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Recent Activities in Research of Casting

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This paper describes recent development of high speed tool steel type rolls (HSS rolls) as new work rolls for hot rolling as the primary subject together with the concept of developing the following processes and rolls: (1) Centrifugal casting production process for HSS rolls having superior uniformity and economy achieved by adding Nb and V together, (2) Former stand HSS rolls with the increased rolling load being suppressed by increasing the amount of eutectic carbide and (3) New high performance HSS rolls having remarkably improved surface deterioration resistance through strengthening of the carbide itself by remarkably increasing the Cr and Mo contents.

The body can be viewed from the next page.

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1 Introduction

Hot rolling methods have made great progress through pursuance of better quality rolled products and higher productivity and also have made technological innovations for actualizing schedule free rolling and continuous rolling in recent years.

Under such circumstances, the development of long-life rolls having superior wear resistance and surface deterioration resistance have been increasingly demanded in order to endure severe rolling conditions. As a type of new rolls to meet such requirements, the so-called HSS roll (high speed tool steel roll) was developed about ten years ago.[1,2] This roll is a compound roll having remarkably improved wear resistance with the shell material being made of high alloy composition corresponding to the high speed tool steel and with the matrix made of hard MC type carbide (mainly of vanadium or tungsten carbide).

Kawasaki Steel has concentrated its studies mainly on HSS rolls which would be the major work rolls for hot rolling and has studied the following subjects: (1) Production of HSS rolls by means of the economically advantageous centrifugal casting method, (2) Suppression of the increased rolling load when using HSS rolls and (3) New HSS rolls with highly improved surface deterioration resistance.

This paper reviews the studies on cast rolls over the last ten years.

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2 HSS Roll Production by Centrifugal Casting

In centrifugally casting high alloys of high speed tool steel type with high C and high V contents, segregation occurs in the carbide structure, and globular V-carbide segregates on the inside surface of the solidification shell with feathery V-carbide segregation on the outside surface. As shown in **Fig. 1**, this segregation is caused by a phenomenon that primary VC with a low specific gravity crystallized in the initial period of solidification is segregated inside of the solidification shell by centrifugal force, therefore, in order to suppress centrifugal separation, the following technological standpoints have been found to be effective. (a) Reducing differences in density between the V-carbide and the molten steel and (b) Avoiding duration for V-carbide to be crystallized and centrifuged by controlling the temperature close to that of γ-phase crystallization.

With respect to (a), we presumed that the difference in specific gravity could be reduced by adding Nb to the primary VC to make it (V, Nb)C double carbide so that its specific gravity increases. W carbide is often used for cast rolls because the wear resistance of the material improves by adding W, however, it has only a small effect and it is not indispensable. On the other hand, the specific gravity of molten steel increases by adding W. For these reasons, we considered it better not to add W. With respect to (b), we discovered that it is also possible to reduce the difference between the temperature of MC

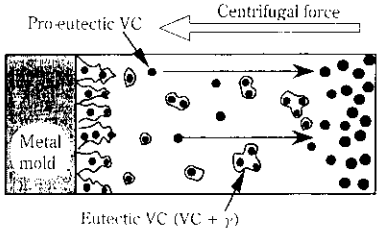

Fig. 1 Segregation mechanism of V carbide in inner surface side of a high C-high V steel roll during centrifugal casting

type carbide and the crystallization temperature of γ by adjusting the contents of Nb, V and C. Namely, we could have fair prospects of dissolving the problem of structural segregation caused by the difference in the specific gravities in centrifugal casting by adding an appropriate amount of Nb and thus balancing the compositions of C, Nb and V without adding W which had been considered essential for HSS rolls. Accordingly, we could actualize production of HSS rolls by means of centrifugal casting.[3,4] For the HSS roll production method by means of centrifugal casting, we were awarded the Technology Development Prize from the Japan Institute of Metals in 1993. We have recorded production of many HSS rolls of this newly developed type as latter stand work rolls for hot strip mills.

3 Development of Rolling Load Reduced Type HSS Rolls

When HSS rolls were used for the former stands of finishing mills at the early stage of development, the rolling load increased by 20–30% compared to conventional high Cr cast iron rolls and caused various problems including scale scratches. **Photo 1** shows the observation results for wear surfaces of a high Cr cast iron roll and an HSS type alloyed steel roll after hot wear tests.

In the case of the high Cr cast iron roll, the surface shows relatively gentle protuberances with the matrix being worn by abrasion and eutectic carbide coming up. Whereas, in the case of HSS roll, it can be seen that granular MC type carbide forms protuberances and the surface shows microscopically sharp irregularities. The increased rolling load with HSS rolls is considered to be caused by an increase in the friction coefficient against rolled materials due to irregularities of the roll surface. In other words, it can be understood that increasing the flatness of the wear surface of the rolls is effective for suppressing increased rolling load.

We developed reduced rolling load type HSS rolls which are designed to make it possible to increase the flatness of the wear surface by increasing the amount of eutectic carbide forming a quasi-hard phase as shown in **Fig. 2** and by suppressing abrasive wear of the matrix in

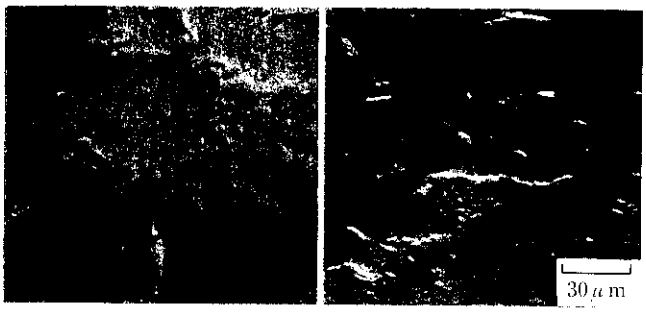

Photo 1 SEM images of wear surface of high Cr and HSS type alloyed steels after hot wear test

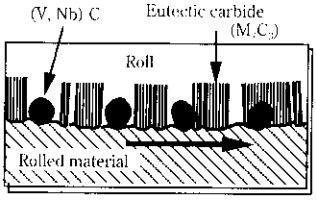

Fig. 2 Illustration of roll surface with low frictional resistance

MC type carbide.[5-7] We have confirmed that the rolling load of HSS rolls of the new composition is reduced to a level equivalent to that of conventional former stand high Cr cast iron rolls and that the wear resistance is superior to that of conventional HSS rolls. Many rolls of this newly developed type have been in use as work rolls for former stands of finishing mills.

4 Development of High Performance HSS Rolls with Remarkably Improved Surface Deterioration Resistance

Chipping and surface roughening of work rolls for former stands have a serious influence on the quality of products. Minute chipping of the roll surface is caused by cracks and fractures in carbide, therefore, it is effective for improving roll properties to suppress damage in the carbide itself. **Figure 3** shows the effects of adding amount of C, Cr and Mo and carbide on the wear resistance. It can be seen that wear resistance remarkably improves by adding adequate quantities of Cr and Mo together. Using various means of observation and analysis, we could infer that wear resistance improved because the carbide was toughened by increasing the contents of Cr and Mo.[8] This means that by increasing the toughness of the carbide itself and by increasing the quantity of toughened carbide, it can be expected to be possible to develop new former stand HSS rolls which have excellent surface deterioration resistance. The microstructure of high performance HSS rolls (Super-

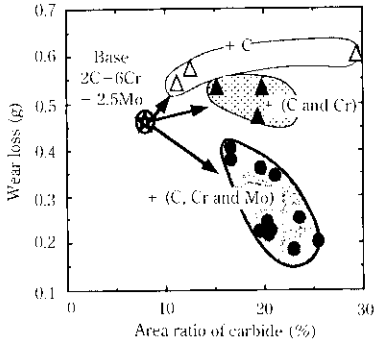

Fig. 3 Effect of area ratio of carbide on wear resistance

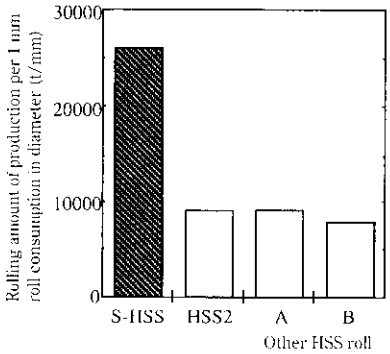

Fig. 4 Results of actual use at F1 stand in Mizushima Works

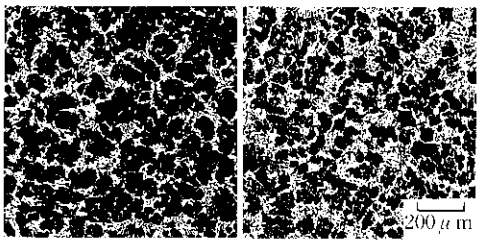

Photo 2 Micrographs of a developed and a newly developed centrifugal cast HSS rolls

HSS rolls) with well balanced highly increased quantities of C, Cr and Mo is shown in **Photo 2** compared with that of previously developed rolls. The results of actually using HSS rolls of various type are shown in **Fig. 4**. This roll performance index of the surface deterioration resistance is calculated as the cumulative product tonnage which could be rolled per 1 mm wear in roll diameter. As shown in Fig. 4, the value for super HSS rolls is near three times that of conventional HSS rolls and we could confirm the markedly superior rolling performance of Super-HSS rolls. These new rolls are increasingly installed and used in actual production lines at a very high pace at present.

5 Closing Remarks

This paper described the HSS rolls which are used as major work rolls for finishing mills. We have also been engaged in various tasks for development and improvement of quality of cast rolls shown below: (a) Ni gain cast iron rolls produced by suppressing structural segregation in the radial direction, (b) Graphitic adamite rolls for shape steel rolling having excellent antiseizure and wear resistance properties and (c) Austemperring treatment in order to improve the wear resistance properties of cast rolls.

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