NONDESTRUCTIVE EVALUATION OF THE EFFECTS OF DYNAMIC STRESS PRODUCED BY HIGH-POWER ULTRASOUND IN MATERIALS

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ABSTRACT

Results of measurements made during high-power ultrasonic insonation of metal specimens give new insight into the mechanical and thermal processes involved. Changes observed in the ultrasonic attenuation of test specimens during insonation indicate that high-power ultrasound can create and/or move dislocations. Measurements of the ultrasonic velocity indicate change in the moduli of the material during insonation. Heating of the test specimen to various degrees, depending upon both the specimen configuration and material has also been observed during high-power ultrasonic insonation. Details of these and further results are discussed.

INTRODUCTION

Various effects of high-power ultrasound on materials have been observed and used for many years. Some of these are plastic welding, metal welding, and metal fatigue. One of the most intriguing effects is the apparent "softening" of metals during simultaneous deformation and high-power insonation. This "softening" of metals was first reported by Blaha and Langenecker in 1955, who observed an immediate reduction in the tensile load necessary to cause further deformation of zinc single crystals during the application of high-power ultrasound. Upon termination of the ultrasound the tensile load returned to the value it has prior to insonation. These observations initiated a great deal of new research into the

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effects of large amplitude, high frequency vibrations on the plastic deformation of metals. Since that time many other investigators have made similar observations during simultaneous deformation and high-power ultrasonic insonation of various metals. Much controversy pertaining to the mechanism causing the reported load decrease or "softening" of metals undergoing deformation and simultaneous application of high-power ultrasonic vibrations also developed in the years following Blaha and Lange-necker's initial publication. The interest in this apparent softening effect stems from both the possible basic inferences into the nature of plastic deformation and the potential applications to many industrial processes involving plastic deformation.

Three mechanisms which have been proposed to account for the observed volume effect are simple superposition of the quasistatic stress and the dynamic stress produced by the high-power ultrasound, heating of the specimen caused by the applied high-power ultrasound, and interaction of the high-power ultrasonic waves with dislocations in the test specimens. Although the proposed mechanisms causing this "softening" of metals are still somewhat controversial, high-power ultrasound is currently being used in tube drawing, wire drawing, and other related industrial processes.

In deformational processes involving dies or forming tools, the softening effect may be broadly divided into two categories: volume effect and surface effect. The influence of high-power ultrasound on the mechanisms of deformation are included in the volume effect. The surface effect includes possible interactions of the high-power ultrasonic vibrations with frictional forces between the specimen or work piece and the forming tool or die.

A series of experiments have been conducted in order to determine the actual mechanisms causing the volume softening effect. A sufficient number of parameters to test all of the proposed mechanisms for the influence of high-power ultrasound on metal specimens were simultaneously measured or controlled. The parameters either measured or controlled were the test specimen temperature, low-power ultrasonic (8 MHz) wave velocity (directly related to elastic moduli) and attenuation (directly related to dislocation motion), the applied tensile load, specimen elongation, contact pressure between the high-power ultrasonic horn (20 kHz) and test specimen, electrical power supplied to the horn, and the high-power