The Sims Power and Labour PyRoll Plugin

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May 10, 2022

This plugin provides the roll force and roll torque model developed by R. B. Sims Sims [1]. The basic equations are derived from classic strip theory with suitable simplifications suitable for hot rolling (e.g. static friction, neglect of elastic material behaviour). Usage of the equations for groove rolling is only valid, when using a equivalent rectangle approach. Heights used for calculation and therefore equivalent values for a equivalent flat pass. In contrary to the original work by Sims, the current implementation doesn't integrate a flattened roll radius but calculates the roll force and torque using the nominal roll radius R. Furthermore, the used variable h is the height of the equivalent flat workpiece, $k_{f,m}$ represents the mean flow stress of the material and ϵ the reduction of the equivalent pass in height direction. The indices 0 and 1 denote the incoming and exiting profile.

1 Model approach

To calculate the roll force in hot rolling, the following equation was developed:

$$F_{Roll} = k_{f,m}\sqrt{R\Delta h}Q_{Force}(\frac{R}{h_1}, \epsilon_h) \tag{1}$$

The function Q_{Force} is a which combines the influence of the reduction of the pass. This function depends on the height of the workpiece at the neutral line h_n. Calculation of the neutral line angle is done through equation 2b and the height of the workpiece dependent on the roll angle α is express with equation 2c.

$$\begin{split} Q_{Force} = \frac{\pi}{2}\sqrt{\frac{1-\epsilon}{\epsilon}}\arctan\left(\sqrt{\frac{\epsilon}{1-\epsilon}}\right) - \frac{\pi}{4} - \sqrt{\frac{1-\epsilon}{\epsilon}}\sqrt{\frac{R}{h_1}}\log\left(\frac{h_n}{h_1}\right) + \\ \frac{1}{2}\sqrt{\frac{1-\epsilon}{\epsilon}}\sqrt{\frac{R}{h_1}}\log\left(\frac{1}{1-\epsilon}\right) \end{split} \tag{2a}$$

Table 1: Hooks specified by this plugin.

Hook name	Meaning
`equivalent_height_change`	Equivalent height change Δh
`equivalent_reduction`	Equivalent reduction ϵ
`equivalent_neutral_line_angle`	Equivalent angle of neutral line α_0

$$\alpha_n = \frac{\tan\left(\frac{1}{8}(4\arctan(\frac{\epsilon}{1-\epsilon}) + \frac{\pi\log(1-\epsilon)}{\sqrt{\frac{R}{h_1}}})\right)}{\sqrt{\frac{R}{h_1}}} \tag{2b}$$

$$h(\alpha) = h_1 + 2R(1 - \cos(\alpha)) \tag{2c}$$

$$k_{f,m} = \frac{k_{f,0} + 2k_{f,1}}{3} \tag{2d}$$

As for the roll torque M_{roll}, Sims developed a similar equation.

$$M_{roll} = 2R^2 k_{f,m} Q_{Torque} \tag{3}$$

The function Q_{Torque} depends on the entry angle of the equivalent flat pass α_0 which is calculated from equation 4b. Furthermore, L_d is the contact length of the equivalent flat pass.

$$Q_{Torque} = \frac{\alpha_0}{2} - \alpha_n \tag{4a}$$

$$\alpha_0 = \arcsin\left(\frac{L_d}{R}\right) \tag{4b}$$

2 Usage instructions

The plugin can be loaded under the name `pyroll_sims_power_and_labour`.

An implementation of the `roll_force` and `roll_tourque` hook on `RollPass` and `Roll` is provided, calculating the roll force and torque using the equivalent rectangle approach.

Several additional hooks on `RollPass` are defined, which are used in spread calculation, as listed in Table 1. Base implementations of them are provided, so it should work out of the box. For `sims_force_function` and `sims_torque_function` the equations 2a and 3 are implemented. Provide your own hook implementations or set attributes on the `RollPass` instances to alter the spreading behavior.

References

[1] R. B. Sims. "The Calculation of Roll Force and Torque in Hot Rolling Mills". en. In: *Proceedings of the Institution of Mechanical Engineers* 168.1 (June 1954), pp. 191–200. ISSN: 0020-3483, 2058-1203. DOI: 10.1243/PIME_PROC_1954_168_023_02. URL: http://journals.sagepub.com/doi/10.1243/PIME_PROC_1954_168_023_02 (visited on 05/09/2022).