

Detection and evaluation of surface decolorization on rolled aluminum-magnesium sheets

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1. ABSTRACT

In the aluminum industry providing good quality materials is of utmost importance. Recently, after surface roughness, surface color became a role-playing factor for the customer. Producers require measurable values for classifying the surface decolorization to settle an agreement between the factory and the customer during a complaint. In this study two sources of the surface decolorization are identified in the case of aluminum-magnesium alloy sheets. Based on the results an evaluation scheme is introduced, which analyses the color components of the reflected light from the aluminum-magnesium sheet surface.

2. INTRODUCTION

Aluminum-magnesium alloys are frequently used by the automotive industry. The addition of magnesium increases the strength of the alloy and decreases its weight. Additionally, the cold plastic deformation gives an extra hardness due the strain hardening of the alloys [1]. Most of the products used by the automotive industry is in the form of sheets. In a classic DC slab processing or in a continuous casting process the final stage of the processing scheme is the cold rolling and annealing. As it is mentioned above the big advantage of the aluminum-magnesium alloys is the improved strain hardening [2]. In the aspect of production this means a reduced ductility, annealing heat-treatment is necessary during the cold rolling of the sheet products. Recrystallization and recovery of the deformed sheets reduce the yield and tensile strength of the sheets and increase plasticity [3]. So, after an annealing the cold rolling can be performed safely with reduced energy.

Every aluminum alloy sheet has a shiny metallic surface. This is the commercially acceptable appearance of these products. For achieving the required mechanical properties, thermomechanical treatment is necessary. But after these treatments, like hot and cold rolling, or heat treatment, the surface can decolorize. On one side this phenomenon does not affect to the mechanical properties of the products, but this is not acceptable from an aesthetical view. Therefore, it is important to study the basics of the decolorization for a possible improvement of the processing technology to reduce the extent or eliminate the problem.

In this study two different decolorization factor were identified. These factors may occur separately, but the practice shows that they can occur together, strengthening each other. The magnesium-oxide formation is a spontaneous process. The oxidation

potential of the magnesium is larger than the aluminum, therefore the magnesium “burns out” from the surface during the heat-treatment. Precisely the magnesium diffuses to the surface, and magnesium-oxide forms in the surface region, in the alumina layer. The appearance of the magnesium oxide gives a brownish color to the surface. If the magnesium segregates in the slab, this process has a larger rate near the segregated volumes. This appears as decolorization of the sheets.

During the cold rolling process, a water-based oil emulsion is used for lubrication. If some oil remains on the surface of the sheets after washing, the remaining oil can be burnt to the surface during annealing. This also creates a decolorization on the surface of the sheets.

Observing this decolorizations is an easy process because in a large surface area these deviations is clearly visible with the naked eye. But documentation or evaluation are hard tasks because they need special illumination. Therefore, the extent or the measurement of the decolorization is hard to define. In this case it is easier to analyze the color components of the surface.

The aim was to develop a fast and simple industrial test, which can be applied on-site in a claim process. For measuring this decolorization two different methods were created. The first method was based on a small portable camera system, the second solution uses a color sensor for the analysis.

3. EXPERIMENT

Aluminum-magnesium alloy sheet samples (EN-AW-5182) from an industrial manufacturer were analyzed. The sheets were in an annealed state, and decolorization was observed on the surface in different areas. Sample was taken for SEM-EDS analysis. The nature of the decolorization and the chemical composition were analyzed with a Zeiss EVO MA 10 microscope, equipped an EDAX EDS system. The decolorized elements were classified.

Two experiments were performed to evaluate the decolorization. Both were based on the analysis of the color component of the reflected light from the surface of the sheets. In the first experiment a simple USB microscope-camera is used with its own illumination. White high intensity LEDs illuminate the surface. To avoid the problems of the different quality of the images and the large reflectance of the sheets the camera was defocused and used in 50x magnification. The advantage of this method is the larger observed surface. The intensity (in HSI color scheme) of the pixels is calculated and averaged over the whole image.

The second method uses a TCS34725 RGB sensor. Similarly, white LED is used for illumination. This method is easy to automate but it can only provide information on a smaller area. The sensor can measure the intensities of Red-Green-Blue components, and additionally calculate the color temperature. In this method the color temperature is evaluated as well.

4. DISCUSSION

Samples from the industrial manufacturing process are examined with SEM-EDS. Two groups of decolorization can be created based on the results:

1. Burned oil on the surface,
2. Oxidation of the magnesium component.

Figure 1. shows a typical result of burned oil. On the SEM micrograph a dark spot is visible (marked with 1). This is the decolorized surface area. The other part of the examined surface, which is not decolorized, is marked with 2. The EDS analysis reveals a higher carbon and oxygen content in area 1. This identifies the burning of the oil from the emulsion. The magnesium content is nearly the same in area 1 and 2. Sample was taken from the emulsion used for the rolling of the examined sheets. The TG test of the emulsion is performed by 10K/min. Figure 2 shows the results. The curves show that until 175°C the emulsion evaporates, burning starts at ~210°C. During the annealing of the sheets, higher temperature (260°C) is applied. Naturally the heating rate is lower in the annealing process, but still there is a risk of burning as it is shown by the examinations.

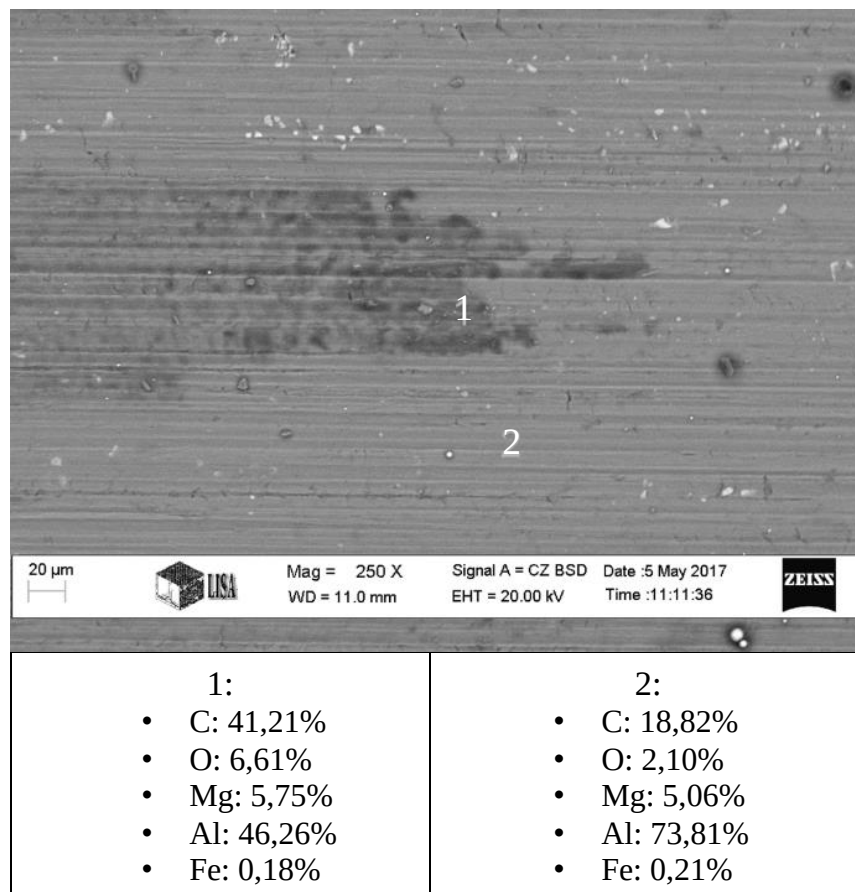


Fig. 1. The results of the SEM-EDS analysis of a decolorization which is originated to the burning of the emulsion used in cold rolling process. The numbers mark the different area elements. 1 denotes the decolorized area, 2 denotes the shiny surface. The decolorized area contains more carbon and oxygen then the rest of the surface. The magnesium content is nearly the same.

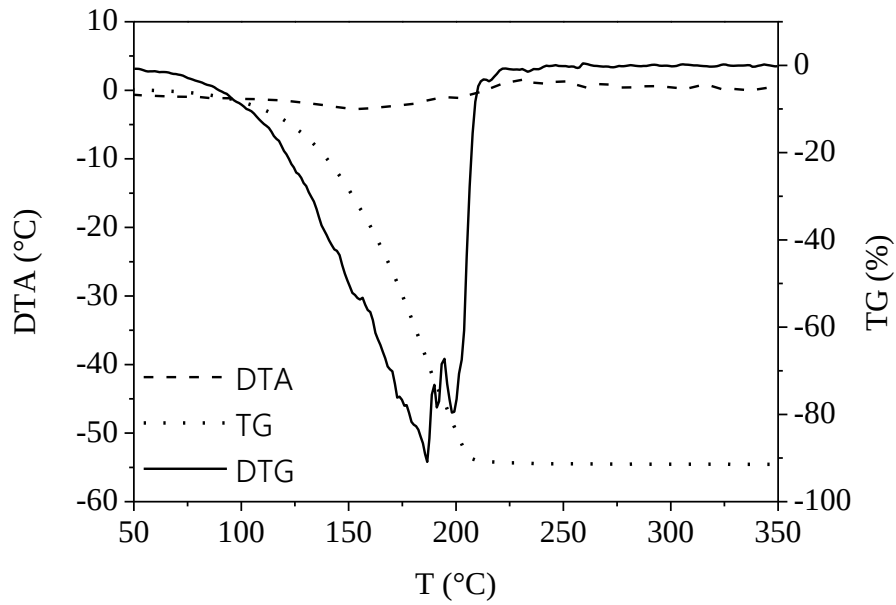


Fig. 2. The results of the TG measurement of the used emulsion in the cold rolling of the sheets.

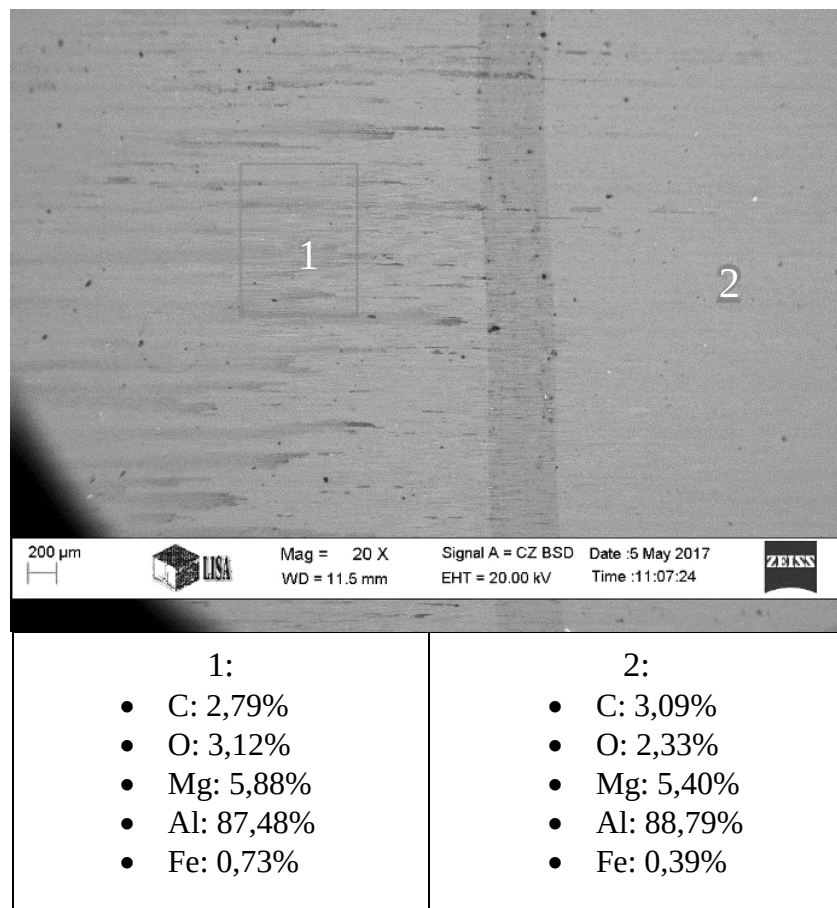


Fig. 3. The results of the SEM-EDS analysis of a decolorization which is originated to the magnesium oxidation during annealing. The numbers mark the different area elements. 1 denotes the decolorized area, 2 denotes the shiny surface. The decolorized area contains more oxygen and magnesium then the rest of the surface.

The second type of the decolorized surface elements is also examined (Fig. 3.). Figure 3 shows that the magnesium and oxygen contents are higher in the decolorized surface. The appearance of both types is nearly the same. These cannot be distinguished with naked eye, only with the introduced measurements, and generally these types could occur together. Therefore, the main task is to detect and evaluate these decolorizations without the analysis of the formation process.

The trivial method for the evaluation is a camera system. But industrial tests show that the sensitivity of a simple camera with normal illumination is not suitable. In the present study a USB microscope camera is used. It is lightweight, portable, and easy to use, but the observed area is smaller than in the case of a normal camera. The first problem, the illumination is solved, because USB microscope cameras are installed with high intensity white LEDs. The second problem is the quality of the image. This has a great influence of the repeatability and the accuracy of the results. To eliminate this problem, the camera was defocused in 50x magnification. On a defocused image, the shapes and colors disappear and only the intensity of the objects can be examined. This method uses this property of the image. The intensity of all pixel is calculated (based on the RGB to HSI conversion scheme) and averaged on the whole image. This method gives us only one number, which describes the color difference between the surface elements. The problem of this method is the set-up of the test. The intensity of the illuminating light, the focal distance, and the magnitude of defocusing are important parameters. So, a calibration, and therefore a series of etalon samples are necessary before every test.

A color sensor TCS34725 was tested. This is an RGB sensor with installed illumination (high intensity LED). The sensor has no optical system, so a 10mm distance was set from the examined surface. The sensor measures the Red, Green and Blue color components and the color temperature. The sensor measures average values from the observed area. During the tests the intensity value was used in this case as well, but the sensitivity was not enough to distinguish the decolorized surface. The color temperature is also originated to the color components [4]. The tests show a good resolution in it.

A calibration series was composed. Different metals with different surface condition were used. Not only aluminum but copper samples were also tested. The series contains polished samples with shiny surface and annealed samples with brownish dark surface. All samples had different, clearly distinguishable decolorization. Figure 4 shows a photograph taken from the series. The surfaces of the samples in the series are tested with both introduced measurements. The results are shown in table 1.



Fig. 4. The reference series of samples for calibration of the measurement units.

Table 1. The measured values on the reference series.

Sample	TCS34725 color temp., K	microscope cam. Intensity
1	2400-2500	75.6
2	2250-2330	63.1
3	1950-2100	67.7
4	1950-2050	55.7
5	2900-3000	69.4
6	2300-2500	64.5
7	3200-3400	56.5
8	2700-2800	66.9
9	2800-2900	57.5

Table 1 shows that both method can be used to identify and evaluate the decolorization. The average intensity value of the microscope camera varies within a narrow range. But the camera observes a larger surface area. The color temperature varies in a relatively larger range, but the observed surface area is smaller. In both cases a calibration is necessary for an evaluation. Table 1 shows that after this calibration the introduced method can evaluate the decolorization.

5. SUMMARY

During annealing of aluminum-magnesium sheets decolorization can form on the surface of the sheets. The root causes of the formation of these decolorizations were studied. The first problem is the burning of the remaining oil on the surface. The second possible root cause is the oxidation of the magnesium component. Both processes can result in decolorization. The commercially acceptable status of the rolled sheets is the shiny surface. The main task is to detect and evaluate the decolorized surface. Two test methods and equipments were developed. The first method is based on a USB microscope camera. A defocused image is taken, and the intensity value of the pixels is averaged over the whole image. The second method uses an RGB color sensor. In this case the color temperature is used for the evaluation. A calibration series was composed. The series contains different metals with different surface condition. The tests show that both method can be used in the evaluation of decolorized surfaces. The microscope camera observes a larger area, but for the set-up of the camera a calibration is necessary before every test. The RGB sensor collects the information from a smaller area, but immediately gives average values. Additionally, it is easier to build up a stable test equipment using the RGB sensor.

ACKNOWLEDGEMENT

The described presentation was carried out as part of the EFOP-3.6.1-16-2016-00011 “Younger and Renewing University – Innovative Knowledge City – institutional development of the University of Miskolc aiming at intelligent specialisation” project implemented in the framework of the Szechenyi 2020 program. The realization of this project is supported by the European Union, co-financed by the European Social Fund

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