Kawasaki Steel has tried to enhance the accuracy of microstructure control for developing various types of automotive ferrous materials having markedly improved properties, as well as to develop technologies for effectively using ferrous materials.

This paper outlines two examples of newly commercialized automotive steel sheets. The first is a new high strength hot rolled steel sheet that has excellent strain age hardenability, the tensile strength of which is increased by paint baking treatment (BHT steel sheet). The second is a highly formable high strength hot rolled steel sheet obtained by applying dynamic recrystallization to refining crystal grains (Super HSLA steel sheet).

ing tensile strength of the materials. The new and conventional steel sheets show identical correlation between the absorbed energy and tensile strength when tested in the as-produced condition. When they were tested after giving 10% prestrain and paint baking treatment, the absorbed energy showed a positive correlation with the tensile strength of each material. However, the absolute value of absorbed energy for the newly developed steel sheet is higher than that for the conventional steel sheet. The absorbed energy is increased by work hardening for both the conventional steel sheet and the newly developed steel sheet, but for the latter there is also the contribution of tensile strength increase due to strain age hardening. The contribution of strain age hardening is equivalent to the tensile strength increase of about 60 MPa in as-produced materials. The tensile strength increase (BHT) observable in normal tensile tests appears also in high strain rate tensile tests.

Based on the data obtained in this test, FEM analysis was carried out to evaluate the effect of the newly developed steel sheet on improving crashworthiness when used as a structural member of a vehicle. It was found that the contribution from the strain age hardening corresponds to a half-gauge (0.1 mm) increase in the sheet thickness and to a 60 to 70 MPa increase in tensile strength. Thus, it was confirmed that the newly developed steel sheet can make a vehicle significantly lighter as thinner gauge sheets can be used. It also helps make a vehicle lighter thanks to its excellent formability for various parts of complex shapes that are difficult to form, thus reducing the strength of sheet required for such parts.[3)]

Conventional steel sheets that have strain age hardenability suffer deterioration of mechanical properties while held at room temperature. In contrast, the newly developed steel sheet held at room temperature for one year showed only negligible changes in properties: the tensile strength showed almost no change, the yield strength increased by about 30 MPa, and the elongation lowered only by 1%.

The newly developed steel sheet is produced by controlling the chemical composition and grain size of steel and is characterized by excellent strain age hardenability and less deterioration of properties by room temperature aging.

The newly developed steel sheet allows crashworthiness to be improved without increasing vehicle weight, or conversely a vehicle to be made lighter while maintaining crashworthiness, and is expected to make a significant contribution to safety and environmental issues associated with motor vehicles. It was already reported that the use of this steel sheet for anti-collision members reduced the weight of a mass-produced vehicle by more than 10%.[4)] This steel sheet is expected to be widely used in motor vehicles in the future.

3 Highly Formable High Strength Hot Rolled Steel Sheet Obtained by Applying Dynamic Recry Applyi 10 363.. ( )14. fbrlT T (Recpes that 2a2Se m5. it was confirarou0.05 Tm so elas2l sheet16 It w (loa

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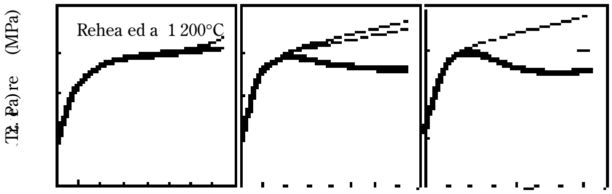

tic. In other words, Ti does not cause much grain elongation, which deteriorates hole expansion, even if the rolling temperature moves from the dynamic recrystallization region to the static recrystallization region near the final pass of hot rolling.

Steels having different Ti contents were experimentally prepared, reheated to different temperatures, and compressed at 850°C, a temperature corresponding to the finish rolling temperature zone in hot rolling. The relation between true stress and true strain was examined in each case (**Fig. 5**). When a material undergoes dynamic recrystallization, its true stress-true strain curve exhibits a particular shape that has a peak. The stress increases with increasing strain until the strain reaches a certain strain level (ε_p), where it shows the peak stress (σ_p), then begins decreasing and becomes constant after the strain passes a certain value. These curves show that dynamic recrystallization tends to take place when the Ti content is high, and the reheating temperature is low. This is because the amount of TiC precipitation increases with decreasing compression temperature, and accordingly the γ grain size becomes smaller. In the case of low-carbon steel as in this test, dynamic recrystallization takes place even in the finish rolling region when the austenite grain size is less than about 50 μm.

The values of the peak stress obtained by the compression test were plotted against the values of the parameter (**Fig. 6**), and used to calculate the apparent activation energy. The value obtained was 340 kJ/mol, which is near the self-diffusion activation energy of iron (285 kJ/mol). Thus, dynamic recrystallization that takes place in these materials is interpreted with good consistency in terms of activation energy as well.

The ferrite grain sizes in the materials experimentally compressed to the true strain of 0.7 and cooled at a rate of 50°C/s were plotted as a function of reheating temperature (**Fig. 7**). The ferrite grain sizes in the materials in which dynamic recrystallization took place (shown by solid keys in the figure) are markedly smaller than those in the materials in which static recrystallization took place. Thus, it was confirmed that a microstructure with very fine and uniform grain sizes of less than 5 μm was obtained by dynamic recrystallization.

3.2 Material Properties of the New Steel Sheet

Currently, the Super HSLA steel sheets of 590 MPa class and 780 MPa class are being produced at Chiba Works. In both classes of steel sheets, it was confirmed that the flaw stress is reduced by 10 to 20% during finish rolling, and that dynamic recrystallization can be achieved in a commercial hot rolling process. **Photo 2** shows the microstructures of the newly developed Super HSLA steel sheet and conventional HSLA steel sheet. The average ferrite grain size in the conventional steel sheet is 6 to 7 μm, while that in the Super HSLA steel sheet is as fine as about 2 μm. Thus, the company was the first in the world to successfully produce, on an industrial scale, steel sheets that have ultra-fine grains.

The EBSD (electron back scattering diffraction) analysis of the microstructure of the newly developed steel sheet confirmed that the boundaries of adjacent grains have high angles of more than 15°. **Table 2** shows the mechanical properties of the newly developed steels of 590 MPa class and 780 MPa class. **Figure 8** compares the elongation and hole expansion ratio of the newly developed steel sheet of 780 MPa class those of the conventional HSLA steel sheet. Both elongation and hole expansion ratio are improved, whereas generally in the past, it was difficult to improve these two properties