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Surface state of Inconel 718 ultrasonic shot peened: Effect of processing time, material and quantity of shot balls and distance from radiating surface to sample

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ABSTRACT

Plates of Inconel 718 in precipitated state have been subjected to ultrasonic shot peening (USP), varying the distance from the radiating surface of the booster to the sample, the processing time and the material (WC/Co and steel) and number of shot balls, in order to study the effect of these parameters on the final state generated by the USP process. A change to more compressive residual stresses at the surface of the treated parts has been measured in all cases. For higher USP processing times and/or lower booster-sample distances, the degree of plastic deformation in the treated material increases, leading to a change to more compressive surface stresses and a higher density of impact marks in the treated surface. The same occurs when WC/Co balls are used instead of steel balls. The tendency to more compressive stresses reaches a saturation level after a certain processing time, when the system is not able to force the material to continue with more plastic deformation. If a higher quantity of balls is used, there will be less impacts of the shots with the surface and their energy will be lower (due to losses of energy after inelastic collisions). This diminishes the effect of the impacts in introducing compressive stresses and leads to less and shallower impact marks in the treated surface.

1. Introduction

Ultrasonic shot peening (USP) is a mechanical surface treatment that consists of impacting the surface of a component with spherical shots accelerated using high-power ultrasounds. This results in a very high number of multi-directional impacts in a short period of time. Like conventional shot peening, USP is usually employed to enhance stiffness, strength and fatigue life of the treated components. This enhancement of mechanical properties is attributed to several factors, such as surface nanocrystallization, surface hardening and strong compressive residual stresses induced in the surface layers of USP treated parts.

The surface nanocrystallization induced by USP has been studied by several authors and in several materials. For example, Guo et al. [1–3] and Tao et al. [4] have obtained on pure Fe, a nanocrystalline layer of around 20 μm thickness, where the former have observed that the thermal conductivity decreases due to the larger volume fraction of interfaces. Liu et al. [5] have USP treated 316L stainless steel using different processing times ranging from 30 to 810 s. In all cases they have observed a grain refinement in the surface layer of the processed parts, obtaining nanocrystalline structures up to 30 μm thickness. Similar nanocrystalline layers have been obtained by Todaka et al. [6] in various steels and by Wu et al. [7] in aluminium alloys. Villegas et al. [8,9], with WC/Co balls of 7.9 mm diameter, have obtained nanocrystalline layers in Ni-base C-2000 alloy of increasing layer thickness with processing time. Their conclusion is that the mechanisms responsible of surface grain refinement in this severe plastic deformation (SPD) process are dislocation activity and deformation microtwins, being this second factor the most important in the case of low stacking fault energy materials.

The grain refinement induced and the work-hardening associated with the USP process itself lead to a surface hardening of the USP treated parts, as measured for example by Abramov et al. [10], who observed a hardness increase in 16MnCr5 steel when displacement amplitude increases and/or distance between radiator and sample decreases. Hou et al. [11] have observed, in a magnesium alloy high-energy shot peened, a hardness increase that nearly triplicates the initial hardness of the non-USP treated material.

The severe plastic deformation process that leads to nanocrystallization and surface hardening is also behind the surface compressive stresses induced by USP processes. Xing and Lu [12], by means of Moiré interferometry, and Cheng et al. [13], by means of neutron and X-ray diffractometry, have measured compressive residual stresses at the USP treated surface of different steels, which become less compressive as the distance to the surface increases. The compressive residual stresses induced at the surface of USP treated components prevent the nucleation and

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