Development of an ingenious composite roll system for merchant mill

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A recent international trend is to improve performance of rolls for use in wire, rod, and bar mills and upgrade the quality of rolled products. Further, attempts are being made to replace the existing mono-block system of roll by a composite roll. In composite roll design, toughened and shock resistant arbor is used as the basic module on which a hardened and wear resistant rolling ring is securely clamped in proper place with the help of a suitable locking device. In the present work, an attempt is made to design and develop a composite ring roll system such that the roll assembly becomes dimensionally as well as functionally same as a conventional mono-block roll system. The friction lock mechanical shrink fit device proposed in the composite roll system, has been developed based on the basic principle of friction lock. Torque is transmitted by friction between the contact surfaces of locking system, roll shaft and rolling ring, resulting from tightening of the screws. A scale down model of a composite roll is developed and tested thoroughly to assess its torque transmitting capacity. The results demonstrate the feasibility of a composite roll.

Keywords: Composite roll, Hot rolling, Circular wedge lock, Rolling ring

Introduction

Rolling is the most widely used metalworking process because it lends itself to high production and close control of the final product. Hot rolling is accomplished above recrystallisation temperature but below the melting point of the metal. The process of hot rolling basically consists of passing the hot billet through two rolls rotating in opposite directions at a uniform peripheral speed. During deformation of metal between the rolls the work is subjected to high compressive stresses from squeezing action of the rolls and to surface shear stresses as a result of the friction between the rolls and the metal. Therefore, work rolls for hot rolling mill should have superior resistance to compression and thermal shock. In addition the material of rolling mill, roll is required to have excellent wear resistant to meet the demand of high dimensional accuracy and surface smoothness of the rolled products.

The conventional rolling mill design, practiced in India, consists of mono-block cast or forged roll which can be made of either carbon steel or alloy steel. At present, this mono-block roll system cannot use advanced material like, high speed steel, tungsten carbide because it is expensive and difficult to manufacture. The rolls are used by repeated re-grindings till the end of roll life when the whole roll is replaced by another roll. The replaced roll evidently cannot be further used and becomes a scrap, leading to huge cost of inventory and wastage of costly material.

In recent years the improved performance of rolls for use in wire rod and bar mills as well as upgraded quality of rolled products has assumed significant importance. A demand is felt for high speed rolls in order to sustain in competitive market due to globalization of the world economy. High quality rolls composed of high-speed tool steel and tungsten carbide have been rapidly adopted as work rolls in the finishing stand of hot rolling mill. This is because of the demands for longer life of work rolls, higher quality of products, higher productivity etc. High speed tool steel and tungsten carbide are expensive materials and for their economical use the larger rolls should preferably have the composite design.
Composite Rolls

In a Merchant mill the roll that is used outside India, is of composite design wherein the arbor or the core portion of the roll is provided with a separate surface member such as, rolling ring, which comes into direct contact with the metal billet being subjected to rolling. This separate circular surface member has to be locked on to the arbor or the core portion of the roll. The strength requirement of a roll has to be such that the inner portion or arbor has to be toughened and shock resistant and the outer surface or ring has to be hardened and wear resistant. The prior art search covering literature, patent data bases, and industrial survey reveals that there are a few designs of composite roll. Such rolls have been formed either by shrink-fitting the rolling ring on the roll shaft or by pouring the metals of the arbor and ring separately into a mold as the roll is cast. A hard wear resistant rolling ring has poor tensile properties. When such a ring is shrink-fitted over an arbor, it is placed under a residual tensile stress which may cause it to break. When a ring and arbor are cast together of different metals the ring is metallurgically bonded to the arbor and cannot be separated when worn or damaged.

Over the past two decades, many composite designs have emerged in abroad. They are using roll shaft, ring roll and mechanism for fixing ring rolls securely in place. These ring rolls are assembled with shaft with other accessories so that on assembly the ring and shaft assembly is dimensionally the same as would be the case in the situation when using mono-block cast or forged roll with the conventional rolling mill. Some of the designs used for composite rolls are epoxy bonding, Belleville spring, and intermediate tapered sleeve.

At present there is a definite need for providing roll-locking unit in a composite roll for rolling metal billets and to provide an improved composite roll. In the present work, an attempt is made to design and develop a composite roll, consisting of suitable locking system for holding the rolling ring in proper position on the roll shaft in such a way that the ring roll-shaft assembly is dimensionally as well as functionally same as mono-block roll system.

Materials and Methods of Proposed Composite Roll

The present design comprising a circular wedge locking unit for a composite roll. The composite roll incorporating the said locking unit is described subsequently.
evenly using a torque wrench, diametrically opposite in two or more stages, until specified tightening torque is reached.

The tapered surfaces of the slit rings get engaged with corresponding taper surfaces of thrust pads. With the tightening of screws, the taper surfaces of thrust pad slide over the taper surfaces of slit rings, which result in elastic contraction of inner slit ring and elastic expansion of outer ring, thus producing mechanical shrink fit between shaft and rolling ring. The torque is transmitted by contact pressure and friction between four seating surfaces.

Hence the condition of the contact surfaces and the torque of tightening of the cap screws are important. All contact surfaces including screw heads and screw head bearing surfaces must be clean.

Analysis of Transmissible Roll Torque

The proposed locking system is designed to transmit rolling torque and dynamic load through various components of locking assembly from roll shaft to rolling ring. The amount of torque that can be transmitted by the locking system depends on the normal force \( F_n \) exerted between the roll shaft, locking mechanism, and rolling ring. The maximum permissible contact pressures are governed by the yield points of the materials. Force analysis of the locking assembly shows that:

\[
F_a = F_n \tan(\alpha + \rho),
\]

where, \( F_a \) = Total axial locking force given by tightening of screws, \( \rho \) = Angle of friction, \( \alpha \) = Taper angle (it should be greater than friction angle to avoid self-locking)

The transmissible torque \( T \) will be,

\[
T = \frac{F_a \mu d_s}{2},
\]

where, \( d_s \) = Roll shaft diameter and \( \mu \) = coefficient of friction.

Combining above two equations,

\[
T = \frac{F_a \mu d_s}{2 \tan(\alpha + \rho)}.
\]

One main advantage of this locking system is that actual stress conditions in the rolling ring or roll shaft are more predictable than in a thermal shrink fit. The improvement arises because the locking force in this wedge locking arrangement is determined by locking screw torque. Furthermore, minor machining tolerance deviations can be easily bridged by the locking system without affecting its performance. In a thermal shrink fit the induced stresses depend entirely on the final machined dimensions of the shaft and ring roll. If a single lock cannot transmit the required torque, several assemblies can be used in series. In that case the transmissible loads can be increased in direct proportion to the number of locking assemblies used.

Results and Discussion

The scaled down prototype is developed and experimental data is generated, by carrying out torsion test using Sushma torque wrench test rig of capacity 500 N-m, as given in Table 1.

The novelty of the present system has been achieved by the inventive step in the creation and relative positioning of the designed components and...
in the synthesis of the circular wedge locking assembly. This provides means for the rolling ring to sit firmly locked onto the roll shaft and also whenever needed, can be dismantled for replacement of either or any of the components. Further, it has made possible for the roll shaft, in billet rolling, to be re-used and not discarded after its life is over, by replacement of the outer active part of the roll. The locking mechanism of both the outer ring and the inside shaft is very strongly and reliably secured for longer duration of use, before the next replacement. It is a contribution to better maintainability.

Conclusions

In this paper, a locking system has been proposed for holding rolling-ring in proper position on the roll shaft. Composite roll ring model has been fabricated, based on the proposed design, and transmitted roll torque is estimated. The torque is transmitted by proper tightening of the clamping screws resulting in sufficient contact pressure and friction between the frictional surfaces. The proposed locking system is expected to have the following advantages:

(i) Locking between ring roll and shaft is possible without keyways, splines or close-tolerance fits,

(ii) Since the connectors grip by a mechanical shrink fit, there is no backlash and no high stress concentration,

(iii) Transmission of high torques is possible,

(iv) Easy assembly and dismantling,

(v) Completely tight fit around shaft,

(vi) Easy axial and angular adjustments.

The proposed composite roll design with ring rolls assembled on a roll mandrel, reduces the tooling cost of roll mill because only roll ring is replaceable and different shaped ring rolls can be used over the same roll shaft assembly. Composite-roll kind model has been fabricated based on the proposed design, and transmitted roll-torque is estimated.

References

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7 Uwe Kark, Composite roll with roll ring of material which is sensitive to tensile stress, US Pat 4099311, 11 July 1978.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Value</th>
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<tbody>
<tr>
<td>Outer diam. of the roll, mm</td>
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<tr>
<td>Diam. of the roll shaft, mm</td>
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<td>Outer diam of locking assembly, mm</td>
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<td>Number of tightening screw</td>
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<tr>
<td>Number of releasing screw</td>
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<tr>
<td>Tightening torque applied to each screw, N-m</td>
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<tr>
<td>Torque transmitted by locking unit during experiment, N-m</td>
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