ANALYSIS OF STRESSES IN ADI INTERNAL GEARS MOUNTED WITH INTERFERENCE: DISTORTION AND RESIDUAL STRESSES EFFECTS

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***Abstract*— The stress state in ADI internal gears mounted with interference in aluminum casings is numerically simulated, considering working load as well as circularity distortion (ovalization) and residual stresses resulting from heat treatment. Ovalization exerts the greatest influence on interference and residual stresses, leading to a significantly high compressive stress which does not affect the gear structural integrity due to the high compression strength of ADI. This grants this alloy a competitive edge over steels of similar tensile strength. Still, ovalization has to be minimized considering its unfavorable effect on performance and working load capacity.**

***Keywords*— Stresses state, ADI internal gears, Interference fit, Distortion, Residual stresses, FEM**

I. INTRODUCTION

The austempered ductile irons (ADI) employed in mechanical parts under severe service demands have probed to yield excellent results, placing these alloys as an alternative material before high-resistance steels (Martínez *et al*., 1998; Hornung and Hauke, 1984).

The internal gears of the motoreducers planetary system used in freight elevator equipments are an example of an already consolidated industrial application of ADI, which meets the main requirements. However, the microstructural changes produced by heat treatment result in dimensional change (DC), ovalization, tooth profile distortion and residual stresses (Keough, 1991; Moncada and Sikora,1996; Sosa *et al*., 2001 and Echeverría *et al*., 2002), anomalies possibly leading to an irregular mechanical assembly operation, to a reduced service life and load capacity. Below, a descriptive synthesis of the studies determining the causes of the already mentioned anomalies as well as the current data available on the subject is presented.

On the one hand, DC alters the interference established by the design for the gear-casing interference fit. However, this effect is largely compensated by the prior correction of machining linear dimensions according to experimental data (Echeverría *et al*., 2000; 2001), since it allows to predict DC avoiding that machining should be carried out after heat treatment under a unfavorable machinability conditions (Moncada *et al*., 1998).

Ovalization resulting from non-uniform residual stresses generated by teeth shaping in gear shaping machines (Sosa *et al*., 2001) and tooth profile distortion are typical defects in this process. Regarding ovalization, it makes gear-casing assembly interference vary along the contour, notoriously increasing towards the oval major axis. As a consequence, interference stress increases (Sosa *et al*., 2001); though this increase becomes irrelevant if ovalization is minimized by reducing the variation range of machining residual stresses through a strict control of the process (Echeverría *et al*., 2002).

In turn, austempering heat treatment -by itself- results in residual stresses of little significance for being isothermal cycles of relatively homogeneous phase transformations (Canonico, 1981). Nevertheless, the small and variable wall thickness, characteristic of tubular toothing shapes, promote more distortion than simple and compact shapes, as well as a greater fluctuation of residual stresses, stresses increasing with ovalization (Echeverría *et al*., 2002).

The stresses state of the gear-casing assembly derives from three sources: working load, interference fit and residual stresses. Total stress should not exceed the admissible value of the material, especially in critical areas where stress is concentrated due to section abrupt changes and small thickness.

Since working load is cyclic, it generates variable stresses within a range, which after interference and residual stresses overlap, can cause fatigue. High mean tensile stresses require the reduction of the admissible range of stresses (Goodman, 1930). However, studies on cast irons (Pomp and Hempel, 1940; Hempel, 1941) and alloyed steels (Ransom, 1954) demonstrated that, under compression, the admissible range increases with mean stress, as long as the maximum stress does not exceed the material compression elastic limit.

An analysis performed on stress fields and deformation by finite elements allows to determine the parameters of greater influence and sensibility, and to establish optimization criteria for geometric and dimensional design as well as for the fabrication process, so avoiding costly experimental trials.

The aim of this work, is to study the influence that ovalization and austempering residual stresses exert on total stress for the minimum interference required,