Surfacing of Steel Mill Rolls by Submerged Arc Welding

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INTRODUCTION

The techno-economic possibility of rebuilding Steel Mill Rolls by submerged arc welding process is well-known. It has been adopted as a regular practice in U.K., U.S.A., U.S.S.R. and continental countries. Initiative has also been taken by some Steel Plants in India in this respect and welding procedures have been successfully established for a few types of rolls. It is felt, however, that there is considerable scope to enlarge the reclamation activities to cover a wider range of rolls and also in developing the technique for manufacture of "Weld Surfaced" duplex rolls, a relatively new concept in the manufacture of rolls.

In the earlier stages, there had been some failures, giving rebuilt rolls a "poor risk" reputation. These failures were mostly due to lack of appreciation of the metallurgical considerations involved in the application of welding technology for roll rebuilding. With the advancement of welding technology, procedures and techniques have been established for a wide variety of rolls, some of which were considered impossible or impractical to salvage.

A reclaimed roll not only costs less, but additional savings can be had from the prolonged service life. This considerably cuts the roll cost per tonne of steel rolled and makes roll reclamation all the more economically attractive. It is being observed that quite a few of the developed countries are adopting roll reclamation on a wider scale and research work is going on to develop better equipments and consumables for this purpose.

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This paper reviews the technological aspects involved in selection of equipments and consumables for rebuilding rolls and the approach to manufacturing 'Weld Surfaced' duplex rolls.

TYPES OF ROLLS

Rolls may be sub-divided as follows:—

A. Primary Rolls

1. Cogging, blooming and slabbing mill rolls.

B. Secondary Rolls

1. Roughing/Intermediate rolls.
2. Finishing rolls.
3. Ancillary rolls and rollers.

Reclamation by SAW process can be adopted for all the above types of rolls, except finishing rolls. Most of the finishing rolls are made of cast iron or highly alloyed steels, having poor weldability. Moreover, the surface hardness required is quite high and should be free from defects. Reclamation, therefore, is considered risky. The modern approach, however, is to manufacture finishing rolls by surfacing with work hardening or age-hardening type of alloys on a weldable core, which can be resurfaced as and when necessary.

ROLL MATERIALS

The metallurgical demands placed on rolling mill rolls are quite complex. The main requirements are:—

1. High wear resistance and long life
2. High resistance to fracture
3. Insensitivity to fire cracking
4. Insensitivity to spalling
5. Good surface quality and
6. Adequate bite

An appreciation of the above requirements is necessary not only during roll manufacture, but also in the selection of the correct overlay alloys for reclamation of these rolls. It is not difficult to meet any of the above requirements, but the combination presents serious problems as the solutions are mutually contradictory, especially for resistance to wear and resistance to fracture. Roll metallurgy, therefore, is a metallurgy of compromises.

In general, primary mills such as blooming and slabbing mills require a roll in which strength is paramount. These rolls are subjected to tremendous shock and extreme pressures in rolling large ingots with heavy reductions. The thermal shocks on the rolls have a tendency to cause fire cracks through differential expansion of the surface. The strength and toughness of such rolls should be such as to resist further development of these cracks. The secondary mills require progressively harder rolls.

A comprehensive classification of roll materials are given below:—

Primary rolls are normally made of forged steel of hypoeutectoid or eutectoid compositions. Reclamation of these types of compositions are done, using judiciously controlled heating cycle and appropriate surfacing alloy compositions.

Secondary mill rolls, which are commonly made of hypereutectoid alloyed steels and cast irons—double poured and differentially hardened types, are difficult to reclaim due to poor weldability and it is reported that alloy steel weld metals, do not always compare favourably in roll performance i.e. roll cost per ton of steel rolled.

The European practice shows that most of the rolls which are systematically surfaced and rebuilt, have compositions varying between the following limits.

C	%	—	0.25 to 0.7
Mn	%	—	0.80 to 1.2
Si	%	—	0.30 to 0.5
Cr	%	—	0.50 to 1.5
Ni	%	—	0.10 to 0.3
Mo	%	—	0.25 to 0.5

Such compositions are considered to be weldable, without stringent precautions. With appropriate precautions it is possible to surface successfully rolls containing up to 1.2% C.

The above discussion pertains to reclamation of conventional rolls. For manufacture of duplex rolls, the core material for the roll is selected from a good weldable composition, either carbon or alloy steels in the cast or forged condition. The design of the roll arbor is of equal importance to that of the weld metal for the type of roll, primary or secondary. In fig. 1, a comparison between the core toughness of conventional rolls and arbors of duplex rolls is shown. The objective of selecting

		Forged	Hypoeutectoid Steel
		Steel	Euctectoid & Near
	Steel	Cast	Euctectoid Steels
		Steel	Hypereutectoid Steels
Roll		No	
Materials		Graphite	Pearlite Matrix
	Cast	Flake	Fine Lamellar Pearlite Matrix
	Iron	Graphite	Bainite Matrix
		Nodular	Martensite Matrix
		Graphite	Pearlite & Ferrite Matrix

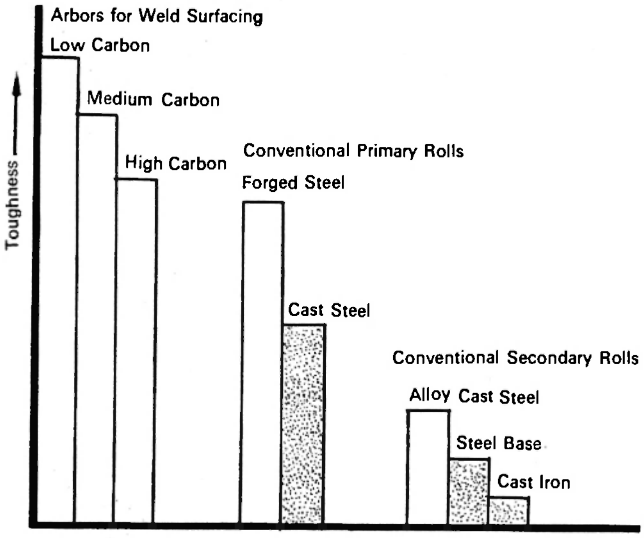

Fig. 1. A comparison between the core toughness of conventional rolls and the arbors of weld surfaced rolls

a good weldable composition is to enable successive complete reconditioning by welding. The composition of such blanks generaly lies within the following range:—

C	about	0.5%
Mn	,,	1.0%
Si	,,	0.5
Cr	,,	0.5 to 0.8%
Mo	,,	0.3%

The corresponding strength is around 700 N/mm^2. The blanks can be used in double normalised condition and even tempered to spheroidise the pearlite.

APPROACH TO RECLAMATION

There appears to be two general lines of approach to roll reclamation. The first method consists of depositing a few layers of surfacing alloys with the minimum of machining. In such partial rebuilding, the roll may be reclaimed up to 100 times and reclamation is carried out on a continuous basis. In these cases, the thickness of the weld layer is generally limited to around 10 mm. This is considered a valuable method of maintenance of continuous billet mills, where the different stands are driven by a single motor and where the ratios of the outer diameters of the rolls must remain nearly constant.

The second method is to use a roll to scrap size, then to rebuild it completely to the dimensions of a new roll. This practice is commonly used in some German Mills, expecially for Blooming and Slabbing Mill Rolls. In this case, the amount of deposited metal can be as high as 8 tonnes and the thickness of the rebuilding can be 100/120 mm.

The approach to manufacture of duplex rolls is similar to the second method.

GENERAL WELDING PROCEDURE

The welding procedure generally followed for rolls where carbon equivalent* does not exceed 0.9%, is as follows :—

(a) For partial rebuilding, preliminary stress relieving treatment is generally not required. For complete rebuilding, a partial treatment at around 500°C is considered a good precaution.

(b) For complete rebuilding, a preliminary ultrasonic check test is also considered necessary, including the journal and the wobbler.

(c) Whatever may be the type of rebuilding, the rolls are always machined to remove the circumferential cracks up to the full depth. Axial cracks can, however, be tolerated to a certain extent.

(d) Preheating is performed in ovens with gas burners. The heating rates are normally between 10/20°C per hour. It is very important that the temperature throughout the volume of the roll is uniformly distributed. According to the composition of the roll or roll blank, the preheat temperature ranges between 200°C to 300°C. In fig. 2, the soaking times at the preheat temperature in relation to the roll diameters, has been given.

(e) Depending on the type of roll and surfacing alloys, it may be necessary to ensure continuous welding. The interpass temperature should never be allowed to fall below the preheat temperature.

(f) For complete rebuilding, a buffer layer of suitable composition is required to be deposited to a thickness of about 10/15 mm.

(g) In most cases, after welding is completed, the roll is allowed to cool slowly, protecting it from air draughts.

$$^{*}C.E = C + \frac{Mn}{6} + \frac{Cr + Co + V}{5} + \frac{Ni + Cu}{15}$$

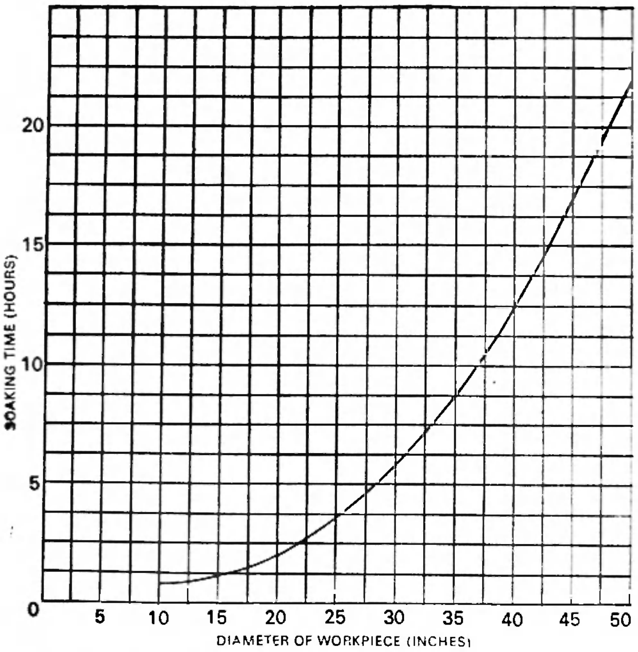

Fig. 2. Soaking times at the preheat temperature before welding should commence

(h) Post weld heat treatment is considered necessary only for heavily built up rolls. Normally, low temperature stress relieving treatment at about 350°C is practised, depending on the metallurgical reactions, such as, secondary hardening or tempering of the martensite or upper bainitic structures, which may take place in the surfacing alloy deposits.

For rolls whose carbon equivalent is between 1.0 and 1.5%, the following additional precautions are necessary:—

(a) Preheat temperature may have to be increased to as high as 450°C. It may be noted that normal approach to the calculation of preheat temperature on the basis of C. E. value is based on manual arc welding process, which is generally higher than that required for SAW process. This is due to the general uniformity of preheating and welding in an automatic set-up, which reduces the cooling rate. Moreover the hydrogen content of the deposited metal is, also low.

(b) Buffer layers with alloys, which are compatible with the base metal and surfacing alloy compositions and tolerate dilution should be deposited. All operational measures, such as, low heat input parameters, positioning of welding head, etc. should be taken to minimise dilution of the deposited metal.

(c) Post weld heat treatment is generally a full stress relief at about 550°C/600°C.

EQUIPMENT FOR REBUILDING

The essential equipment for partial building up are relatively simple and standard equipments can be used, but for heavy building up and manufacture of duplex rolls, the equipments may have to be custom-built and the layout of the shop also should be specially considered, taking into view the welding procedure requirements, outlined above. The equipments normally comprise of:—

1. A lathe type manipulator for turning the rolls at a predetermined rate, incorporating a system for maintaining and controlling the preheat temperature.

2. A suitable type of welding carriage, which is capable of positioning the welding head on the roll surface and movement along the longitudinal axis of the roll at a predetermined speed.

3. Welding heads, power source, wire feed and control system.

4. Flux delivery and recovery equipment.

5. Preheating and soaking furnace.

6. Arrangement for post weld heat treatment.

While for partial rebuilding, standard type of welding head is considered adequate for the deposition rate and duty cycle; for heavy building up or manufacture of duplex rolls, welding heads may have to be specially designed to withstand high duty cycle at currents up to 1200 amperes and modified to accommodate twin wire with water cooling system, to increase the deposition rate.

While either DC or AC can be used, DC with electrode negative is preferred for such applications as it gives maximum deposition rate with minimum dilution. Deposition rate of 7 kgs/hour is considered to be economical for roll reclamation, but higher deposition rates (between 9-19 kgs/hr) are desirable for manufacture of duplex rolls. Deposition rates for different modes of submerged arc welding are given in figure 3.

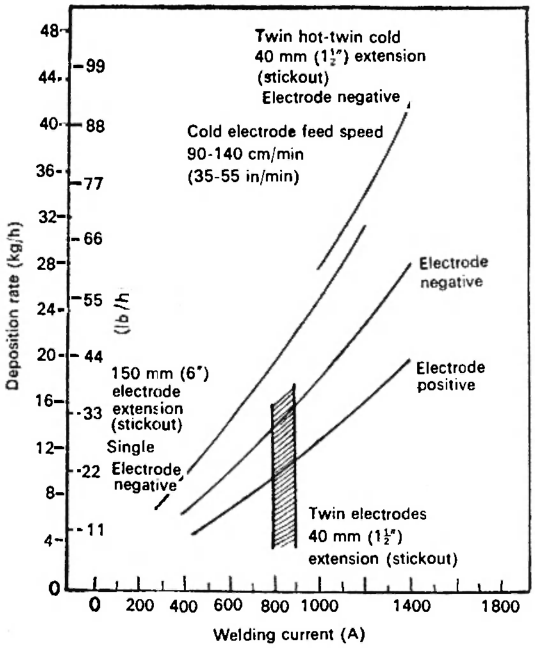

Fig. 3. Deposition rate for different modes of submerged-arc welding

WELDING CONSUMABLES

The alloys used for weld deposits are generally quite different from those used in making the original roll. This is because the roll material usually contains more than 0.6% carbon as a cheap hardener. In the weld metal, the carbon content is kept relatively low to reduce cracking tendencies and the required mechanical properties are obtained with more expensive alloying elements e.g. Mn, Ni, Mo & Cr. Such alloys usually give improved wear life with less fire cracking than the original roll material.

The chemical composition of the deposited metals normally used for partial and complete rebuilding are given in Table-1.

The alloy compositions for the buffer layers and the surface layers can be obtained from any of the following types of combinations:—

(a) Solid wire and matching flux, fused or agglomerated.
(b) Wire wound flux coated electrode with a matching flux, fused or agglomerated.
(c) Flux cored electrode and matching flux, fused or agglomerated.
(d) Strips with matching flux.

Amongst the four different types of combinations, only the first two are now available in our country in limited varieties. Development work is going on and it is expected that the increasing demand for various types of deposited alloy compositions required for this purpose would be available to the industry.

For welding roll materials having C. E. values, 0.9% or 1.0% to 1.5%, it is necessary to use consumables having low hydrogen content for intial buffer layers to reduce the possibility of hydrogen induced cracking of the HAZ. The composition of the buffer layer should also be selected in such a way that the hardness of the layer, even after dilution, remains below the hardness of the surface alloy and adequately crack resistant. In case of heavy build up, the composition of the buffer layers may have to be altered progressively to achieve the intermediate hardness, below that of the surface layer.

As regards surfacing alloy deposits, optimum roll performance can be obtained by using alloyed solid wire with a neutral type fused flux, as this type of combination gives uniform deposit compostion with low hydrogen content, under wide vaıiations of welding parameters. Unalloyed agglomerated basic types of fluxes can also be used, provided facilitiesa re available to bake the flux before use.

Mesh wound flux coated electrodes, also give consistently uniform deposit composition and are less costly than alloyed wires. The availability of alloyed wires being rather poor, mesh wound flux coated electrodes have a great potential in this country, because of their inherent flexibility to deposit any desired alloy composition that may be required for roll surfacing.

Solid wire and alloyed agglomerated fluxes are widely used, mostly for reasons of availability. but as alloys are transferred to the deposit via the flux, care is needed to maintain close control of the welding conditions, which can have a marked effect on the flux consumption and hence on the deposit analysis.

PERFORMANCE AND ECONOMICS

This can be broadly gauged by considering the following factors:—

(a) The cost of new rolls.
(b) The cost of rebuilt rolls.
(c) The service life of both types.

It has been found that the average service life of a resurfaced roll is increased by 1.3 to 2 times, as compared to the service life of a new low alloyed carbon steel roll. This increase in service life is generally attributed to the better fire crack resistance of the surfacing alloy.

TABLE 1

Chemical Composition on Deposited Metals Normally Used

A. Surface Alloys

Types of Alloys	*C*	*Cr*	*Mo*	*Mn*	*Si*	*Ni*	*V*	*W*	*Types of Welding Consumables**	**Applications**
5Cr. Mo.	0.30	5.0	2.0	1.5	0.6	—	—	—	1,2	General purpose for good mechanical wear. Suitable for primary and secondary rolls. Hv = 650 approx.
16Cr. 8Ni. 6Mn.	0.10	18.0	—	6.0	0.8	8.0	—	—	1,2	Work hardens. Suitable for mill rolls requiring maximum bite.
12Cr.	0.15	0.12	—	1.5	0.8	—	—	—	1,2	Suitable for surface layer where greater hot strength and wear resistance than 5Cr. Mo alloy. Hv = 400 approx.
5Ni. 5Mo.	0.35	—	5.5	1.0	1.0	5.5	—	—	1	Suitable for crack resistant, high hot hardness applications. Hv = 400 approx.
7Cr. Mo. W.	1.0	7.5	1.0	1.0	1.2	—	—	1.5	1	General purpose for good hot strength. Hv = 550 approx.

B. Buffer Alloys

Types of Alloys	*C*	*Cr*	*Mo*	*Mn*	*Si*	*Ni*	*V*	*W*	*Types of Welding Consumables**	**Applications**
Mn. Mo.	0.10	—	0.5	1.0	0.5	—	—	—	1,2	Buffer for 5Cr. Mo. surface alloy. Hv = 200 approx.
Cr. Mn.	0.35	1.0	—	1.2	0.7	—	—	—	2*	Suitable for surfacing also. Hv = 250 approx.
Mo. V.	0.07	1.5	0.5	2.0	0.5	—	0.10	—	1	Hv = 200 approx
18Cr.	0.80	18.0	—	1.2	0.8	—	—	—	2	Used on base metal upto 0.8%C Hv = 400 approx.
24Cr. 13Ni.	0.20	24.0	—	2.0	1.0	15.0	—	—	2	Suits as buffer to 16Cr. 8Ni. 6Mn. Alloy.
Cr. Mo.	0.1	1.0–1.50	0.5–1.0	1.0	0.6	—	—	—	1,2	Suitable for surfacing also Hv = 300-400.
Soft Iron	0.15	—	—	0.6	0.35	—	—	—	2	Used for lowering Carbon level by dilution.

* Type of Consumables 1 = Wire wound flux coated flux 2 = Solid wire/flux
Fluxes may be (a) fused type (b) agglomerated type.

As regards cost of rebuilding, the price per kg. of deposited metal is about 2/3 times higher than the cost per kg. of a new special quality roll. Labour cost and overheads, constitute a major factor of this cost and varies from country to country and even from place to place. On an average, the cost of a rebuilt roll is about 65/70% of that of a new roll. Considering the increased service life of rebuilt rolls and reduced down time on account of roll changes, the roll cost per ton of rolled steel becomes appreciably lower. Moreover, a roll can be rebuilt many times, before it is scrapped.

CONCLUSION AND REMARKS

Rolls constitute a major item of the cost in rolling mills. Normally, only about 10% of the roll is used and rest 90% scrapped. This is inconceivable in the present economic situation and surfacing by SAW Process provides an excellent means to reclaim the rolls and make substantial savings.

The stringent demands of the modern steelworks for better wear resisting surfaces, combined with an ability to withstand bending and torsional stresses, have led to the development of high performance 'weld surfaced' duplex rolls. These rolls would particularly be of immense value for secondary mill applications, where presently resurfacing poses some problems.

In India, work has been done by some of the steel plants in reclamation of rolls by SAW process, using the available wire/flux combinations. There is, however, considerable scope to enlarge the activities to cover a wider variety of rolls and also in the development of suitable consumable, specially flux cored wires and mesh wound flux coated wires. It is felt by the authors that work should be undertaken jointly by the manufacturers of welding consumables and the steel plants for the development of 'weld surfaced' duplex rolls, which would definitely have a great potential in this country.

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