DIMENSIONAL CHANGE PREDICTION IN AUSTEMPERED DUCTILE IRON PARTS USING FUZZY MODELLING

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Abstract—This work focuses on the development of a model to help in the qualitative and quantitative estimation of the changes in linear dimensions of austempered ductile iron (ADI) parts during the heat treatment cycles. The model was developed by applying fuzzy concepts using experimental data of dimensional changes taken from a large number of actual parts. It is able to predict the changes expected to take place on selected linear dimensions of ADI parts. Each part is characterised by ten input variables, which include data about chemical composition, heat treatment process and part size. The model is considered a useful tool to help in the estimation of dimensional change in ADI actual parts and it is being used in the design of new components.

Keywords—ADI, Dimensional Change, Fuzzy Modelling

I. INTRODUCTION

Most metallic actual parts suffer dimensional changes as a consequence of the heat treatment cycles carried out to adjust final microstructure and mechanical properties. The quantitative variation of some specific linear dimensions, referred as "Dimensional Change" (DC), must be taken into account to enable the final piece dimension to be within the required tolerance. The information available in the literature allows to predict DC for homogeneous materials extensively used in the industry, as for example some standardised steels (Metals Handbook, 1981). Austempered Ductile Iron (ADI) is an emerging material and many factors affect the magnitude and repeatability of DC. To the best of the authors knowledge the information about this topic is scarce and imprecise yet.

Taking into account that the machinability rating of any ADI part is significantly lower than the same ductile iron piece in the as-cast condition, it is important to reach a good prediction of DC in order to allow the machining operations can be done before heat treatment, availing better conditions and involving lower cost.

Some studies about the qualitative influence of the processing variables on DC have been reported in the literature. Dodd and Gundlach (1984), Keough (1991) and Bahmani et al. (1997) have studied the influence of the prior microstructure on DC. Gundlach et al. (1985) and Hornung and Hawke (1984) have considered also the effect of austenitising and austempering temperatures. Moncada and Sikora (1996) obtained quantitative data about the individual influence of some variables making systematic measurements on test samples and actual parts, studying also the anisotropy of DC. Recently, Echeverría et al. (2001) have studied the magnitude and dispersion of DC and its influence on the fabrication steps in ADI actual parts, making a comparison with a quenched and tempered SAE 4140 steel, both with similar mechanical properties.

Echeverría et al. (2001) and Sosa et al. (2001) have reported that ADI parts (gears) with the same external diameters but different thickness, made with the same alloy and identical heat treatment cycles, presented different DC on those diameters. They stated that when these parts are mounted on machine components, the DC can cause variations on the allowance or interference, producing deficiencies in service. In some of the mentioned studies (Gundlach et al., 1985; Moncada and Sikora, 1996) it has been determined that the DC can range from noticeable positive (+0.7% expansion), to slight negative values (-0.05% contraction).

The reported studies take into account the individual effect of some variables on DC. Most of these variables exert influence on phase transformations and therefore on DC. Nevertheless, the simultaneous effect that the variables altogether can exert on DC is very complex to know.

The Metallurgy Division of INTEMA has extensive experience in the industrial application of ADI (Sikora et al., 1991; Martínez et al., 2002). Many different actual parts and test samples produced at commercial foundries were austempered and analysed. The metallurgical and mechanical characteristics of those parts, as well as the DC produced during the ADI heat treatment, were systematically determined and the results were accumulated in a database.

Artificial Intelligence techniques were employed to develop an Expert System in an attempt to improve the knowledge on ADI. This Expert System allows to establish the optimal heat treatment variables for a given ADI actual part taking into account the required mechanical properties (Dai Pra et al., 1996, 1998).