EFFECT OF HOT ROLLING CONDITION ON TEXTURE OF COLD ROLLED AND ANNEALED ULTRA-LOW-CARBON STEEL SHEET

S.HASHIMOTO, T.KASHIMA AND T.INOUE

Iron & Steel Research Laboratories, Kobe Steel, Ltd.

INTRODUCTION

The r -value of cold rolled steel sheet is affected greatly by the properties and production process of the hot rolled steel sheet. It has been pointed out that the r -value of Al-killed steel^{1, 2} or Ti added-ultra-low-carbon steel³ hot rolled under A_{r3} is lower than that rolled in the γ region, and furthermore, it has been concluded that it was necessary to hot roll the steel in the γ region in order to ensure a high r value. On the other hand, the results reported in recent works⁴⁻⁸ have shown that the r -values of the hot rolled sheet hot rolled in the α region were high, which suggests that the r -value of the cold rolled sheet hot rolled in the α region were not necessarily low. The difference results from the lubrication condition during hot rolling which affects the formation of a sheared texture. In order to prove the suggestion mentioned above and elucidate the effect of hot rolling temperature on the r -value of cold rolled sheet, the authors performed the hot rolling in highly lubricated conditions so as to eliminate the inhomogeneity throughout the thickness of the steel sheet.

EXPERIMENTAL MATERIALS AND PROCEDURES

The chemical composition of the steel used in this experiment is as follows: C/0.0020, Si/0.02, Mn/0.11, P/0.002, S/0.008, Al/ 0.024, Ti/0.032 wt%.

Plates of 20mm thick were reheated to 1150 °C and rolled to a 10mm thickness through two passes in the γ region. Subsequently they were isothermally heated for 3 min. at different temperatures from 950°C to 750 °C and then underwent final hot rolling of 50% using tallow as a lubricant. In this paper the isothermal holding temperature is denoted by FET (Final hot rolling Entering Temperature). After being pickled, these hot rolled sheets were cold rolled with a reduction of 70, 80, 90 or 93% and annealed at 750 °C for 3h. The (200) pole figures and X-ray integrated intensity of low index crystalline plans were determined and are denoted by I(222), I(200) etc.

EXPERIMENTAL RESULTS AND DISCUSSION

The R-Value of Cold Rolled Steel Sheet

Ar₃ and Ar₁ temperatures of this steel were 880°C and 855°C respectively. The recrystallized ferrite grains did not begin to mix until the temperature was lowered to 820 °C. A small amount of recrystallized α grains still appeared at 750 °C.

The relationship between the r-values and FET, as well as cold rolling reduction (CR), is shown in Figure 1. The r-value increased with the

Figure 1 Effects of hot rolling temperature and cold reduction on r-value.

decrease of FET in the case of 70 or 80% CR. The opposite behavior was obtained for the steel cold rolled by 93%. In the case of 90% cold rolled steels, a high r -value, 2.35, was obtained for all FET range, and the effect of FET on the r -value was not obvious.

Figure 2 shows the relationship between r -value and CR for the FET 750 °C, i.e., hot rolled in the non-recrystallized region of α , as well as for the FET 880 °C, i.e., hot rolled in the range from the intercritical region to the recrystallized region of α . In the case of steel hot rolled at 750 °C, the maximum r -value, 2.3, was obtained in the range of a CR of 80-90%, and the r -value of the steel cold rolled by 93%

decreased to 2.0. Also the anisotropy was changed from a V shape through a linear shape to an inverse V shape. On the other hand,

in the case of the steel hot rolled at 880 °C, at a CR of 70 and 80%, the r -value decreased greatly for FET=880 °C, while it reached a maximum at a CR of 90%. At a low CR, the anisotropy showed a larger V shape than that for FET=750 °C, and no inverted V shape appeared at a CR of 93%. The steel hot rolled in the non-recrystallized region of α showed the maximum r -value at a lower cold reduction as compared with the steel hot rolled in the region of recrystallization region of α mentioned above or the steel hot rolled in the region of γ .

Figure 2 Effect of hot rolling temperature on relationship between r -value and cold reduction.

Texture of Cold Rolled and Annealed Steel Sheet

The effect of CR on (200) pole figures of cold rolled and annealed steel sheets being hot rolled at 750 °C is shown in Figure 3. As the CR was increased on the order of 70,80, and 90%, the intensity of near {554} <225> was increased, while that of {100} <011> was reduced. As the cold reduction was raised to 93%, the intensity of {554} <225>, with rotation around RD-60 ° // <110> which takes place usually under high CR, was further increased. Besides the intensity of {100} <011> was stronger than that of CR of 70% and I(222)/I(200) became the lowest, resulting in a low r-value, as shown in Figure 2.

Figure 3 Effect of cold reduction on (100) pole figures of cold rolled and annealed steels. (FET=750°C)

Textural Changes Through Each Process

The effect of FET on the (200) pole figures of hot rolled sheets, cold rolled sheets and annealed sheets is shown in Figure 4. The rolling texture developed during hot rolling at 750°C was similar to that formed after cold rolling of low reduction. With subsequent cold rolling of 70%, the main component, {112} <110>, was developed strongly, and after annealing, a near {554} <225>

was developed. On the other hand, with hot rolling at $FET=880\text{ }^{\circ}\text{C}$, a $\{110\} \langle 001 \rangle$ component was formed in the hot rolled sheet, and $RD//\langle 110 \rangle$ fibre texture shown in the cold rolled sheet of $FET=750\text{ }^{\circ}\text{C}$ was not well developed after cold rolling of 70%. After annealing, $ND//\langle 111 \rangle$ fibre texture was weak, and conversely the $\{100\} \langle 011 \rangle$ component was strong compared with the annealed sheet of $FET=750\text{ }^{\circ}\text{C}$.

Figure 4 Effect of hot rolling temperature on (100) pole figures of hot rolled steels, cold rolled steels and annealed steels.

The effect of FET on hardness and $I(222)$ of hot rolled sheet, $I(222)$ of cold rolled sheet and r -value of annealed sheet is shown in Figure 5. The hardness and $I(222)$ of hot rolled

Figure 5 Effect of hot rolling temperature on hardness and $I(222)$ of hot rolled steels, $I(222)$ of cold rolled steels and r -value of annealed steels.

sheets shows almost the same tendency. The larger the amounts of deformed ferrite retained in the steel, the higher would be the value of $I(222)$. The change in $I(222)$ of a cold rolled sheet with FET was almost the same as that of a hot rolled sheet. The deformed texture in the sheet hot rolled in the non-recrystallized region of α evidently promoted the formation of cold deformation texture in subsequent cold rolling. Correspondingly, a high r -value was obtained in 80% cold rolled sheets through the high $I(222)$ and low $I(200)$ of annealed texture.

CONCLUSION

Only hot rolling in the non-recrystallized region of α resulted in a satisfactory development of the rolling texture in the hot rolled sheet. With this type of hot rolled sheet as the basic material and subsequent cold rolling of low reduction, the recrystallization texture of ND// $\langle 111 \rangle$ after annealing was correspondingly well developed, resulting in a high r value in spite of the low cold reduction.

REFERENCES

1. S.R. Goodman et al., *Metall. Trans.*, 1(1970), p.1629
2. S.D. Bhole et al., *Met. Sci.* 8(1974), p.277
3. H. Saitoh et al., *Proc. THERMEC 88, Tokyo*, p.628
4. S. Hashimoto et al., *Proc. ICOYOM 8, Santa Fe*, p.673
5. T. Senuma et al., *Tetsu-to-Hagane*, 73(1987), p.1598
6. S. Hashimoto et al., *Tetsu-to-Hagane*, 74(1988), p.1617
7. T. Nakamura et al., *Proc. THERMEC 88, Tokyo*, p.644
8. S. Hashimoto et al., *Proc. THERMEC 88, Tokyo*, p.652