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# Material Properties of High-Speed Steel Rolls

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***Abstract*— Recently, it has been required to improve the material properties of high-speed steel (HSS) rolls, because of the low wear resistance and low mechanical properties. To improve them, several new steels have been proposed, which have high wear resistance as well as excellent mechanical properties, e.g., hardness and tensile properties, where additional elements (V, Cr and W) were employed. However, their steels may have still technical issues, as the roll surfaces become roughened during the production process. The reason for this problem is found to be affected by the oxidation of the HSS surface. In this work, we have provided the suggestions to make high wear resistance of the HSS rolls.**

***Index Terms*—high strength streel, rolling process, wear property, mechanical property**.

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## I. INTRODUCTION

In recent years, hot roll process (Fig. 1) to make various engineering materials is significantly important in our industries. In fact, the production amount of the rolling steel increases. Basically, a number of hot rolling steels have been made of conventional graphite cast-iron. However, the wear resistance is very low, so improvement of the mechanical properties of steel rolls is required. To make this, several alloying elements, e.g., Cr, V and W, were added to the conventional steels, i.e., HSS (high speed steel) [1,2]. With addition of the chemical elements, the microstructural characteristics could be created with complicated structure. This occurrence may lead to the high hardness of HSS [3]. The mechanical properties of HSS are much higher than that for the graphite cast-iron.

The HSS rolls, made by the centrifugal casting at Sumitomo Heavy Industries Himatex Co., Ltd. (SHI), have been used in several industries. Although the material properties have been improved for the HSS rolls, those steels have still technical issues, since the failure on the surfaces of the HSS roll occurs in a short period of times. Fig. 2 displays the schematic and actual photograph showing the surface of HSS roll. As seen, rough HSS surface is observed. To solve this, some industries have tried to interpret the reason, but it could not be clarified yet. Hence, an attempt was made to reveal the cause of the failure in the present study.

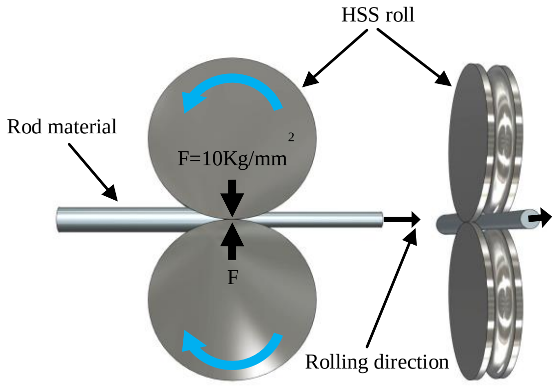


Fig. 1 Schematic illustration showing hot rolling process.

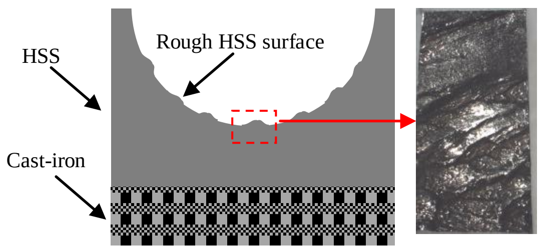


Fig. 2 Schematic and actual photograph of the surface of the HSS roll.

## II. EXPERIMENTAL PROCEDURE

In the present research, some HSS rolls, made by SHI, were employed. Table 1 indicates chemical composition of the HSS roll. The HSS samples with round plate shape were made by the centrifugal casting at about 600 rpm. The outside and inside of the HSS roll are formed by two layers (HSS and cast-iron), i.e., laminated structure. In this case, the HSS sample is worn away, which makes rough HSS surface and severe damage. The worn area on the HSS roll is created in the different area of the surface. This can be caused by the high stress and corrosion

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of the HSS roll during the production. In this case, high stresses arising from the heating-cooling (with water) and applied pressure would be affected mainly.

Table 1 Chemical composition of HSS roll (wt.%).

| C | Si | Mn | Ni | Cr | Mo | W | V | Co | Fe |
|---|---|---|---|---|---|---|---|---|---|
| 1.68 | 0.42 | 0.34 | 0.14 | 8.21 | 5.22 | 1.38 | 6.56 | 1.44 | Bal |

## III. RESULTS AND DISCUSSION

Fig. 3(a)(b) shows the optical micrographs and EDX analysis of the roll sample, where cross-section of the roll is observed. It is clear there are two different materials (HSS and cast-iron), and different microstructural characteristics are observed. From the EDX analysis, V, W and Mo based eutectic phases are created in-between the grains in HSS [3]. On the other hand, round shaped graphite is observed in the cast-iron. Note that in the area around the boundary between the HSS and cast-iron, large porosities are detected. For revelation of the mechanical properties of the roll sample, the hardness measurement was carried out.

(a) Optical micrograph

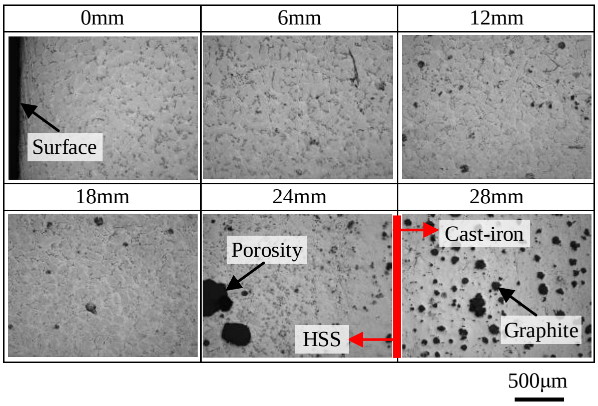


Fig. 3 cont.

Fig. 4 shows the Vickers hardness results of the HSS and cast-iron. The hardness of HSS adjacent to the surface is about 580HV, and the hardness level decrease slightly even in the HSS sample near the cast-iron, e.g., less than 500HV. This could be attributed to the change of the grain size caused by the different solidification rate during the casting process. On the contrary, low hardness values can be detected in the cast-iron, e.g., 300HV.

To further understand the mechanical properties of our samples in details, the hardness measurement was conducted in several specific microstructures. In this approach, the hardness indentation was directly loaded on the representative phases at the low applied load. The obtained hardness data and the related micrographs are shown in Fig. 5. As seen, very high hardness is obtained in the V based structure, about 1000HV. In Mo based phases, high hardness of about 600HV is detected. In contrast, much low hardness approximately 25HV is seen in graphite of cast-iron.

(b) EDX analysis

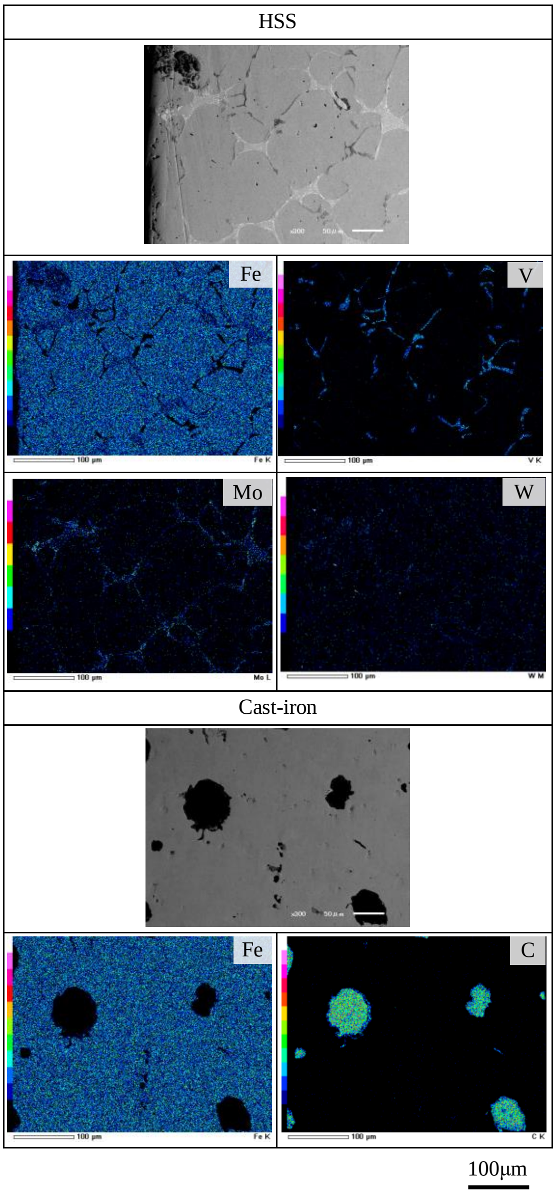


Fig. 3 Microstructural characteristics of the HSS and cast-iron: (a) optical micrographs; (b) EDX analysis.

To examine the failure characteristics of the HSS sample, EDX analysis was conducted on the HSS roll around the surface. Fig. 6 shows the SEM images of the failure HSS sample. From this analysis, it could be clarified that there are many cracks generating from the surface; moreover, slightly dark regions are seen around the cracks and on the surface [4,5].

From the EDX analysis, the dark areas are found to be related with oxide as indicated in Fig. 7, where high amount of oxide element (30%) is detected. It is considered that the material properties of the oxidation zone would be brittleness, so the related regions could be removed during the rolling process. Hence, the oxidation area could be worn away, leading to the rough surface of HSS roll. On the basis of this, the associated wearing mechanism can be explained using models shown in Fig. 8.

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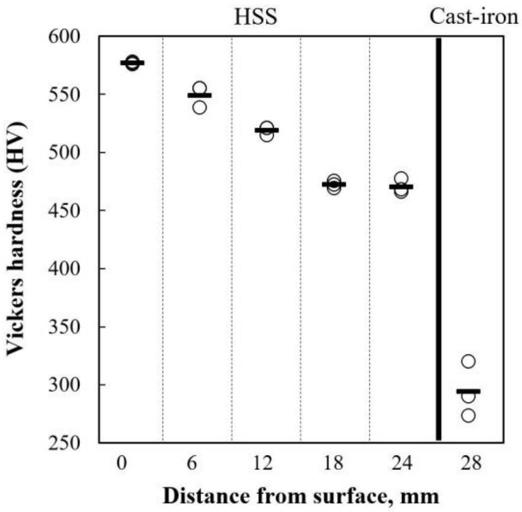
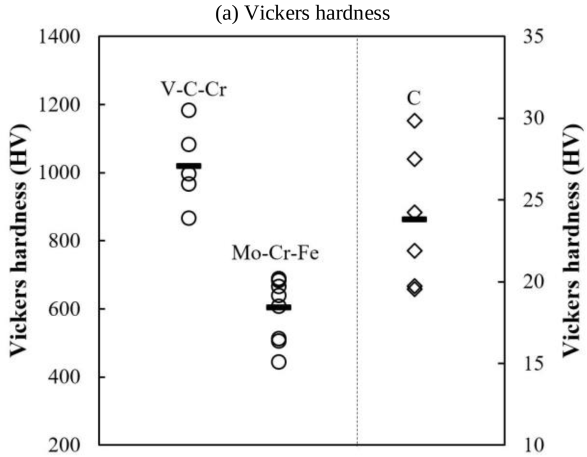



Fig. 4 Vickers hardness of the HSS and cast-iron.

(a) Vickers hardness




(b) Optical micrograph

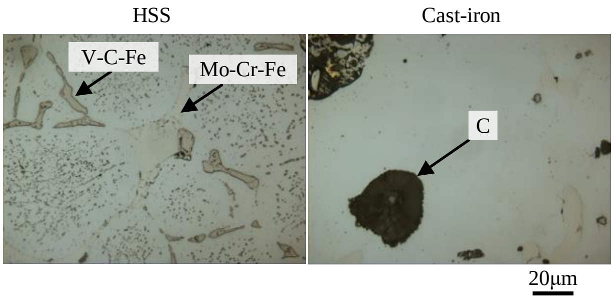



Fig. 5(a) Vickers hardness of the specific eutectic phases of the HSS and cast-iron; (b) optical micrographs of both samples showing the microstructures.

## IV. CONCLUSIONS

1) High strength HSS rolls made by SHI are clarified. This is attributed to the complicated microstructure arisign from V-C-Cr phase. This phase has high hardness above 1000HV.
2) The surface of HSS rolls is worn away resulting in rough HSS surface. This would be affected by the oxidation ununiformly distributed on the surface and around the cracks.

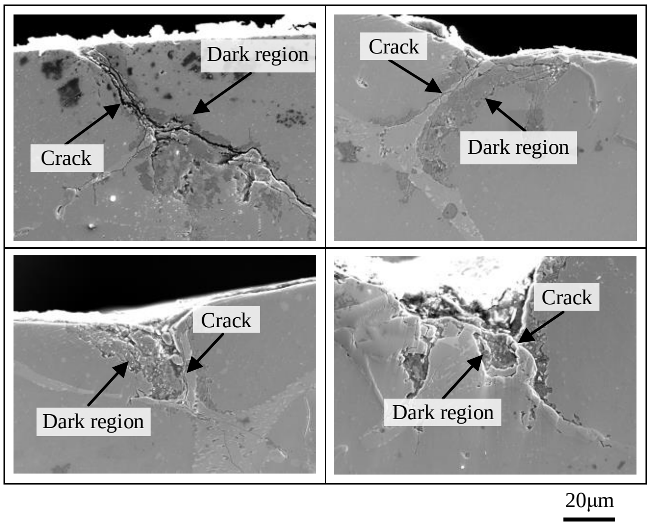



Fig. 6 SEM images of the HSS roll showing the oxidation characteritics around the suface and cracks.

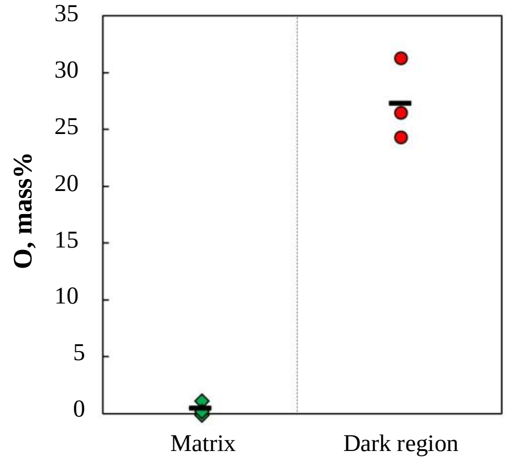



Fig. 7 EDX analysis with oxide on the matrix and dark regions.

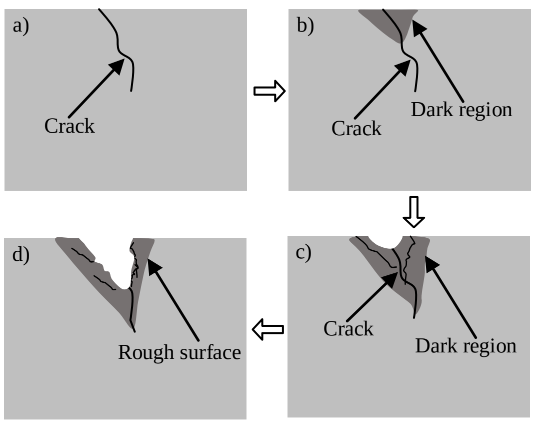



Fig. 8 Wearing model for the HSS roll during the production process.

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