BRIEF CHARACTERIZATION OF THE CHROMIUM COATING AND COMPARISON OF WETTABILITY OF SKIN PASS SOLUTION ON SURFACES OF ROLLS COATED AND NONCOATED*

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Abstract

The competitive scenario of steel industry requires studies and developments to improve manufacturing processes focusing on increasing productivity and reducing costs. The practice of coating rolls for cold rolling with the chrome aims to increase the rolling campaign, reducing their wear by increasing the surface hardness, which guarantees a greater homogeneity in the surface of the rolled products. The present paper presents a study on the effect of the chromium coat on a forged steel rolls on the wettability of a SkinPass solution. The hardness of the coated layer and the contact angle were measured for two concentrations of solution on two types of surfaces, comparing the coated and uncoated surfaces. The results show that there is an influence of the coating on the wettability of the fluid when comparison are made with chrome coated and uncoated materials, being verified through tests in Goniometer. The productivity of the coated rolls showed higher productivity than the uncoated ones.

Keywords: Wetting; Cold Rolling, Work Rolls. Chrome Coating; Work Rolls Coated.

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1 INTRODUCTION

The World steel production is in a very competitive environment, especially with the recent modernization and growth of the Chinese steel mills. Currently, its share in the world market corresponds to approximately 50% of the production amount, pushing the reduction of international prices. The manufacturing processes end up undergoing continuous changes to meet the demands of quality while at the same time achieving an ever increasing cost reduction. According to the World Steel Association in its annual report, in 2017 China produced 808.3 million tons in a world production of 1.628 billion steel [1]. In the production of flat rolled products, the rolls give quality to the products in the main aspects: surface finish (roughness), flatness, and dimensional accuracy (thickness) [2]. The guarantee of these aspects in the rolled strip is directly related to the performance of the Rolls, which in turn depends on its mechanical properties such as hardness on the contact surface and its wear resistant properties [3]. Another important aspect to be considered during the rolling process is the type of solution used for cooling and lubrication in the contact region, as is the case with the skin pass solutions applied in the process of Skin Pass in the final step of finishing the thin strips. According to the adhesion or wettability of the fluid on the surface of within the roll and the strip surface, a homogeneous fine film is formed between the surfaces in contact, which results in better product finishing and extended cylinder life [4], due to this coating.

The aim of the present work is to evaluate the wettability of a skin pass solution on the surface of a forged steel roll by comparing the results of contact angle measurement for two concentrations applied on two distinct surfaces, one coated with chromium and the other with no coating.

1.1 Effects of friction in the rolling process

The role of the friction in the rolling process is fundamental as the friction between the surfaces in contact simultaneously guarantees the initial gripping of the process in the strip engagement and the resistance to the passage of the same, causing the plastic deformation process to occur as the desired dimension [5]. The friction during the rolling process must be controlled because the direct contact of the material surfaces and the roll might generate heat by the friction, which added to the heat generated by the mechanical work of the metal deformation can promote high heating, allowing for changes unwanted in the process that affect the final product. One of the ways to control friction is based on the use of lubricating fluids, which eliminate direct contact by the formation of intermediate films between the components, in addition to extracting heat and keeping the cylinder and plates in conditions of stable friction [6]. This lubrication guarantees products with scratch-free surfaces or "scratches", known as friction marks [7]. The coefficient of friction can also be modified in the rolling process through changes in the parameters: type and intensity of lubrication, thermal and thermochemical treatments of the rolls surface, increase of hardness, among others. In the rolling processes, the Flow Constancy Law [7] is applied, in which the mass flow is constant between the inlet and outlet of the mill, and the following formula can be applied:

$$h_1 . v_1 = h_2 . v_2 = h_n . v_n \quad (1)$$

where: h_1 = entry thickness of the strip, h_n = final thickness of the strip, v_1 = entry velocity of the strip, v_n = velocity of the strip. Figure 1 shows the geometric components at the entrance and exit of the strip in each chair. The rolling process must take place under a stable regime,

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which means maintaining the relationship between thickness and volume of equation (1) without variation throughout the process, or with minimally reduced variation to avoid interruptions due to failure and to affect the surface quality of the laminates . In the case of the skin pass process, where a small alongantion are apllied with a light surface deformation in the formed strips is imposed for the stabilization of the mechanical properties and avoiding the Distension lines (8).

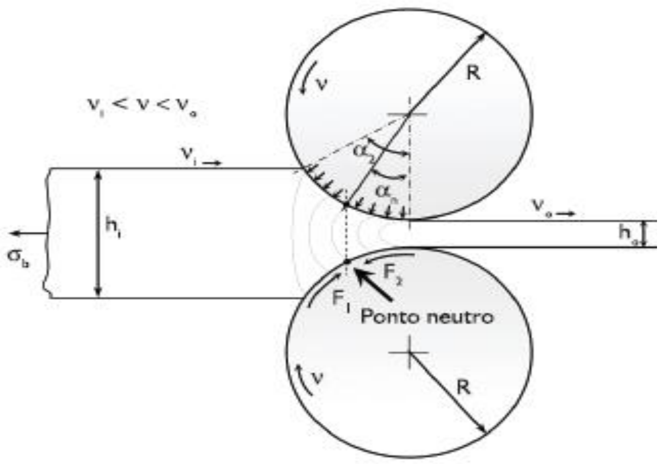

Figure 1 –Mass Flow, the position of the neutral point and the friction forces (Adapt. de Muratoni, 2012).

v_1 entry velocity of the strip v_2 exit velocity ot the strip F_1 friction force entry side F_2 friction force exit side R Roll Radius V Roll speed

1.2 Wetting

The model formulated by Young, in which the three surface tensions (solid vapor, solid-liquid and liquid-vapor) in a contact line are in equilibrium in the condition of minimum free total energy, is the result of the equation:

$S_v = S_l + L_v$ cosθ (1)

where γ_{sv}sv is the solid vapor surface tension, γ_s is the liquid solid surface tension, and γ_{lv} is the vapor liquid interfacial tension. In this classical construction, the three mechanical surface stresses, S_v, S_l, and L_v , are in equilibrium in the direction parallel to the solid surface. The figure 22 shows schematically the mechanical balance of the three surface voltages, indicating the contact angle between the drop surface and the solid surface. [9]. The interaction between a cooling fluid and the surface of the rolling cylinder results from intermolecular interactions when they are in contact, strongly influenced by the physical characteristics of the surface. Therefore, both the roughness and the type of coating or finishing element are factors to be considered in the analysis of these interactions.The higher the value of the theta angle, the lower the wettability of the liquid on the solid surface.

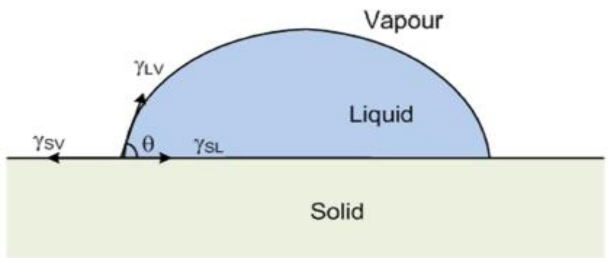

Figure2 – Young's Model for surface tension of a drop at the three phases on the contact line (Makkonena, 2017).

2 MATERIAL AND METHODS

2. 1 Samples surface preparation

The samples analyzed were extracted from a forged steel work roll from a cold rolling mill. The characteristics of this roll are a diameter of 495 mm at the end of life with hardness 81 HS-C, whose chemical composition is presented in Table 1.

(2)

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Table 1 . Chemical Composition – Forged Steel Roll

C	Mn	Si	P	Cr	S	Ni	Mo	V
0,90 ~ 0,86	0,80 ~ 0,50	0,33 ~ 0,20	0,03 0~ 0,00	4,7 ~ 4,3	0,03 ~ 0,00	0,35 ~ 0,00	0,39 ~ 0,11	0,10 ~ 0,0

The surface of this Roll was grinded eliminate wear imperfections in service. The parameters of the grinding process as advance and amperage with grinding wheel type A 80, with abrasive containing aluminum oxide are on the table 2.

Table 2 – Grinding Process Parameters

Wheel	Abrasive	Wheel Rotation	Roll Rotation	Wheel advance	Car Speed
A 80	Al Oxid	500 rpm	50 rpm	0,001 mm	400 mpm

The aim was to obtain the polished surface and surface finish of 0.60 μRa. The grinding machine used was a Farrel Giustina Grinder - Model 36 "X 16 '. After that the roll was shotblasted acording to parameters at table 3.

Table 3 – Shot Blasting process parameters

Turbine	Car Speed	Roll Rotation	Motor load	Blast size
1500 rpm	0,30 mpm	5 rpm	35 A	G – 40

The samples were tested to measure the hardness with a Procecq type durometer and Type LE Impact unit and the measurement conversion to Shore C. The characterization of the surface roughness as finished was carried out by measuring with a Sutonic 25+ model rugosimeter. There were also done metallographic characterization of samples, roughness, and microhardness on the surface.

2.2 Skin Pass Solution

The fluid used for wettability analysis was a hardening solution according to table 4,
The physicochemical properties (FISQ) shown in accordance with Brazilian Standart ABNT NBR 14.725-4, with two distinct concentrations of 3% and 5% by weight diluted in demineralised water.

Table 4 - Solução de Encruamento

	Amínics e aditives (tensoatives)	
Chemichal Composition	Trihidroexietilamina	5 a 10% wt
	Tolutriazol	1 a 3 % wt
Physycal Properties	Estado físico	Liquid turve
	Colour	yellow
	Smell	typical
	pH	2,5 a 5
	Density	1,05
	Solubilidade	water
	Flash point	Water basis
	Boiling Point	>100

The samples were tested at the research center of an oil manufacturer in the Netherlands. The fluid was prepared by mechanical stirring until its total dilution prior to performing the assays. The evaluation of the wettability of the hardening solution on the previously prepared surfaces was done in a VCA 2000 - AST type goniometer. The samples were previously cleaned with Isopropanol to eliminate the influence of any contaminant from the preparation steps. The experiment consisted in the application of a drop of 2-3 μl on the surface, after which a sequence of images was obtained with time intervals of 0.2 seconds, 0-10 seconds were selected to measure the contact angles and the stabilization time was obtained afterwards.

The assays were planned according to Table 5 for concentrations of 3% and 5%

Table 5. Assays Plan

Surface condition	Concentration wt	Fluid
Shotblasted Coated	3%	Skinpass solution
Shotblasted Coated	5%	Skinpass solution
Shotblasted Noncoated	3%	Skinpass solution
Shotblasted Noncoated	5%	Skinpass solution

3 RESULTS AND DISCUSSION

3. 1 Productivity

The production data were collected along comparing the values produced with work rolls in the two conditions: with coating

and without, in the evaluated period three months. The results obtained are shown in Table 6 below. It can be observed that the increase in both the production volume and the operating time were significant
.

Table 6. Production Results

Roll Surface	Production (t)	Operational time (h)
Shotblasted Coated	2926	19,51
Shorblasted Noncoated	776	5,17
Benefits	2150	14,34
Variation %	277%	277%

3.2 Metallography analyses

Metallography was performed on a sample of the roll surface coated with chromium and analyzed under an optical microscope. The chromium layer is homogeneous and accompanies the relief of the substrate as can be seen in figure 3 and 4 below.

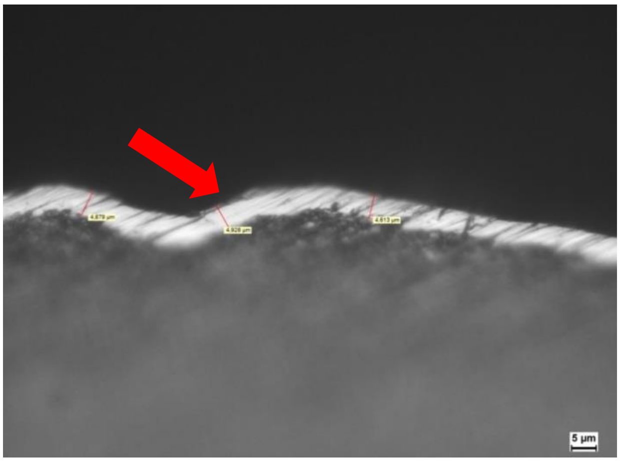
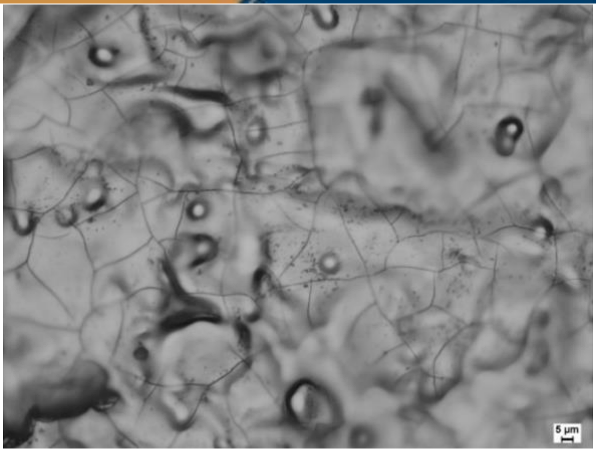


Figure 3 . Cross section layer of the shotblasted surface coated with Chromium – 1000X

Metallographic analyzes revealed homogeneity in the layer and the substrate flow due to deformations from shot blasting remain on the surface in this way even roughness with coating remained unchanged.



3.3 Microhardness Testing

The samples were submitted to Vickers micro hardness tests, the values obtained for the samples are shown in table 7.

Table 7. Micro hardness

Sample	Hv(100)	Standart Desviation
Grinded	883,2	38,0
Shotblasted noncoated	997,0	93,0
Shotabasted coated	1236,3	125,5

The tests performed with the hardening solutions were carried out on shotblasted and shotblasted and chromed samples sent to a Goniometer to determine the contact angle and consequently its wettability.

3.4 Droplet testing

The higher the surface tension will be the contact angle and therefore its wettability with the surface studied [9]. The representative samples of the two situations showed their stabilization in 10 seconds. The stabilization curves for the sample of the blasted surface are shown in figure 4.

The graph shows the contact angle was given at approximately 50.4 ° for the concentration of 3% and 35.3 ° for concentration of 5% of solution of hardening. In this case, the improved wettability accompanies the increased concentration of the hardening solution, which in turn ensures a better lubrication of the process.

In Fig. 5 the droplet shape can be checked at the end of the test, its flattened shape showing a larger interaction with the 5% solution content

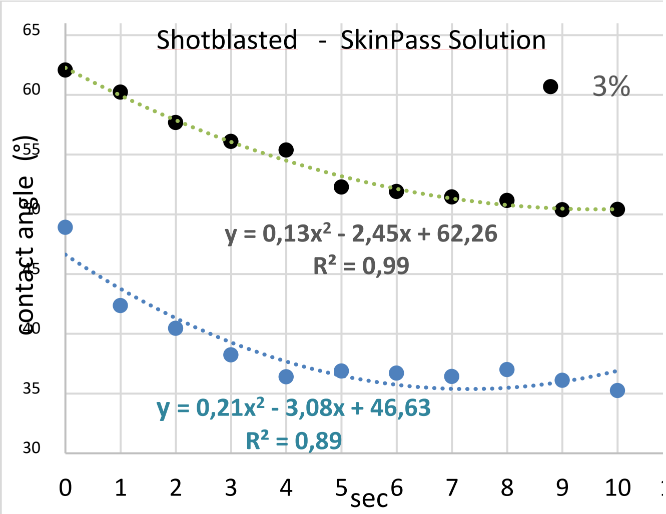
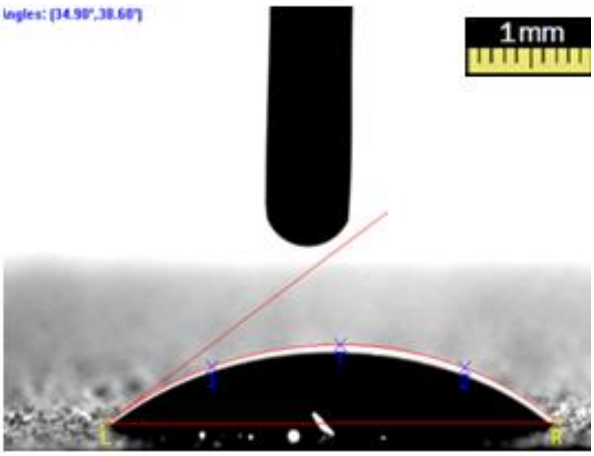


Figure 4. Stabilization Curve of the contact angle for shot blasted surface.



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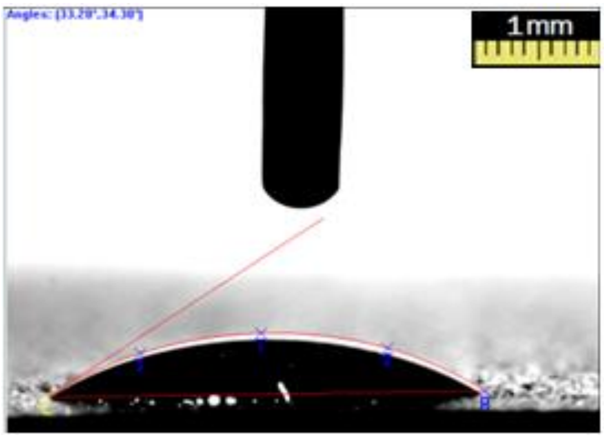


5B

Figure 5A and 5B. Drop shape for 3% and 5% wt.

The chromed surface presented smaller angles than the uncoated surface, indicating that this type of surface indicates a better wettability when compared to uncoated rolls, shown in figure 6.

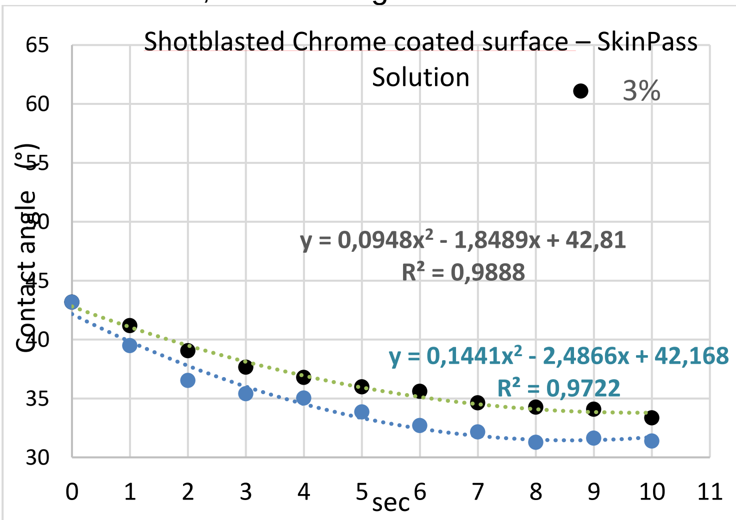
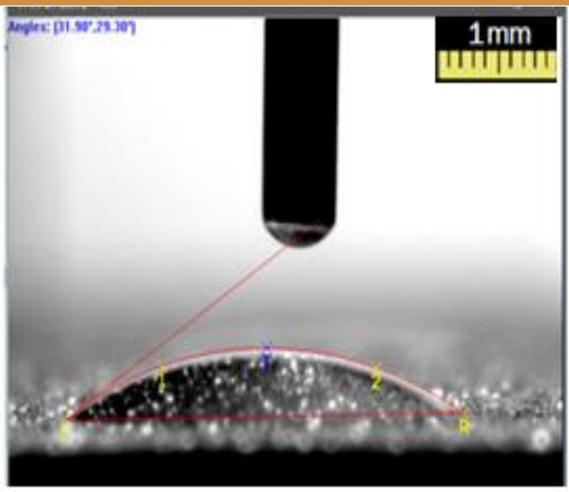


Figure 6 Stabilization Curve of the contact angle for Shot blasted Chrome coated surface

The values found for both solute concentrations were close when compared only to the chromed surface, evidencing that the solute composition in this finishing condition has little influence on the wettability, for the ranges studied. The samples with non-chromed surfaces had the highest solute content, 5%, and presented a lower wetting angle, indicating a higher wettability than the 3% solution. It can therefore be considered that the increase in concentration interferes more significantly when the surface is not chromed.

In Figure 7 A and B it is possible to observe the images obtained in the goniometer for the drops on the surface of each surface condition in the instant of 10 seconds.



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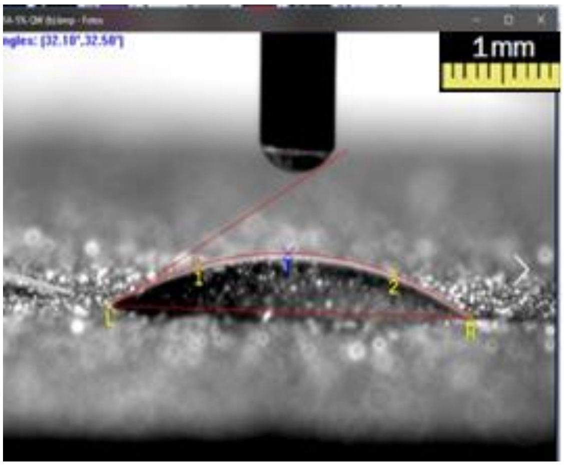

7B

Figure 7 A and B.Contact angle after 10 sec.

The chromed surface presented smaller angles than the uncoated surface, indicating that this type of surface indicates a better wettability when compared to uncoated rolls. The values found for both solute concentrations were close when compared only to the chromed surface, evidencing that the solute composition in this finishing condition has little influence on the wettability, for the ranges studied. The samples with non-chromed surfaces had the highest solute content, 5%, and presented a lower wetting angle, indicating a higher wettability than the 3% solution. It can therefore be considered that the increase in concentration interferes more significantly when the surface is not chromed.

4 CONCLUSION

The results show that the samples with chromium surface coating had higher wettability levels than in the non - chromed samples, showing that there is an interaction of the chemical composition of the surface of the rolls that affects directly the of the fluid with the surface.
The increase of solute concentration in the skinpass solution increased the wettability in all cases analyzed, being more effective the effects in non-chromed surface for the ranges studied .
The comparative study between the wettability of the rolling fluids, comparing the surface appearance of the rolls shows the important relationship between the finish and the wettability, which could interfere with the wear of the cylinders and also the surface finish of the rolled strips.
It can be said that if the samples analyzed on chromed surfaces indicate a better formation of fluid film in rolling processes, independent of the chemical composition analyzed in this work, which guarantees a better processing of thin strips and possible increase of the same.
The productivity of the coated rolls was higher than the uncoated ones about 3 times higher.

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