

PyRoll Hensel Roll Force and Torque Plugin

Max Weiner

Christoph Renzing

2022-04-04

This plugin provides the empirical roll force and roll torque models developed by A. Hensel and coworkers¹². The models are empirical master curves dependent on the dimensionless parameter A_d/A_m , which is the ratio of contact area to the mean cross-section area of the profiles. It is called the roll gap ratio hereinafter. It is similar to the dimensionless parameters R/h_1 and L_d/h_m often used in flat rolling.

Model Approaches used in the Plugin

Approach to roll force

The roll force is calculated by

$$F = \frac{k_{Wm}}{k_{fm}} \times k_{fm} \times A_d$$

where k_{fm} is the mean flow stress, A_d the contact area and k_{Wm} the deformation resistance. k_{Wm}/k_{fm} is the inverse efficiency of the rolling process.

For the mean flow stress k_{fm} a weighted mean as below is used, since this provides a more suitable average than simple arithmetic mean. The indices 0 and 1 denote the entry resp. exit side as usual.

$$k_{fm} = \frac{(k_{f0} + 2k_{f1})}{3}$$

The similar is the case for the mean cross-section A_m :

¹Hensel, A., P. Poluchin, und W. Poluchin. Technologie der Metallformung. Deutscher Verlag für Grundstoffindustrie, 1990.

²Hensel, A., und T. Spittel. Kraft- und Arbeitsbedarf bildsamer Formgebungsverfahren. Deutscher Verlag für Grundstoffindustrie, 1978.

$$A_m = \frac{(A_0 + 2A_1)}{3}$$

The value of k_{Wm}/k_{fm} is obtained from the master curve in dependence on A_d/A_m as shown in the figure. The figure shows accordingly several experimental measured values and the hull curves around all measurements. The red line is the weighted mean curve and is given by

$$\frac{k_{Wm}}{k_{fm}} = 0.9901 + 0.106 \frac{A_d}{A_m} + 0.0283 \left(\frac{A_d}{A_m} \right)^2 + 1.5718 \exp \left[-2.4609 \frac{A_d}{A_m} \right] + 0.3117 \exp \left[-15.625 \left(\frac{A_d}{A_m} \right)^2 \right]$$

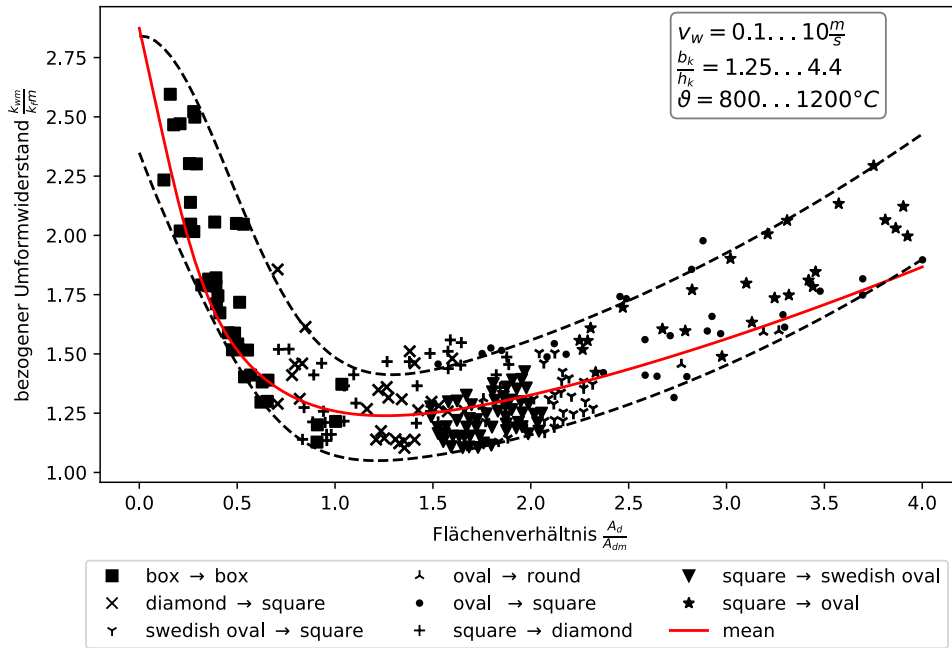


Figure 1: Hensel deformation resistance curve

Approach to roll torque

The roll torque is calculated by

$$M = F \times L_d \times m$$

where L_d is the contact length and m is the lever arm coefficient.

The dependence of the lever arm coefficient on A_d/A_m is shown in the figure with experimental data and their hull curves accordingly.

In additional dependence on the celsius workpiece temperature ϑ and rolling velocity v , m can be calculated by the following equation, as was implemented in the current case.

$$m = \left(\exp \left[-0.6 \frac{A_d}{A_m} \right] + 0.076 \frac{A_d}{A_m} \right) v^{0.005} \exp [-0.0003 (\vartheta - 900)]$$

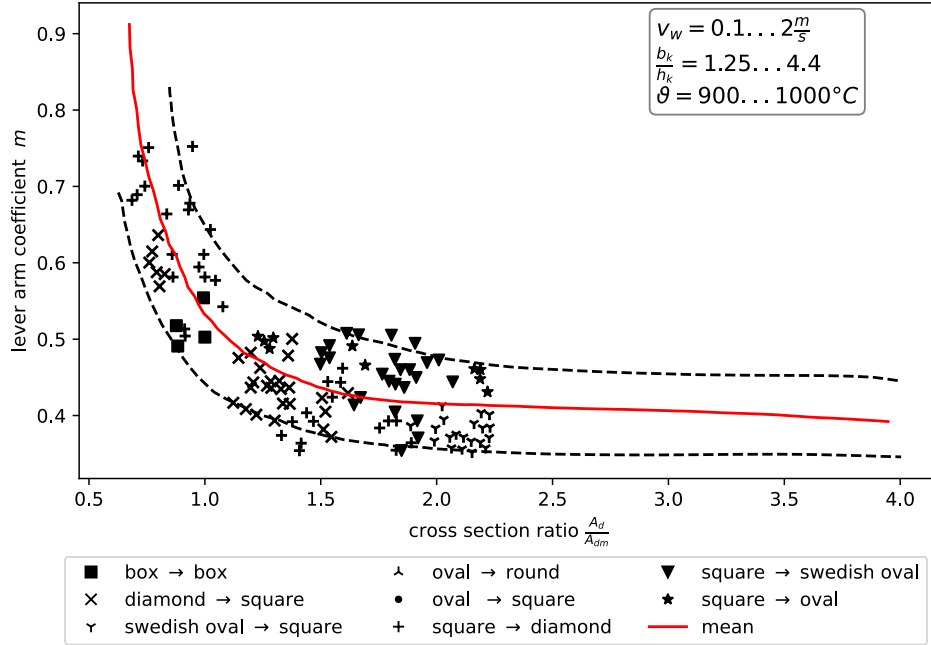


Figure 2: Hensel lever arm coefficient curve

Usage of the Plugin

The plugin provides implementations of the following core hooks:

RollPass.roll_force The roll force occurring in this pass calculated by the models described above. Uses the `RollPass.deformation_resistance` and `RollPass.contact_area` hooks.

RollPass.roll_torque The roll torque occurring in this pass calculated by the models described above. Uses the `RollPass.roll_force`, `RollPass.contact_length` and `RollPass.lever_arm_coefficient` hooks.

The following hooks are specified and implemented additionally:

RollPass.roll_gap_ratio The ratio of contact area to cross-section A_d/A_m . Uses the core hooks `Profile.cross_section` and `RollPass.contact_area`.

RollPass.rolling_efficiency The efficiency of the rolling process, that means the inverse of k_{Wm}/k_{fm} obtained from the model shown above. Uses the `RollPass.roll_gap_ratio` hook.

RollPass.deformation_resistance The deformation resistance k_{Wm} calculated using k_{Wm}/k_{fm} and the mean flow stress as described above. Uses the `RollPassProfile.flow_stress` and the `RollPass.rolling_efficiency` hooks.

RollPass.lever_arm_coefficient The lever arm coefficient m obtained from the model described above. Uses the `RollPass.roll_gap_ratio`, `RollPass.velocity` and `Profile.temperature` hooks.

One can modify the behavior of the plugin by providing constant attributes or custom implementations of the hooks. The plugin needs no additional material data or coefficients to be given on the initial profile or on the roll passes. Commonly it should work out of the box, without additional definitions by the user.