Conversion to Oil Hydraulics for Improvement in Strip Shape at Five Stand Tandem Cold Mill

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Abstract

The shape or flatness defects develop due to mismatch of the profiles of incoming strip and the active roll gap resulting in a transverse stress distribution and variation in elongation along the width of the strip. The roll bending and balancing system creates the positive or negative bending on the work rolls to counter the thermal crown developed on the roll during rolling and to achieve better shape of the strip.

The water hydraulic system, used for roll bending system and mill auxiliary drive units at Tandem Cold Mill(TCM) of Bokaro Steel Limited(BSL), led to often failure of bending cylinders and pumps due to damage and leakage of seals. It resulted improper control of roll bending system and affected the product quality as well as productivity.

In order to have a better control on shape and flatness of the cold rolled strip, the water hydraulics system had been converted to oil hydraulics for roll bending and balancing system. The new oil hydraulics system had resulted in improvement in strip shape by 18%, reduced mill delays by 25% and reduced leakages with higher viscosity hydraulic oil.

Keywords: Shape, Roll Bending, Hydraulics

1 Introduction

Strip profile, shape and flatness are all important parameters from the point of view of product quality. Strip shape is the manifest of the roll gap contour during cold rolling and a composite parameter defining both strip crown and flatness. The shape or flatness defects develop due to mismatch of the profiles of the incoming strip and the active roll gap resulting in a transverse stress distribution and variation in elongation along the width of the strip. Normally the roll crown and loading pattern is so adjusted that active roll gap matches with the profile of the incoming strip. However, in a cold mill, producing material with various grades, width and thickness, it is not possible to select a pre-determined roll crown to match all the conditions. Therefore, the roll gap is being adjusted according to the profile of input feedstock through roll bending and balancing system to have a better control on shape and flatness of the strip.

The water hydraulic system was used for roll bending system and mill auxiliary drive units at TCM. This system led to often failure of bending cylinders and pumps due to damage and leakage of seals, and affecting mill productivity due to delay or stoppage.
For better control on shape and flatness of the cold rolled strip, the conversion of water hydraulics to oil hydraulics system had been implemented in 5-Stand Tandem Cold Mill(TCM) for effective roll bending and balancing systems separate out from mill auxiliary drives, which was operated through common water hydraulics system.

2 Background

The hydraulic systems of the mill comprise of both oil hydraulic and water hydraulic. The water hydraulic system is used to transmit power to the roll bending and balancing systems and mill auxiliary equipments where as oil hydraulic is used for operating entry and exit equipments of the mill and in the mill proper,

2.1 Auxiliary drives

The auxiliary drives facilitate the feeding of the strip to the mill and changing of rolls. Different operations like load cell retract, back up and work roll locking, entry guide, cobble guard, striper apron, spindle positioner, were actuated through 19 cylinders for each stand of mill proper as shown in Fig. 1.

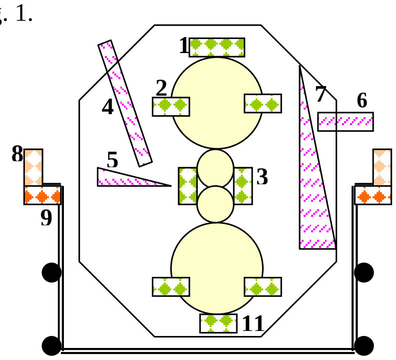

Fig.1 Cylinders for auxiliary drives

1. load cell retract- 1no **2**. backup lock - 4 no
3. work roll lock- 2 no **4**. cobble guard -1 no
5. striper apron- 1no **6**. side guide open-2no
7. entry guide - 1no **8**. wedge lock - 2 no
9. car latch - 2 no **11**. back up rig - 1 no

Total 19 nos. of cylinders for auxiliary drives per stand

2.2 Bending and balancing system

The roll bending and balancing system was actuating the bending cylinders to create the positive or negative bending on the work rolls to counter the thermal crown developed on the roll during rolling as per requirement. It prevented the roll and the strip to undergo the plastic deformation as asperities flatten under pressure and the area of the flattened asperities adjusts itself to carry the load by plastic deformation and to create pressure on the boundary lubrication; so that better shape of the rolled strip can be achieved.

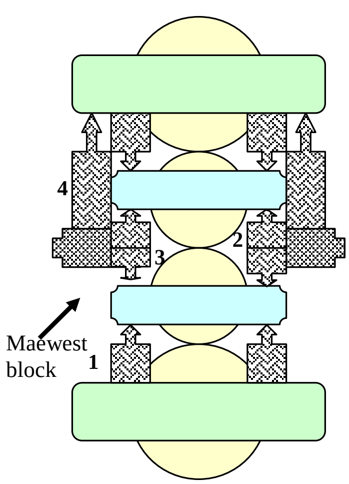

Fig. 2 Bending and balancing system

1. crown out – 8 nos
2. top crown in – 4 nos
3. bottom crown in – 4 nos
4. back up balance - 4 nos

Total no of cylinders per stand - 20 nos

3 Earlier system deficiencies

3.1 Seal failures

The probable reasons of failure or damage of piston seals and leakages was due to various operating conditions like poor life of seals, very high temperature, excessive load, speed, vibration, high pressure etc.

- ❖ Low viscosity of fluid also dependence on temperature and pressure (Fig.3). Because of the low viscosity of the water, the thermo physical properties of the mating surface were affected adversely and the critical temperature of servo-vital film (oil film) becomes very low. Consequently, when the film raptures, the temperature rises at the contact point and damages the seal. With the rise in temperature, viscosity of fluid drops, i.e. there is a significant drop in shear stresses, which opposes the motion of neighbouring elements in the flow.

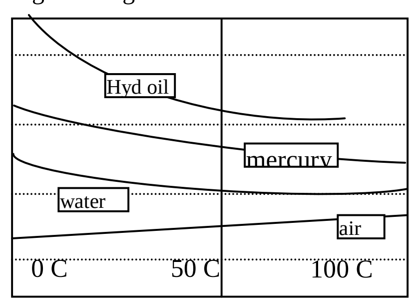

Fig.3 Viscosity vs. Temperature

- ❖ The degree of swelling of oil resistant rubbers mainly depends on the content of aromatic components in the fluid. The chemical aggressiveness of fluid can destroy the rubber partially or completely. The sulphur or chlorine containing substances in the fluid, which were activated by heat, causes a speeded ageing of rubber.
- ❖ Physico-chemical process in the area of contact leading to the distortions of the geometry of the components due to wear or deformation leads to leakages. Wear, largely induced by temperature, becomes catastrophic. Other factors like pressure, speed, co-efficient of friction etc., affect wear mainly through tem-

perature changes. All these properties or factors are greatly dependent on the nature of the fluid being sealed. Excessive pressure on fluid increases the radial force, restricts the supply of lubricant to the contact region, enlarges the part of the contact area where dry rubbing takes place, and raises the friction force and contact temperature. These conditions result in weakened tightness and shorter seal life.

- The design configuration of the seals like the surface geometry (leap seal, face seal), surface treatment method, etc. also contribute towards seal failure.

3.2 Failure of Bending cylinders

Failure of bending cylinders takes place because of damage piston seal, scuffing or scoring of cylinder and piston.

- The normal and tangential forces applied to the seal originate large deformation of the surface layer in the softer member. With the increase in roughness of mating surfaces (2.5μ to 1.25μ), co-efficient of friction rises and disruption of fluid film is possible. A very smooth surface (0.04 micron to 0.16 micron) is incapable of holding a low-viscous lubricant. The “film starvation” at the contact area gives rise to higher shear resistance and increased real area of contact causes the molecular component of friction force to grow. Owing to low thermal conductivity of rubbers, these factors lead to temperature rise in the contact zone during boundary friction, increase the co-efficient of friction, and wear rate.
- The viscosity of oil and the temperature of contact zone determine load capacity of oil film and oil film thickness at contact area depends on piezo-coefficient of viscosity (Fig.4).

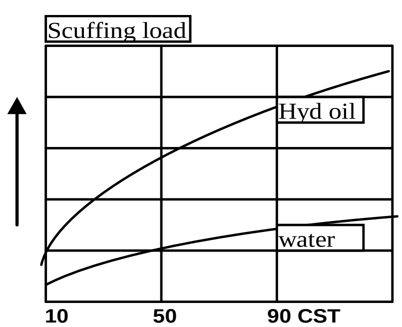

Fig. 4 Effect of Viscosity on scuffing load

- Physico-mechanical properties of lubricant like temperature, load, coefficient of friction etc. Ingress of dirt, moisture, or abrasive particles in the lubricant increases heat evolution due to friction.

3.3 Failure of pumps & gland seals

- Frequent loading of pumps due to frequent changing of pressure mode for thinner gauge rolling causes leakages from joints and actuators.
- Sudden drop of pressure in 200kg and 100kg line due to external or internal leakages of the auxiliary drive cylinders and valves operating both roll bending system and auxiliary drive units with the same water hydraulic system causing excess loading on the pumps.

4 Experimental

- Hydraulic shaping consists of supplementing mechanical and thermal crowning by applying hydraulic forces on the work roll chocks. The hydraulic forces acted through hydraulic cylinders located at different position of work roll chock for top and bottom crown-in, and for crown-out as shown in Fig. 5. These cylinders are actuated with the variable plunger stroke subjected to hydraulic force developed on each chock. These roll separating force deflected the top work roll upward and the bottom work roll downward to create the desired work roll bending crown for ensuing proper profile of the strip at the roll gap. The modified roll bending and balancing system designed with conversion of water hydraulics to oil hydraulics and installed at the all the Stands # 1, 2,3, 4 & 5 of TCM-II to correct the shape defect as far as possible.

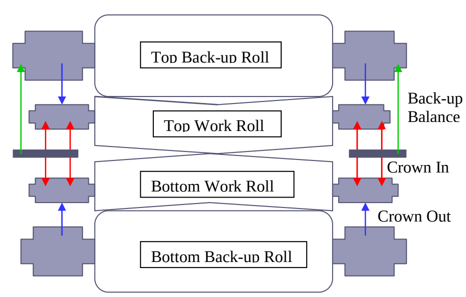

Fig. 5 Roll Bending Cylinders Actuation

- Existing roll bending & balancing systems and mill auxiliary units were made two separate units for better control and trouble free operation. Water hydraulic for the bending and balancing system had been converted into oil hydraulics with the commissioning of a new hydraulic power pack consisting of hydraulic pumps, different control valves, filtration units and pressure accumulator, etc as shown in Fig.8. The new oil hydraulic system has been retrofitted to the existing roll bending and balancing system for the actuation of 100kg and 200kg pressure line.

The system consists of variable volume pump controlled by a pressure compensator. The pressure compensator maintained the preset pressure by varying the volume of oil discharged by positioning a wobbling plate on the drive shaft of the pump piston. The delivery pressure of the pump ranged from 0 to 320bar. The pump suction was connected to a 10m^3 oil tank. A duplex type pressure filter was fitted in the discharge end of the pump ensuing 5μ filtration level of hydraulic oil to the directional control valves placed in each valve stand. These valve stands were located almost closer to application end of each Stand of the mill. The valve stands comprised of four directional control valve, bladder type accumulator and pressure gauges for ensuing steady and constant pressure to the hydraulic cylinders in the roll chocks. The system was protected by a pressure relief valve set at 0-100-200 bar with on/off solenoid valve. A plate type heat exchanger was also incorporated in the return line of the hydraulic circuit for cooling down the returned hydraulic oil prior to the entry to the oil tank. A duplex type return filter was fitted in the return line of the hydraulic circuit ensuing 20μ filtration level of hydraulic oil returning to the oil tank. The hydraulic pressure was controlled as per desired shape correction of the strip through visual observation.

- ❖ Leakages reduced through improving the clearance of the seal by hydraulic resistance. Proper sealing obtained by changing from low viscosity oil to high viscosity hydraulic fluid.

Viscosity of water and hydraulic oil at 288^{o}k & 1.0325x10*N/m2

	Dynamic Centipoises	Kinematics cst
Water	0.001x10*	1
Hydraulic oil	0.1x10*	46

- ❖ Pistons were redesigned with larger size and chrome plating carried out to each pistons to minimize scuffing and double seals were provided to each piston in order to arrest leakage of hydraulic fluid from the pistons. The surface roughness of the piston and cylinders had been optimised at 0.17micron to 0.24 micron for reduced co-efficient of friction. Maewest blocks modified for each stand to accommodate higher size bolts.
- ❖ Piston rubber seals were also redesigned with high heat resistance and low coefficient of friction. Nitrite poly acrylic or fluro-elastomer rubber was used as seal material. The surface area of the lips he seal increased for effective removal of heat generated at contact zone. Hydraulic fluid leakages reduced through the clearance by improving the hydraulic resistance of the seal. Seal performance factor (i) should be more than 0.

$$i = 1- m/m_p,$$

where m = actual mass of leak substance
m_p = permissible mass of leak substances
when $m<m_p$, $i> 0$ and when $m>m_p$, $i< 0$
Increase in surface area of the lips had helped for removal of heat generated at contact zone (Fig. 6 & 7).

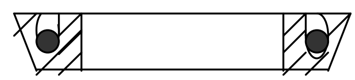

Fig.6 Old Seal

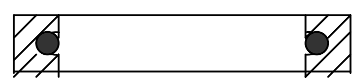

Fig.7 New Seal

- ❖ Changing of hydraulic fluid from low viscosity oil to high viscosity oil had helped for proper sealing. The oil film destruction minimized with the use of high viscosity oil. Change to oil hydraulics from water hydraulics responds more positively to additives and possesses better lubricating properties.

5 Result & Discussion

The modified roll balancing and bending system designed with oil hydraulic system, commissioned at all the Stands of TCM-II by varying the roll separating force as per the requirement for controlling the shape defects like centre buckles / edge waviness of the strip and processing of improved strip shape. Analysis of various parameters with the oil hydraulics for roll bending and balancing system has resulted in the following

- ❖ The modified system helped to correct the shape defects like edge waviness and centre buckles on rolled strip and reduced bad shape defect by 57%

- ❖ Flatness of rolled strip improved by 10%
- ❖ The system was easy to operate and retro fitted to existing roll bending system.
- ❖ Roll changing delay reduced from 30min to 15min of each stand
- ❖ Delay in Hydraulic 'A" system reduced from 6 hrs/month to 1 hr/month due to leakages
- ❖ Consumption of seals reduced by 80% due to modified seal design
- ❖ Reduction in leakages resulted in substantial saving of hydraulic oil by 25%
- ❖ Substantial reduction in seal consumption by 50%
- ❖ It also improved customer services by reduced customer complaints.

6 Conclusions

The following conclusions drawn based on the performance evaluation of the implemented modified system; equipments, components, etc were given below

❖The conversion of water hydraulics to oil hydraulics for actuation of hydraulic actuators of modified roll bending system at all Stands of TCM-II led to the following conclusions

- Corrected the shape defects like edge waviness and centre buckles on rolled strip and reduced bad shape defect by 57%
- Improved strip flatness by 10%
- Improved the shape and profile of the cold rolled strip
- Easy to operate and retro fitted to existing roll bending system.
- Reduced delay on account of roll changing by 50% of each stand due to faster operation
- Reduced customer complaint on account of bad shape.

❖Redesigning of piston, seals, maewest blocks and use of higher viscosity hydraulic oil had helped

- to reduce delay in Hydraulic 'A' system by 80%
- substantial saving on account of oil consumption by reduced leakages

❖ Trouble free operation with higher financial benefit to cost ratio 20:1

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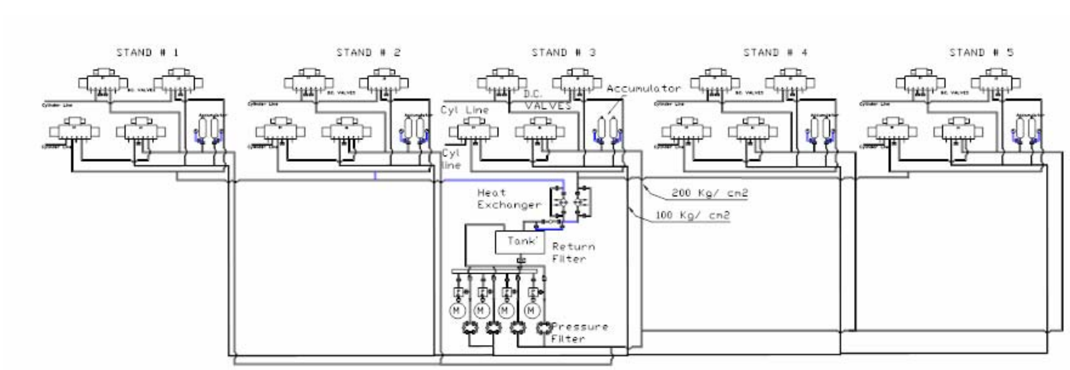

Fig. 8 Schematic Diagram of hydraulic arrangements of all valve stands after modification