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Case Study

Failure analysis of work rolls of a thin hot strip mill



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ABSTRACT

In hot rolling mills, premature failure of rolls is a major concern as it adversely affects the mill operation as well as production. Analysis of failed roll materials and actual rolling conditions in service are therefore necessary to understand the roll failure mechanism and thereby improve the wear resistance and extend the service life of rolls.

The hot strip mill referred here consists of six stands wherein high chromium (Hi-Cr) iron rolls and Indefinite Chilled Double Poured (ICDP) cast iron rolls are being used for finishing rolling of the strips in the last two stands. The thin strip mill produces strips in the thickness range of 1.0–12.7 mm. This work describes two different types of roll failure cases and their analysis which was carried out using destructive as well as non-destructive testing techniques (NDT). The cases are as follows:

- (a) Case I: enhanced ICDP bottom roll of fifth stand (F#5) which failed from the neck portion.
- (b) Case II: analysis of sub-surface defect of ICDP rolls of the last stand (F#6).

Destructive testing (including metallography and chemical analysis) was carried out on the failed roll samples in the first case and gross abnormality in microstructure was observed. Some foreign particle/entrapment was observed after dressing of the working surface of roll at 566 mm diameter (initial diameter of roll was 620 mm and scrap diameter was projected to be 540 mm). The chemical composition of the particle was analyzed by a portable X-Ray Fluorescence (XRF) alloy analyzer and it was confirmed that the particle is basically a ferroalloy which was entrapped in the shell of the roll, probably during casting/manufacturing of roll.

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1. Introduction

In line with the recent industrial development the demand for rolled steel sheet products is seeing a sharp surge today. Substantial increase in productivity and simultaneous reduction in cost of production is therefore a challenge for steel plants and particularly their strip and sheet rolling mills. This process route is considered to be more economical and productive than the conventional route. At this new facility, thin cast slabs are continuously fed to a tunnel furnace and then are immediately subjected to rolling operation. Rolls form one of the most important component categories in the last stages of

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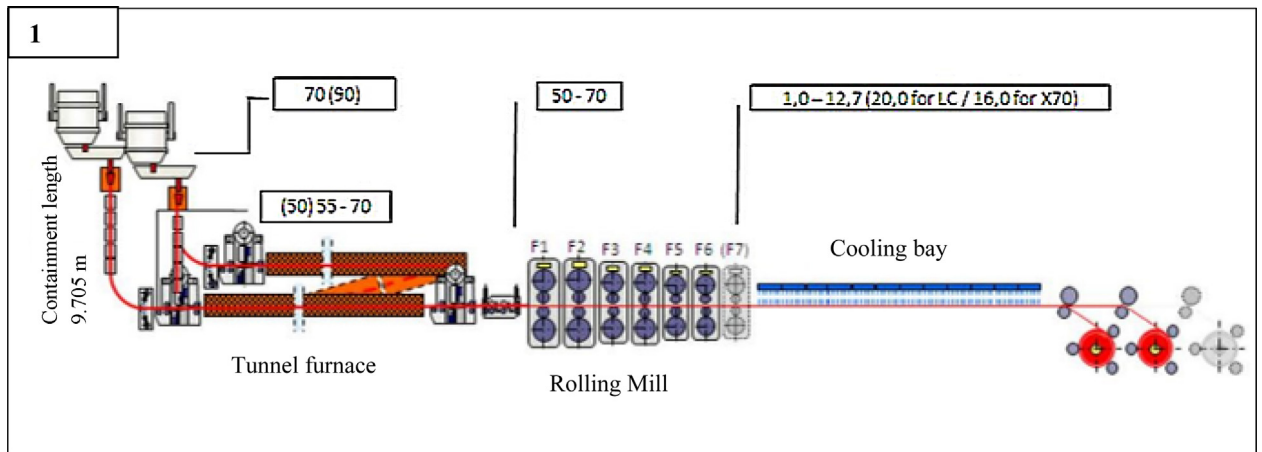


Fig. 1. The mill layout of LD#3, TSCR. Different zone has been shown in the fig.

the entire process route. It is very important to have the right quality of rolls for desirable rolling to produce flat products [1]. The thin strip mill produces strips of thickness in the range of 1.0–12.7 mm. The annual production of the mill is approximately 1.7 million tons. The schematic layout of the process flow of the mill is shown in Fig. 1.

There are six rolling stands out of which the last two are the finishing stands. After the casting operation, the slab is first passed through the tunnel furnace and then to the roughing stand. This is where maximum reduction in thickness is achieved. Following this, the material is passed through the finishing stand where the thickness is reduced further but the reduction after each single pass is much less as compared to a single pass in roughing stand. The finishing stand consists of 4 sets of rolls in F#5 to F#6. In finishing stand, surface finish rather than thickness reduction is the objective. Here the contact time and material temperature is lower than that in case of roughing stand [2]. The rolls in the finishing stand must have such property for the successful rolling operation like, (a) good wear resistance, (b) resistance to oxidation, (c) resistance to fire cracking, and (d) excellent surface finish which is vital for the finished product quality.

In the initial stands of rolling mill (F#3 and F#4) Hi-Cr cast iron roll is used, whereas, the ICDP cast iron rolls are used in the final finishing stands – F#5 and F#6. The shell of an ICDP roll consists of alloyed white cast iron and the core is made of spheroidal graphite (SG) iron. The shell hardness must be around 70–75 Shore C to achieve optimum strength and wear resistance property [3]. It is manufactured by both static casting method and centrifugal casting method. The shell matrix having proper distribution of carbides along with graphite particles dispersed in it imparts high wear resistance, stability in shape and good surface finish. The softer core ensures good mechanical properties and resistance to cyclic thermal and mechanical loads [4]. Failures of two different ICDP rolls have been discussed in the present study.

2. Case I: failure of enhanced ICDP bottom rolls of stand F#5

2.1. Background and visual observation

The rolls of F#5 stand of the Thin Slab Caster Rolling (TSCR) mill failed during operation. Visual observation of the failed component is shown in Fig. 2a–c which indicates that the fracture line had initiated from the outside and spread over the whole cross section starting from the fillet area. The closer view of the fracture surface showed ratchet marks on the periphery of neck portion. Thus the fracture surface indicates that the roll failed in brittle manner.

2.2. Chemical analysis

One small failed portion was collected from the broken portion and chemical analysis was carried out using combustion infrared technique (LECO, TC600) for carbon and sulphur contents. An Inductively Coupled Plasma Atomic Emission Spectroscopy (ICP-AES) instrument was used to determine amounts of rest of the elements. The chemistry of the roll sample confirmed it to be cast iron. As it was not feasible to cut or collect sample from the surface of the roll, chemistry of roll surface was analyzed using portable XRF alloy analyzer and the material was found alloyed iron. Carbon (C), sulfur (S), phosphorus (P), and silicon (Si) contents could not be analyzed by the portable XRF alloy analyzer equipment. Chemical analysis result is presented in Table 1.

2.3. Metallography

The failed sample was mounted and polished and etched with 3% nital and studied under microscope. Clusters of ferrite surrounding graphite were revealed in the microstructures. These clusters correspond to the shiny locations observed in the

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