# LASER HOMOGENIZATION OF Al-Si COATING ON 22MnB5

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**Abstract**

There is a persisting trend in automotive industry to increase safety of passengers while decreasing the cost and fuel consumption of the car. Usage of ultra and advanced high strength steels for manufacturing of car body parts is a way, how to achieve this goal. However, the manufacturing process of these parts requires presence of Al-Si coating on the surface of the steel. This coating is composed of multiple sublayers, which are cause of various issues affecting the stability of welding process and strength of adhesive bonds between those parts. This paper investigates the possibility of homogenization of Al-Si layer by laser treatment in order to improve strength of welded and adhesive joints.

**Keywords:** Al-Si coating, hot stamping, homogenization, laser treatment

## 1. INTRODUCTION

The automotive industry is supposed to meet strict emissions standards. In order to do so, the amount of emissions produced by cars needs to be decreased. This goal can be achieved by several ways. One of them is to decrease the weight of a car simply by using thinner and lighter parts than before [1]. However, car manufacturers are supposed to maintain or even improve the safety of the passengers. These two requirements can be met by using Advanced High Strength Steels (AHSS) or Ultra High Strength Steels (UHSS). These materials are known for their high yield and tensile strength. In the beginning, the part is made of ferritic-pearlitic steel. The blank is hot formed and the final shape is subsequently quenched to obtain the martensitic structure during the process. In order to prevent excessive oxidizing during the austenitization and quenching, thin protective Al-Si coating is applied to the blank surface [2]. Presence of this coating is necessary for hot stamping process, however it is causing problems during successive manufacturing processes as e.g. welding and adhesive bonding [3].

### 1.1. Influence of Al-Si coating on welding and adhesive bonding

The protective Al-Si layer is usually consisting of multiple sublayers with different chemical mechanical and physical properties [4, 5]. Concerning the welding, different values of electrical resistance are the main reason causing instability of the process and are believed to be the main reason of spatter occurrence [6]. These sublayers are formed during austenitization period and quenching of the blank. Adhesive bonding is more affected by different mechanical properties of the coating. Different values of elasticity modulus of sublayers and substrate are causing peeling of the coating from the substrate.

## 2. EXPERIMENT

The presumption was made that undesired side effects of Al-Si coating on manufacturing processes of welding and adhesive bonding could be eliminated by homogenization of the coating. The laser treatment was chosen as a way to perform this task. The main goal of this experiment was to obtain homogenous coating on the steel substrate with minimal heat affection of the substrate. The JKF400FLwas used in the experiment. The surface of the specimens was evaluated by SEM and optical microscopy. Specimens were cut perpendicularly to the laser trails on the surface and then again examined by SEM and optical microscopy. Based on the coating thickness four different sets of parameters were selected. Power was gradually increased by ten from 20 to 150 Watts. The speed values were 500 and 1000 mm/min, spacing of laser trails 0.2 and 0.3 mm. Focal point was constantly 8 mm above the material surface.

### 2.1. Surface evaluation with optical microscopy

In the first step, specimens were evaluated by optical microscopy. For low powers (below 30 W) laser traces were barely visible no matter what combination of other parameters was selected (**Figure 1**). For medium power range (40-100 W) the change of the Al-Si coating was visible with apparent presence of the laser trails (**Figure 2**). For high power (above 100 W) values, the coating evaporated from the surface of the steel and laser burned deep trails into substrate (**Figure 3**).


**Figure 1** Low power laser trails


**Figure 2** Medium power laser trails


**Figure 3** High power laser trails

### 2.2. Surface evaluation with SEM

While at low laser beam energy (**Figure 4**) the surface oxidation level was similar as for untreated surface, SEM analysis revealed that with increasing power the oxidation of surface occurs more intensively (**Figure 5**). Oxides manifest themselves as through charging in SEM (visible as bright paths in **Figure 5**).

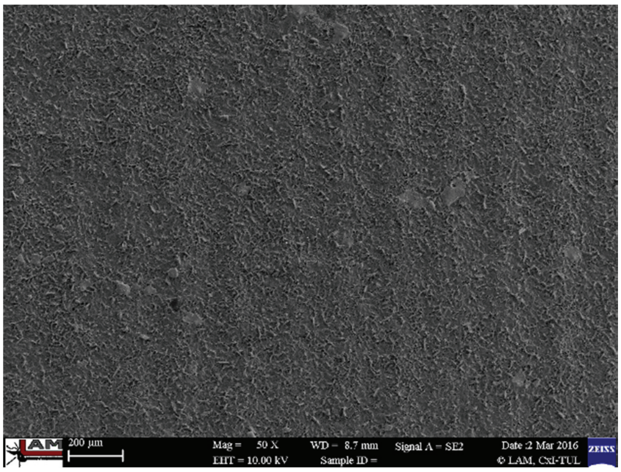


**Figure 4** Surface after low power treatment

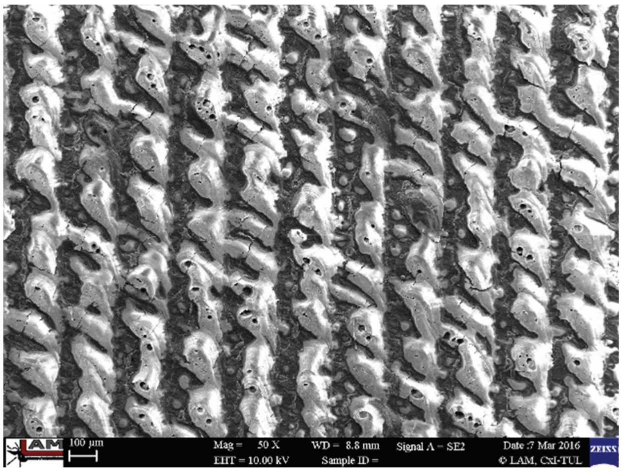


**Figure 5** Surface after high power treatment

On the other hand, for higher values of power the formation of oxides on the surface ceased almost completely. It can be explained through evaporation of the aluminium layer.

### 2.3. Evaluation of coating in cross section with optical microscopy

While evaluating the specimens with optical microscopy, it was discovered, that homogenization of the coating was achieved in all cases. For lower power, the presence of diffusion layer was observed. The thickness of heat affected zone in the substrate material was decreased for higher spacing of the laser trails and higher speed values ranging from 35 µm (**Figure 6**) for the lowest power of 20 Watts with 1000 mm/min speed and 0.3 mm spacing to the 300 µm for power of 150 Watts at 500 mm/min speed and 0.2 mm spacing (**Figure 7**).

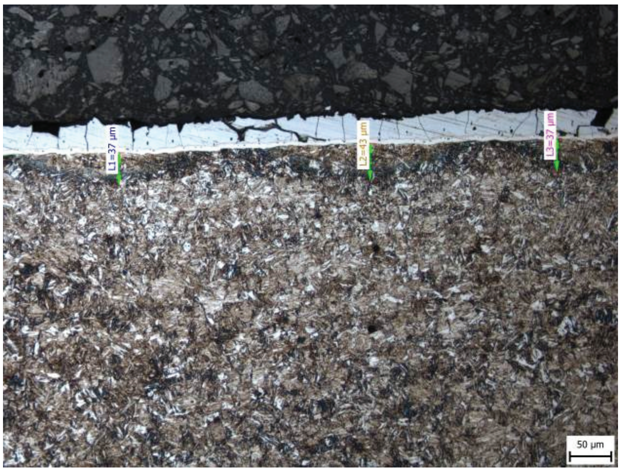


**Figure 6** Thin heat affected zone


**Figure 7** Thick heat affected zones

### 2.4. Evaluation of coating in cross section with SEM

Evaluation of specimens in cross section with SEM revealed, that layers which appeared to be the homogenized coating for medium power values are in fact intermetallic phase of Fe and Al with major content of Fe. EDS line scans showed that for low power the content of three basic elements remain the same throughout the coating (**Figure 8**). The effect of selected speed range was negligible as well as the effect of spacing. Thus only the effect of different laser powers was considered.

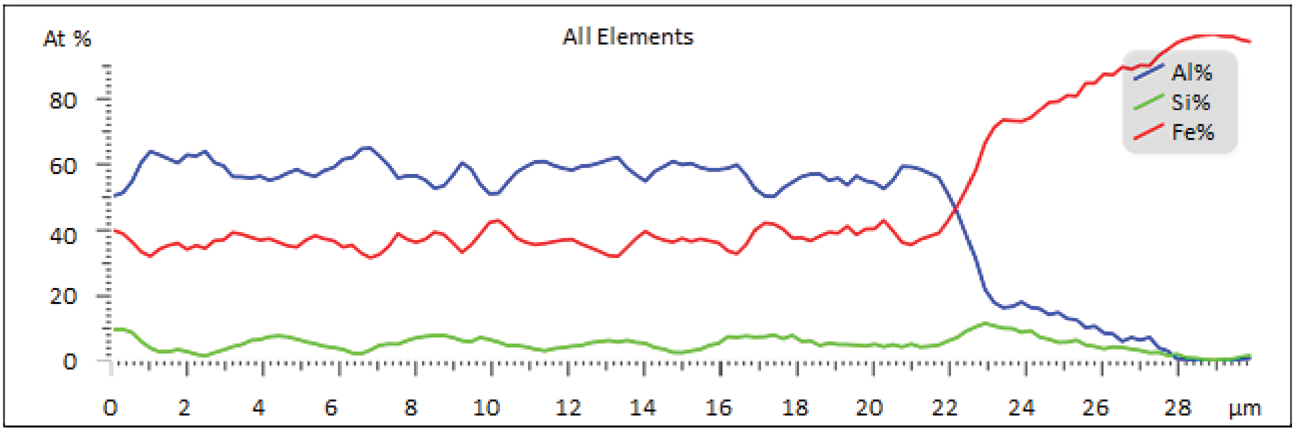


**Figure 8** EDS linescan for low power treatment

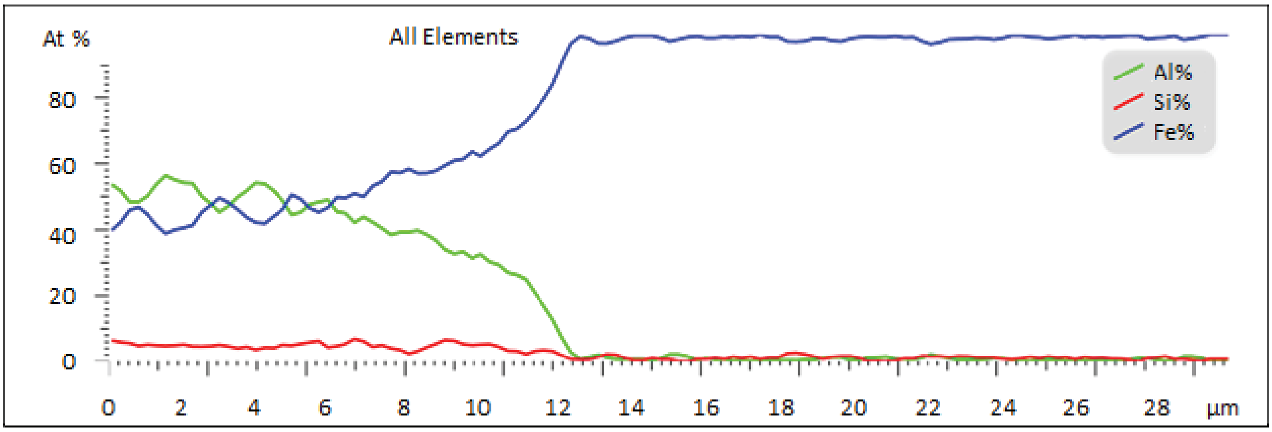


**Figure 9** EDS scan for medium power

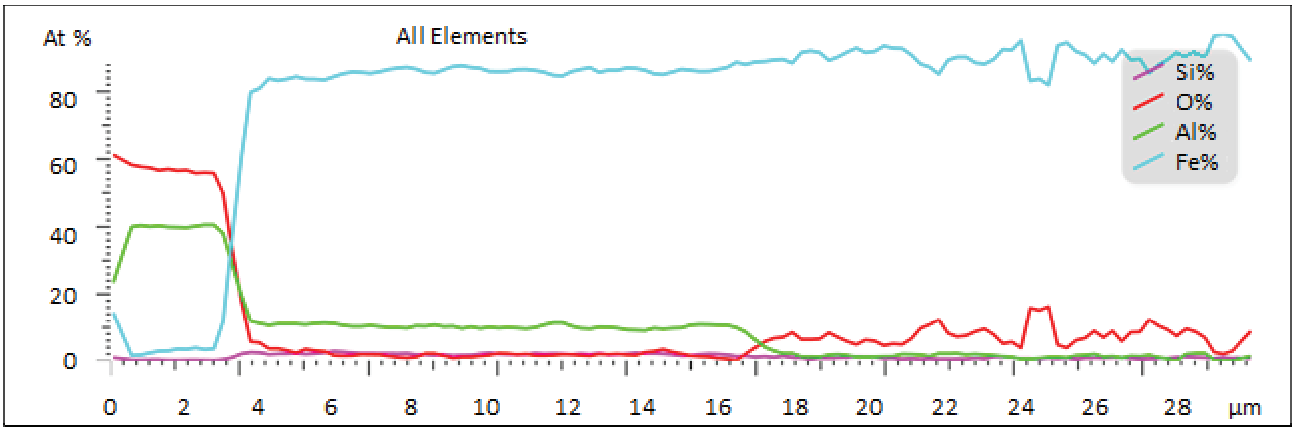


**Figure 10** EDS linescan for high power

As it can be seen from line scans in **Figure 9** and **Figure 10**, an increase of power causes aluminum to diffuse deeper into the base material. It can be also observed that the aluminium content gradually decreases with the depth. For low power values, the aluminum content remained almost the same throughout entire coating and then suddenly dropped to really low values. That is reflecting the optical microscopy results for which the presence of a diffusion layer was observed. The content of aluminum remains constant throughout the body of the coating for medium power, but is lower than in case of low power. The classical diffusion zone (**Figure 12 B**) which was not visible for optical microscopy is present in a different form for medium power and is much thicker than in previous case. The decrease of aluminum content in this zone is less steep than for low power. For high power the former Al-Si coating is not uniformly covering the surface of a specimen. However, isolated volumes of former coating can be found on the surface instead. According to results of EDS majority of aluminum from the coating is diluted or diffused in the substrate. The presence of 120 µm thick Al enriched zone is apparent under the isolated $Al_2O_3$ remnants of the former coating (**Figure 11**).

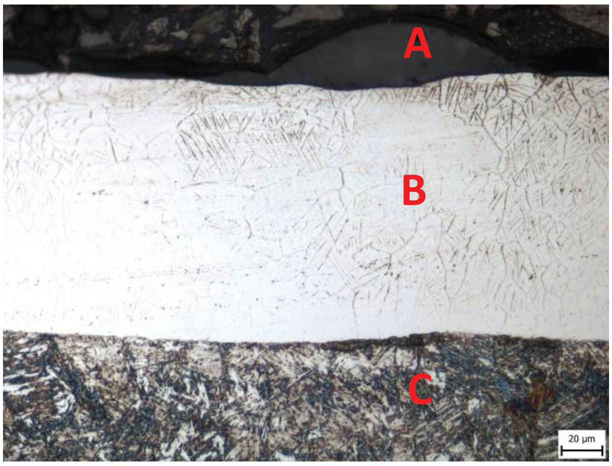


**Figure 11** Specimen treated with high power. A - $Al_2O_3$, B - Al enriched zone, C - base material

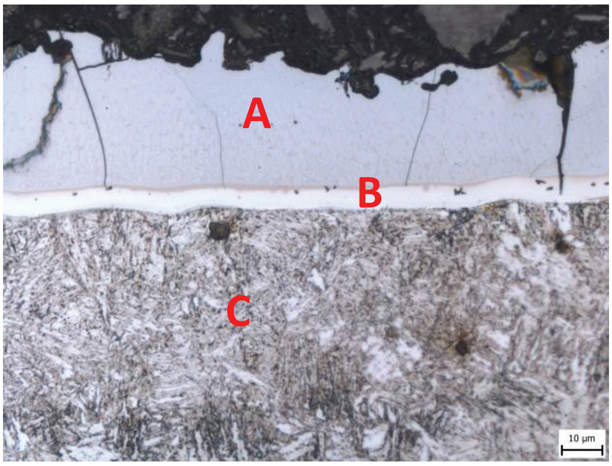


**Figure 12** Specimen treated with low power. A - homogenized Al-Si coating, B - diffusion layer, C - base material

## 3. DISCUSSION

The laser treating of Al-Si coating is dependent on selected parameters. The higher power which seemed to be removing Al-Si coating from the surface in the beginning is causing dilution and diffusion of aluminum from the coating to the base material forming undesirable brittle intermetallic phases. The thickness of the zone related to the thickness of the part (steel sheet 1.6 mm) is relatively large. If we consider presence of heat affected zones which are closing on 0.3 mm, then 25% of the former thickness of the material is being affected either by heat treatment or chemical composition changes. These values are of course extreme and are not acceptable. On the other side lower power values with wider spacing and faster speeds seem to be a promising way to achieve optimal homogenization of the Al-Si coating with acceptable thickness of heat affected zones. Mechanical properties and weldability along with adhesive bonding are about to be addressed in future experiments.

## 4. CONCLUSION

The effects of laser treatment on the Al-Si coated specimens were examined in this work. Furthermore experiments with various laser treatment parameters- power, spacing and speed were performed. It was found that power has major impact on homogenization of the coating as well as on size of heat affected zones in the material. Speed and spacing had negligible effect on coating homogenization but affected the size of heat affected zones noticeably. Weldability and properties of adhesive bonds are yet to be examined in further experiments.

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