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INFLUENCE OF COOLING OIL ON THE SURFACE QUALITY OF THE ROLLED STRIP

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ABSTRACT

The excess of emulsion used in the lamination process leads to the formation of drops which in the annealing process forms spots of burned emulsion. It was also shown to cause formation areas with high carbon concentrations on the surface of the steel strips, after annealing. In the cold rolling process, the surface of the rolled strip is contaminated by cooling oil or emulsion and other chemical compounds, which could considerably influence the final quality of the strip.

The microscopic analysis of the spots of burned emulsion showed a complex phase structure resulting from the combustion rate through the interaction between the emulsion and the contaminating residues, as well as the one between the emulsion and the steel substrate.

KEYWORDS: rolling process, splices, scratches, plies, cooling oil

1. Introduction

In the cold rolling process, the surface of the rolled strip is contaminated by cooling oil or emulsion and other pollutants, which could considerably influence the final quality of the strip. Unfortunately, this will usually become visible only after subsequent operations such as annealing, galvanizing, phosphate or powder coating, etc. [1].

The emulsion is a system consisting of two liquid phases, one dispersed in the other. This is lubricating oil in water emulsion, in which different ingredients are introduced to ensure some characteristics and to improve others [2, 3]. In the case of the cold rolling process, the proper lubrication can facilitate: reduction of the thickness of hot rolled strips at acceptable rolling speed; control of heat losses; corrosion protection of the steel band that will be processed and also of the rolling equipment; obtaining quality surfaces of rolling thin strips [4, 5].

The classification of the defects of cold rolled strips can be done on two criteria [6, 7]:

- appearance and structure of the defect;
- technological step.

The experimental research aimed at identifying and explaining surface defects caused by oils used in cold rolling. These oils can reach the cold rolled and heat treatment process, decompose and burn causing the appearance of specific surface defects [8].

2. Experimental research

The methods of analysis used were:

- thermogravimetric analysis to assess the stability of emulsions and oil heat treatment applied on cold rolled thin strips;
- analysis of macroscopic surface defects;
- microscopic analysis of emulsion formation burnt spots.

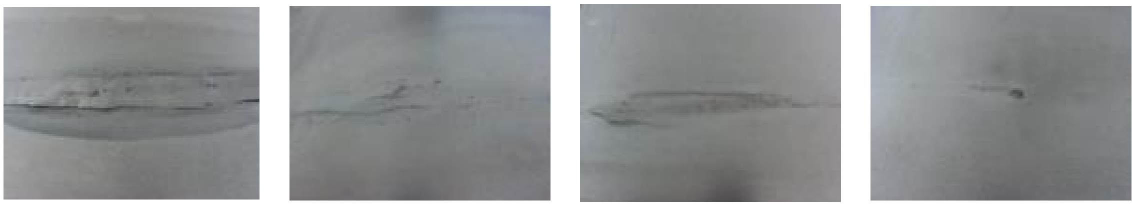
The analysis of surface defects on thin steel strips produced by Galfinband S.A. led to the identification of several cases of production.

A primary cause of the occurrence of defects on the surface of very thin steel strips is the most common raw material. The identified raw material surface defects are: printing cylinder rolling folds of drawing up, scratches, splices (Fig. 1).

Surface defects caused by cooling emulsion occur mainly during the heat treatment when the emulsion used in excess generates spots of burned emulsion.

Emulsion and oil removal from steel strips can be done through several simple methods, which provide low removal efficiency.

One of these methods applied at Galfinband S.A. is carried out by means of the cloth scraper or stitched textile parts, which rapidly absorb the oil and/or emulsion. These scrapers are unusable in a short time. In addition, the release of textile fibers contributes thus to the staining of the strip and decreases its quality (for example, the occurrence of scratches on the strip surface).



plies splices printing scratches

***Fig. 1.** Raw material surface defects (x1/1)*

The presence on the surface of the steel strip of fine iron oxides particles acting as a catalyst provides a highly favorable environment for the process of oil oxidation. During heat treatment, the products are reacted in the gaseous atmosphere of the heat treatment furnace and on the surface of the steel strip.

The annealing treatment was shown to cause the formation of areas with high carbon concentrations on the surface of strip.

3. Results and discussion

The rolling behavior of emulsions during heat treatment according to their degree of wear and temperature was determined by thermogravimetric analysis (Figure 2) and was set based on transformation temperatures and mass loss.

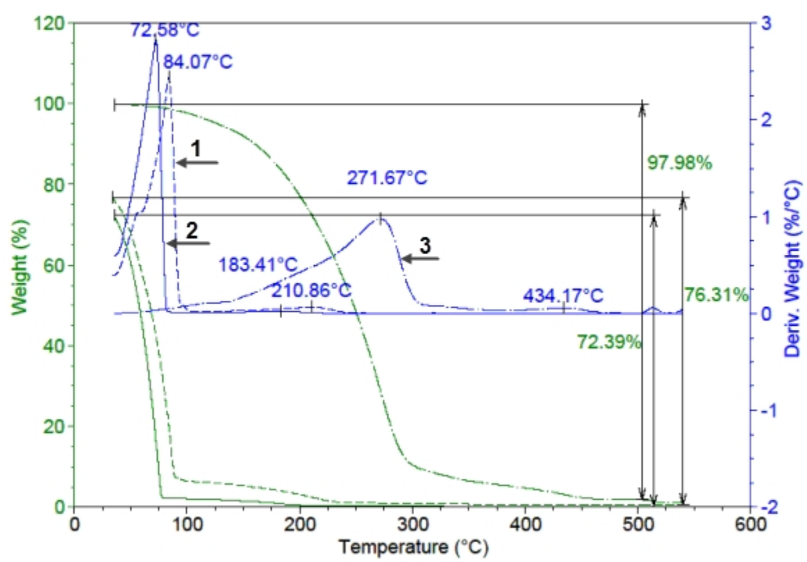


***Fig. 2.** Analysis of emulsion stability according to temperature*
1 – used emulsion; 2 – fresh emulsion; 3 – mineral oil

For clean emulsion (oil 4.5% and water), mass loss is 76.31%. A temperature of 72.58 °C corresponds to the maximum kinetics of water evaporation. The next inflection is at 183.41 °C and corresponds to the maximum kinetics of lubricating oil mass loss. At temperatures above 200 °C, no mass losses are registered. For used emulsion two transformation temperatures were observed, and a total mass loss of 76.31%. A temperature of 84.07 °C corresponds to the maximum kinetics of the water evaporation process and a temperature of 210.86 °C corresponds to the lubricating oil. At temperatures above 350 °C mass losses are insignificant.

Note that the transformation temperatures of emulsions and oil are under the heat treatment temperature and therefore the mentioned transformations occur during heat treatment. Weight loss shows that residues will remain on the board even higher with more waste emulsion.

Carbonaceous residues that remain on the surface of the strip after rolling must be strictly limited because of their negative influence on all subsequent processing stages [9]. Research has shown that increasing the degree of contamination of the emulsion by recirculation and wear can generate an amount of carbon residue up to 8 mg/m^2. During heat treatment, residual products are reacted further with the gaseous products, the heat treating furnace atmosphere and with the surface of the steel strip, causing the formation of areas of high carbon concentration on the surface of the strip, subjected to the annealing process [10].

The presence on the surface of the steel strip of fine iron oxide particles acting as a catalyst leads to a highly favorable environment for oil oxidation [11].

Emulsion spots and burned emulsion are emulsion cracked residues deposited on the surface of the steel strip after cold rolling and heat treatment.

Emulsion spots are easily recognized with the naked eye. They are dark and of irregular shape, spread on the cold rolled strip surface and heat treated as seen in Fig. 3.

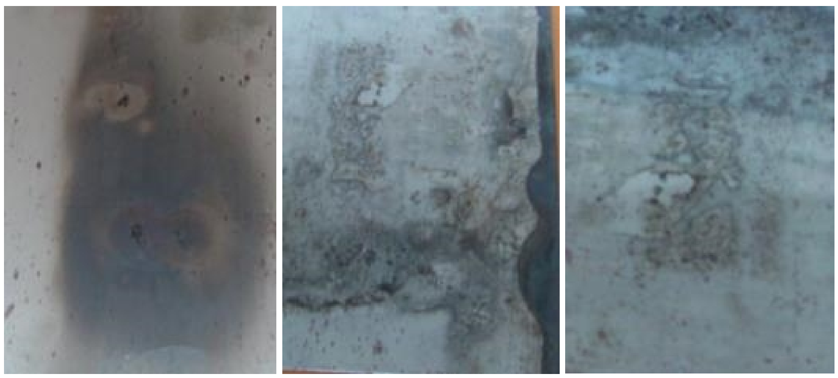


Fig. 3. *Burned emulsion on the surface of the heat treated strip (x1/10)*

The burned emulsion spots on the surface of the cold-rolled steel strip are caused by cracked emulsion residues from the thermal treatment of annealing. These residues are the result of unevaporated emulsion during annealing, which occurs due to an excess of emulsion on the cold rolled strip.

The microscopic analysis of defects was performed only on the heat treated steel strip [12].

The defects observed in the highest proportion on heat-treated steel bands are burned emulsion spots. The microscopic analysis of such black spots showed a complex phase structure of the resulting residues from the combustion rate. This is due to both emulsion interactions with contaminating residues, as well as due to the emulsion interacting with steel support.

It was also found that, as explained above, the main cause of the formation of this defect is emulsion excess [10]. In Figure 4 it can be seen that the emulsion starts to stain a large drop that flowed on the surface of the steel forming radiating streams.

The spot droplet formed is dense and dark and the area where they spread is diffuse, without allowing compactness to reveal the steel bracket that appears white. At a magnification higher than 100, it can be seen that the core of started emulsion stain has also a heterogeneous structure showing black and gray burnt areas and less brown burnt areas. Large drops of emulsion are formed due to several causes.

Emulsion spots are formed from singular and excessively high drops and will have nearly circular shapes (Fig. 5a). Burned emulsion spots come from several neighboring droplets whose small streams flow intertwined, forming less compact large spots (Fig. 5b).

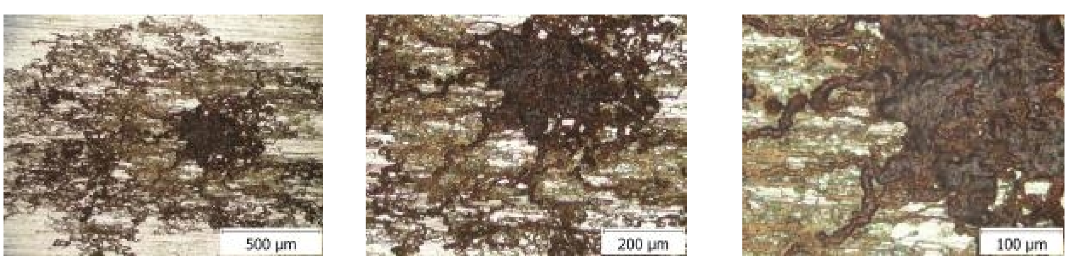
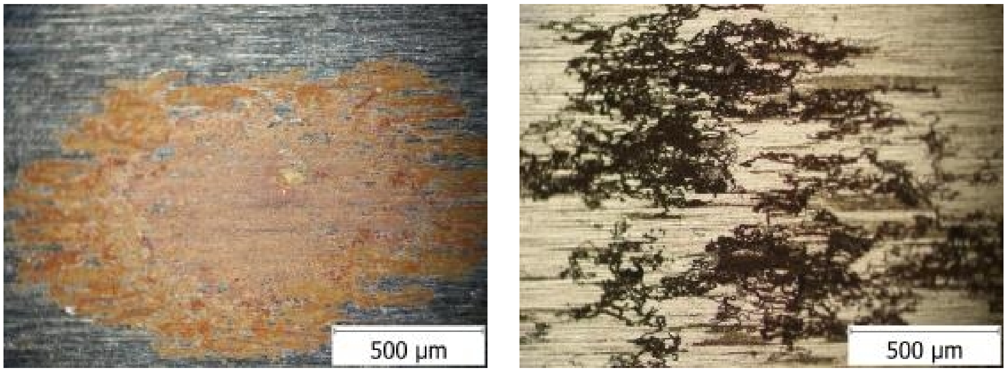


Fig. 4. *Formation of emulsion spots at different magnifications*

We also observed atypical distributions compared to those listed above, as shown in Figure 6. These spots, very diffuse and difficult to see with the naked eye, are formed from the excess of emulsion accumulated on bumps during the cold rolling process.



a b

Fig. 5. *Aspects of burned emulsion spots*
a - compact spots; b - less compact spots

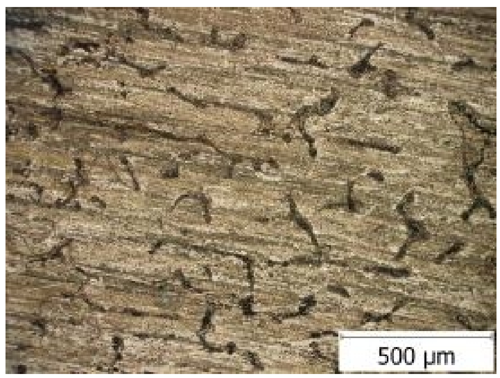


Fig. 6. *Spots of burned emulsion with atypical forms*

Figure 7 shows the structure of a burned emulsion spot with areas of corrosion of steel support (rust) areas that formed carbon or combustion ash (light gray) and areas of black burned emulsion.

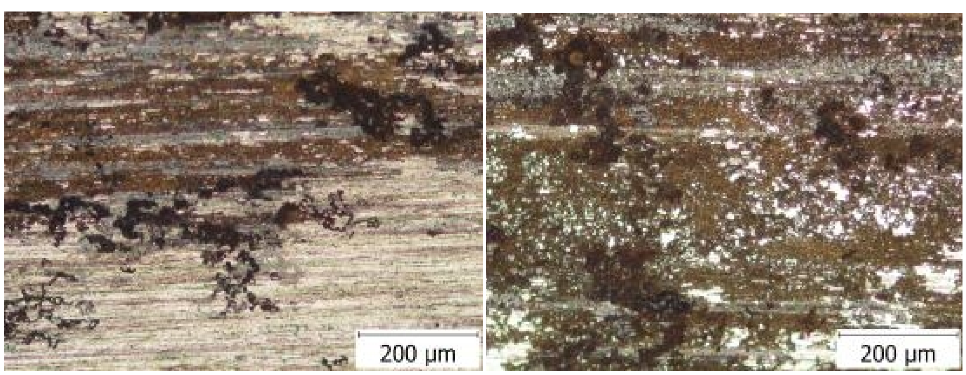
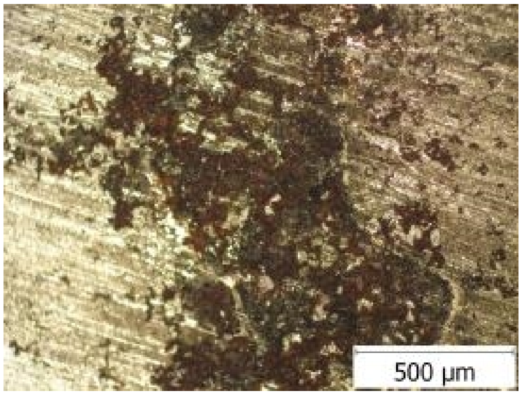
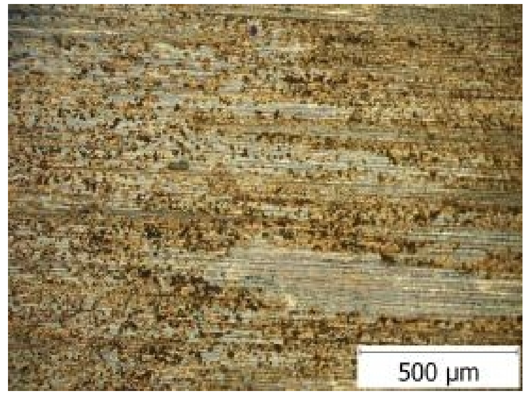


Fig. 7. *Spot of burned emulsion with rust*

Emulsion spots intimately associated with rust are shown in Figure 8a. Corrosive attack with singular formation of iron oxides in rolling direction can be seen in Figure 8b.



a. Emulsion spots intimately associated with rust



b. Corrosive attack in rolling direction

Fig. 8. *Spot of burned emulsion with rust*

4. Conclusions

The microscopic analysis of spots of burned emulsion showed a complex phase structure resulting from the combustion rate, due to the interaction of the emulsion with contaminating residues and with the steel substrate. Spot emulsion usually starts from a large drop that falls on the surface of the steel forming radiating streams. Spot drops are dense and dark and the area where they spread is diffuse, without allowing compactness to reveal the steel support. At magnification higher than 100, it can be seen that the core of started emulsion stain also has a heterogeneous structure showing both burnt black areas, as well as gray and slightly burnt areas.

Carbonaceous residues that remain on the surface of the strip after rolling must be strictly limited because they negatively influence all subsequent stages of processing. Research has shown that increasing the degree of contamination of the emulsion by recirculation and wear can generate an amount of carbon residue up to 8 mg/m^2.

The excess of emulsion used in the lamination process leads to the formation of drops which in the annealing process form spots of burned emulsion. It was also shown to cause formation areas with high carbon concentrations on the surface of the steel strips, after annealing.

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