SELECTIVE OXIDATION AND HOT-DIP-GALVANIZABILITY OF ADVANCED HIGH STRENGTH STEELS

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INTRODUCTION

There is a growing demand for Advanced High Strength Steels (AHSS) in the automotive industry owing to their high specific strength and good formability. The mechanical properties satisfy the demands for improved passenger safety and decreased vehicle weight due to thinner cross sections. Hot-dip galvanizing is a common procedure to prevent corrosion of steels, galvanized steel forms the basis for further processing as organic coating.

Galvanizing of AHSS is troublesome because of the selective oxidation of the oxygen-affine alloying elements Mn and Si during annealing at 840 °C in 5%H_2 in N_2 at a dew point (DP) of -30 °C (which is equivalent to 380 ppm H_2O or pO2 = $3{,}16 \cdot 10^{-22}$ atm). Although the annealing conditions are reducing for Fe, the ignoble elements are oxidized. Due to the resulting concentration difference, ignoble elements segregate from the bulk to the surface and form an amorphous, vitreous, Si-rich oxide layer. The covering oxides show a poor wetting behaviour when the steel strip immerses in the Zn(Al, Fe)-bath, resulting in bare spot defects and bad Zn-adhesion.

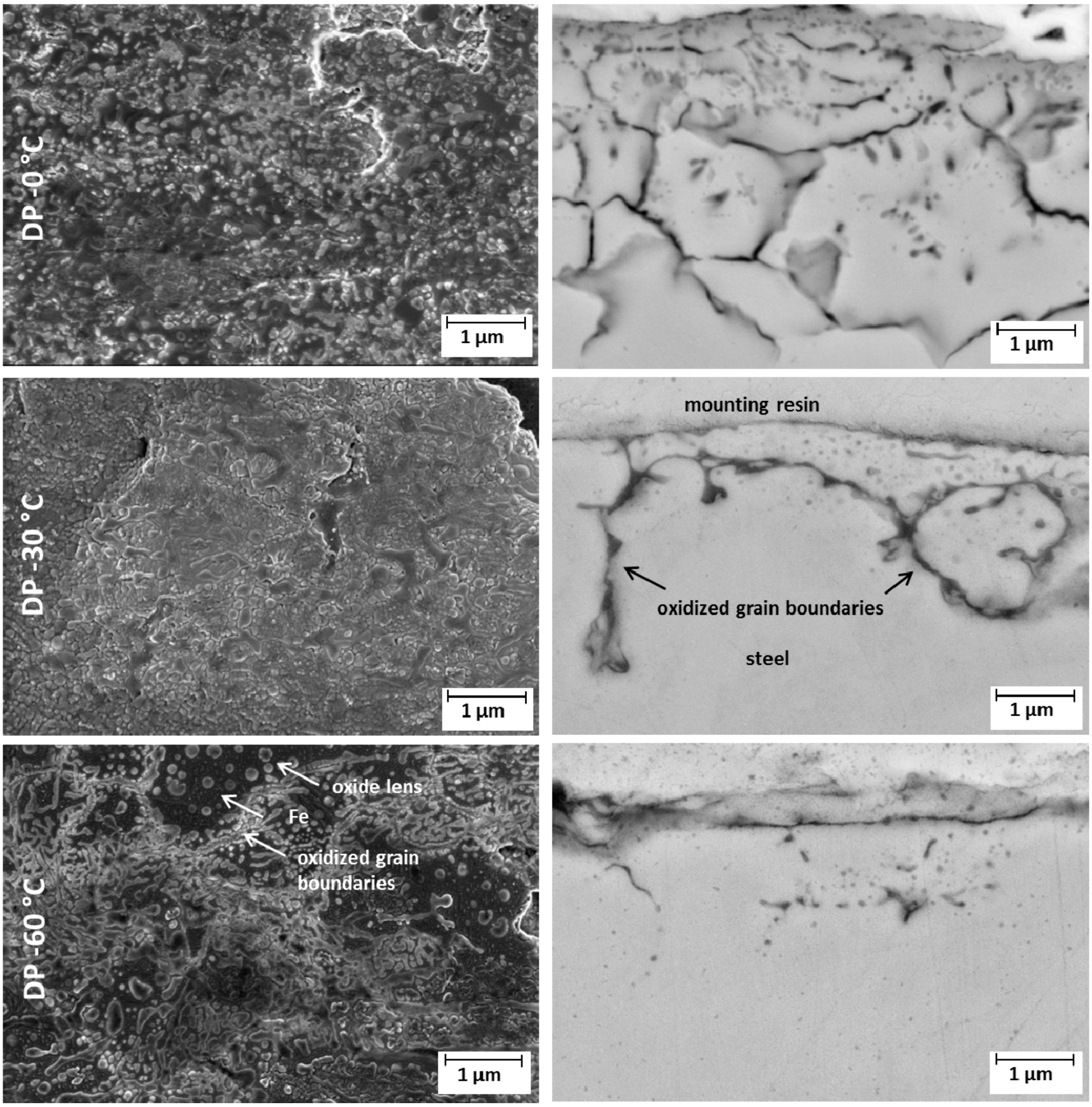
EXPERIMENTS

The effect of DP (and therefore oxygen partial pressure) during annealing of 2.5Mn-1.5Si-AHSS on subsequent hot dip galvanizing is evaluated. DP is set to 0 °C (6056 ppm H_2O, humidified), -30 °C (380 ppm H_2O, general industrial conditions) and -60 °C (14 ppm H_2O, dry). Annealed specimens are analysed by Scanning Electron Microscopy (SEM), depth profiles are generated by Glow Discharge Optical Emission Spectroscopy (GD-OES). Galvanized specimens are judged by coating quality (lack of bare spot defects) and Zn-adhesion during forming.

RESULTS AND DISCUSSION

The more oxygen containing an annealing atmosphere is, the more oxides are formed. According to Wagner's theory of selective oxidation, internal oxides are formed, when the mass flow of oxygen into the substrate is superior to the mass flow of ignoble elements from the substrate to the surface[1]. At DP 0 °C, the surface consists of finely dispersed Mn-rich oxides, uncovered Fe is visible. The grain boundaries are severely oxidized up to a depth of 3 µm. At DP -30 °C, the surface is completely covered by Mn-Si-mixed oxides. The grain boundaries are partly oxidized to a depth of 2 µm. At DP -60 °C, the oxygen content is very low. Nearly no internal oxidation occurs, as the flow of ignoble elements to the surface exceeds the offered oxygen. Metallic Fe is apparent on the surface, the formed oxides consist mainly of Si.

Best Zn-coating quality is observed at DP 0 °C, DP -60°C is only slightly better than DP -30 °C. Zn-adhesion during forming is poor for DP 0 °C, as the massive grain boundary oxidation weakens the integrity of the surface region, corn breakouts may occur.



Picture 1: SEM-micrographs of the annealed surface (left) and cross-section (right) of 2.5Mn-1.5Si-AHSS, annealed at DP 0 °C (top), DP -30 °C (middle), -60 °C (bottom).

CONCLUSION

Although there is metallic Fe on the surface to enable good reactive wetting with the Zn(Al, Fe)-bath at DP -60°C, there are also plenty Si-oxides at the surface, which are known to a have a deteriorating effect on galvanizing[3].

AHSS cannot currently be satisfactory galvanized by adjusting the annealing atmosphere. Further research is necessary.

REFERENCES

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[2] Marder, A. R. "The metallurgy of zinc-coated steel." Progress in materials science 45.3 (2000): 191-271.