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Numerical treatment of carburising process

Improvement of the mechanical and chemical properties of workpieces is often realised by the application of surface layers. In industrial practice, in case of iron or iron-based workpieces, the most widely applied procedure to do it is carburising. It is thermochemical surface treatment that is commonly applied in order to improve the corrosion and wear resistance as well as the fatigue endurance and load-bearing capacity of iron or iron-based workpieces. Among the various competing methods gaseous, liquid, solid and plasma carburising processes can be distinguished. The type of carburising depends on the source of carbon used in the process. The present paper is devoted to gaseous carburising. Upon conventional gaseous carburising by annealing in gas mixtures rich in carbon compounds at high temperatures carbon is provided to an iron-based surface by atmospheres possessing carbon chemical potential sufficiently high to diffuse into workpiece and form surface layers of increased carbon concentration. In spite of many years of industrial experiences still many open questions about carburising exist.

It should be emphasized that carburising process has to be performed carefully to avoid the situation when the surface carbon content has risen the value which corresponds to the solubility limit of austenite at process temperature. Any further carbon transfer beyond this value at that temperature would lead to carbide formation in the surface, and to a deterioration of the mechanical properties of the case-hardened layer.

In order to avoid this, gaseous carburising is performed with variable carbon potential of atmosphere. During the subsequent diffuse stages of low carbon potential of atmosphere, the carbon diffuses inwards workpieces lowering the carbon content at the surface and increasing the depth of carburized layer.

In this paper the model of gaseous carburising was formulated, implemented and tested. In the analysis of gaseous carburising, processes taking place in the gas phase, at the gas-solid interface and finally in the solid phase were taken into account. The carbon flux into the surface under the different gaseous atmosphere conditions was predicted by the carbon potential. Then, diffusion model using the values of the carbon flux into the surface and calculating on that basis the carbon flux diffusing into the steel by solving nonlinear Fick's second law with the help of appropriate numerical method was constructed. Performed analysis showed that the size of the carbon flux into the surface and inside the workpiece strongly depends on temperature, carbon potential of atmosphere, mass transfer coefficient and diffusion coefficient.

One of the important aims of the paper was to suggest numerical method for the solution of constructed model to make its implementation possible by means of programmable logic controller in order to incorporate it into the control system of gaseous carburising. Consequently, the tradeoff between the model accuracy and computational complexity of the numerical method used to solve it had to be taken into account. It appeared that the model had to be correctly simplified and appropriate numerical method for its solution had to be designed to reduce computational complexity and obtain satisfactory implementation on programmable logic controller.