Cairo University

A PARAMETRIC STUDY OF THE SHOT PEENING PROCESS

By

Bassam Mohamed Imam Said

A Thesis Submitted to the
Faculty of Engineering at Cairo University
in Partial Fulfillment of the
Requirements for the Degree of
MASTER OF SCIENCE
In
Mechanical Design and Production Engineering

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Under the Supervision of

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Title of Thesis:

A Parametric Study of the Shot Peening Process

Key Words:

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Summary:

Shot peening is a cold working process widely used to extend the fatigue life of metallic components that undergo cyclic loading conditions such as in aerospace and automobile industries. Shot peening is one of the most interesting surface treatments as this treatment is controlled by variables that lay under a stochastic and probabilistic nature, attempts are made increasingly to control these variables to represent a controlled environment for the shot peening process. The repeatability and effectiveness of this treatment depends greatly on the process parameters, such as almen intensity and surface coverage. Although great attention is directed to the shot peening finite element modeling (FEM) existing FEM studies are invested in a single shot impact with limited investigation on a collective multiple shot results. In addition, a systematic study to support the selection of the process parameters for general purpose is lacking.

This thesis will provide a detailed study based on experimental setup and finite element models on how different process parameters affect the peening results and this leads to define the limits of beneficial shot peening through the following objectives. The First objective is to analyze the coverage progression of peening indentation through a novel approach using image processing. The second objective is to develop parametric studies to examine the effects of the variation in the process parameters such as shot size, velocity and impact angle. The third objective is to use a novel interpretation algorithm based on the super position principle in assessing the overall induced residual stresses. The fourth objective is a selection procedure designed to decrease the number of experiments required to select the shot peening parameters, the proposed procedure is used to present a novel peening diagram that relates the almen intensity directly to the residual stress.

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Thank you.

Bassam Said

Dedication

This thesis is dedicated to all scholars of Cairo University, my family, and my friends….

Table of Contents

List of Tables

List of Figures

Nomenclature and Abbreviation

A	Indentation rate
AVG	Average stress plot path
C	Coverage percentage
$\dot{\varepsilon}_0$	reference strain rate
ε1	relaxed strains
F	friction force
FEA	Finite element analysis
FEM	Finite element model
GPa	Giga pascal
H1	strain hardening parameter
I. R Stress	Induced residual stress
Lc	Cut off Length
Mpa	Mega Pascal
m_s	Shot mass
N	normal force
P	momentum
Ra	average roughness
S	residual stress standard deviation
S11	Stress in X direction
S33	stress in Z direction
Sic	Silicon carbide
STD	standard deviation
T	Time
t	time
T*	influence of temperature
$t1$	Depth of maximum compressive residual stress
$T1$	current temperature
$t2$	Depth where the residual stress changes sign (from compressive to tensile).
T_{room}	room temperature
u	coefficient of friction
UTS	Ultimate tensile strength
v_s	Shot velocity
WP	target material
μm	micro meter
$\overline{\sigma_{res}}$	average residual stress

$\sigma_{ind_{ij}}$	induced residual stress in direction i and j
σ_1	Principal Stress in X axis
σ_3	Principal Stress in Z axis
σ_{max}	Maximum compressive residual stress
σ_{res}	Residual stress
σ_{surf}	Surface compressive residual stress
σ_t	Maximum tensile residual stress
$\tau 13$	shear stress

Abstract

Shot peening is a cold working process widely used to extend the fatigue life of metallic components that undergo cyclic loading conditions such as in aerospace and automobile industries. Shot peening is one of the most interesting surface treatments as this treatment is controlled by variables that lay under a stochastic and probabilistic nature, attempts are made increasingly to control these variables to represent a controlled environment for the shot peening process. The repeatability and effectiveness of this treatment depends greatly on the process parameters, such as almen intensity and surface coverage. Although great attention is directed to the shot peening finite element modeling (FEM) existing FEM studies are invested in a single shot impact with limited investigation on a collective multiple shot results. In addition, a systematic study to support the selection of the process parameters for general purpose is lacking.

This thesis will provide a detailed insight based on experimental setup and finite element models on how different process parameters affect the peening results. This leads to represent and define the limits of beneficial shot peening through the following objectives. The first objective is to analyze the coverage progression of peening indentation through a novel approach using image processing. The second objective of this research is to develop parametric studies to examine the effects of the process parameters such as shot size, velocity, and impact angle. The third objective is to use a novel interpretation algorithm based on the super position principle in assessing the overall induced residual stresses. The fourth objective is a selection procedure designed to decrease the number of experiments required to select the peening parameters, the proposed procedure is used to present a novel peening diagram that relates the almen intensity directly to the residual stress.