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Modelling the softening behaviour during galvanizing of various steel grades

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ABSTRACT

The chemistry and process conditions necessary to obtain a desired hardness value after galvanizing has been investigated for a range of steel grades using physical simulation and mathematical modelling. Annealing cycles, similar to those experienced during two galvanizing lines, were simulated on cold-rolled or as-pickled (undeformed) specimens of extra-low C, low C, peritectic C, low C–Nb, and low C–Nb–Ti steels using a Bahr 805D deformation dilatometer. Microstructures were examined after etching with Marshall's reagent and correlated with hardness values. The recrystallization (softening) behaviour of the steels was quantified in terms cold work, Mn and Nb contents using the following sigmoidal equation: $T_{max} = T_s[(H_{max} - H_{min})/(H - H_{min})-1]n$ where T_{max} is the highest temperature experienced by the strip during annealing, T_s is the temperature corresponding to the maximum rate of change in hardness, and n is an exponent. H_{aim}, H_{max}, and H_{min} are the aim, maximum (cold-worked), and minimum (fully softened) hardness, respectively. Temperature regions to avoid due to excessive scatter in hardness are identified for each steel group. The above equation was incorporated into a simple, but effective, control model based on energy consumption and can also be used to predict the hardness in continuous annealing lines. In coldrolled material, the H_{min} increases with increasing Nb and Mn contents and decreasing thickness. In undeformed Nb strip, the hardness increases up to a maximum temperature due to Nb(C, N) precipitation in ferrite, after which the material starts to soften. Good agreement in hardness values was found between laboratory simulations and industrial measurements.

KEYWORDS: galvanizing, simulation, recrystallization, annealing cycles, mathematical modelling, steel