Reclamation By Welding - Improvement In Cost & Productivity

A. Dutta Roy, M. K. Sarkar & N. K. Sharma
Tata Steel, Jamshedpur - 831 001, India

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ABSTRACT

Spare parts management is integral to successful and cost effective maintenance practice in integrated steel plants. As the maintenance philosophy is gradually transformed into reliability based maintenance, the reliability and predictability of parts' life gains higher significance. Reliability of reclamation by proactive techniques for spare parts is viewed in this context, along with the importance of maintenance cost reduction. This paper deals with the focus areas of cost reduction in spare parts management in maintenance of steel plants with particular reference to reclamation and reconditioning practices. Field experience at Tata Steel proves the gains achieved in downtime and replacement costs. These are explained on the basis of actual work done at various plant locations.

INTRODUCTION

Reclamation of components plays an important role in spare parts management for integrated steel plants. Besides reducing the inventory it contributes to downtime reduction, reduction in repairs and maintenance (R&M) cost and most importantly, serves as insurance against catastrophic outage situations arising out of unforeseen failures of key components. The spare parts addressed in this paper cover specifically the components of tribo-systems i.e. parts subjected to progressive loss of material in service.

Strategy For Reclamation

The surface of most components which have been worn, corroded or mismatched/mismachined can be built up by depositing new material on the surface. The new material can be applied in many different ways like welding, thermal spraying, plating, etc.

All fusion welding processes can be applied for surfacing, but all consumables are not available in a form to suit every process. Also, it is important to check the ability of the chosen process to achieve the deposit properties for which the consumable is selected. Since most surfacing materials have higher alloying elements than the substrate, the welding process involves intermixing or dilution. To overcome this a number of deposit layers are chosen on the basis of the process.

Since manual processes are extensively used for repair work, the skill of the welding operator needs to be established before commencement of the job. Having decided on the consumable, process and operator, planning of the actual job is essential. This is done in the following stages :

- Identification of component material and its weldability characteristics.
- Hardening and/or embrittlement as a result of temperature during and cooling rates following welding.
- Loss of strength in hardened components owing to

tempering effect at welding temperature.

- Reduction in corrosion resistance in certain grades of stainless steel.
- Condition of the surface of the substrate.

The component setting up for welding will depend on the process chosen. The setting up should ensure productivity of the operator. Also, suitable preheating fixtures should be attached as required. The welding operation follows predefined parameters and techniques to ensure the desired quality. Overall reclamation strategy aims at low cost replacement of components along with higher equipment uptime.

Impact Of Reclamation On Maintenance Cost

The approach to the cost effectiveness in repair surfacing is on a relative cost/life basis, in addition to reduced downtime, reduced inventories, and above all matching the performance of individual components to the overall equipment performance. For example, blast furnace campaign life is now decided by the condition of the charging equipment and not the refractory life. If the charging system can match the refractory life, an enormous gain in campaign life can be achieved. Such factors make the actual repair cost insignificant.

Impact of reclamation on maintenance is realised under condition of:

- Increase in mean time between failures (MTBF).
- Extension of life expectancy cycle i.e. higher life/cost ratio.
- Elimination/minimisation of replacement purchase.
- Reduction in downtime.

These are elaborated in the later sections.

Increase in MTBF of Components

The term failure here refers to the planned withdrawal of the component from service due to wear. Study of tribological conditions of the component is the usual approach. This means identification of the nature and cause of wear and achieve improvement in material and surface properties.

Problem : Improvement in life of jack shaft crab coupling of 46" Blooming Mill main drive. RM-2 Mill drive jack shaft linking the armature shaft with the cogging roll is coupled to the armature with a crab coupling. The coupling has taper seating at the keyways which is assembled to the jack shaft male coupling. Details of the assembly are shown in Fig. 1. The coupling transmits load of 5000 HP at rpm varying between 50 to 100 in the reversible mill. Changing of the coupling involves mill outage of more than 48 hours and hence, can only be done during major shutdown of the mill.

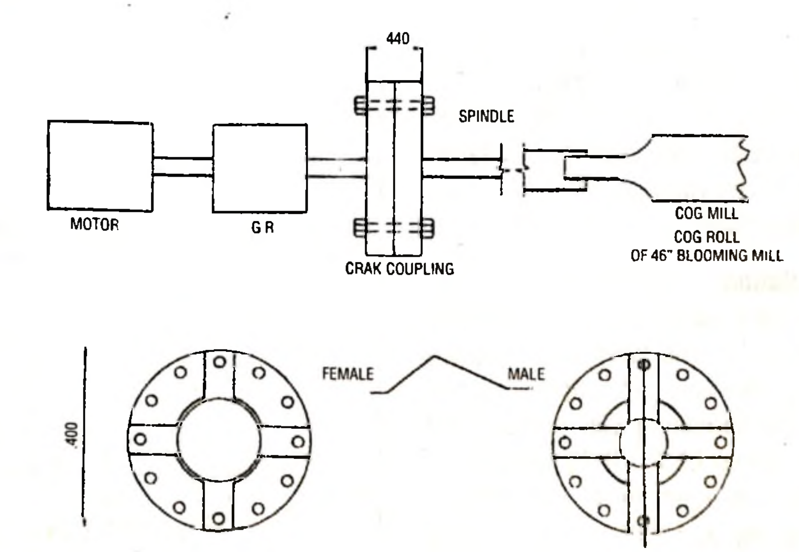

Fig. 1 : Carb coupling and jack shaft of 46" Mill drive

Weld Metal Chemistry %

Existing	Modified
C - 0.3-0.5	C - 0.07/0.09
Mn - 0.50	Mn - 1.20/1.70
Cr - 2.5 - 3.0	Si - 0.15/0.25
	Cr - 2.5/3.0
	Ni - 1.8/2.2
	Mo - 1.0/1.5
	V - 0.1/0.2

Mechanical properties

Hardness 350 -400 BHN (other properties not specified)	UTS - 96/110 kgf/sq.mm YS - 86/100 kgf/sq.mm
	% E - 14 min Hardness - 360/430 BHN after stress relieving

Problems faced with the coupling were :

a) Failure of the bolts under shear.

b) Wear at the keyways to the extent of 12-15 mm.

It was concluded that the wearing of keyways resulted in transmission of torque through the bolts, which ultimately failed in shear. The bolt holes wore out excessively to elliptical shape.

Solution : The drawing calls for surface hardness of R 45 at the keyways. The worn out coupling was dressed by machining and flame hardening was tried out. But hardness of R 20-22 could only be achieved with the CK 45 material and with the facilities at the disposal. Hardfacing to about 350 BHN was done at the coupling face. The bolt holes were enlarged and resieved.

With the above reconditioning method, the life obtained from the couplings could be extended by only one campaign, i.e. between two successive major shutdowns, although failures of bolts were encountered in between. Further analysis identified the cause as fretting wear arising out of oscillatory motion due to mill reversions, followed by adhesion between the mating surfaces in close proximity. Prevention of fretting would minimise oscillatory motion between the components, resulting in less adhesive wear at keyways. This would prevent excessive torque transmission through the bolts.

Wear loss under fretting is a function of :

a) Amplitude and frequency of oscillatory motion.

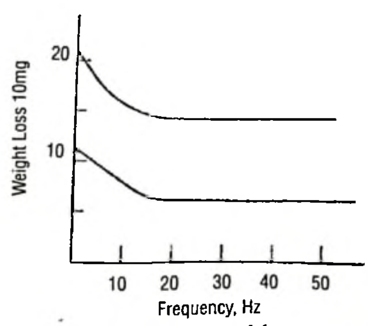

Fig. 2a : Fretting wear as a function of frequency of fretting vibration

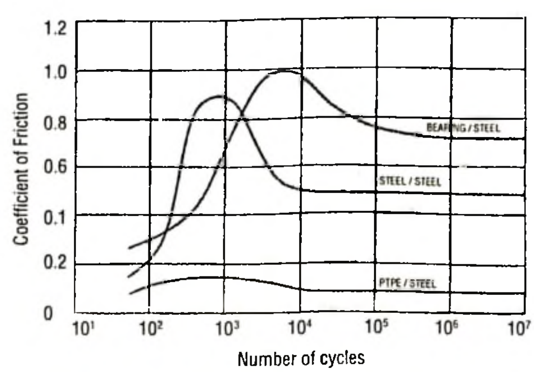

Fig. 2b : Fretting wear vs. coefficient of friction

b) UTS/YS of the material.

c) Surface finish of the mating parts (related to the co-efficient of friction, Fig. 2).

Parameter (a) is related to plant operation and cannot be altered. Hence reconditioning strategy focused on the balance issues.

The approach to the selection of hardfacting deposit was changed from "hardness related" to "strength related" i.e. weld metal of high UTS/YS combination, combination with good machinability was selected. The keyways and keys were ground finished and assembled with required accuracy.

Results : The coupling thus reconditioned was put into service in the year 1992 and is currently running through its fourth campaign without any appreciable wear. During the past three major shut downs the coupling was not changed and plant outage due to failure of coupling bolts was eliminated.

5. Extension Of Life Expectancy Cycle

With the help of proactive measures the life expectancy of components are enhanced. Reliable reclamation also extends the life expectancy of critical components. The reliability element is introduced by :

a) Identification of critical attributes of the components, like metallurgical homogeneity, mechanical properties, internal soundness, residual stresses, surface finish, etc.

b) Quantification of acceptance limits of each attribute indentified for monitoring.

c) Select technology and monitoring parameters to achieve these limits.

d) Build-in the same attributes during reclamation.

Problem : Reclamation of worn out journals of Blooming Mill leading spindles. Leading apindles at blooming mills are the constliest single piece forgings of about 15-25 tonne weight. The universal head at the drive end is integral to the spindle while it is press fitted at the roll end. Normally wear at the slipper seating portion of universal heads is encountered in service along with wear at the journal. The journals are designated to higher safety factors and worn out surfaces are dressed by machining to restore the profile. The heads are normally reclaimed by welding. The life of the spindle is the stage at which the journal diameter reaches discard size.

Solution : The Journal is the most critical location of the spindle. After a service life of about 20 years, the substrate is stressed and attempt to weld build up may worsen the situation.

For reliable reconditioning the following atteibutes were identified :

a) Surface residual stress after welding and machining should preferably avoid any tensile component or should be lower than the level of stress before reconditioning.

b) Adoption of automated CO_2 welding with solid wire consumables.

This gave the following advantages :

— Very low diffusible hydrogen in the weld metal (in the range of 0-2.5 ml per 100 gm. of weld).

— Weld induced stresses are low due to low heat input per unit length of weld. This combined with shot peening would contain the residual stress within desirable limits.

— Low dilution with parent metal amongst the various fusion welding processes.

c) Ultrasonic examination of journals before and after welding to ensure freedom from weld defects.

d) Finishing the journals by machining, grinding and roll polishing. The final operation will induce residual compressive stress.

The spindle was stress relieved before undercutting although no appreciable drop in stress was noticed. After undercutting the journals were ultrasonically tested

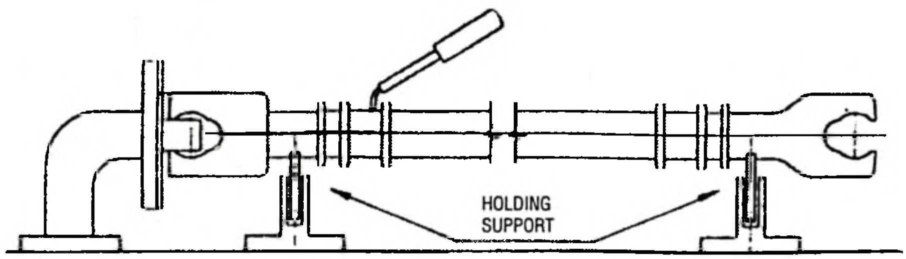

Fig. 3 : Arrangement of automated welding fixture of sleading spindle

and then welded by automated MAG (Metal Active Gas) process with solid wire. Arrangement of the automated fixture is shown in Fig. 3.

Results : The as welded stress level was measured at + 25 ksi in the weld direction and +7 ksi in the perpendicular to the weld direction. After stress relieving, machining and grinding, the stress was - 14 ksi, i.e. compressive in nature.

Thus the internal stress was maintained below the initial level. The internal soundness was assessed by ultrasonic tests.

The 40" Blooming Mill spindle was successfully put into service and till six months of operation, no defect was noticed at the Journal. With the success of the process, the 46" Mill spindle is now taken up for reconditioning.

Problem : The Hot Strip Mill of Tata Steel has different varieties of transfer rolls for the descaler, coil box, transfer table, run-out table down coiler sections due to different service conditions. The OEM supply is of En 24/En 19 varieties with flame hardend surface. After the initial composition the rolls are to be reconditioned for future use. The problem occurred in almost all sections due to the (1) absence of flame hardening facilities of the newly manufactured rolls and (2) non availability of suitable were resistant material for reconditioning.

The initial approach was to match the hardness requirement of Re 44-48 on the roll barrels. Indigenously available SAW consumables were tried and established which have the following chemistry :

C - 0.2%, Mn - 1.0%, Cr - 12%, Ni -2.25%, Mo - 1.0%

However the roll life is reduced to as low as 0.2 mt (average) which call for frequent mill shutdown. For a mill of 1 mtpa capacity, the outage is costly although roll life is not the newly contributor for the outage. With steady improvement in other maintenance areas, the outage due to roll changing is critical for mill operation. Considering the urgency of the situation it was decided to adopt the best practices elsewhere in the world. The benchmarking team studied the reconditioning/manufacturing practice in 10 plants worldwide

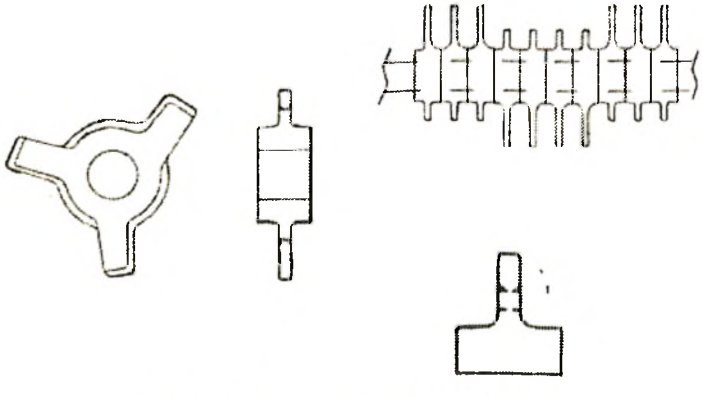

Fig. 4 : Redesigned sinter crusher tips

and decided in 34 MiCrMo6 base materials with 5% Cr-3% Mo hardfacting deposit. The process is stabilised now and the rolls have been just inducted into service.

Problem : Inconsistency in the life of Billet Caster Shear Blades :

The two billet casters at Tata Steel produce 127 mm and 100 mm billet through the concast route. The billets are sheared at 9m interval by Rotary shears. The problem occurred with inconsistent life of the shear blades. In a six shear caster premature failure of shear blade in one stand not only causes unplanned outage, but also affects product quality. The trials with different electrodes could not eliminate the inconsistency.

By Juran Quality improvement approach the problems were analysed and traced to the manufacturing sequence as the root cause. After modifying the sequence the inconsistency is eliminated and further life enhancement was achieved through selection of hardfacing consumables.

Eliminate/Minimise Replacement Purchase

Successful reclamation eliminates or minimises replacement purchase, thereby reducing spares cost. Under normal service conditions a component is withdrawn from service due to wear in localised portion and restoring that location to original shape and size will minimise or eliminate the replacement purchase. This, however, sometimes involves redesigning of the component as shown below.

Problem : Sinter crusher at Sinter Plant 2 is located between the sintering machine and sinter cooler and it breaks the red hot sinter lumps to 19mm - 20mm mean size. The basic construction is shown in Fig. 5.

10 discs are mounted on the rotor shaft. The discs are made out of cast steel and hardfaced at the arms as well as at the hub locations. The cause of wear is high stress abrasion from the hot sinter. During service, the central discs are worn out faster since the major portion of the burden is processed in this zone. The wear was so severe that the breaker arm portion of 6 discs was completely worn out and replacement with new discs or with complete rotor assembly was imminent.

Solution : If the disc arms are suitably replaced, complete replacement would not be necessary. This would also save the lead time of 6-8 months required for procurement of castings. Hence it was decided to use fabricated arms welded on to the existing hubs, without disturbing the other parts of the

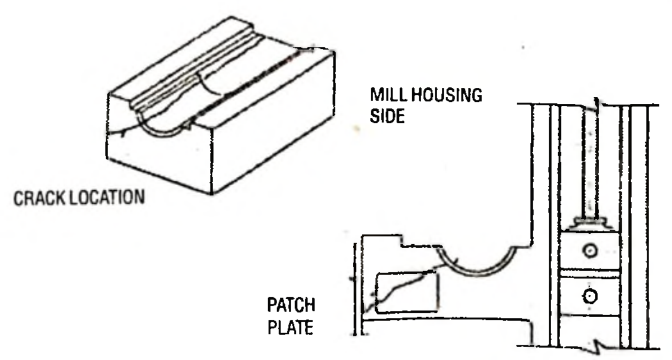

Fig. 5 : Location of breakage at second feed roll housing of 46" Mill housing

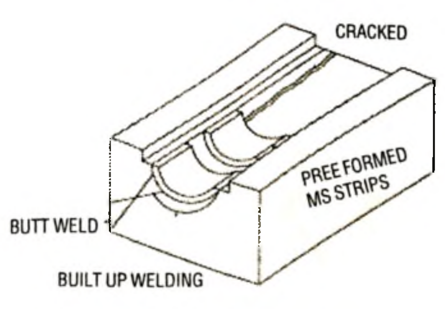

Fig. 6 : Placement of pre-formed strips on the housing

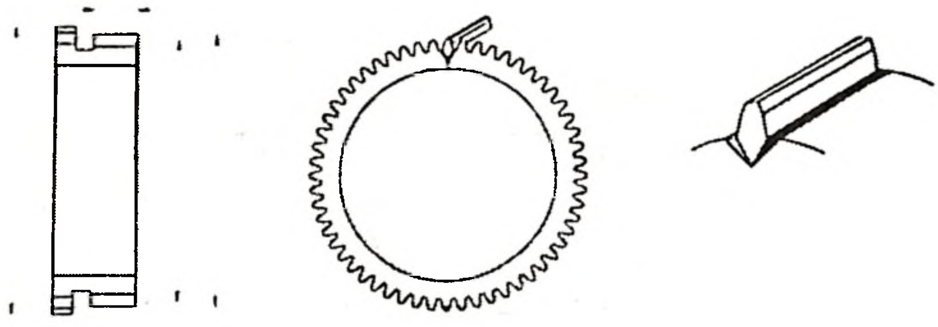

Fig. 7 : Assembly of pre-machined gear teeth on the hoist of billet handling crane

assembly. The design developed is also shown in Fig. 5.

The existing discs were machined to 310 diameter at the hub portion and prefabricated arms 63 mm thick, IS 2062 GrB were assembled to the hubs. Both the hubs and fabricated arms were machined to provide double Vee weld preparation. The asembly of arms on the hub was done in dismantled condition to facilitate downhand wdlding. Back gouging was resorted to for ensuring full penetration weld.

Subsequently the rotor arms were re-assembled on the rotor shaft and hardfaced with air hardening Cr-Mo alloyed iron deposits. The hardfacing was done with a buffer layer of 17% Cr - 3% Ni weldmetal.

Results : The reclaimed sinter breaker was put in service in Nov. 95 and handled more than 1.8 million tonnes of sinter till the next shutdown. The rotor was again put back into service after rehardfacing. Replacement purchase of approximately Rs. 30 lakhs could be eliminated by redesigning the rotor arms.

Reduction in Downtime

Impact of innovative reclamation is felt to the maximum when unplanned plant outage can be saved, thus saving on lost opportunity cost. The component is reclaimed and put back into service within a short span which otherwise, would require replacement at higher equipment outage. This is elaborated in the following two examples.

Problem : 46" Mill housing at RM-2 has both 1st and 2nd feed roll housings integral to the main housing. In Dec, 90, the bottom portion of 2nd feed roll housing showed crack, which was welded during a weekly shutdown. However, within 48 hours of operation the housing failed from the same location resulting in total mill outage.

The failure resulted in breakage of the roll neck housing into two pieces. The bearing seat was found worn out and built up on previous occasions, the crack originationg from the earlier welds (Fig. 6a). While cleaning the broken piece and main housing the existing defective welding had to be removed. The problems of reconditioning were :

a) Achieve sound welding between the broken piece and the main housing with full penetration.
b) Build up the missing section arising out of cleaning of existing defective welding.
c) Arrest further crack initiation
d) In the absence of finishing facilities, control the welding operations in a way that the finish of the housing bore matched the bronze bush profile.
e) Adequately reinforce the weld with external stiffeners to eliminate chances of failure.

Solution : The weldable faces were prepared by gas cutting and grinding and then assembled as shown in Fig. 6 Normal weld precautions were taken and after achieving full penetration welds on the double Vee type of joint, the groove was built up to the required profile. Welding consumable selected was AMS E 7016 type.

Four mild steel strips were formed to suit the O.D. of the bronze bush and were assembled on the housing after centering with the housing bore of the opposite side. These strips acted as formers for the final weld shape. The weld build up from underneath was carried out till the level of strip O.D. and then, the space in between the strips, was filled in to firmly secure the strips (fig. 6).

The matching of the bronze bush with the housing was accomplished with minor grinding of the weld ridges in between the strips. The strips also acted as reinforcement bars to prevent initiation of cracks. The entire assembly was finally reinforced externally with 200 mm sq. blooms as shown in Fig. 6b.

Results : The broken housing was brought back into service within 36 hours and since then is working satisfactorily for the past six years.

Problem : The CC billet yard crane at LD shop no. 1 handles continuous cast billets from the cooling bed to the shipping yard. Uninterrupted service from both the billet cranes is required for plant operation. In April 93 the 1.2

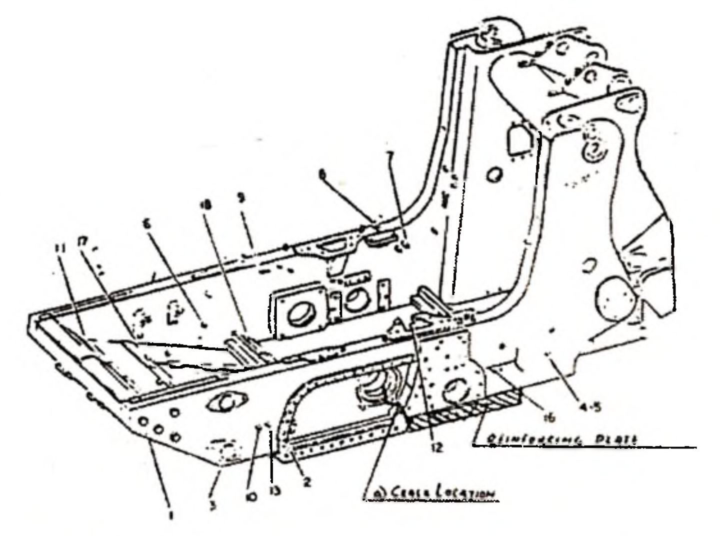

Fig. 8 : Location of crack on Caterpillar underframe

meter dia. hoist gear of crane no. 1 failled due to 5 broken teeth at locations shown in Fig. 7. The crane operation was stalled due to non-availability of a spare gear.

Repair of the gear involved finish machining to the accuaracy demanded in service. The tooth build up could follow the conventional route of building up after putting studs at suitable locations. This however, was ruled out due to the possibility of localised stress build up while welding such thick gear tooth and associated chances of field failure of a critical equipment.

Solution : 5 individual gear teeth were made out of forgings of IS 2004 grade and then machined at the root to ensure full penetration weld preparation. The portion of the gear with uprooted teeth was machined down and individual pieces were then assembled to the gear. Full penetration welding of individual tooth were done with necessary precaution of preheating, back gouging, etc. The arrangement, similar to fixing of dentures by dentists, is shown in Fig. 7. After welding, the gear was machined to the required accuracy.

Results : The reliable reclamation method save downtime of the crane by at least 20 days and the gear is still in service.

Improvement in MTBR

Problem : Caterpillars (model 973) used at steel melting shops are put into extremely demanding service condition of pitside material handling. The underframe of the vehicle showed repeated failure at the particular location marked in Fig. 8. Site as well as shop repair by gouging and welding could not prevent repeated occurrence.

Solution : The cracks were originating from the bottom edge of the frame, near the location of change in section. It was noticed that the failure was common to both the vertical sides of the underframe at identical locations. Also, all vehicles of the prticular model were prone to similar chassis failures. Analysis of the design revealed chances of stress rising at the section changeover location due to tensile loading. Hence the location was strengthened with a butt plate as shown in Fig. 8.

Results : Failure of Caterpillar 973 underframe was completely eliminated by this modification.

Improvement in Repair Cycle Time

Problem : The grinding rolls of the coal pulveriser mill of the coal injection plant of 'F' and 'D' Blast Furnaces are originally of Nihard Gr. 4 material. Each roll costs about Rs. 8.00 lakhs in foreign exchange. After the original supplies got worn out, attempts were made to reclaim the Nihard rolls which could not be materialised due to poor weldability of the material. Choice was to import the rolls or to develop suitable alternatives.

Solution : The Nihard material was replaced with steel casting to IS 2644 Gr. 2 material. The castings were annealed, proof machined and subsequently hardened and tempered to 260-280 range.

Wear resistance was ensured by suitable hardfacing. Since the rolls cannot be machined after hardfacing to +55 Re, the welding system was automated for uniform deposition. The rolls were mounted on welding positioners to enable the operator to tilt the roll as per requirement and at the same time provide rotational motion on it. The welding process selected was FCAW (Flux Cored Arc Welding) with C-Cr-Mo weld deposit.Prior to hardfacing, buffer layer of 17% Cr-3% Mn deposit was given to minimise the extent of cracks in the final layer.

Results : Use of modified roller resulted in uninterrupted availability of coal grinding equipment for further campaign of 14 months at an average of approx. 180 tpd of coal charge. The life obtained from Nihard roll was about 12 months at lesser throughput.

CONCLUSIONS

The role of reclamation in spare parts management is understood under compulsive situation to tide over equipment downtime. With growth in metal deposition and surface engineering techniques, and by systematic approach involving cross functional disciplines, it has been possible to contain expenditure on spare parts at Tata Steel within desired limits. As the plant is being modernised, the efficiency of equipment and demand on component reliability have increased many folds. At the same time, the cost of replacement spares is reaching alarming proportions. In the present context, continuous improvement in technology and practices is aimed at to provide the desired component integrity and reliability while reconditioning.

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