PERFORMANCE TESTING OF WEAR RESISTANT MATERIALS USED ON SHREDDER HAMMERS

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Abstract

Various hardfacing materials were tested on shredder hammer heads under operational conditions. A typical test chart is included together with some illustrations of good and badly worn hammers. Deposition and metal recovery rates by stick and wire electrodes are compared along with basic material costs. A few replaceable heads were tested with promising results.

Introduction

The importance of good cane preparation in extraction is now well established. One of the factors affecting the degree of cane preparation is the condition of the shredder hammers and most of the sugar factories in South Africa use welding material to hardface and recondition worn hammers. This is an extremely costly operation which must be repeated at regular intervals. One of the projects undertaken by the SMRI during the 1979/80 crushing season was to determine the performance of wear resistant materials when applied to shredder hammers.

Various suppliers of hardfacing welding material, namely Sulzer Bros., Fedgas, S.A. Liquid Air, GKN Rockweld, Besco, Afrox, Bohler Steel, Linkweld and S.A. Weld agreed to participate in SMRI supervised tests of their products. Two basic methods of welding deposition were observed : the stick electrode method and the continuous wire method.

The Australians[1, 2] have for a number of years been using detachable head shredder hammers with a fair amount of success and have tried various types of hardfacing on these detachable heads. Following their reported success with tungsten carbide inserts it was decided to test this material and other hard wearing materials. Apex Foundries supplied wear resistant blocks while wear resistant material was purchased fom GKN Rockweld, Bohler Steel and Sandvik. No attempt was made to design a detachable head but rather to find a suitable wear resistant material which could be incorporated into a detachable head.

The wear resistance of various materials was not the only criterion to be considered but also the deposition rates, metal recovery rates, and basic material costs which would give an indication of the economic performance of the materials.

The Noodsberg shredder was used as the test bed for the shredder hammers. This shredder was selected because the hammers used in this Smithtech-designed shredder are reasonably heavy, approximately 12 kilograms, and the club heads cover the full shredder width at each row.

Equipment

The shredder hammers on which the hardfacing welding consumables and wear resistant tips were tested were to Smithtech's design drawing No. 7800/05/02.

The hammers were fabricated from cast steel to specification BS : 3100:1976 Grade A2 and were supplied by Pinetown Engineering Foundry Co. Each hammer was ultrasonically tested by SABS for casting defects.

Unfortunately the quality of the castings was poor with several of the hammers badly twisted. All the unsatisfactory hammers were rejected and the full complement of 50 hammers was only received after the third casting attempt. Because the hammers were supplied from 3 different casting and machining batches there were slight variations in some of the dimensions and masses of the hammers.

As most of the welding of the hardfacing materials was done at the suppliers' premises they used their own welding machines. To ensure that all the dressed hammers had the same effective length they were tested in "go / no go" jig. Figure 1 below shows a photograph of this jig, which was made to suit the existing hammers and shredder at NB.

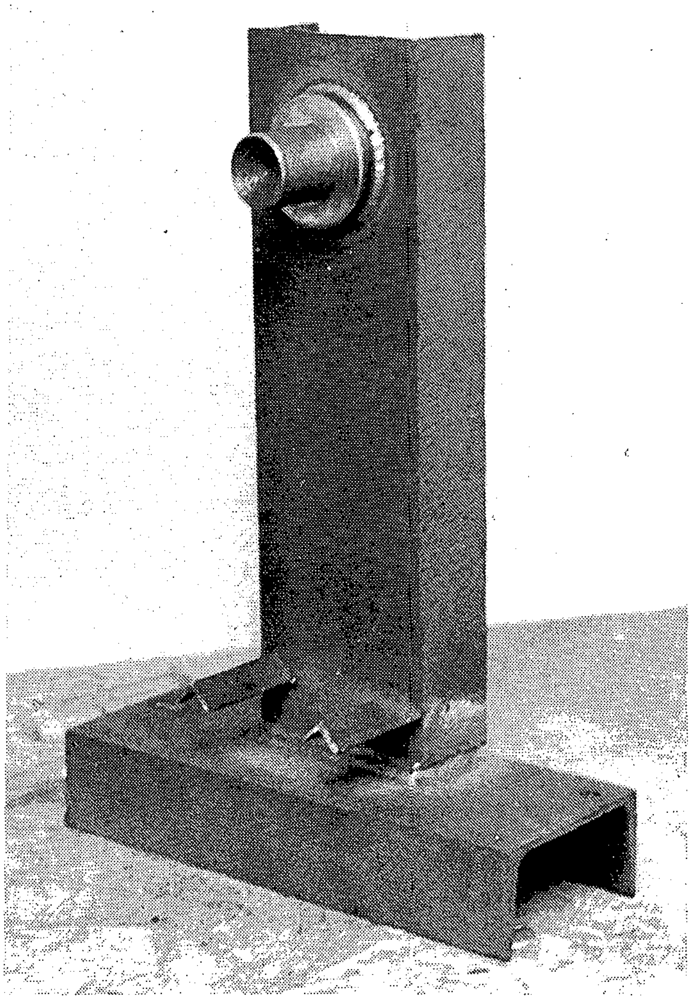

FIGURE 1 'Go/no go jig'.

Procedure

The Welding and Testing of Wear Resistant Materials.

Each welding supplier was given a pair of hammers for each hardfacing product that he wished to submit for testing. Deposition of the welding consumables was normally done by a welder appointed by the product supplier using his own equipment. No restriction was placed on the welding technique except that on completion all hammers had to pass the "go/no go" jig test and that all edges on the welded hammer were to be as square as possible. Prior to welding each welder was given an indication as to what areas were to be hardfaced.

This was done to obtain a certain amount of uniformity of the welded hammer heads.

Records were kept of the number of electrodes used to dress new hammers and repair worn hammers. Based on the number of electrodes/kilogram (this information was provided by the welding supplier), the cost of welding consumables could be estimated. The welding time was also noted. Unfortunately it was not always possible to weigh accurately a spool of welding wire when this method of hardfacing was used. Various wear resistant blocks were also tested and three different types of blocks were welded on to suitably machined hammer heads. Two other types of blocks were bolted on to the heads.

Details of these mounting arrangements are shown in Figures 2 and 3. Each hammer had a number punched on the back for identification purposes.

Wear Test Procedure.

All the hammers were run in the NB shredder. Before and after each test period most of the hammers were photographed, all were weighed and notes were made on their wear pattern. The position of each hammer in the shredder was noted as was the weekly percentage ash throughput during the test period. Where possible hammers were located in the shredder at positions which normally suffered high wear rates. The NB shredder had a distinct wear pattern across the shredder length. During the early part of the season the hammers at NB were replaced every two weeks, with the hammers being rotated after one week. However, during the latter part of the season the hammers were only replaced every four weeks with the hammers being rotated after two weeks. Several of the hammers with block inserts only had one shredding edge and were thus not rotated mid-way through the test period but operated on one working face for the entire test period, and the welded hammers were run for a minimum of two periods in the shredder.

Recovery Test/Deposit Rate Test.

As initial observations had indicated that the stick welding process was extremely wasteful and that the continuous wire process resulted in far higher deposition rates it was decided to check more accurately this observation on three of the better hardfacing welding materials. This was done by consuming a known mass of weld material and then determining the actual mass of material deposited on a mild steel plate. The time required to deposit this material was also noted. This test was done in conjunction with the Afrox technical representative, who did the welding.

Results

Table 1 shows the results from one of the hammer tests. Initial and reconditioning costs shown are per hammer. The loss of material from the hammers for this test was so slight that comparison could only be based on the radius of shredding edge.

Shown in Figures 4 and 5 are two worn hammers. In Figure 4 the wear pattern has tended to continually present a good square shredding edge while in Figure 5 the wear pattern has returned a badly rounded shredding edge.

Table 2 shows the results of the deposit/metal recovery rate tests done to compare the performance of stick and wire electrode welding.

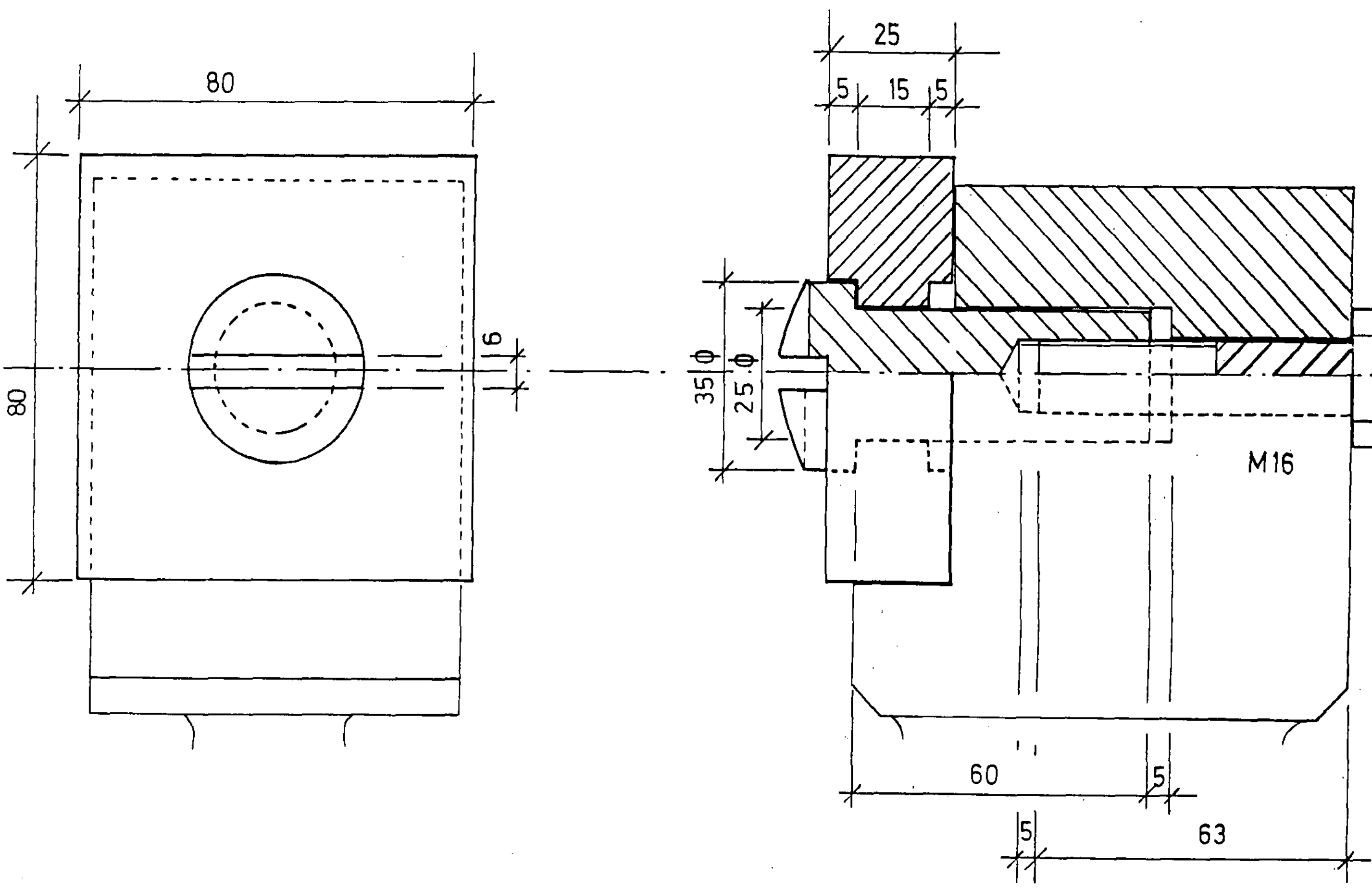

FIGURE 2

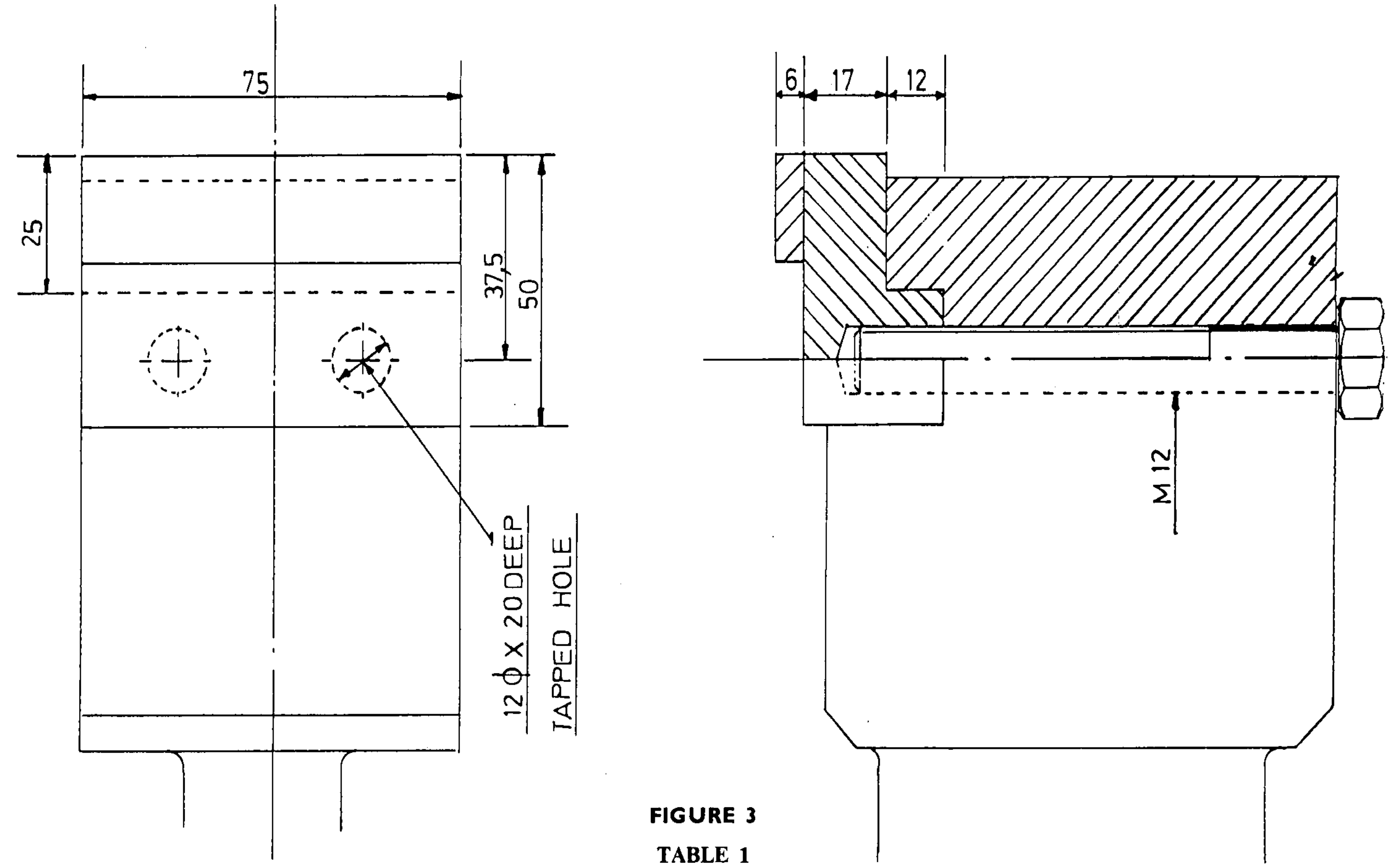

FIGURE 3

TABLE 1

Test 1	Date 18/6-2/7/79 (2)		Ash throughput: 518 tons			Fibre throughput: 10 482 tons	
Hammer No.	Electrode Type	Initial Cost (R) (4)	Welding Time (Min)	Position (3)	Mass Loss (kg)	Relative grading (Edge condition) (1)	Reconditioning Cost (R) (5)
23	Gridur 7	R17,70	60	6	0,14	Poor	R7,75
25	Cobalarc 1A	R8,00	45	17	0,16	Good	R4,67
49	Stoody 2134	R13,35	50	21	0,11	Good	R2,60
41	Gridur 18	R30,46	68	6	0,07	Very Good	R12,99
15	Gridur 600 S	Wire	34	16	0,25	Poor	—
4	Cobalarc 9	R13,00	67	20	0,15	Good	R3,00
17	Cobalarc 1A	R8,00	45	6	0,15	Good	R4,67
26	Gridur 7	R17,70	60	16	0,17	Poor	R7,75
11	Cobalarc 100 m	Wire	43	20	0,15	Good	—
40	Gridur 18	R30,46	68	6	0,07	Very Good	R12,99
31	Gridur 46	R19,33	67	16	0,21	Poor	R13,70
32	Cobalarc 100 m	Wire	43	20	0,15	Satisfactory	—

NOTES: 1. This is relative grading based on the radius of the shredding edge (large radius — poor/small radius — good).
2. The shredder hammers were rotated midway through the test.
3. Position of hammers — position 1 nearest shredder motor drive.
4. Initial cost — cost of welding consumables/hammer.
5. Reconditioning cost — cost of welding consumables/hammer.

It is difficult to compare accurately wear resistance. However, it was felt that a fair indication would be obtained if hammer weight loss and wear pattern were considered. During the earlier tests the hammers were not subjected to very bad sand throughput conditions and the wear pattern comparison was based on the radius of the shredding edge.

Welding Consumables.

The wear resistance of the hardfacing welding consumables appears to be proportional to the cost of the product. Of all the products tested it is felt that the following returned consistently good wear results : Cobalarc 1A, Cobalarc 9, Cobalarc 100M, Hobrudur 62, Stoody 2134 and Sulzer CP 660.

These electrodes showed a good resistance to wear and when the hardfaced edges were penetrated the wear pattern always returned good shredding edges.

Cobalarc 1A and 9 initially suffered from slight flaking of the hardfacing layer. It is felt that this flaking was probably caused by their high degree of hardness and the severe stress relieving which these electrodes experienced. Before the flaking situation deteriorated the Afrox technical representative removed some of the hardfacing and base layer, then deposited a medium hardness hardfacing (Superweld 400) before putting down the final hardfacing. This medium hardfacing seemed to reduce the flaking effect as well as produce a good shredding edge. Cobalarc 1A and 9 are priced at R9,12 and R12,00 per kg respectively. Cobalarc 100 M is a welding wire and at R5,10 per kg is the cheapest of the above materials. It also has the advantages of high deposition rate and good metal recovery.

Stoody 2134 and Hobrudur 62 both returned satisfactory performances and are priced at R9,40 and R8,00 per kg respectively.

Sulzer CP 660 performed reasonably well when deposited with or without the underlayer of CP 400. It is priced at R10,40 per kg.

Gridur 18, Vidalloy 31 and 37 returned promising results initially although they did not maintain this performance under high sand throughput conditions. Vidalloy 31 being a wire product should also return good metal recovery. Both Vidalloy products returned good deposition rates, with 37 returning a metal recovery of approximately 80%. Both Vidalloy 31 and 37 are reasonably priced at R5,25 and R7,20 per kg respectively.

Eutectrode 6006 with a CP 400 underlayer performed reasonably well. However at R36,00 per kg it did not perform any better than the cheaper CP 660 (R10,40 per kg). Fox 60 hardfacing is reasonably priced at R7,00 per kg and returned a good shredding edge, but when subjected to high sand throughput conditions its wear resistance deteriorated. Haynes 90 also returned a good shredding edge with reasonable resistance to wear but was no better than cheaper electrodes. Haynes 90 is priced at R30,00 per kg.

Of the cheaper welding electrodes only Stoody 21 and CR 70 showed possibilities as suitable hardfacing materials.

These hardfacing electrodes are not as good as the more expensive electrodes but returned reasonably good shredding edges. When the hammers which were initially hardfaced with CR 70 were renovated an underlay of Chromoid 101 was deposited before appplying the final layers of hardfacing.

This combination of Chromoid 101 and CR 70 had good wear resistant properties and returned a good shredding edge. This hardfacing underlayer appeared to perform as well as Cobalarc 1S hardfacing which was being used by NB on the hammers while our Chromoid 101/CR 70 hammers were tested.

Electrodes CR 70, Chromoid 101 and Stoody 21 are priced at R2,00, R6,50 and R5,10 per kg respectively.

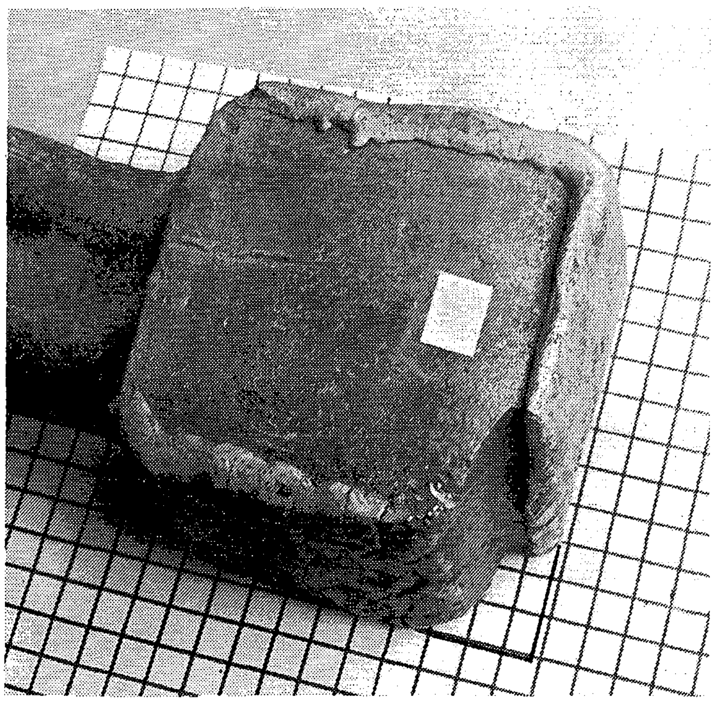

FIGURE 4 Worn but square shredding edge.

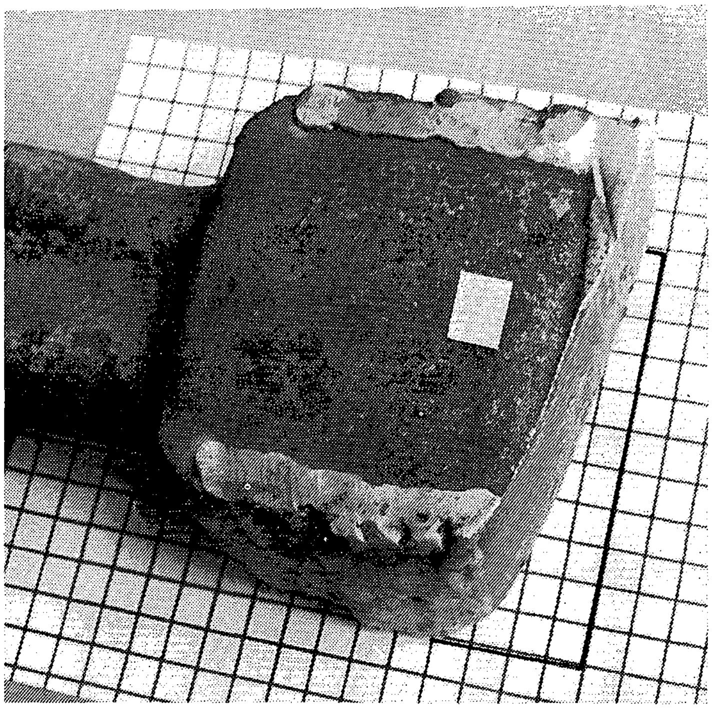

FIGURE 5 Badly worn no shredding edge.

TABLE 2
Deposition Rates

	Wire	Stick	
Electrode (Cobalarc)	100 m	1 A	CR 70
Electrode diameter (mm)	2,8	6,4	4
Weight of plate after (kg)	1,646	1,504	1,545
Weight of plate before (kg)	1,164	1,149	1,175
Material deposited (kg)	0,482	0,355	0,370
Weight of electrodes used (kg)	0,550	0,505	0,560
Number of electrodes used (kg)	—	6	5
Weight stubs (kg)	—	0,060	0,061
% Recovery	88%	70%	66%
Actual cost/kg	R5,70	R10,20	R2,20
Effective cost/kg	R6,48	R14,56	R3,33
% Stubs mass/consumed mass	—	12%	11%
Welding time	7 min 37 sec	16 min 35 sec	19 min 25 sec
Specific time (min/kg deposited)	15,8 min	47,7 min	52,5 min

$$\text{Metal recovery} = \frac{\text{Weight of material actually deposited}}{\text{Weight of welding material consumed}}$$

$$\text{Metal deposition rate} = \frac{\text{Weight of material actually deposited}}{\text{Time taken to deposit material}}$$

A number of very expensive welding products in excess of R45/kg were tested and generally their performance was not as good as the previously mentioned products.

Wire and Stick Electrodes.

An examination of the price structure of wire and stick electrode welding products will reveal that wire material is generally considerably cheaper than the equivalent stick electrode material. It must be indicated at this stage however that the wire welding equipment is slightly more expensive than stick welding equipment.

From observations made while the hammer heads were being hardfaced it became apparent that the metal deposit rate with wire products was generally very much higher than for stick electrodes. The total metal recovery for the various stick electodes varied from 40 to 80%. The wasted material was lost as splatter, flux coating and stubs. Approximately 13% of the stick electrode ends up as a waste stub. These observations were subsequently confirmed as shown in Table 2. What was also revealed by the results in this table was that of the products tested, the wire product had a better metal recovery than the stick products. In fact the wire product on test deposited at least three times as much material as the stick products for the same welding period.

Welding Technique.

Generally, high welding currents are associated with the fast deposit rates of wire products. This makes welding on the edges of the hammer head fairly difficult. This problem was overcome by using four copper plates clamped to the hammer head to retain the molten weld metal on the edges. These plates, which were used by the Vidalloy technical representative when welding with Vidalloy 31, were also used during the renovation of worn hammers. This system of 4 separate plates was a bit cumbersome and could be improved to take the form of jigs as used by the Australians[3] for electro-cast welding.

None of the welders applying the hardfacing used any special technique but followed the information in his product handbook. These handbooks are readily available to all purchasers of hardfacing products. Most of the welders heated the hammers slightly before welding but to a lower temperature than generally reported in Queensland. The Australians have also reported that their hammers are cooled slowly in lime after being hardfaced but this was not practised by any of the welders. This slow cooling would probably reduce the amount of stress relieving which takes place by cracking of the hardfacing.

One of the most important rules with regard to hardfacing is not to apply too many layers. If the hardfacing is very hard and susceptible to stress relieving, the hardfacing will probably tend to flake off, while if a softer hardfacing is used the leading shredding edge will radius badly.

Wear Resistant Inserts.

None of the wear resistant materials, tested in block form, has proved entirely successful, but results indicate an excellent potential for cost savings.

The tungsten carbide inserts lasted less than half the test period. However since conducting the tests the supplier has indicated that the grade (H 20) they recommended had poor impact properties and this was probably one of the reasons for its short life. The Apex blocks gave indications that they had good wear resistant properties but a suitable mounting arrangement will have to be used before their true properties can be proved.

The Bohler steel blocks showed significant wear even when heat treated to maximum hardness. The mounting arrangement used to hold the Bohler steel blocks onto the hammer head which is shown in Figure 2, gave no trouble during the tests and allowed the blocks to be rotated fairly quickly.

Conclusion

Of all the wear resistant materials tested, none of them had outstanding properties when used on shredder hammers. The performance of these materials appears to be proportional to the price of the material. However some of the very expensive products returned rather disappointing results. The following electrodes returned consistenty good results: Cobalarc 1A, Cobalarc 9, Cobalarc 100M, Hobrudur 62, Stoody 2134 and CP 660.

The properties of the Cobalarc products were improved by depositing a medium hardness underlayer before depositing the final hardfacing layers. Of the cheaper stick electrodes CR 70 performed fairly well with its wear resistance being improved by depositing a Chromoid 101 underlayer.

Even though wire welding equipment is slightly more expensive than stick electrode equipment the high deposition rate and metal recovery make wire deposition of hardfacing attractive. The metal recovery of some of the stick electrodes varied from 40 to 80 percent.

None of the wear resistant materials tested in block form was very successful but the system of detachable blocks has shown promise.

When wear resistant products are tested for their suitability at individual mills, care should be taken to ensure that inaccurate results are not obtained because of variations in sand throughput; and position in the shredder. The product price per kg should not be the overruling factor in selection of welding materials. Deposition rates, metal recovery rates and the wear properties must also be considered. The testing of wear resistant materials is to be continued during the 1980/81 crushing season.

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