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CLOSED LOOP CONTROL FOR ROLL PROFILE ON CNC GRINDING MACHINE

BY

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Abstract. The need for higher quality and productivity in the metal rolling industry has driven the development of increasingly sophisticated models of metal rolling, both for mill set-up and for on-line control. One important area in which these models can be improved is in the strip profile in thin strip rolling. The quality of ultra thin strip production in a wide strip rolling mill depends on the careful selection of initial ground work roll profiles for each of the mill stands in the finishing train. These profiles were determined by human expert and manufactured on CNC ground machine. The rolls profiles, obtained with closed loop control, designed for straight, convex, concave or CVC rolls, is presented.

Key words: grinding, closed loop control, work roll profile, steel strip production.

1. Introduction

The need for higher quality and productivity in the metal rolling industry has driven the development of increasingly sophisticated models of metal rolling, both for mill set-up and for on-line control. One important area in

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which these models can be improved is in the strip profile in thin strip rolling. The quality of ultra thin strip production in a wide strip rolling mill depends on the careful selection of initial ground work roll profiles for each of the mill stands in the finishing train (Sun *et al*, 2005). These profiles were determined by human expert and manufactured on CNC ground machine.

Variations in rolling process parameters (e.g. reduction ratio, rolling speed, roll condition, etc.) together with strip temperature (Chien *et al*, 2005) , raw material composition and inclusions give rise to spills, seams, surface roughness, bad profile and flatness (Ubice, 2001). Instability of the rolling force may lead to excessive vibration that can cause chatter. As a result of chatter, transverse marks covering the strip width are impressed at the exit of the considered mill stand.

The main discriminator for steel strip from different manufacturers is quality, which has two aspects: strip profile and strip flatness. Strip profile is defined as variation in thickness across the width of the strip. It is usually quantified by a single value, the crown, defined as the difference in thickness between the centre line and a line at least 40 mm away from the edge of the strip (European Standard EN 10051).

2. Closed Loop Control for Work Roll Profiles

To compensate for the predicted bending and thermal expansion, work rolls are ground to a convex or concave camber. Due to the abrasive nature of the oxide scale on the strip, the rolls also wear significantly. Due to this roll wear, the rolls need to be periodically reground on CNC grinding machine after a specified duty cycle, to re-establish the specified profile. The work rolls camber is usually sinusoidal, CVC (continuously variable crown) or polynomial in shape. The challenge is to find suitable work roll profiles – for each rolling program – capable of producing strip flatness and profile to specified tolerances. These are often later changed, e.g., by the rolling mill technical personnel in an effort to establish optimum profiles. This fine-tuning of the roll profiles is nearly always carried out empirically.

There are many different profiles and combinations of profiles of mill rolls. The most common mill rolls are defined by the function f(Y) which is a polynomial function where x=distance from the centre of the roll (Table 1). In designing the roll profile, four principal factors must be considered:

The first factor is the compatibility of the roll gap profile change caused by roll shifting with the desired change of the strip profile. When the rolls having polynomial profile of the n^{th} order are shifted, the shift produces a change of the strip profile that is expressed by a polynomial of the $(n-1)^{th}$ order.

Table 1
Work rolls camber

Function	f(Y)
Linear	Y = 0.02x
Quadratic	$Y = 0.002x^2$
Cubic	$Y = 0.00lx^3$
Quartic	$Y = 0.000002x^4$
CVC roll	$Y= 0.0001634x^3 - 0.3021x$
UPC roll	$Y = -0.00002374x^3 + 0.002590X^2 + 0.05640x$
K-WRS roll (Kawasaki Steel-Working Roll Shifting)	$Y = 0.00000081x^4 - 0.000034x^3 - 0.000293x^2 + 0.015x$

The second factor is the effectiveness of the roll shifting "E". This factor is defined as the ratio of the change in the strip profile, Δc, to the roll shifting stroke, s, as shown in equation (1):

$$E = \frac{\Delta c}{s}. \tag{1}$$

The shorter the roll shifting stroke, s, that can produce the same change in strip profile, Δc, the more effective the roll shifting actuator is. To increase the effectiveness of the roll shifting *E* it is necessary to use a roll profile that curies both up and down in respect to a roll axis. Among the known roll profiles, only cubic and CVC profiles meet this requirement.

The third factor is the shape of the roll contact between the rolls. To reduce the local contact stresses it is desirable to avoid "bulging" shapes in the roll such as typical for quadratic, CVC, and UPC (universal profile crown) roll shapes (Fig. 1).

The fourth factor is the simplicity of grinding the roll profile. In the conventional rolls, the roll profile is symmetrical with respect to the center line of the roll. It permits to use of standard CNC grinding machines achieve a very high precision with which the roll profile can economically be made. All known roll profiles that are used with shifting rolls are non-symmetrical. This means they are not symmetrical with respect to the roll center line. To grind this profile, more expensive CNC grinding machines are required. The non-symmetrical roll profile is unavoidable to produce the effect of roll shifting on strip profile.

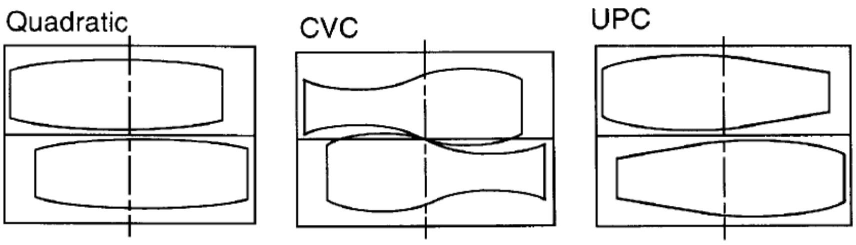

Fig. 1 – The shape of the roll contact between the rolls.

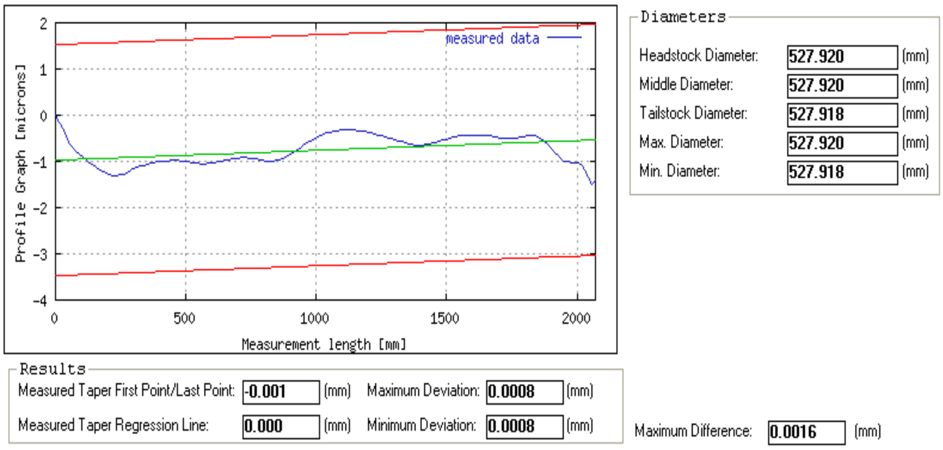

Fig. 2 – The linear shape of the roll.

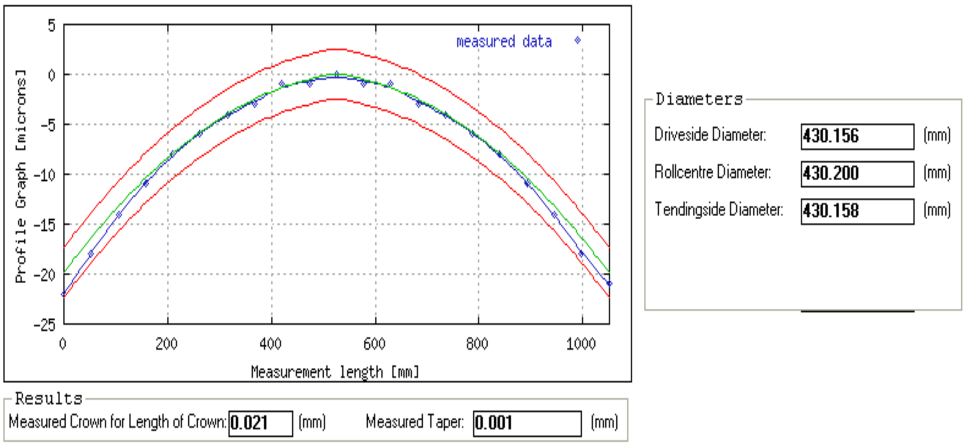

Fig. 3 – The sinusoidal shape of the roll.

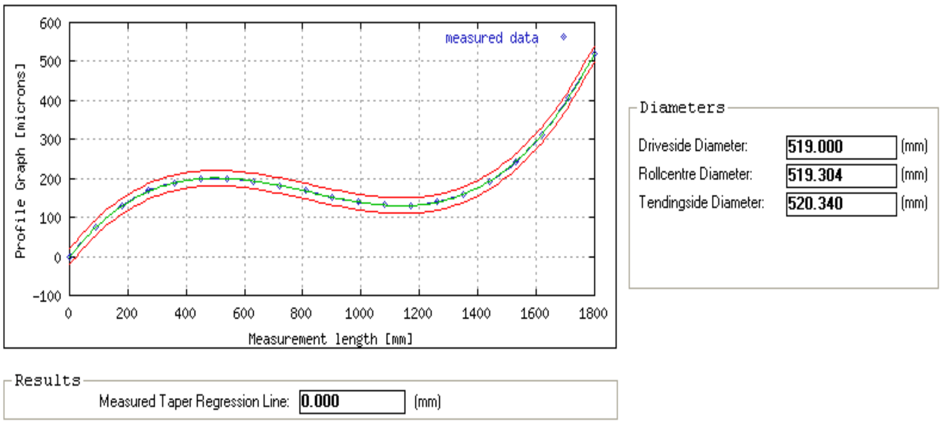

Fig. 4 – The CVC shape of the roll.

In Figs.2-4 the rolls profiles, obtained with RGC 2500x4000 grinding CNC machine (WORLD MACHINERY WORKS Bacău – România), designed for straight, convex or concave rolls grinding, are presented. The research effort developed open-loop correction techniques for wheel path. This effort involved predicting roll profile, supporting real-time, closed-loop machining with the integration of machining and inspection working steps within the NC program, for specified machining conditions and compensating by modifying the tool path. A CAD model with the planned wheel path was used to determine the grinding parameters (Fig. 5).

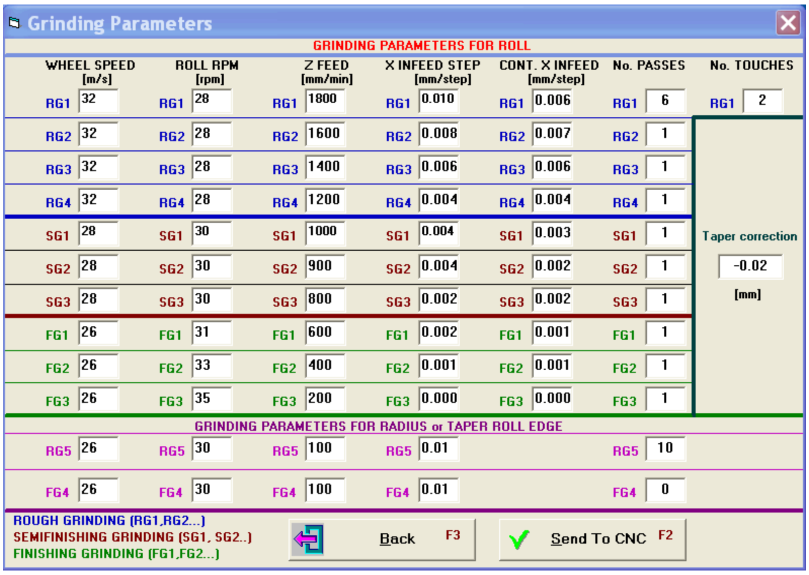

Fig. 5 – The grinding parameters.

Compensation for tool wear has proven very successful and errors can be reduced.

3. Conclusions

The qulity of ultra thin strip production in a wide strip rolling mill depends on the careful selection of initial ground work roll profiles. The experiment shows that the closed-loop machining with the integration of machining and inspection workingsteps within the NC program can improve the measurement precision more and is fit for engineering application.

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COMANDA ÎN BUCLĂ ÎNCHISĂ LA PRELUCRAREA CILINDRILOR DE LAMINOR PE MAŞINI DE RECTIFICAT CU CNC

(Rezumat)

Calitatea benzilor de tablă laminate la cald sau la rece depinde în mare masură de alegerea tipului de profil pentru cilindri de lucru pentru fiecare cajă de finisare. Aceste profiluri sunt alese de specialiştii in procesul de laminare şi se realizată pe maşini grele de rectificat cu CNC. Lucrarea prezintă principalele tipuri de profiluri utilizate şi factori care se iau in considrare la proiectarea acestora. Sunt prezentate profilurile obţinute prin prelucrare şi măsurare în buclă închisă, pe maşina RGC 2500x4000 CNC (WORLD MACHINERY WORKS Bacău – România).