MODIFICATION OF THE RESIDUAL STRESSES AND MICROSTRUCTURES IN HARD CHROMIUM PLATING BY SHOT PEENING

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ABSTRACT

The present study shows the modification of the residual stresses distribution and microstructure in hard chromium plating coating by shot peening. The shot peening is used as a finishing treatment before the chromium plating. The residual stress distribution obtained for different processes will be shown. Two techniques will be studied: conventional eletrodeposition and eletrodeposition by pulsed current. The results of residual stresses concerning the coating layer with and without shot peening will be analysed. It can be seen that the shot peening modifies the residual stresses state of the substrate and of the coating layer. The combination of shot peening and the pulsed current process produces the more favorable residual stresses distribution.This study shows that it is possible to optimize the residual stresses state in the hard chromium plating. The shot peening can be used as material improvement treatment of the hard chromium platint coating.

KEYWORDS

Chromium plating, pulsed current, incremental hole drilling method, residual stress measurement, crack free coating.

INTRODUCTION

The use of protective coatings in industrial applications is rapidly increasing in many new areas. The adhesive properties of the coating are of prime importance since they limit the coatings useful life. One important factor which contributes to coating failure is the residual stress produced during its manufacture.

The sources of stress-induced failure can be divided into two factors. Firstly, residual stresses present in the coating, and secondly, mechanical stresses generated during the service of the component. Although residual stress in coatings and substrates is often considered, very little written material exists concerning its actual measurement.

The use of hard chromium plating as an eletrodeposited surface layer on other metals is now a well established industrial practice. The chromium layers are deposited in order to take advantage of the high hardness, corrosion resistance and the wear resistance or the low coefficient of friction of such deposits. But in most cases, the electrodeposits of chromium are often extensively cracked. Their formation is due to the residual stress in the eletrodeposit as it is formed [1]-[5]. Williams and Hammond [14] have shown the influence of shot peening before chromium plating on the fatigue strength (fig.1). The fatigue strength increases when the Almen intensity used increases.

The present study shows the modification of the the residual stresses distribution and microstructure in hard chromium plating by shot peening. The shot peening is used as a finishing treatment before the chromium plating. The residual stress distribution obtained for different processes will be shown. Two techniques will be studied: conventional electrodeposition and eletrodeposition by pulsed current. The results of residual stresses concerning the plating layer with and without shot peening will be analysed.

PROCESS OF THE ELETROPLATED CHROMIUM

In our study, chromium was deposited from aqueous solution of chromic acid. The following bath composition was used : 250 g/l of Cr_2O_3 , 2.5 g/l of H_2SO_4. The bath temperature was about 50 °C $\pm$ 2 °C.

One characteristic of the deposit made from this bath, by direct current plating (30 to 40A/dm^3) is its tendency to spontaneous cracking. Using a pulse reversed current process developed by CETIM [6-8], crack free chromium deposits can be produced . The currrent shape shown in fig.2 is described by the following parameters : T cathodic = Duration of the cathodic impulsion, T anodic = Duration of the anodic impulsion, I an = Anodic current density, I catho = Cathodic current density .

In our work, the following plating procedure was used : Surface preparation (grinding or shot peening), Precleaning, Electrolytic cleaning, Sulfuric acid etching, Chromium plating, With or without degassing.
The deposits produced were grey, mat in appearance, but readly polished. Surface of DC and pulsed reverse current deposits are shown in fig.3.

SAMPLE PREPARATION CONDITIONS

In the previous paragraph, we have described the process of the electrodeposited chromium coatings. The advantage of the pulsed current method is the possibility to minimize the microcrack formation. But in [9], it is shown that the fatigue strength is not higher for the case of the coating obtained by pulsed current method. The [10] is concerned with the development and understanding of shot peening as controlled process, applied prior to hard chromium and nickel deposition. The main effect of shot peening is to introduce the compressive residual stresses to stop the propagation of the crack initiated in the coating layer. Up to now, very few litterature have shown a systematic study of residual stresses in different combination of coating system.

The substrate is a 30CND 8 grade steel and the chemical composition is shown in table 1. Tables 2 and 3 show respectively the shot peening conditions used and the eletrodeposited condition. Table 4 shows the different case studied in this work.

RESIDUAL STRESSES MEASUREMENT METHOD

Concerning the measurement techniques, different methods can be used. The reference [2] shows a large review of these techniques applied to chromium platings . One of these cited methods is the use of a thin metal strip plated on one side only, in order to determine the residual stresses in that plate by the measurement of deflection it caused to the strip. He has also mentionned the possibility to use X-ray diffraction method. In a study carried out in CETIM [9], it was shown that it is possible to evaluate the residual stresses by X-ray diffraction method. But the microcracked structure of the chromium plating induces errors of calculation of stress. Another difficulty is the time-consuming task for the layer removal. In this study, the measurement technique used is the incremental hole drilling method. The principle of this method is largely developed in references [11] -[13].

RESULTS AND DISCUSSIONS

Fig.4 shows the residual stresses obtained in a layer manufactured by a chemical chromium plating. In the coating layer, the tensile residual stresses are observed up to a depth of 200 μm , compressive residual stresses are obtained from this depth. It can be seen that the level of the residual stresses measured are very important. The fluctuation of the level of residual stresses can be explained as following : in fact, the level of residual stresses depends on the number of cracks in the chromium coating. The coating manufactured by conventional chromium plating is microcracking. When the hole depth corresponds to a high crack density zone, the level of the stresses is smaller (fig.5).

The [2] has shown a very instructive illustration of the relationship between stress produced and the cracking that occurs in chromium coating, as its thickness increases .

Fig.6 shows the residual stresses measured in a sample manufactured by the pulsed current process. It can be seen that the level of residual stresses is smaller than a conventional plating. As described previously, this process induce a cracking free coating. So the corrosion resistance is more important for this kind of coating. But the level of tensile residual stress is quite important (about 370MPa). In fact, for this case, the duration of cathodic impulsion is long and the duration of anodic impulsion is short, the manufacture condition is near the case of conventional method.

Fig.7 shows the results measured in a sample manufactured by the conventional method but with a shot peening pretreatment. The tensile residual stresses are smaller than the case without the shot peening in the coating layer. In the subsurface layer, the compressive residual stresses of shot peening are observed.

Fig.8 shows the residual stresses measured on a sample manufactured by the pulsed current process with a shot peening pretreatment. On the surface, the tensile residual stresses have the same level as compared with the case without the shot peening. But the tensile layer is smaller for the coating with a shot peening pretreatment. On the subsurface, compressive residual stresses are observed. So the residual stresses of shot peening are not relaxed during the chromium electroplating.

Fig.9 shows the residual stresses obtained on a sample manufactured with the pulsed current process using a shot peening pretreatment and a degassing post treatment. It can be seen that the degassing treatment is stress relieving post treatment and the surface tensile stress decreases under this condition.

CONCLUSION

This study shows that it is possible to optimize the residual stresses in hard chromium electroplating and the incremental hole drilling method is a suitable method to evaluate the residual stresses distribution in depth on the chromium eletroplating coating. The shot peening process is an efficient pretreatment to introduce the compressive residual stresses in the substrate.

The chromium plating does not modify these stresses. The pulsed current process introduces a smaller tensile residual stresses in the plating layer. The pulsed current condition seems to play a very important role on the tensile residual stresses on the coating. Fig.10 shows the comparison of the residual stress obtained with two coatings manufactured by different conditons. A smaller duration of cathodic impulsion introduces a smaller tensile residual stress. The degassing is also a post treatment which is benefical for the residual stresses distribution in the plating layer. Moreover further, the fatigue test will be carried out to evalute the effect of shot peening pretreatment in the case of pulsed current process. The previous study [9] shows that the corrosion resistance is better for this case but the fatigue test shows the fatigue resistance were not increased using a simple pulsed current process in comparison with the conventional method in the case of coating without the shot peening pretreatment.

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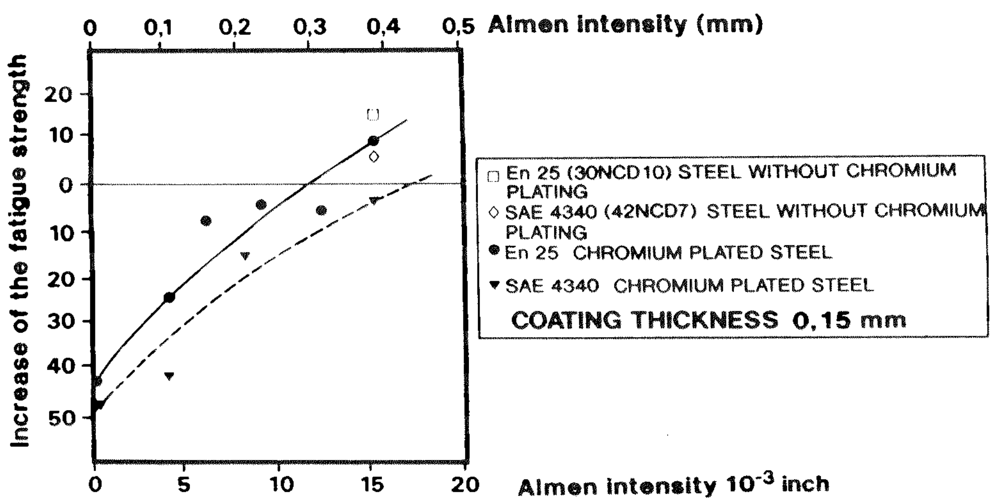


Fig.1 Influence of shot peening before chromium plating on the fatigue strength (from [14])

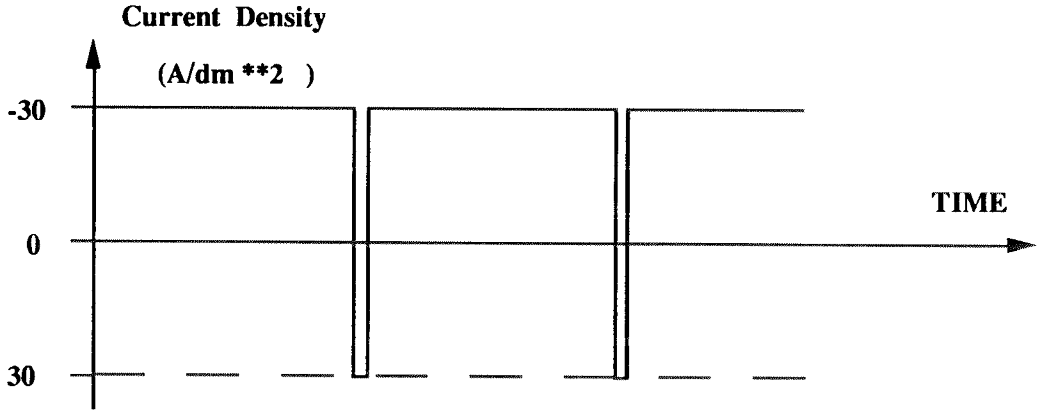
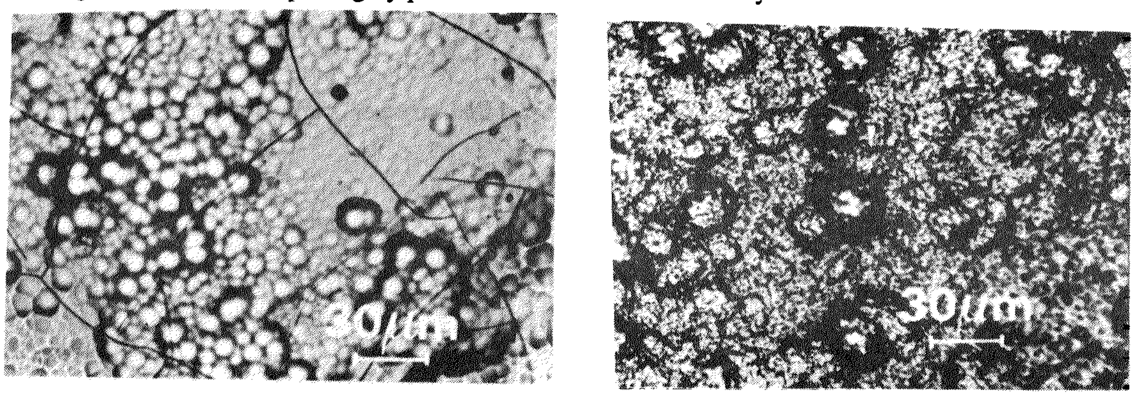


Figure 2. Chromium plating by pulsed reverse current. Electrolysis current



(a) (b)

Figure 3 : Microstructure of Cr coating surfaces, (a) By conventional method (DC) : I=30A/dm^2 , (b) By pulsed reverse current

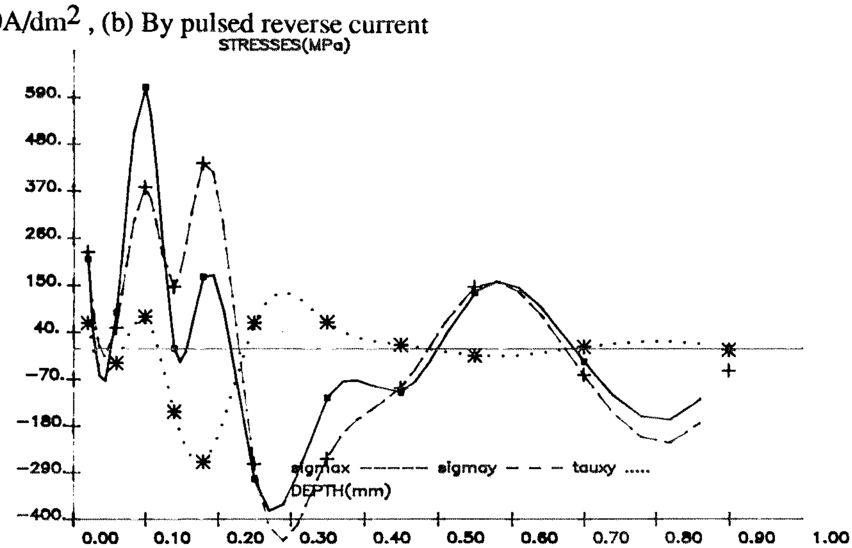


Figure 4 Residual stresses measured in a plating obtained by conventional method.

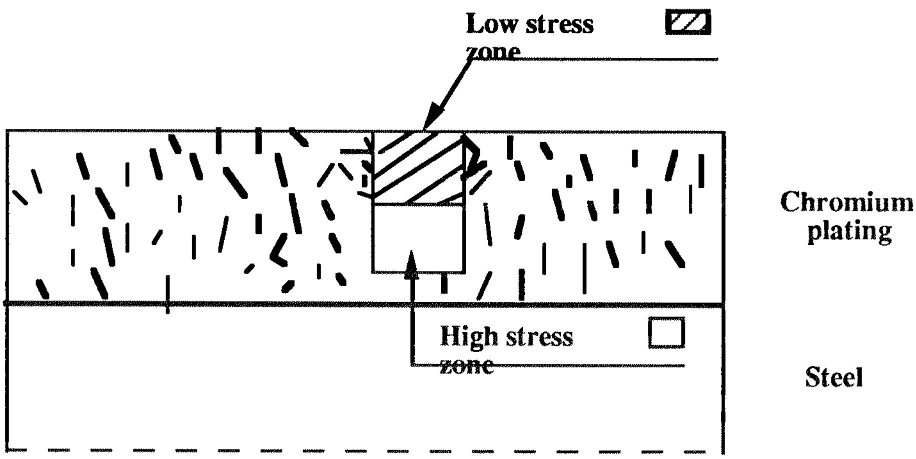


Figure 5 Mechanism of the oscillation of the residual stresses through a hard chromium plating.

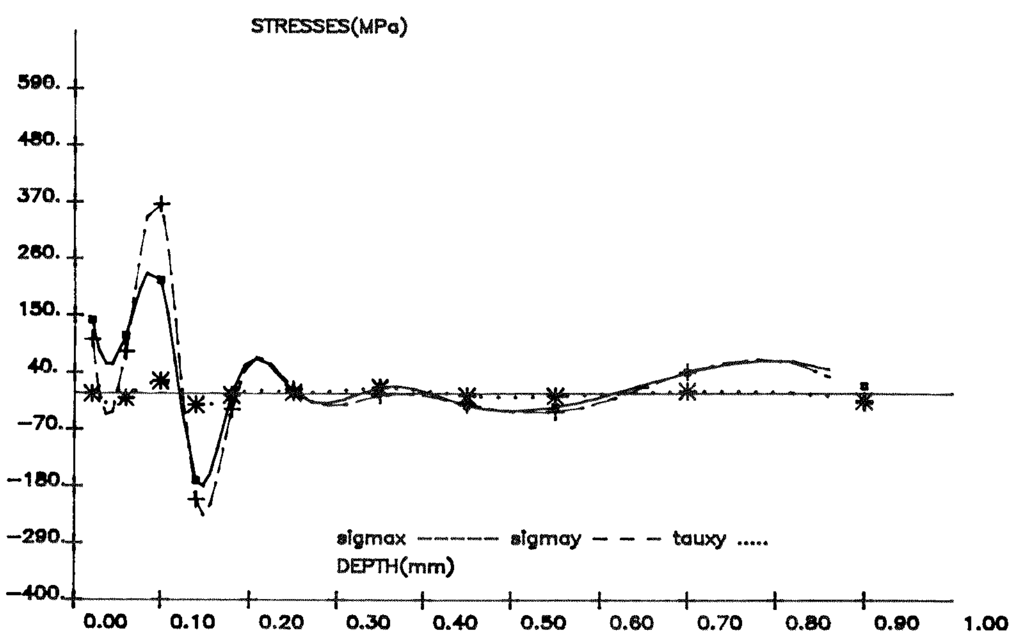


Figure 6 Residual stresses obtained on an sample manufactured by pulsed current method.

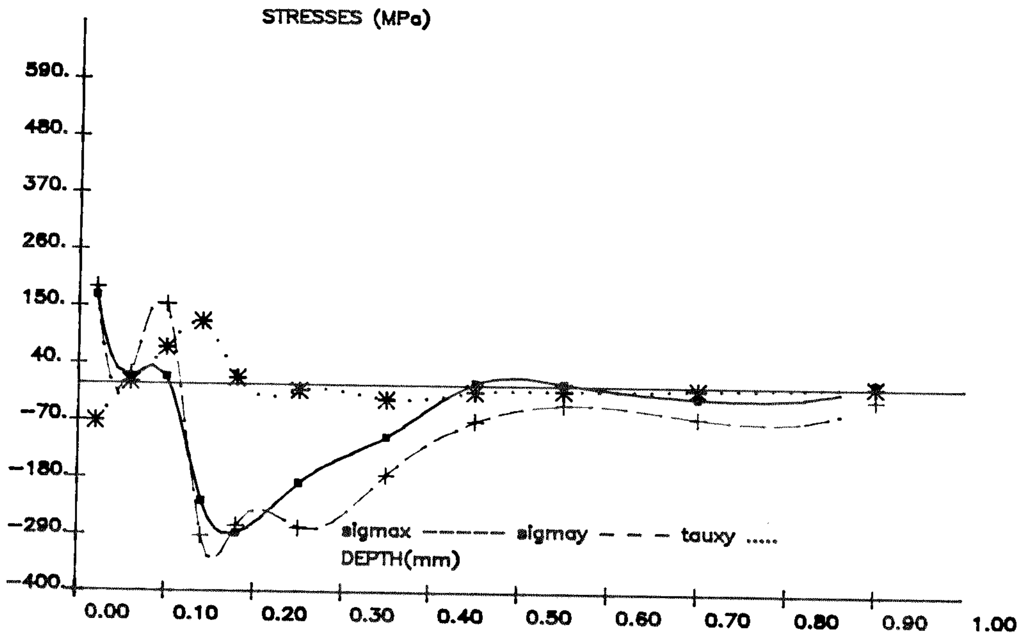


Figure 7 Residual stresses distribution measured on a sample obtained by conventional process with a shot peening pretreatment.

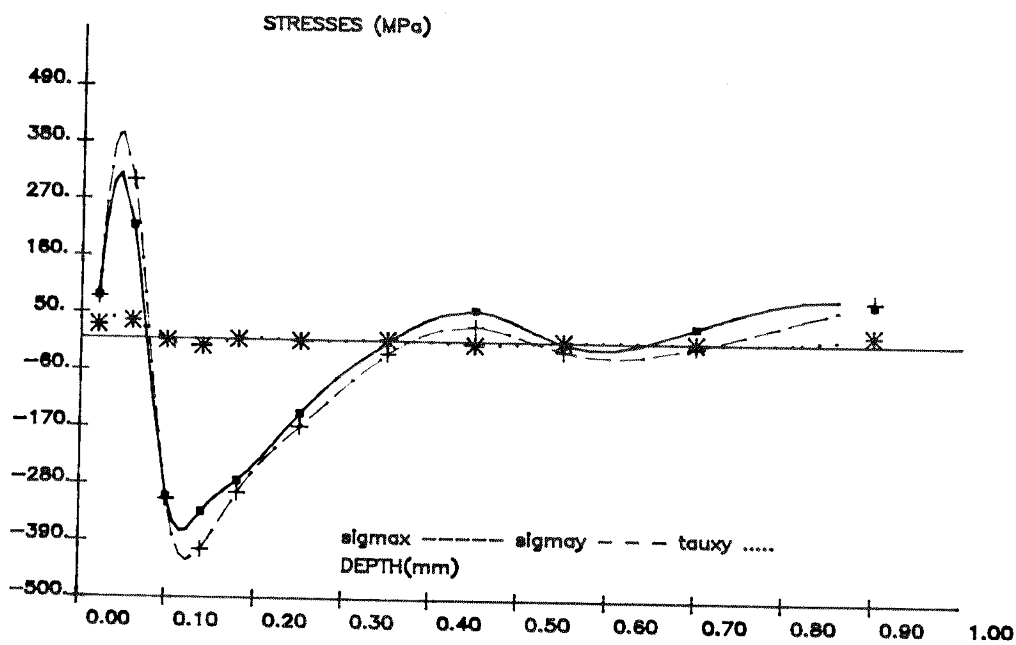


Figure 8 Residual stresses measured on the sample manufactured by pulsed current process with a shot peening pretreatment.

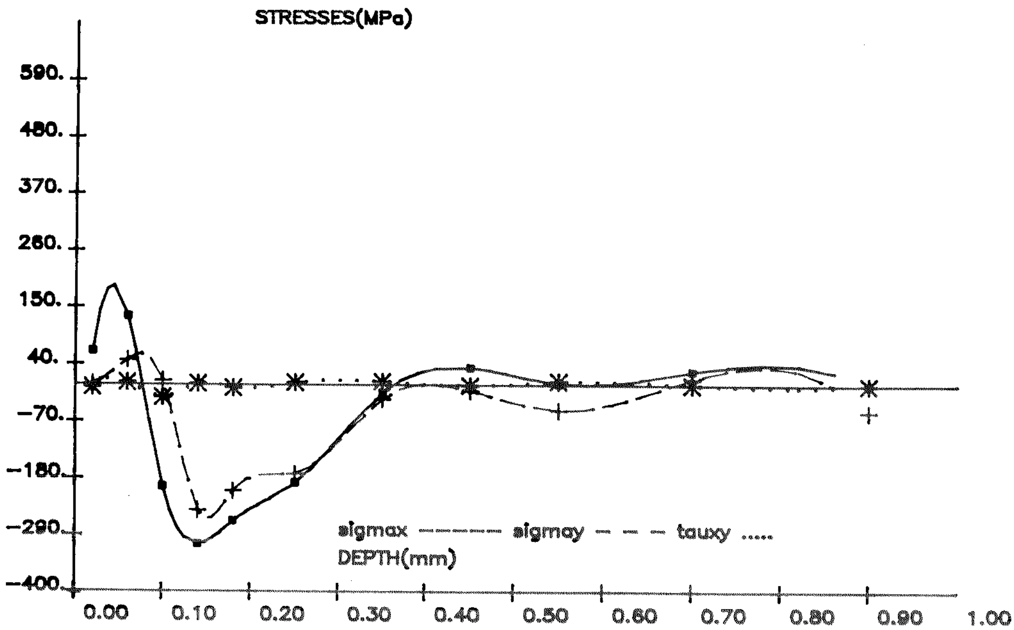


Figure 9 Residual stresses measured on the sample manufactured by pulsed reverse current method with a shot peening pretreatment and a post treatment of degassing.

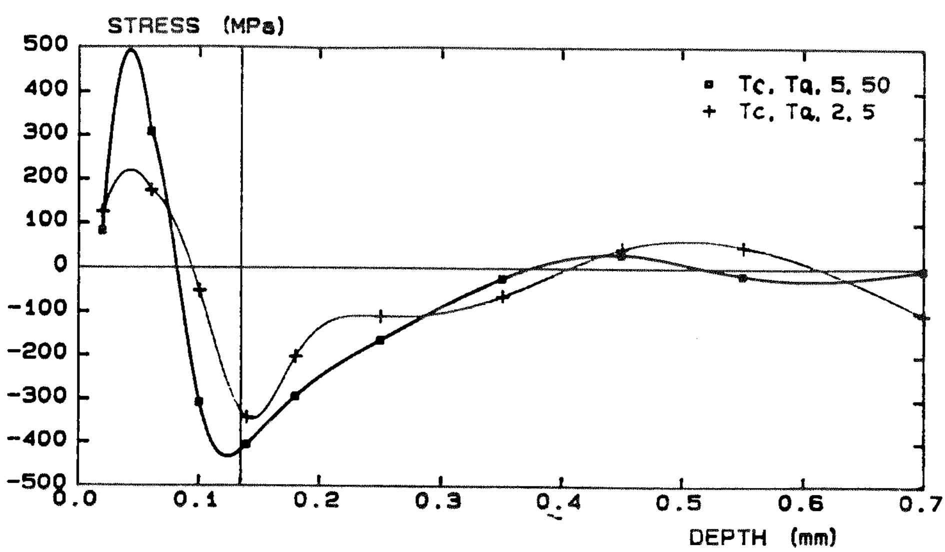


Fig.10 Effect of the condition of pulsed current on the tensile surface residual stress

C	Mn	Si	Ni,max	Cr	Mo	P, max	S, max
0.3	0.34	0.35	2.4	2.15	0.7	0.03	0.025

Table 1 Chemical composition of 30CND8 grade steel

Shot size	Almen Intensity	Coverage
S230 (0.6mm)	0.2-0.25mm A	125 %

Table 2 Shot peening pretreatment condition

T cathodic	T anodic	Degassing treatment
5 s	50ms	200 °C during 3H

Table 3 Electrodeposited condition

Chromium process / Surface Preparation condition	Conventional chomium plating	Pulsed current chromium plating
Without shot peening	CASE 1	CASE 2
with a pretreatment of shot peening	CASE 3	CASE 4
with a pretreatment of shot peening and a post treatment of degassing		CASE 5

Table 4 Sample preparation conditions