Lendl's equivalent rectangle method PyRoll Plugin

Christoph Renzing

April 21, 2022

This plugin provides the equivalent method after Lendl for calculation of a equivalent rectangle used for spread calculation.

1 Model approach

A common approach for groove rolling is to calculate some equivalent rectangular profile to be able to use spread models for flat rolling in groove rolling. This method is valid if the groove design is a simple irregular one. For this case, the roll pass is characterized by a change in height that varies across the width, with the caliber having more than one axis of symmetry. Lendl [1, 2, 3] proposed a method for calculation of a equivalent rectangle using the incoming profile of the roll pass and the groove used in the pass. The method can be divided into four different steps witch are explained in detail in the following subsections.

- Calculation of intersection points between the incoming profile and groove
- Calculation of Lendl Area of the roll pass
- Calculation of Lendl width of the roll pass
- Calculation of Lendl height

1.1 Calculation of intersection points

As for groove and profile contour lines are so called `LineString` objects provided by the shapely package published by Gillies et al. [4]. For calculation of intersection points between incoming profile and groove the shapely method `intersection` is used. This method returns the points where two lines intersect each other. As an example the following figure 1 shows the intersection points of a incoming round profile and a oval groove.

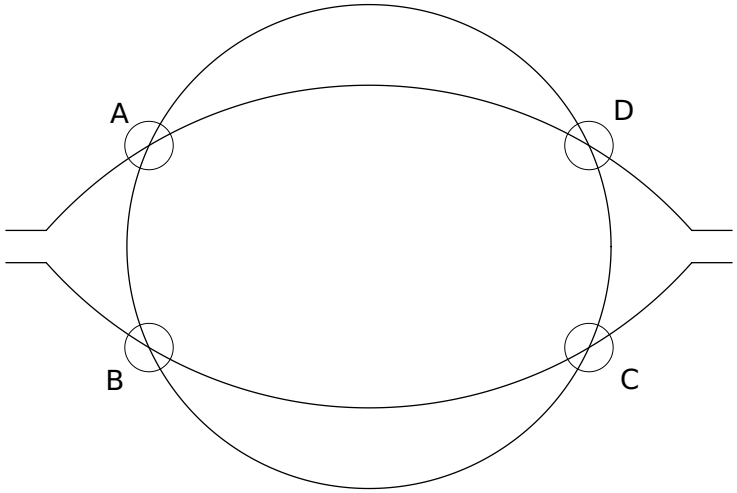

Figure 1: Intersection points A to D for a round - oval roll pass

1.2 Calculation of Lendl's area for incoming profile and roll pass

Lendl's area for the incoming profile ($A_{0,L}$) is the area under direct pressure from the work roll. For the groove, Lendl's area is the area under direct pressure inside the groove ($A_{1,L}$). As an example Lendl areas for the already shown round - oval roll pass are shown in figure 2. One can also derive the following condition for these areas in relation to the total area of the incoming (A_0) and outgoing profile areas (A_1).

$$A_{0,L} < A_0 \tag{1a}$$

$$A_{1,L} < A_1 \tag{1b}$$

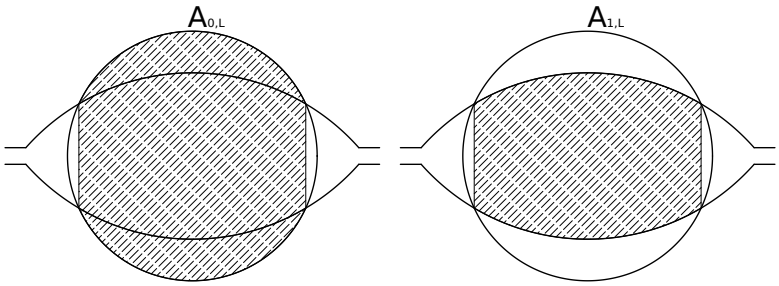

Figure 2: Lendl areas for a round - oval roll pass

Table 1: Hooks specified by this plugin.

Hook name	Meaning
`wusatowski_temperature_coefficient`	temperature correction coefficient a
`wusatowski_velocity_coefficient`	velocity correction coefficient c
`wusatowski_material_coefficient`	material correction coefficient d
`wusatowski_friction_coefficient`	friction correction coefficient f
`wusatowski_exponent`	spread exponent w

1.3 Calculation of Lendl's width

Lendl's width is calculated as the distance of the vertical connection between the intersection points A and B and C and D. For calculation the shapely method `distance` is used.

1.4 Calculation of Lendl's equivalent height

Calculation of Lendl's equivalent height is carried out by dividing Lendl's area through Lendl's width. The resulting height is used as the height of the equivalent rectangle used in the equivalent flat roll pass. As for the initial width of the incoming profile Mauk and Kopp [5] stated that using the maximum width of the incoming profile is suitable

2 Usage instructions

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

An implementation of the hook on `RollPass` is provided, calculating the spread using the equivalent rectangle approach and Wusatowski's model.

Several additional hooks on `RollPass` are defined, which are used for calculation, as listed in Table 1. For and the equations **??** and **??** are implemented.

References

[1] A. E. Lendl. "Rolled Bars - Part I - Calculation of Spread between non parallel roll surfaces". In: *Iron and Steel* 21.14 (1948), pp. 397–402.

[2] A. E. Lendl. "Rolled Bars - Part II - Application of Spread Calculation to Pass Design". In: *Iron and Steel* 21.14 (1948), pp. 601–604. ISSN: 0021-1532.

[3] A. E. Lendl. "Rolled Bars - Part III - Application of Spread Calculation to Diamond Passes". In: *Iroan and Steel* 22.12 (1949), pp. 499–501. ISSN: 0021-1532.

[4] Sean Gillies et al. *Shapely: manipulation and analysis of geometric objects*. toblerity.org, 2007–. URL: `https://github.com/Toblerity/Shapely`.

[5] P. J. Mauk and R. Kopp. "Breitung beim Warmwalzen". In: *Der Kalibreur* 37 (1982).