

# Improvement of surface texture on the hot dip galvanized and galvanized steel sheets

M.-H. Hong, H.-J. Tark, J.-S. Park, D.-J. Paik

*Customers of hot dip galvanized and/or galvanized steel sheets for automotive are more and more demanding on high surface quality, paintability and press-formability. The roll texture for temper-rolling in continuous galvanizing line should be very precisely treated to give a special roughness, which can be transferred to the Zn-coating surfaces during temper-rolling. Among the various texturing methods, in the present study, we adopted a newly developed TCT (TopoCrom Texturing) technology and both roll roughness (high/low Ra) and Cr structures (Open/Closed types) are tested. The products applying TCT had a uniform and dense roughness pattern and surface characteristics is also compared with the conventionally used EDT (electron discharge texturing) treatment. It should be noted that TCT technology on commercial galvanizing coating surface is firstly used and the best condition was  $Ra=1.2\ \mu\text{m}$  with closed type; the roughness value decreases about 35% compared to the conventionally used EDT. On the other hand, in hot-dip galvanized steel sheets, the best condition was  $Ra=3.0\ \mu\text{m}$  with closed type. The friction coefficient was significantly improved by the effect of the formation of oil pockets on the hot-dip galvanized steel sheet.*

## Keywords:

Surface texture, Galvanized steel sheets, EDT and TCT, Friction coefficient

## INTRODUCTION

The fast development of the manufacturing technology for the hot-dip galvanized steel sheets has substituted its market share from electro-galvanized(EG) to mostly galvanized(GI) steel sheets in European automotive and mostly galvanized(GA) steel sheets in Asian automotive industries. Generally, hot-dip galvanized steel sheets are manufactured by passing through a molten zinc bath after annealing the cold rolled sheet steels. Continuous galvanizing lines (CGL) are comprised of several sections, which are the cleaning section for obtaining the material cleanliness, the continuous annealing section for achieving mechanical properties, zinc pot with miscellaneous facilities like air knife, mini-spangle chamber and galvanized furnace and temper-rolling mill to improve their surface morphology [1]. Hot-dip zinc coated steel sheets are classified into GI and/or GA where coatings are comprised of pure zinc and iron-zinc intermetallic compounds, respectively. GA coating layer is usually alloyed with 8~12% Fe by 450~500°C heating to improve their weldability [2]. An aesthetical visual appearance of GI and GA coatings after the painting is critically demanded by automotive market [3, 4]. The quality parameters for both GI and GA coatings should be divided into internal specifications like yield strength, tensile strength, elongation and r-value and external specifications like coating adhesion, homogeneous roughness, defect-free surface and flatness [5]. The greatest impact on both internal and external quality-related parameters is affected by the temper-rolling mill with a tension leveler installed down

stream [6, 7]. Generally, texture roll roughness is transferred to the strip during passing temper-rolling and strip roughness is affected by roll surface texturing technique [8-12]. A lot of different material and surface specifications of the metal coatings underline the difficulties on properly designing of the temper-rolling mill [13]. In the present study, to obtain the high quality surface roughness, press formability and paintability, newly developed TCT (TopoCrom Texturing) technology with various roll roughness and Cr structures has been investigated.

## EXPERIMENTAL PROCEDURE

Samples with 0.8mm in thickness are taken from the industrial CGL at POSCO Kwangyang works, either before and after temper-rolling. Characteristics of various surface texturing technologies used in the industrial CGL are listed in Fig. 1. Most widely used electro-discharged texturing (EDT) and electron beam texturing (EBT) are prepared by electrical sparks and electron beam, respectively.

In the case of TCT, hemispheric Cr-Coating with various density and size upon the bonding layer can be prepared by controlling the Cr solution temperature and current density as shown in Fig. 2. So, in TCT, the texture topography of roll and transferred strip and/or coating can be precisely controlled compared to the EDT where roll surface is textured by mechanical or physical process.

## RESULTS AND DISCUSSION

Fig. 3 shows the SEM images of 6 different types of TCT manufactured on commercial GA coating surface. Although GA is harder and more brittle than GI coating, hemispheric topography indented from texture roll are clearly observed and it was known that cracks are rarely introduced. The density and diameter of hemisphere are (a) closed  $1.2\ \mu\text{m}$ , (b) opened  $1.2\ \mu\text{m}$ , (c) closed  $2.5\ \mu\text{m}$ , (d) opened  $2.5\ \mu\text{m}$ , (e) closed  $5.0\ \mu\text{m}$  and opened  $5.0\ \mu\text{m}$ , respectively. Note that both closed and opened hemi-

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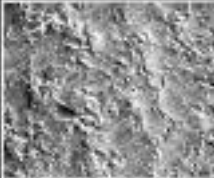

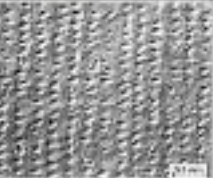
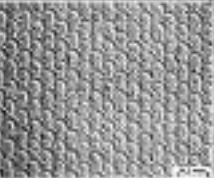

	<b>SBT</b> (Shot Blast Texturing)	<b>EDT</b> (Electro Discharge Texturing)	<b>LBT</b> (Laser Texturing)	<b>EBT</b> (Electron Beam Texturing)	<b>TCT</b> (Topocrom Texturing)
<b>Method</b>	Impact of steel pieces on roll	Electrical sparks	Laser beam	Electron beam	Roll roughness is given when Cr coating
<b>Roughness Control factor</b>	Steel grit size	Electrical parameter	Laser intensity, Chopper velocity	Electron beam intensity	Plating current, Solution temperature
<b>Roughness shape (steel sheet)</b>					
<b>characteristics</b>	Good productivity, large roughness deviation	Good painting & Image clarity. Bad press formability	Developed to overcome the disadvantages of EDT, But application was not expanded because of difficult facilities management		Good painting, formability, roughness abrasion resistance

FIG. 1 Characteristics of various surface texturing technologies for hot-dip galvanizing coating.

Caratteristiche di diverse tecnologie di finitura della superficie per rivestimenti da galvanizzazione per immersion a caldo.

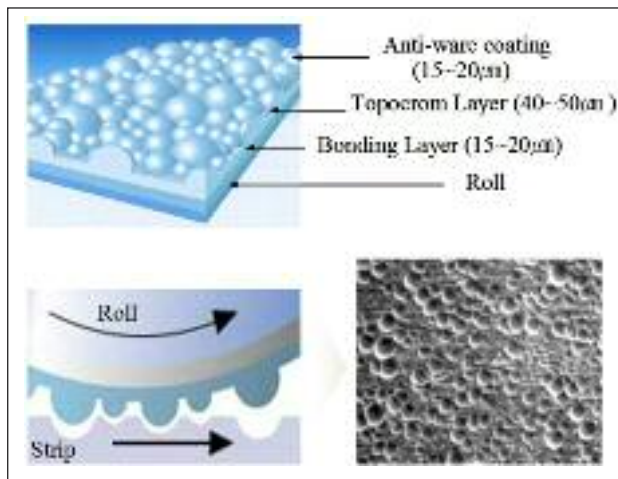


FIG. 2

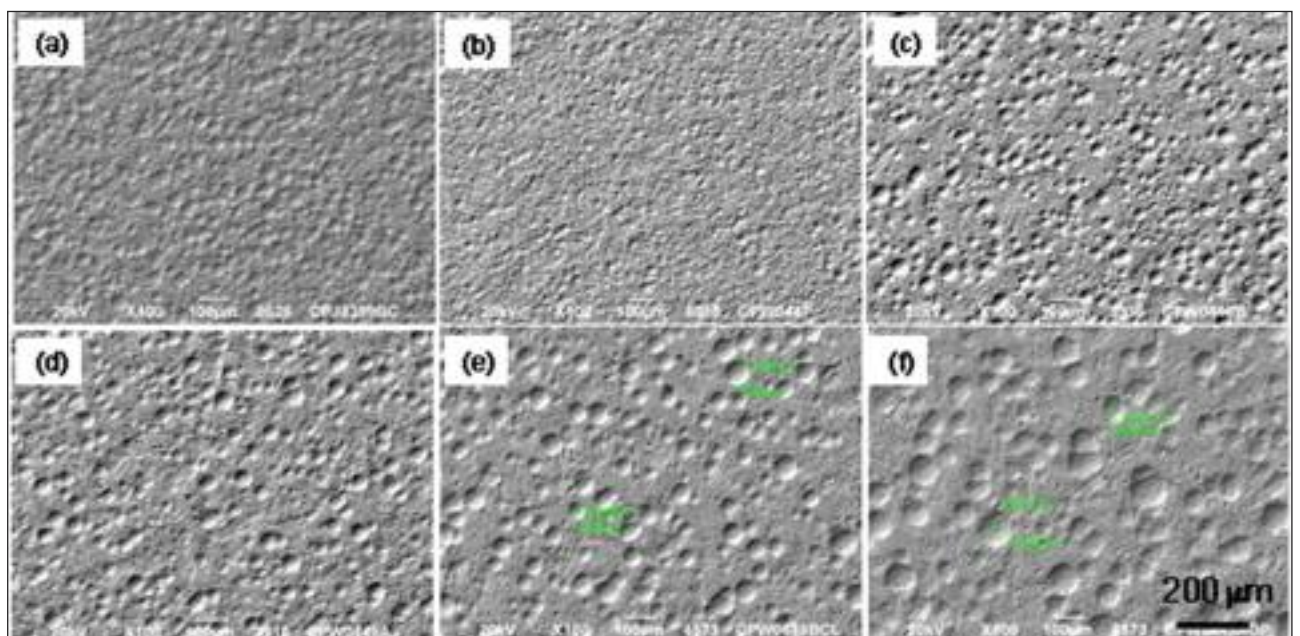
Schematic illustration of TCT with the galvanized coating surface.

Illustrazione schematica della tecnologia TCT e della superficie galvanizzata.

FIG. 3

SEM images of TCT prepared by (a) closed 1.2 µm, (b) opened 1.2 µm, (c) closed 2.5 µm, (d) opened 2.5 µm, (e) closed 5.0 µm and (f) opened 5.0 µm, respectively.

Immagini SEM di TCT preparati rispettivamente mediante (a) chiuso 1.2 µm, (b) aperto 1.2 µm, (c) chiuso 2.5 µm, (d) aperto 2.5 µm, (e) chiuso 5.0 µm e (f) aperto 5.0 µm.



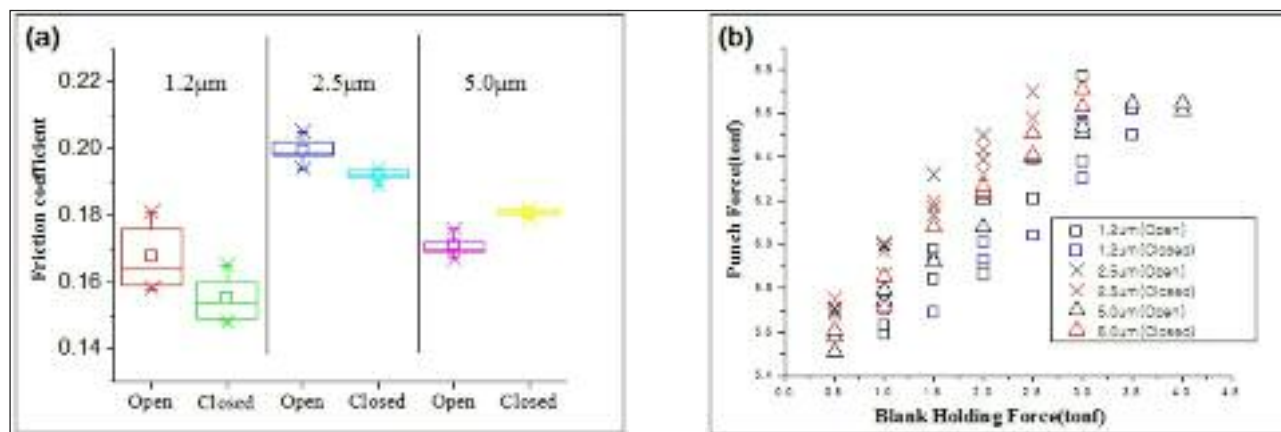


FIG. 4 The relationships between (a) friction coefficient and (b) texture types.

Relazione fra (a) coefficiente di frizione e (b) tipi di finitura.

spheres represent the low and high density controlled by solution temperature and current density during Cr-coating formation on texture-roll. In the case of GA coating, it was expected that TCT is rather difficult to apply compared to GI coating with smooth and ductile surface, because high density of craters existed on the GA coating surface after galvannealing process is expected to prevent the indentation of the homogenous roll-texture. However, contrary to the expectation, roll-texture is successfully transferred without any problems.

Fig. 4 shows the friction coefficients obtained from one-side (Fig. 4(a)) and cup-drawing friction tests (Fig. 4(b)), respectively. One-side test was carried out repeatedly 8 times and it is known that closed 1.2 µm has the lowest friction coefficient, namely 0.155. On the other hand, in the cup-drawing test, the highest blank hold force was obtained at opened 5.0 µm followed by closed

1.2 µm. Although it is not clear why opened 5.0 µm shows the best result, it was considered that the closed 1.2 µm roll-texture is mostly suitable for the GA coating.

Table 1 shows the friction coefficient, maximum blank hood force and roughness as the functions of roll roughness and structure in the GA coating. For comparison, EDT result is also presented and it was known that all properties obtained from closed TCT with 1.2 µm are superior to the conventionally used EDT.

Roughness in 2.5 µm and 5.0 µm is measured as 1.75-2.45 which is very high value demanded for automotive market. Friction coefficient and blank holding force as a function of punch force for EDT and opened and/or closed TCT with the same roll roughness of 1.2 µm are shown in Fig. 5. It is known that closed TCT shows the best result among the 3 texture-rolls and this is in good agreement with the results in Fig. 4 and Table

TAB. 1 Friction coefficient, maximum blank hood force and roughness of the GA coating as the functions of roll roughness and structure.

Coefficiente di frizione, massima forza del premiamiera e rugosità del rivestimento GA in funzione della rugosità e struttura del rullo.

Roll Roughness (µm)	Roll Structure	Friction coefficient (av.)	Max. BHF (tonf)	Roughness (µm)
1.2	EDT	0.167	3.0	0.94
	Open	0.168	3.0	0.99
1.2	Closed	0.155	3.5	0.89
	Open	0.2	2.0	2.21
2.5	Closed	0.192	2.5	1.75
	Open	0.171	4.0	2.45
5.0	Closed	0.181	3.0	2.29
	Open			

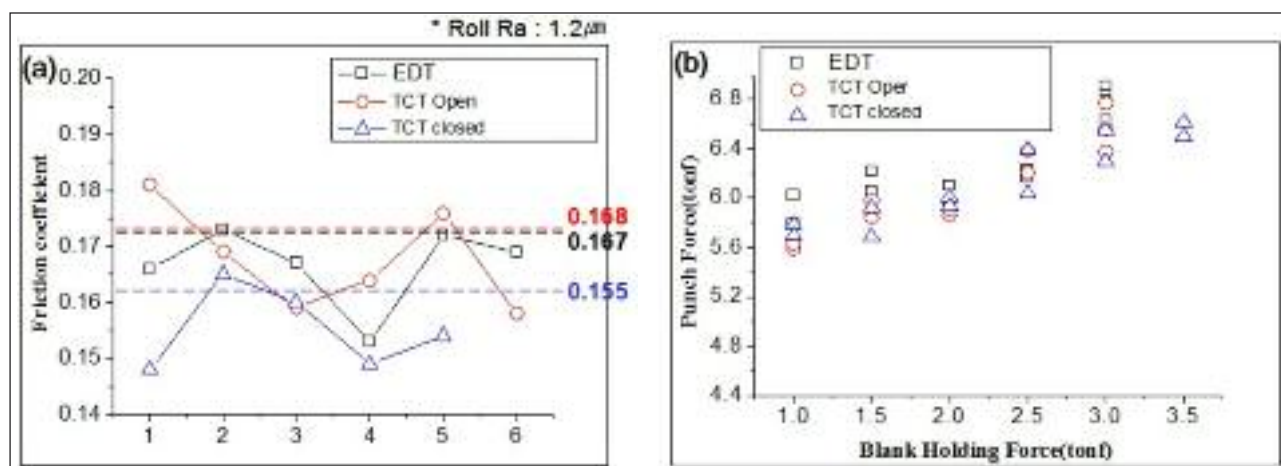
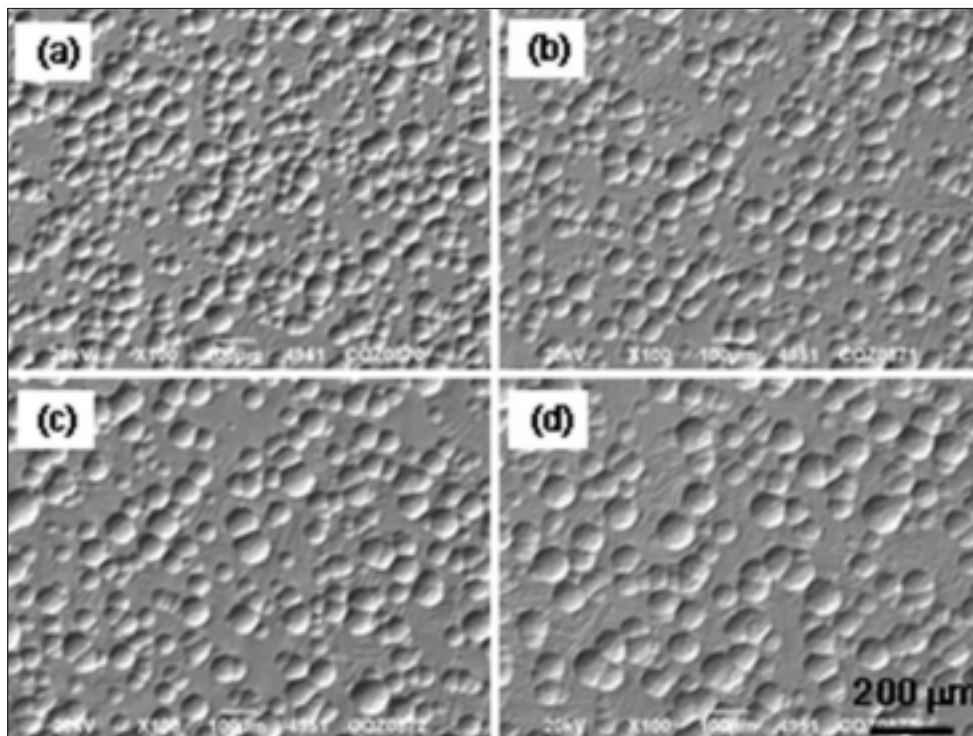


FIG. 5 Friction coefficient and blank holding force as a function of punch force.

Coefficiente di frizione e forza del premiamiera in funzione della forza del punzone.



**FIG. 6**  
SEM images of TCT prepared by (a) closed 3.0  $\mu\text{m}$ , (b) opened 3.0  $\mu\text{m}$ , (c) closed 6.0  $\mu\text{m}$  and (d) opened 6.0  $\mu\text{m}$ , respectively.

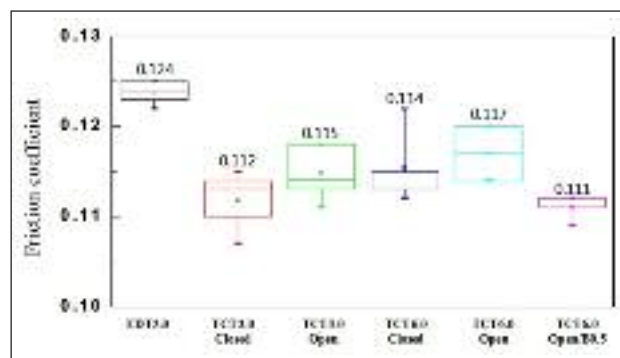
Fig. 6. Immagini SEM di TCT preparati rispettivamente con (a) chiuso 3.0  $\mu\text{m}$ , (b) aperto 3.0  $\mu\text{m}$  e (d) aperto 6.0  $\mu\text{m}$ .

1. Thus, in the GA coating, it is concluded that newly developed closed 1.2  $\mu\text{m}$  TCT is the best choice to substitute already used EDT roll texture.

Fig. 6 shows the SEM images of GI coating surface with 4 different TCT treatments. It is known that typical hemispheric topography in TCT is clearly transferred to the GI coating surface where coating surface is rather smooth and/or ductile compared to the alloyed GA coating in Fig. 3. Note that the roll force for the GI coating is very low compared to the GA coating in the same transfer ratio. The density and diameter of hemisphere are (a) closed 3.0  $\mu\text{m}$ , (b) opened 3.0  $\mu\text{m}$ , (c) closed 6.0  $\mu\text{m}$  and (d) opened 6.0  $\mu\text{m}$ , respectively. Again, closed types roll-texture show a rather high density of hemisphere compared to the open types.

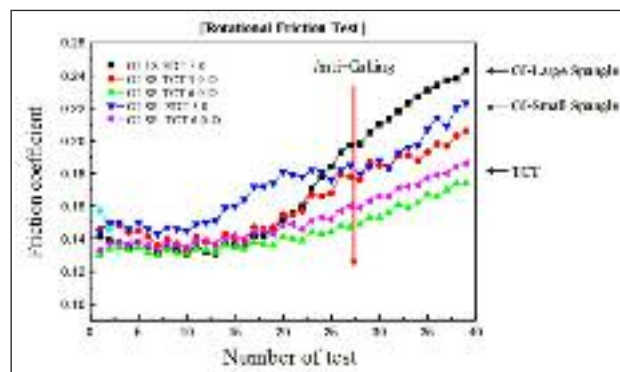
Fig. 7 shows the friction coefficient obtained from the GI coating with the speed of 200mm/s and pressure of 40MPa. Lubricant P-340N was used. It was known that all TCT data show a little lower value compared to the conventional EDT roll texture of 0.124. And closed type is superior to the open types, i. e., higher density of hemisphere in closed types TCT contributes to the decrease of friction coefficient due to the rather strong lubricant pocket effect. Closed 3.0  $\mu\text{m}$  exhibits the lowest friction coefficient, namely 0.112. Note that, in the open 6.0  $\mu\text{m}$ , the friction coefficient is also predominantly improved by introducing the bright roll in the dual temper-rolling system.

On the other hand, friction coefficient for determining the galling properties for various GI coating is tested by rotational friction tester as shown in Fig. 8. It can be said that TCT shows a little lower friction coefficient compared to the conventional EDT regardless to the roughness and type. Here, it should be mentioned that spangle size is also one of the factors to determine the friction coefficient. i. e., GI coating with a small spangle size has a little lower value compared to the large spangle size and this in good agreement with our previous results [4]. In general, it is accepted that galling properties during press-forming is strongly related to the friction coefficient and its value of 0.18 in GI coating is known as the criterion for preventing the galling exfoliation. From this view point, TCT with 6.0  $\mu\text{m}$  texture can



**FIG. 7** Friction coefficient obtained from the GI coating in various texture types.

Coefficiente di frizione ottenuto da rivestimento GI in diversi tipi di finitura.



**FIG. 8** Friction coefficient obtained from the both EDT and TCT rolls with different roughness.

Coefficiente di frizione ottenuto con entrambi i rulli EDT e TCT con diverse rugosità.

successfully achieve the target for guaranteeing the galling. Another important factor for GI coating is paint surface determined by the wave-scan method [1]. It is immediately apparent that the surface roughness has a significant influence on the surface quality after painting, i. e., high roughness value leads to poorer surface properties [8]. In the present study, the roughness values of the GI coating for 3.0  $\mu\text{m}$  EDT, closed 3.0  $\mu\text{m}$  TCT, opened 3.0  $\mu\text{m}$  TCT, closed 6.0  $\mu\text{m}$  TCT and opened 6.0  $\mu\text{m}$  TCT are 1.17  $\mu\text{m}$ , 1.25  $\mu\text{m}$ , 1.35  $\mu\text{m}$ , 1.88  $\mu\text{m}$  and 2.08  $\mu\text{m}$ , respectively. Thus, the conflict existing in the requirements of high roughness with excellent press formability and of lower roughness with an acceptable paint surface quality can be satisfied by choice of an appropriate roughness balance. In Fig. 8, although friction coefficient in both closed and opened 6.0  $\mu\text{m}$  TCT by rotational friction tester seems to be enough to prevent the galling properties, it is recommendable to choose closed 3.0  $\mu\text{m}$  TCT for balancing between press formability and paint quality for the GI coating.

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## Abstract

### Miglioramento della struttura superficiale di lamiere d'acciaio zincate e galvannealed

Parole chiave: trattamenti superficiali, automotive, tecnologie

Gli acquirenti di lamiere in acciaio zincato per immersione a caldo e / o galvannealed per l'industria automobilistica sono sempre più esigenti in termini di alta qualità delle superfici, verniciabilità e press-formabilità. La condizione superficiale del rullo per il temper-rolling in continuo nelle linee di galvanizzazione dovrebbe essere molto curata per conferire una rugosità particolare, che possa essere trasferita alle superfici del rivestimento di zinco durante il temper-rolling. Nel presente studio, fra i vari metodi esistenti per conferire la finitura superficiale, è stata adottata una tecnologia di nuova concezione denominata TCT (TopoCrom Texturing) e sono stati analizzate sia la rugosità del rullo (alto / basso Ra) e sia le strutture del cromo (tipo aperto / chiuso). Applicando la tecnologia TCT la rugosità dei prodotti è risultata avere una struttura uniforme e addensata e le caratteristiche superficiali sono state confrontate anche con il trattamento EDT (electron discharge texturing) convenzionalmente utilizzato. E' utile notare che la tecnologia TCT sulla superficie del rivestimento commerciale galvannealed è stato in primo luogo utilizzato e la migliore condizione è risultato essere Ra = 1,2  $\mu\text{m}$  di tipo chiuso; il valore di rugosità diminuisce del 35% circa rispetto a quello dell' EDT convenzionalmente utilizzato. D'altra parte, nelle lamiere di acciaio galvanizzate per immersione a caldo, la migliore condizione era Ra = 3,0  $\mu\text{m}$  di tipo chiuso. Il coefficiente di attrito è stato migliorato notevolmente per effetto della formazione di sacche d'olio sulla lamiera di acciaio zincato a caldo.