The Simulation of the Influence of Water Remnants on a Hot Rolled Plate after Cooling

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Abstract

In situations when a sheet metal plate of large dimensions is rolled, water remnants from cooling can be observed on the upper side of the plate. This paper focuses on deformations of a hot rolled sheet metal plate that are caused by water remnants after cooling. A transient finite element simulation was used to describe shape deformations of the cross profile of a metal sheet. The finite element model is fully parametric for easy simulation of multiple cases. The results from previous work were used for the boundary conditions.

Keywords: water remnants, FEA, simulation, hot plate.

1 Introduction

Cooling is an integral part of the hot rolling process. In most cases, sprayed water is used to cool down the rolled product. Water remnants can be present on upper side of the rolled plate after it passes through the cooling section (Figure 1). These remnants will eventually evaporate (after 60 seconds), but before that they significantly cool down the rolled plate. This additional unwanted cooling can deform the plate. This problem is observed on the basis of a real case scenario carried out for an international client of the Heat Transfer and Fluid Flow Laboratory. This paper focuses on a numerical calculation (finite element analysis) of rolled plate deformations, and the goal is to find whether the water remnants have a significant influence on the shape of the rolled plate.

2 Finite element analysis

The simulation of the influence of the water remnants is divided into two separate analyses: a transient thermal analysis, and a multiple static structural analysis. The temperature field over time is calculated in the thermal analysis. This temperature field is used to calculate the structural deformation of the rolled plate caused by the non-uniform temperature distribution.

The finite element model makes use of the symmetry of the simulated task. The model is a section cut from a half of a rolled plate (Figure 2). No support is used for the plate, so finite element model (FEM) includes no plate.

Figure 1: Remnants on the top side of a rolled plate after passing through the cooling section. Although the plate is moving, the water remains on the plate until it evaporates

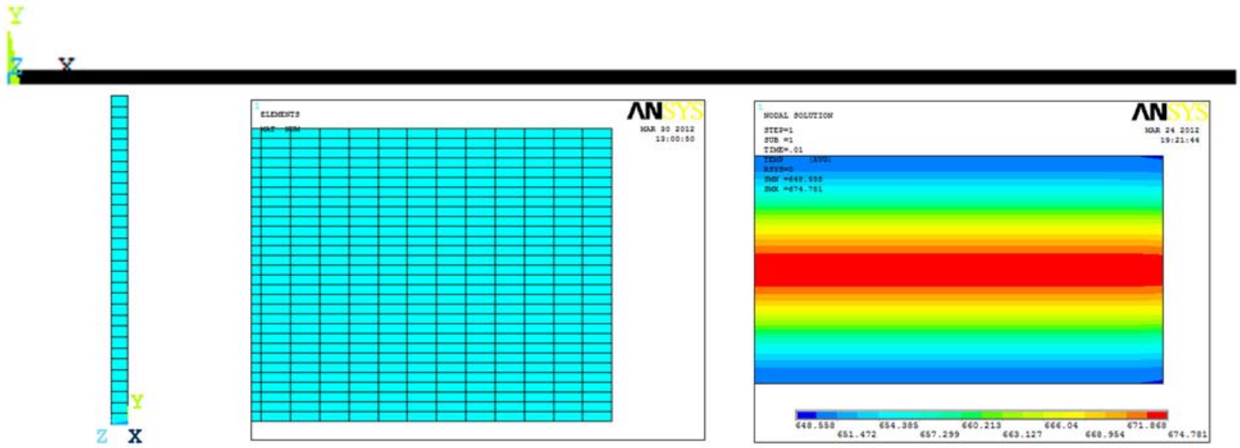

Figure 2: Front view of FEM at the top of the figure; side view of FEM on the left bottom part of the figure; detail of the FEM mesh (element type – SOLID90) in the middle part of the figure; initial temperature distribution in bottom right part of the figure

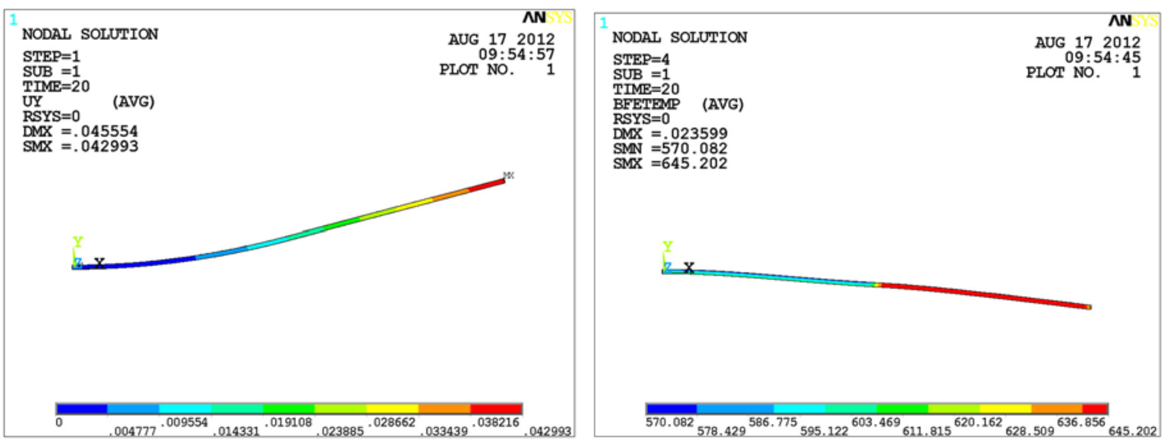

Figure 3: Calculated displacement structure with/without gravitation on the left/right of the figure

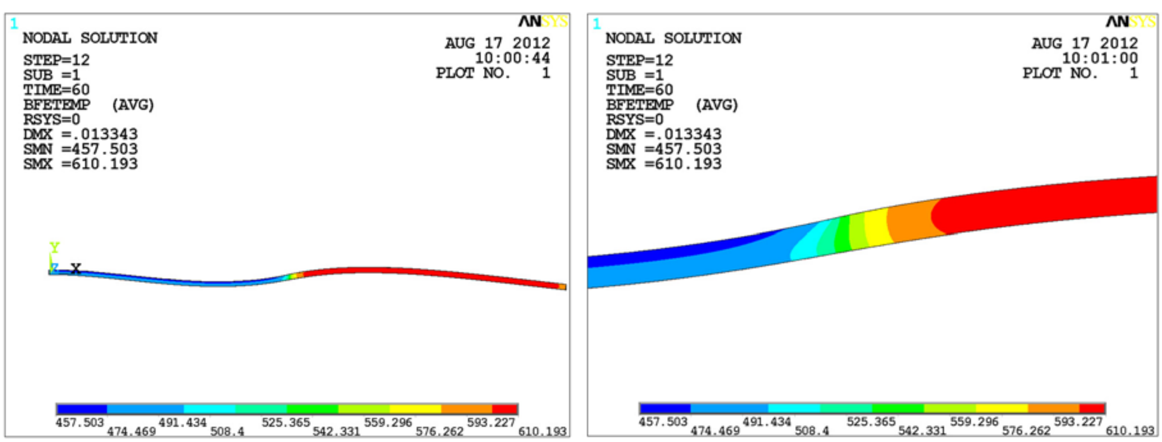

Figure 4: The thermal field of the rolled plate after the water remnants evaporate (on the left side of the figure) with a closer view of the center of FEM (on the right of the figure) Displacement scaling: True scale – 100 : 1

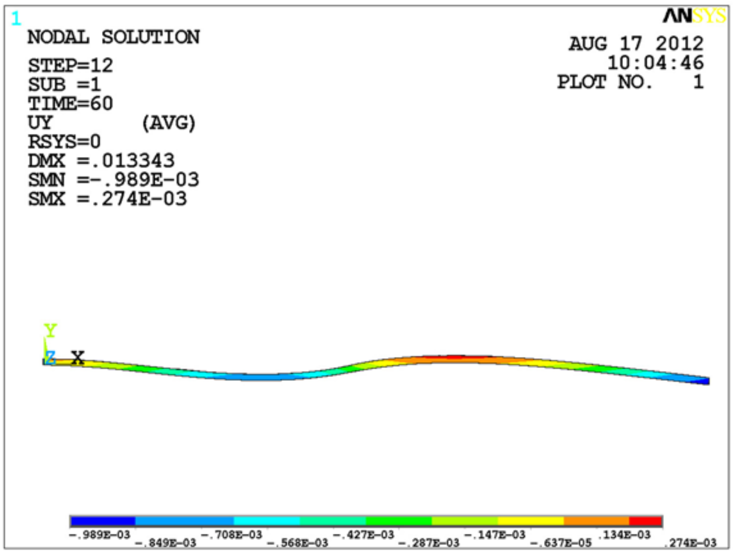

Figure 5: Calculated displacement structure after the water remnants evaporate. Displacement scaling: True scale – 100 : 1

The initial temperature field was recorded in a hot strip mill on the plate during the rolling process. The details cannot be divulged because of a non-disclosure agreement with the customer. There is a parabolic temperature distribution from the core temperature of 675 °C to the surface temperature of 650 °C (Figure 2). The boundary conditions are the heat transfer coefficient (HTC) values on the external surfaces of the FEM in thermal analysis. The HTC values are 400 $\mathrm{W \cdot m^{-2} \cdot K^{-1}}$ for the surface where there is contact between the water and the plate, and 55 $\mathrm{W \cdot m^{-2} \cdot K^{-1}}$. These values were obtained from previous work done in the Heat Transfer and Fluid Flow Laboratory. The boundary conditions applied in structural analysis are the temperature field, the gravitation and the constraints which represent symmetry. The material model is a temperature-dependent bilinear model.

3 Results

The thermal contraction is not strong enough to bend the rolled plate, as shown on the right in Figure 3. The gravitation force is almost two times higher than the bending moment produced by the contraction. The surface temperature beneath the water remnants drops to 458 °C. This is an almost 200 °C decrease from the starting value (Figure 4). Figure 5 shows the displacement structure after the water remnants evaporate (60 seconds). The range of deformation is ±1 mm. No negative displacement in the y-axis is possible in the real case scenario, because of the plate support, but we can see that the plate deformation is small in comparison with the size of the plate.

4 Conclusion

The cooling capacity of water remnants is high enough to produce a non-uniform temperature field in a thin rolled plate (Figure 4). The water remnants significantly cool down the rolled plate, which leads to contraction. This contraction acts as a bending moment (Figure 3). The weight of a rolled plate is sufficient to prevent considerable lifting of its edges (Figure 3). The shape of the plate is just slightly deformed. The maximum displacement does not exceed 1 mm, and the influence of the water remnants is insignificant.

Acknowledgement

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