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Mechanism of Roughness Profile Transfer in Skin-pass Rolling of Thin Steel Strip

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Abstract:

Skin-pass rolling (or temper rolling) is usually the nal process in the production of cold-rolled steel sheets. One of the main objectives in skin-pass rolling is to obtain a certain surface roughness pro le. In this paper, the mechanism of roughness pro le transfer in skin-pass rolling is investigated by experimental rolling tests as well as numerical analysis by elastic-plastic FEM in terms of material deformation and lubrication. Roughness transfer in skin-pass rolling could be modeled as vertical indentation of the roughness pro le because the peak pressure which can be estimated by Hertzian elastic contact is the most important parameter. The effect of

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tion. In addition to these characteristics, the work roll surface is intentionally roughened in some cases to achieve a required strip surface roughness. Because these conditions are quite different from those in conventional hot and cold rolling, conventional rolling theory is not appropriate for analysis of the skin-pass rolling process. To date, calculation of skin-pass rolling

were conducted. The work roll surface was prepared to be 3 μm Ra in the axial direction under the measurement conditions of cut-off of 2.5 mm and measurement length of 12.5 mm. The similar skin-pass rolling experiment was conducted with another laboratory rolling mill with a small work roll of 100 mm diameter (R50 in the following figures) to evaluate the effect of be estimated by vertical indentation at the same load in this figure. That is to say, it is strongly implied that the peak pressure is the dominant parameter for roughness transfer in the case of a large roll.

[12] shows the results of the FEM analyses considering work roll surface roughness. This figure shows the relationship between the local average pressure for one roughness profile in the contact length and the roughness transfer at that profile point in the skin-pass rolling condition. The vertical compression condition and the indentation condition of one roughness profile in Fig. 4 are also drawn with the dashed line. The roughness transfer values for those two conditions almost coincide and are drawn with one line.

In the case of the skin-pass rolling condition, the origin corresponds to the entrance point of the contact length. As rolling progresses, roughness transfer increases along with pressure. The maximum value on the abscissa corresponds to the point of peak pressure, and afterward the pressure decreases moving left on the abscissa and becomes zero, meaning the delivery point of the contact length. The roughness transfer at the peak pressure in the skin-pass rolling condition was in good agreement with the results of vertical compression and simple indentation of the roughness profile. This means that roughness transfer at the peak pressure can be considered to be vertical indentation of the roughness profile in terms of the characteristic of the skin-pass rolling condition, in which a large contact length and sticking region lead to high hydrostatic pressure around the center of the contact length, as revealed in Chapter 2. As a matter of fact, roughness transfer can be organized by peak pressure as shown in Fig. 5, and the peak pressure can be approximated and simplified as Hertzian contact as in Fig. 2.

Although the calculated roughness transfer tends to increase after the peak pressure in Fig. 6, the actual effect is negligible, as can be recognized from Fig. 5. The calculated increase of roughness transfer is due to the relative slide between the work roll and the workpiece in the forward slip region near the delivery point of the contact length, leading to so-called junction-growth. The same tendency was studied in a plane strain upsetting test with small reduction[17, 18].

As is also obvious from Fig. 5, roughness transfers cannot be quantitatively compared between large and small work roll conditions. The characteristic behavior of roughness transfer in skin-pass rolling is obtained as a result of the long contact length of the large work

(CRL) with viscosity of 19 mm^2/s at 50˚C. The lubricants in the neat condition were applied sufficiently to the workpiece and work roll surfaces with a brush before rolling.

In addition to average roughness (*Ra*), the height characterization parameters of the linear material ratio curve defined in ISO 13565 were also evaluated to clarify quantitatively the effect of lubrication on roughness transfer. The parameters used here were the core roughness depth (*Rk*), which expresses the general tendency of roughness transfer, reduced valley depth (*Rvk*), which expresses the average depth of deep pits on the workpiece surface by indentation from roughness profile peaks on the work roll surface, and reduced peak height (*Rpk*), which expresses the average height of protruding peaks above the roughness core profile toward hollows in the work roll surface roughness profile.

[15] shows the relationship between rolling force and the roughness transfer ratio. The transferred roughness was decreased with lubrication above the rolling force of 1 kN/mm, corresponding to elongation of approximately 0.5%. The effect of lubrication differed between the skin-pass rolling and vertical compression conditions. With the small work roll (R50), the tendency did not coincide quantitatively with that of the large work roll (R250), and no effect of lubrication could be observed.

[15] shows the measured values of *Rk* and *Rvk* after rolling. At a very small elongation, *Rvk* increases rapidly, implying formation of pits on the workpiece surface by indentation from roughness profile peaks, and reaches a constant value at elongation of approximately 1%. In this elongation range, the lubricant escapes into spaces between the roughness profiles, and virtually no effect of lubrication on roughness transfer can be seen. Above this elongation limit, the core roughness profile on the work roll surface is transferred to the workpiece surface, resulting in the increase of *Rk* of the work roll surface. The effect of lubrication appears as the difference in the transfer of the core roughness depth *Rk*. This implies that the lubricant trapped between the roughness profiles disrupts roughness transfer. As a lubricant with larger viscosity is used, the effect becomes more intense. Although not shown here, the results confirmed that no effect of lubrication on *Rpk* could be seen.

As discussed above, the effect of lubrication on elongation and roughness transfer was quite reasonably explained by the height characterization parameters of the linear material ratio curve.

In this report, the results of an experimental and analytical investigation of the mechanism of roughness transfer to the workpiece surface in skin-pass rolling were introduced and discussed from the viewpoints of workpiece deformation and lubrication. One of the important characteristics of skin-pass rolling is the use of work rolls having a large diameter compared to the reduction in thickness, resulting in a long contact length with large hydrostatic pressure around the center. Due to this characteristic, the roughness transfer in skin-pass rolling can be modeled as simple vertical compression, and the peak pressure, which is the most important parameter for roughness transfer, can be estimated by Hertzian contact theory. The effect of lubrication is explained clear(en-US)/MCIdple v material ratio curve. After the peaks of the roughness profile on the work roll surface are transferred to the workpiece surface under small elongation, lubricants are packed between the surfaces, reducing further roughness transfer. The small-diameter work rolls commonly used in laboratory rolling mills are not appropriate to model the characteristic phenomena in skin-pass rolling in terms of contact length.

Investigation of the above-mentioned mechanism in skin-pass rolling has progressed as it has become possible to consider surface roughness in FEM analyses. Further incr BT0 CID 579mTEMC /Span en-US