of hardfacing.

- Hardfacing is the most versatile process to improve the life of the worn-out component
- Hardfacing is the best-chosen process these days for reducing the cost of replacements.
- Hardfacing reduces down time because parts last longer and fewer shutdowns are required to replace them.
- Hardfacing can be done on any steel material using wide variety of welding processes.

Different alloying elements can be introduced in to the base metal in the form of weld consumables to achieve any desired property like hardness, wear resistance, abrasive resistance, crack resistance etc

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