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Dimensional analysis of a new type of groove for steel rebar rolling

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In shape rolling process, the determination of roll pass and profile design is very important. For the prediction of workpiece sectional shape, for some rod rolling passes, an analytical model by Shinokura and Takai was proposed and verified. The application of FE techniques to the rod rolling process let to study same other passes with much simplicity.
In this paper, for round-flat oval pass and round-flat pass, in rebar rolling, the experimental values of maximum spread and of radius of the rebar have been carried out and compared with the results of the analytical model and of the FEM analysis.

1. INTRODUCTION

In hot rolling process, there are many factors to take into account, such as roll pass and profile, to transform correctly an incoming billet into a final rolled section. For this reason, many studies to simplify the design engineers job have been carried out. Because of the complexity of the process and the lack of experimental results, it has been difficult to obtain an analytical model which described and predicted the outgoing workpiece characteristics.

Besides the analytical approach, in the last years, thanks to the computers development, the study of rod rolling process has been dealt by the implementation of simulation methods based on finite elements analysis. The utilization of FE simulation models [1-4], applied to rolls groove sizing, let to analyse new rolling passes without making any real model. Unfortunately, because of the large amount of computing time and the complicated mechanical/thermal boundary conditions to use as inputs for the FE model, the application of finite element analysis to the rod rolling is limited to the validation of analytical models and the preliminary study of a new sequence of passes, while it is not favourable for practical use.
In the last years Shinokura and Takai [5] proposed an analytical model to calculate the geometrical characteristics of an outgoing workpiece after some rod rolling passes.

In the present paper, two types of grooves, a round-flat oval pass and a round-flat pass (a new type of groove) have been investigated.

The analysis has been conducted comparing the experimental data with the results obtained by Shinokura and Takai formula and by FE model.

2. ANALYTICAL MODEL

Shinokura and Takai's formula calculates the outgoing workpiece maximum spread (W_{max}) as follows:

$$W_{max} = W_i\left(1+\gamma\frac{\sqrt{R(H_{iS}-H_{0S})}}{W_i+0.5H_i}\cdot\frac{A_h}{A_o}\right) \quad (1)$$

where $H_{0S} = \frac{A_0 - A_s - A_f}{B_c}$ and $H_{iS} = \frac{A_0 - A_s}{B_c}$

with W_i, H_i and A_0 respectively the incoming workpiece maximum width, the maximum height and area, and γ a correction factor, variable in the range 0.8÷1.1, depending on the roll pass. For the present investigated passes the optimum value has been chosen equal to 0.83.

Once calculated the maximum spread, Shinokura and Takai's analytical model calculates the surface profile of outgoing workpiece, computing the radius of surface profile of workpiece at the roll throat R_S such as the linear interpolation of the radius of curvature of the incoming workpiece R_a and the radius of curvature of the groove R_f:

$$R_S = R_a W_t + R_f(1-W_t) \quad \text{where} \quad W_t = \frac{W_f - W_{max}}{W_f - Wi} \quad (2)$$

In the formula (2), W_f is the width of the groove, W_i the width of the incoming workpiece and W_{max} the maximum spread of outgoing workpiece. In figs. 1-2 the geometrical parameters used for the prediction of W_{max} and R_s for the round-oval pass are illustrated.

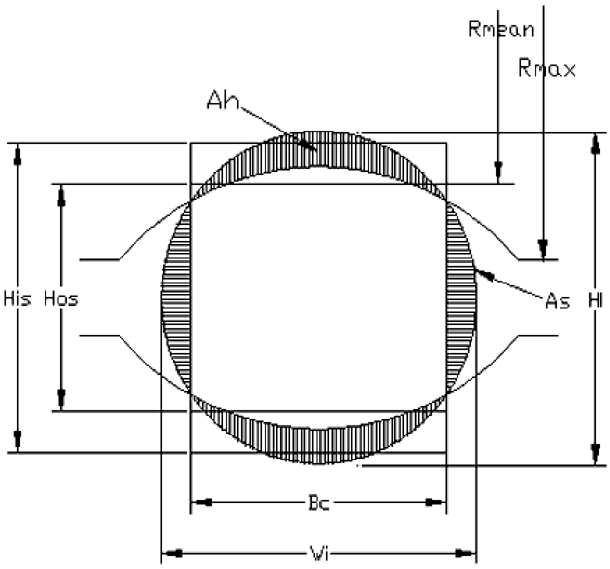

Fig. 1 Geometrical parameters for the maximum spread analytical formula

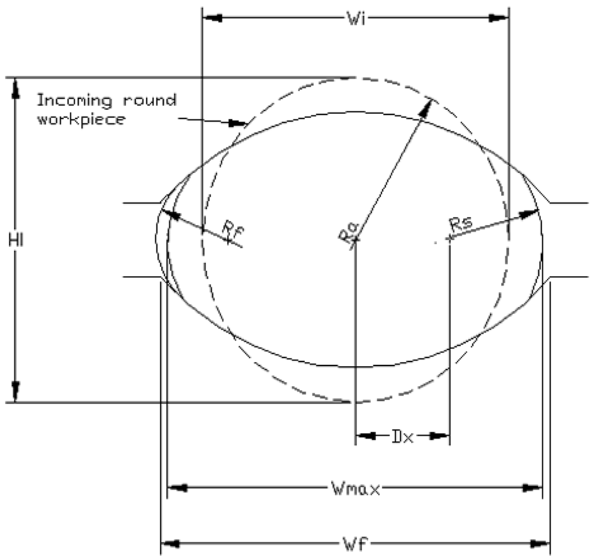

Fig. 2 Geometrical parameters for the radius of curvature analytical formula

3 EXPERIMENTAL MATERIALS AND DATA

The schemes of the two passes analysed, round-flat oval and round-flat, are reported in fig. 3. The diameters of the incoming workpieces were respectively 39 mm (cross section area = 1194 mm^2) and 20.2 mm (cross section area = 320.3 mm^2). The billets, whose material was a low carbon steel (0.2% C), have been heated up to 1200° by a box type furnace. The workpiece temperature has been measured by an optical pyrometer, while the geometrical parameters have been found before and after each pass by cooling the workpiece in calm air. The cast iron rolls were 315 mm in diameter for both passes and the rod lolling speed has been respectively of 4.5 m/s for the round-flat oval pass and of 9.57 m/s for the flat rolling pass.

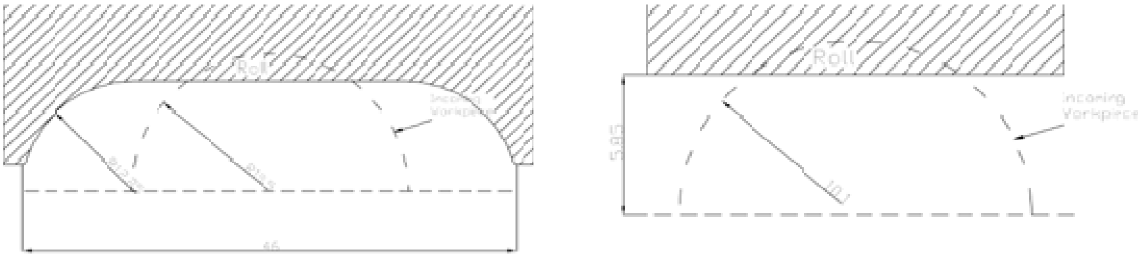

Fig. 3 Groove schemes and dimensions

The outgoing workpiece was respectively characterised by a cross section area of 959 mm^2 and a λ (incoming workpiece cross section area and outgoing workpiece cross section area ratio) of 1.246 for the round-flat oval pass and a cross section area of 262.5 mm^2 and a λ of 1.220 for the flat rolling pass.

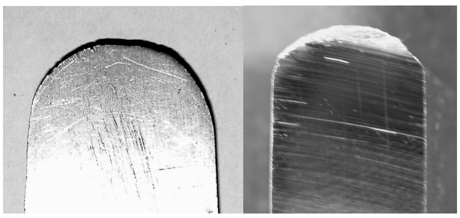

Fig. 4 Cross section of the work pieces after the rolling

4 ANALYTICAL AND FE MODEL RESULTS

Although the Shinokura and Takai formula has been used for many types of pass, it hasn't been tested for the round-flat oval and flat rolling passes. So, the same parameters, shown in figs 1-2 have been used to calculate the spread and the radius of curvature for these passes.

The FE analysis has been conducted with Marc Autoforge program. The material used in this analysis is a C22 steel. A rigid plane element pushes the workpiece to the roll. The contact table has been compiled evaluating the Coulomb coefficient on the groove/workpiece interface equal to 0.36, moreover we have considered an isothermal process with a temperatrure of 1100°C. In the figs. 5-6 some examples, obtained with a quasi static analysis, are reported.

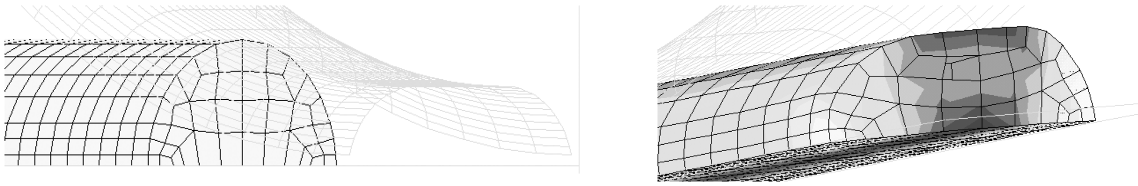

Fig. 5 Scheme of FE model for round-flat oval pass after and before the rolling

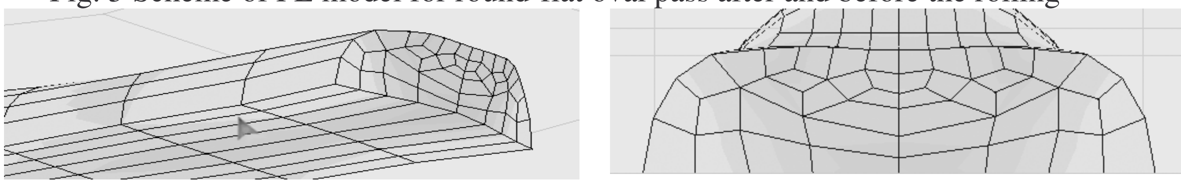

Fig. 6 Scheme of FE model for round-flat rolling pass before the rolling

Maximum spread and radius of curvature of workpiece profile have been estimated carrying out the average of seven measurements; the values of these parameters are reported in table 1.

Table 1 Experimental data, analytical and FEM results of outgoing workpiece geometrical parameters.

	Round-Flat Oval pass			Round-Flat pass		
	Experimental data	Analytical results	FEM results	Experimental data	Analytical results	FEM results
Maximum spread (mm)	43,5	44,2	44,8	27,00	26,30	25,60
Radius of curvature (mm)	13,19	13,70	14,10	11,30	X	12,40

4 CONCLUSIONS

Two passes of a rod rolling sequence for rebar production have been analysed: a classic round-flat oval and an innovative round-flat pass. This paper points out the possibility of using the Shinokura and Takai's formula and the FEM analysis to predict the geometrical parameters of the workpiece during a rod rolling process. The difference in λ between the two passes is nearly 2.08%, but the flat groove regeneration is easier and cheaper than the other one.

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