Preface

Laser shock processing, or laser shock peening (LSP), is the process of hardening or strengthening metal using a powerful laser. It could generate a layer of residual compressive stress on a surface of metallic materials and alloys that is several times deeper than that attainable from conventional shot peening treatments (shot peening), which has been successfully applied to improve fatigue performance of metallic components.

LSP is a new surface modification technology, which uses high strength impact wave of the interaction process between high power density (GW/cm^2) lasers and materials to generate residual compressive stress and high-density dislocation, and improves the mechanical properties of metal effectively, especially the metal materials of hardness, residual stress distribution, and resist fatigue life. When the pressure of high strength impact shockwave exceeds the dynamic yield strength of the metal, the shock wave would induce severe plastic deformation in the surface layer of the metals and alloys. Since laser could be easily directed to fatigue-critical areas, LSP is expected to be widely applicable for improving the fatigue properties of alloys. LSP also has the obvious advantages including no contact and heat-affected zone, excellent control ability, and impact.

In the past three decades, LSP has been widely and intensively investigated over 200 scientific papers and reports. Most studies and investigations have been based on experimental approaches, influences of LSP on mechanical properties and, in particular, fatigue lives of metallic materials and alloys. Many researches have been focusing on analytical models and dynamic finite element models (FEM), to simulate the distribution of three-dimensional residual stresses in relation to materials properties, component geometry, laser sources, and LSP parameters in the last decade. LSP is also an effective surface treatment and post-processing method to eliminate tensile residual stress in the surface layer of metallic material and its weldment in order to improve their mechanical properties and tensile performances.

The book is aimed at audiences at different levels to provide a comprehensive discussion of laser shock peening. Both theoretical work and experimental results on LSP are revealed in this book.

Chapter 2 gives a comprehensive review of numerical simulation which could resolve engineering problems and physical problems, and even the nature phenomena by numerical calculation and image displayed method. At present the main method of numerical simulation is the finite element method, the finite difference method, and the finite volume method. Compared with traditional experiment method, numerical simulation has been widely used in many fields, such as mechanical process, large building fire temperature field, hydrogeology, etc. Simulation methods are introduced in this chapter. For instance, the residual stress induced by laser shock processing and the thermal relaxation behaviors of residual stress in Ni-based alloy GH4169 were investigated by means of three-dimensional nonlinear finite element analysis. Fracture analysis software and crack growth model have found application in finite element analysis.

Chapter 3 presents the influences on 00Cr12 alloy's mechanical properties at high temperatures, on metallographic structure evolution and dislocation configuration of 6061-T651 aluminum alloy at elevated temperature, and on ASTM: 410L00Cr12 microstructures and fatigue resistance in the temperature range 25–600 °C.

Chapter 4 focuses on the effect of the compressive residual stresses generated due to laser shock processing (LSP) on the stress intensity factor (SIF) of a through-the-thickness radial crack at the edge of the circular hole, the effect of laser shock peening (LSP) on the fatigue crack initiation and propagation of 7050-T7451 aluminum alloy, and a new kind of statistical data model which described the fatigue cracking growth with limited data and the effects of the reliability and the confidence level to the fracture growth. Many materials have displayed pronounced improvements in fatigue life after LSP. It has shown that LSP treatment improves the materials mechanical properties, fatigue resistance, foreign object damage (FOD), and fatigue life.

Chapter 5 gives a well-rounded presentation of the continuous synthesis of UNCD via laser shock processing (LSP) of graphite particles suspended in water by an Nd: YAG laser system with high power density (10^9 W/cm^2) and short-pulse-width at room temperature and normal pressure, which yielded the ultra-nanocrystalline diamond of size of about 5 nm. X-ray diffraction, high-resolution transmission electron microscopy and laser Raman spectroscopy were used to characterize the nano-crystals. The method studied is helpful in understanding the formation mechanism and enhancing the yield rate of nano-diamond.

Our book entitled Laser Shocking Nano-Crystallization and High-Temperature Modification does not intend to substitute but be a complement to the related books taking advantage of the developments which appeared in my study. It is dedicated to researchers and engineers involved with LSP, its developments, and implementation. The book is also intended for graduate and undergraduate students wanting to be specials in LSP. This book is also conducive to researchers on laser processing, as well as carries great and profound implications for studying laser shocking peening. In this book, the author utilizes the best arguments and the most popular language to explain the theory of laser nano-crystallization.

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