The Lippmann - Mahrenholz Power and Labour PyRoll Plugin

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This plugin provides the roll force and roll torque model developed by Lippmann and Mahrenholtz [1]. Tge method was inspired by the solution of Sims [2]. The basic equations are derived from classic strip theory with suitable simplifications suitable for hot rolling. For the presented plugin, the specific roll torque at the upper work roll is calculated. Usage of the equations for groove rolling is only valid, when using a equivalent rectangle approach. Heights used for calculation are therefore equivalent values for a equivalent flat pass. Furthermore, the used variable h is the height of the equivalent flat workpiece and b_m it's mean width, $k_{f,m}$ 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 and L_d is the contact length of the pass.

1 Model approach

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

$$F_{Roll} = A_d k_{f,m} Q_F \tag{1}$$

The function Q_{Force} is the inverse forming efficiency and is calculated using equation (2a). This function depends on the neutral line angle β_n, which is calculated through equation (2b). σ_R and σ_V are the forward and backward tension applied to the pass.

$$Q_F = \frac{\sigma_R}{k_{f,m}} + 2\sqrt{\frac{1-\epsilon}{\epsilon}} \arctan\left(\sqrt{\frac{\epsilon}{1-\epsilon}}\right) - 1 + \sqrt{\frac{R}{h_1}}\sqrt{\frac{1-\epsilon}{\epsilon}} \log\left(\frac{\sqrt{1-\epsilon}}{1-\epsilon(1-\beta_n^2)}\right) \tag{2a}$$

$$\beta_n = \sqrt{\frac{1-\epsilon}{\epsilon}} \tan\left(\frac{1}{2}\sqrt{\frac{h_1}{R}}\left[\frac{\sigma_R - \sigma_V}{k_{f,m}} + \log(1-\epsilon)\right] + \frac{1}{2}\arctan\sqrt{\frac{\epsilon}{1-\epsilon}}\right) \tag{2b}$$

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

Table 1: Hooks specified by this plugin.

Hook name	Meaning
`equivalent_reduction`	Reduction ϵ
`neutral_line_angle`	Angle of neutral line α_n

As for the roll torque M_{roll} at a single roll, Lippmann and Mahrenholz developed a similar equation.

$$M_{roll} = b_m R k_{f,m} Q_M \Delta h \tag{3a}$$

$$Q_M = \sqrt{\frac{R}{h_1}} \sqrt{\frac{1-\epsilon}{\epsilon}} \left(\frac{1}{2} - beta_n\right) \tag{3b}$$

2 Usage instructions

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

An implementation of the `roll_force` and `roll_torque` hook on `RollPass` and `RollPass.Roll` is provided, calculating the roll force and torque using (3a) and (1). Several additional hooks on `RollPass` are defined, which are used in power and labour calculations, as listed in Table 1. Base implementations of them are provided, so it should work out of the box. Provide your own hook implementations or set attributes on the `RollPass` instances to alter the spreading behavior.

References

[1] Horst Lippmann and Oskar Mahrenholtz. *Plastomechanik der Umformung metallischer Werkstoffe*. de. Citation Key: Lippmann1967. Berlin, Heidelberg: Springer Berlin Heidelberg, 1967. ISBN: 978-3-642-87885-5. DOI: `10.1007/978-3-642-87884-8`. URL: `http://link.springer.com/10.1007/978-3-642-87884-8`.

[2] 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).