Repair Welding Restoration of the Screw Conveyor for Resin Extruder

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Abstract: A screw conveyor was exposed to an extensive wear at the top and the side surfaces of the teeth. The microstructure of the base metal is martensitic structure. Welding procedure specification (WPS) and Process Qualification Record (PQR) were carefully performed using a scraped part from the screw conveyor. The preheating temperature of 300 to 400 °C was applied and the SMAW process was selected as a welding process. Three types of electrodes were selected which mainly wear and corrosion resistance type. Using chromium Carbide electrodes resulted in a significant appearance of cracks at the weld surface that extended to the heat affected zone. However, Using martensitic electrodes resulted in a crack free weld metal with a significant improve of the wear resistance of the base metal. The effect of applying cushion layer between the base metal and hardfacing layer were studied using two kinds of covered electrodes. The hair cracks that observed using the hardfacing electrodes were greatly reduced using these cushion layers. The results were discussed on the basis of microstructure and the wear resistance of the base metal and the hardfacing layers.

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1. Introduction:

Engineers in many industries are concerned with prolonged the life of the structure, with the repair and reclamation of its worn surface on its broken components (1). Fortunately, there are many cases where the extent of damage or worn is small and localized which enables the component to be repaired economically by welding (1).

Weld surfacing is a useful tool for restoration of worn industrial components. The wide range of consumables available for use with the many welding processes requires careful selection to suit a given working environment (2).

Restoration is indicated when welding is done at a low cost compared with replacement costs especially when the component is large and/or expensive or is a part of a larger structure.

Having suitable welding procedures and fulfilling the metallurgical requirements are the first two vital factors for successful repair (1, 3).

The aim of the research work is to study the repair weldability of the screw conveyor of resin extruder. The results were discussed on the basis of microstructure, hardness, wear index of the base metal and the hardfacing layers and the occurrence of cracks.

2. Materials and Methods:

2.1 Materials

A part of the screw conveyor was used as a base metal. Specification and chemical composition of the base metal is shown in Table 1. Figure 1 shows the complete structure of the extruder and the location of the pair of screw conveyor. The tooth outer surface is exposed to mainly abrasion wear and their diameter was decreased by 10 mm. Also, the side part of the tooth was exposed to worn especially at the mid length of the screw conveyor.

Three types of special SMAW electrodes were applied in the repair welding process. Also, stainless steel and mild steel electrode are applied as a cushion layer between the base metal and the special weld metals. Table 2 shows the specification of these electrodes. The chemical analysis was carried out using optical emission spectrometry instrument.

Table 1 Chemical composition of the screw conveyor, mass %

C	Si	Mn	Ni	Cr	Mo	S	P	Cu
0.6	0.26	0.71	1.89	1.02	0.46	0.003	0.001	0.13

Table 2 specification of welding electrodes applied in repair welding process

Electrode no	specification	
	AWSA 5.1	DIN:8555
A B C D E	E7016	E6-UM-60 E10-UM-60 E10-UM-60 E8-UM-200KRZ

Fig. 1 Complete structure of the extruder and the location of the screw conveyor

2.2 Microstructures of base and deposited metals

Teeth base metal and the hard-faced samples were cut out using cooling disk machine. The cross sections were then ground through grit silicon papers (from 180 to 1000). Final polishing was performed using 0.5µm-alumina past, then cleaned and dried. Microstructures of welded specimens were observed, using Nickon-Epiphot optical microscope.

2.3 Hardness distribution

Hardness test was conducted using DVK-2 Matsuzawa Vickers hardness testing device at a load of 20 kgf. for 15 second loading time, and 70 µm/s load speed.

2.4 Abrasion resistance test

Abrasion wear test pin-on disc, for the weld deposits and base metal was conducted using Tribometer testing machine. All tests were carried out under pure sliding conditions between specimens and abrasive disc (alumina abrasive particles). The abrasion test sample with 8 mm diameter and 11 mm length was machined from the welded specimen, so that the test surface was parallel to the layers of the deposits. The test surfaces were flattened by grinding in order to remove the curvature of the weld bead deposit. The test specimens were cleaned in acetone using ultrasonic, before and after test, then weighted to four decimals. The rotation speed of abrasive disc is 125 rpm with a load of 70 N and for 10 minutes. An abrasive disc of 73 mm diameter and 60 mm mesh size alumina particles is used. Wear index is calculated by dividing the weight loss of the deposited metal of the electrode to the weight loss obtained using the base metal.

3. Results and Discussion:

3.1 Welding procedure specification

Welding procedure specifications were conducted using three different SMAW electrodes, namely A, B and C electrodes as shown in Table 2. Preheating temperature ranged from 300 to 400 0C was applied and the interpass temperature was also adjusted to the same preheat-temperature range. Stringer bead technique was used in depositing the beads at the two edges of the teeth. However, between these two stringer beads, weaving tight bead technique was applied to cover the entire bead surface with minimum dilution. After completion of the first layer, grinding was applied to remove the convexity of the layer surface and also to reduce the residual stresses (half bead technique). By this way, welding was proceeded until making five layers sufficient to restore the original diameter of the screw conveyor.

Application of five layers of electrode C resulted in a formation of transverse surface cracks as detected by dye-penetrant test (Fig. 2a). The same results were obtained with the use of electrode B. However, the crack density significantly decreased than that obtained using electrode C as shown in Fig. 2b. A crack free- weld was obtained with the use of electrode A as shown in Fig. 3 a.

Welding of the whole screw conveyor was conducted with the same welding procedure using electrode A. Dye-penetrant test shows a few transverse surface cracks distributed along each teeth surface. These cracks are extended to the heat affected zone as shown in Fig. 5 b. This could be attributed to the accumulated thermal stresses and the constraint associated with the welding of the whole screw conveyor.

3.2 Effect of cushion layer application

The effect of application of a cushion layer using electrode D and E (Table 2) between the base metal and the hardfacing layers on the soundness of weldment was also studied. Using cushion layers of electrode D (Fig. 3b) or electrode E (Fig. 3c) between the base metal and the hardfacing layers (three layers of electrode B) resulted in a significant decrease in the density of transverse cracks than that obtained without application of cushion layer (Fig. 2c).

Application of cushion layer using electrode E between the base metal and the hardfacing layers of electrode A in welding of the whole screw conveyor resulted in the disappearance of the transverse cracks and a sound weld was obtained as detected by dye-penetrant and ultrasonic inspections.

3.3 Chemical composition of deposited layer

The chemical compositions at the top fifth layer using electrodes A, B and C are given in Table 3. Deposited metal obtained using electrode A has the lowest carbon and chromium content. Electrode B has a higher carbon and chromium content than that obtained using electrode A. Electrode C has the highest carbon and chromium content. Electrode B has a higher Mn, Si, and Mo content than that obtained using electrode A or C. However, electrode A has a higher V content than that of electrode B or C.

The application of a cushion layer of electrode E or D resulted in a significant decrease in the carbon and chromium content of the weld deposited by electrode A and a slight decrease in the carbon and chromium content of the weld deposited using electrode B. Moreover, application of cushion layer using electrode E (stainless steel electrode) resulted in a recovery of some Ni and Mn in the hardfaced layer using electrode A or B as shown in Table 3.

3.4 Microstructure of base metal and weld deposits

The microstructure at the cross section of the teeth of the screw conveyor is shown in Fig. 4. It is martensitic structure.

The microstructure of the heat affected zone in the crack free specimen is shown in Fig. 5a. The microstructure reveals the existence of coarse martensite. The microstructure of the heat affected zone in the cracked specimen is shown in Fig. 5b. It is also a coarse martensite.

The microstructure at the top surface of the weld metals using electrode A, B and C are shown in Fig. 6a, b and c respectively. The microstructure of the weld metal using electrode A reveal the martensitic structure (Fig. 6a). The microstructure of the weld metal obtained using electrode B shows austenite with eutectic carbide (Fig. 6b). Weld metal microstructure obtained using electrode C shows the existence of Cr-carbides with austenite eutectic carbide matrix (Fig. 6c). The chromium carbide using electrode C is much coarser than that obtained using electrode B. It is already decided that the coarser the carbide the higher the wear resistance of the hardfacing layer (4).

3.5 Hardness distribution

Hardness distribution through the cross section of weld using five layers of electrode A is shown in Fig. 7. The hardness values increased from the base metal to the heat affected zone and then gradually increased to near 700 Hv20. The hardness distribution through the cross section of the weld using two layers of electrode E followed by three layers of electrode A is shown in Fig. 8. The hardness value increased from the base metal to the heat affected zone (more than 500 Hv20) and then decreased to more than 200 Hv and then increased gradually to more than 500 Hv20.

Microhardness values of chromium carbides and eutectic matrix at the top layer using 5 layers of electrode B and C are shown in Table 4. The microhardness values using electrode C is a little higher than that obtained using electrode B.

3.6 Abrasion index of base metal and weld deposits

The wear index of the base metal and the different weld deposits are shown in Fig. 9. The wear resistance of all the weld deposits is much better than that of the base metal. Wear resistance of electrode B and C deposits is much higher than that of electrode A deposit.

The higher the difference in hardness between the abrasive particles and the hard phases in the matrix of microstructure the lower the wear resistance and the higher the wear index value (Fig. 9). The microhardness of the alumina particle is about 2100 Hv (5).

However, the cracks appeared on the surface and HAZ while using electrode B and C preclude their usage in the repair welding of the screw conveyor.

From the foregoing results, it is preferred to apply electrode A (martensitic structure) since its deposit has both the characteristics of crack free and high wear resistance. The use of cushion layer before applying electrode, A resulted in a decrease in the wear resistance as shown in Fig. 9. This obviously appears when the pair of screw conveyor was put into service.

4. Conclusion:

A low alloy steel screw conveyor was exposed to an extensive wear at the top and the side surfaces of the teeth. Welding procedure specification (WPS) and Process Qualification Record (PQR) were carefully performed using a scraped part from the screw conveyor in order to repair reclamation of the screw conveyor. The following results were obtained:

1. Using chromium Carbide electrodes resulted in a significant appearance of cracks at the weld surface that extended to the heat affected zone. However, Using martensitic electrodes resulted in a crack free

weld metal with a significant improve of the wear resistance of the base metal.
2. The effect of applying cushion layer between the base metal and hardfacing layer were studied using two kinds of covered electrodes. The hair cracks that observed using the hardfacing electrodes were greatly reduced using these cushion layers.
3. Macro hardness is not an accurate measure of the wear resistance; however, microhardness can give an accurate one.
4. It is preferred to apply electrode a (martensitic structure) in repair welding of worn teeth of the screw conveyor since its deposit has both the characteristics of crack free and high wear resistance. The use of cushion layer before applying electrode, A resulted in a decrease in the wear resistance with a high crack resistance. Moreover, the wear resistance is still higher than that of the screw conveyor material.

Table 3 Chemical composition at the top surface of deposited layers, %

Welding sequence	C	Si	Mn	P	s	Cr	Mo	Ni	V
5 layer A	0.50	0.7	0.36	0.01	0.001	8.4	0.46	0.2	0.57
2 layers E & 3 layers A	0.42	0.49	0.28	0.01	0.001	5.2	0.35	1.8	0.29
2 layers D & 3 layers A	0.43	0.43	0.29	0.01	0.002	5.1	0.29	0.13	0.3
5 layers B	2.49	1.05	1.05	0.03	0.002	26.48	0.95	0.26	0.34
2 layers E & 3 layers B	2.23	0.92	1.47	0.025	0	24.41	0.63	1.58	0.299
2 layers D & 3 layers B	2.3	0.92	0.98	0.03	0.002	23.49	0.86	0.28	0.316
5 layers of C	5.12	0.68	0.412	0.01	0.001	34.8	0.036	0.036	0.03

Table 4. Microhardness of matrix and carbides using electrodes B and C

Electrode type	Microhardness Hv 200gm	
B	700	1200
C	730	1600

a)
b)
c)

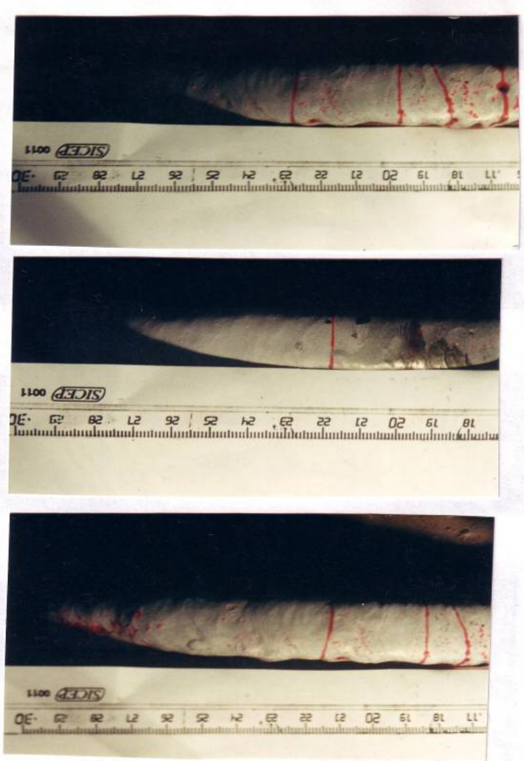

Fig. 2 Transverse surface cracks by dye penetrant test
a) Using electrode C (five layers),
b) Using a cushion layer E and 2layers of electrode C
c) Using electrode B (five layers).

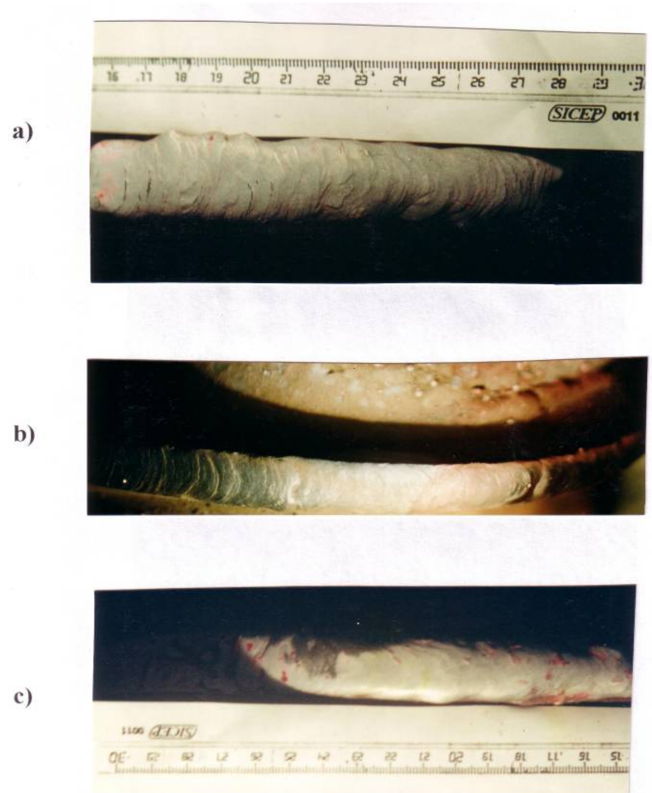

Fig 3 weld beads free from cracks as detected by dye penetrant test

a) **Using electrode A (five layers),**
b) **Using a cushion layer D and 2 layers of electrode B**
c) **Using a cushion layer E and 2 layers of electrode B**

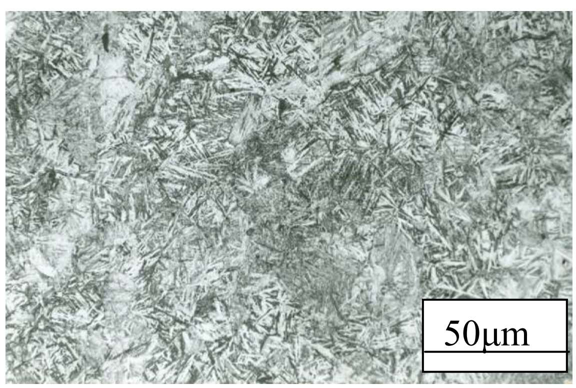

Fig. 4 Microstructure of the screw conveyor

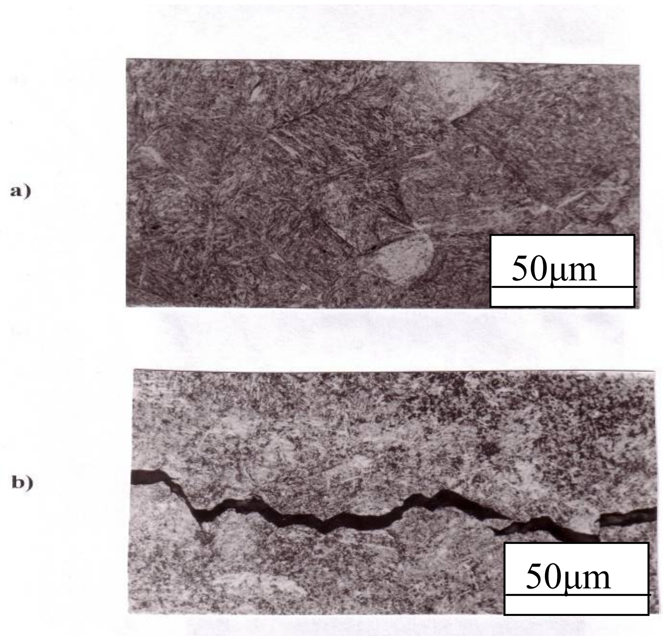

Fig. 5 Microstructure at the HAZ of the base metal a) Crack free specimen,

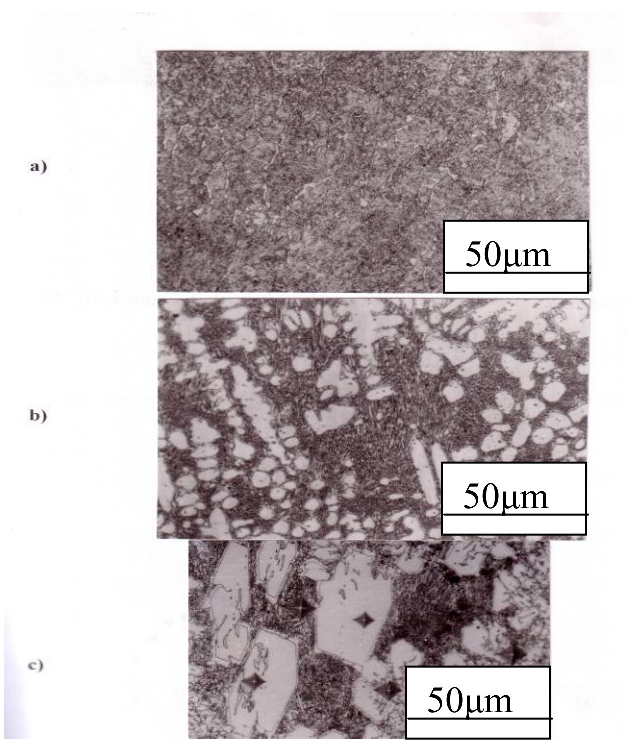

Fig. 6 Microstructure at the top surface of the weld metal using a) Electrode A, b) Electrode B, and Electrode C

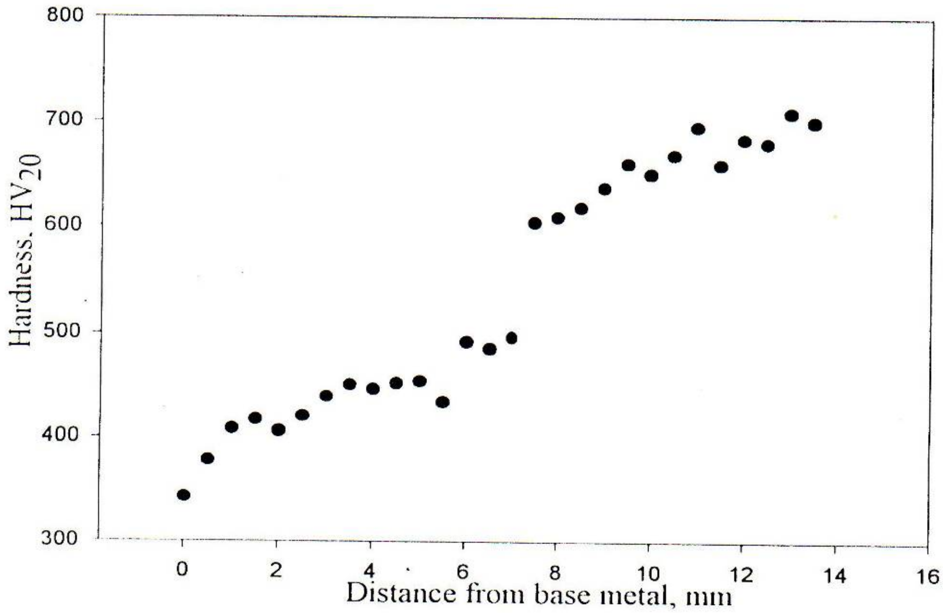

Fig. 7 Hardness distribution along the base metal, HAZ and hardfacing material using electrode A

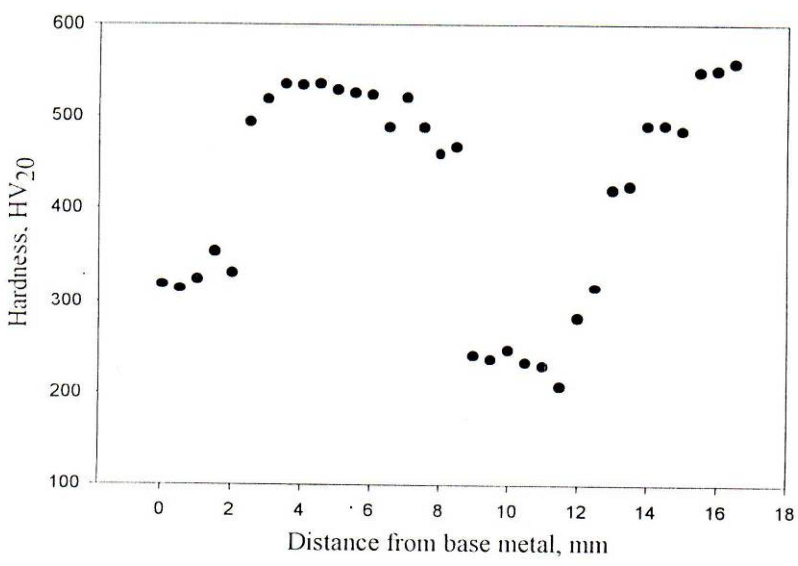

Fig. 8 Hardness distribution along the base metal, HAZ and hardfacing material using electrode E and three layer of electrode A.

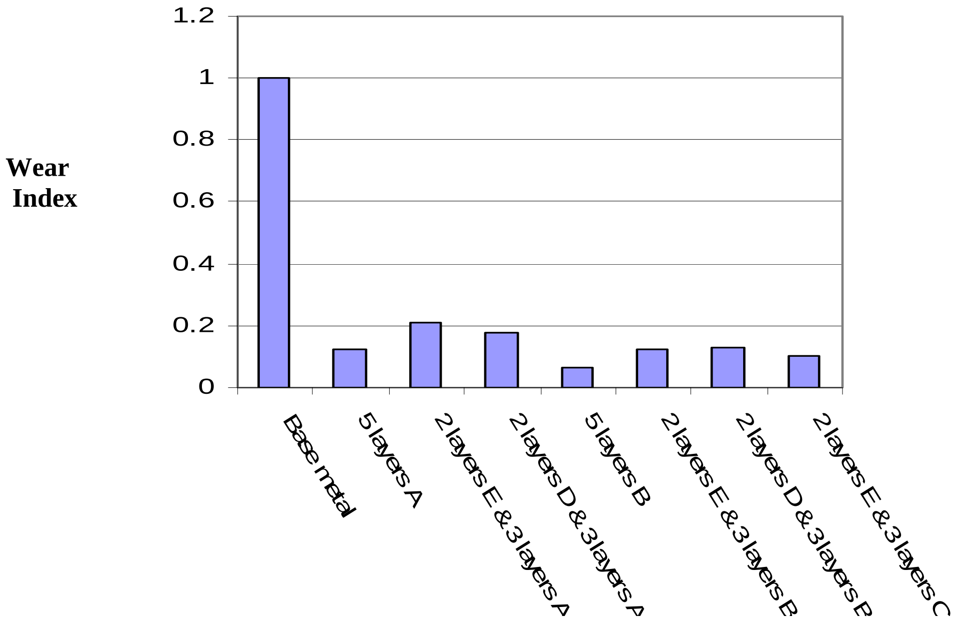

Fig. 9 Wear index for base metal and hardfacing layers

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