Alloy oxidation breakthrough could cut steel production losses

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New strategies of making steel production more efficient have been discovered, thanks to research led by WMG at the University of Warwick on the role of oxidation during alloy additions.

The research, led by Dr Michael Auinger of WMG, together with the Vienna University of Technology (Austria) and voestalpine Stahl GmbH (Austria) developed a better understanding for the oxidation behaviour inside steels during hot rolling, which could potentially help manufacturers to reduce the amount of steel lost during production.

Dr Auinger and his co-researchers analysed the oxidation behaviour of different iron-based alloys. They found that particularly the combinations of iron-manganese and a second alloy addition - representing a simplified version of many high strength steels in automotive - suffer from severe oxide formation along grain boundaries if these alloys are processed in an inappropriate manner.

Adapted process parameters and knowledge about the admissible limits of alloy content – based on the findings of the ongoing research – help to prevent negative effects of grain boundary oxidation in further steel processing and in-service properties of HSS car body parts.

High strength steels are an important backbone for applications in the automotive industry, but cost-efficient manufacture of those materials requires the suppression of oxides within the steel during sheet production.

When steel is produced using rolling mills at high temperatures, the surface oxidises quickly but the grain boundary oxides underneath define the depth of the corroded zone and also the material's forming limit. Hence, oxidation plays an essential role during the manufacturing of high strength steels for automotive applications which often contain a higher amount of manganese. Due to their unique mechanical properties, this allows for a significant reduction of sheet thickness, allowing a vehicle to be lighter and consequently reduce carbon emissions.

"Isotope exchange experiments verified that grain boundaries in manganese containing steels are extremely prone to oxide formation. On the contrary, oxide particles inside the grains strongly bind their oxygen atoms. It means that new oxygen has to penetrate the entire oxide zone before forming a new oxide particle at the front," Dr Auinger says.

"The reduced depth of internal oxidation is suggested to be caused by lowering the oxygen diffusion due to trapping reactions at crystal imperfections."

Dr Auinger argues that from a scientific point of view, this work is particularly important, since it indicates not that the oxidation along grain boundaries is enhanced, but that the oxidation of the alloy additions inside the metallic grains is significantly slower than predicted by theoretical simulations. This helps one understand the mechanisms of oxide formation and also to invent novel strategies which help to prevent unwanted oxidation, which is currently determined by the cooling efficiency after hot-rolling.

Furthermore, Dr Auinger says that it could be shown that pure iron-manganese mostly forms oxides at the sample surface whereas the combination of iron-manganese with aluminium, chromium or silicon suffers from severe oxidation along grain boundaries while still having a shiny metallic surface.

Dr Auinger comments: "This transition behaviour, depending on the manganese content, is relevant to understand the coating behaviour of steels, such as galvanizing with liquid Zn, as wetting on oxidised surfaces is very bad. The ratio between manganese and additional alloy elements in these alloys defines the oxide formation at the surface for a given chemistry. These data can further be used to build a better understanding of the behaviour in real steels."

More information: Auinger, Michael, Praig, Vera G., Linder, Bernhard and Danninger, Herbert. (2015) Grain boundary oxidation in iron-based alloys, investigated by ^{18}O enriched water vapour—the effect of mixed oxides in binary and ternary Fe-{Al, Cr, Mn, Si} systems. *Corrosion Science*, Volume 63. pp. 133-143.

Provided by University of Warwick

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