SIMULATION STUDIES ON THE INFLUENCE OF SHOT PEENING PROCESS PARAMETERS

A project review report submitted for the partial fulfillment of the Requirement for the award of the degree

BACHELOR OF TECHNOLOGY
IN
MECHANICAL ENGINEERING

Submitted by

P.LAKSHMI NARASIMHAMURTHY	**(318126520L25)**
K.DEVA VEERA SRIHARSHA	**(317126520139)**
B.TEJA	**(318126520L28)**
P.SANTHOSH KUMAR	**(317126520162)**
KORUKONDA JYOTEESH	**(317126520144)**

Under the esteemed guidance of

P.S.V.N.B.GUPTA,
M.E., (Ph.D)
Assistant Professor

DEPARTMENT OF MECHANICAL ENGINEERING
ANIL NEERUKONDA INSTITUTE OF TECHNOLOGY & SCIENCES (A)
(Affiliated to Andhra University, Approved by AICTE, Accredited by NBA & NAAC with A grade)
SANGIVALASA, VISAKHAPATNAM (District) – 531162

2020-2021

ANIL NEERUKONDA INSTITUTE OF TECHNOLOGY & SCIENCES (A)
(Affiliated to Andhra University, Approved by AICTE, Accredited by NBA & NAAC with A grade)
SANGIVALASA, VISAKHAPATNAM (District) – 531162

PRAGNANAM BRAHMA
ANITS

CERTIFICATE

This is to certify that the Project Report entitled **"SIMULATION STUDIES ON THE INFLUENCE OF SHOT PEENING PROCESS PARAMETERS"** being submitted by PITANI LAKSHMI NARASIMHAMURTHY (318126520L25), KASINA DEVA VEERA SRIHARSHA (317126520139), BOKAM TEJA (318126520L28), POTNURU SANTOSH KUMAR (317126520162), KORUKONDA JYOTEESH (317126520144) in partial fulfillments for the award of degree of **BACHELOR OF TECHNOLOGY** in **MECHANICAL ENGINEERING**. It is the work of bona-fide, carried out under the guidance and supervision of **MR.P.S.V.N.B. GUPTA**, Assistant Professor, Department Of Mechanical Engineering, ANITS during the academic year of 2017-2021.

PROJECT GUIDE	**Approved By** **HEAD OF THE DEPARTMENT**
(MR.P.S.V.N.B. GUPTA) **Assistant Professor** **Mechanical Engineering Department** **ANITS, Visakhapatnam.**	**(Dr. B. Naga Raju)** **Head of the Department** **Mechanical Engineering Department** **ANITS, Visakhapatnam.**

PROFESSOR & HEAD
Department of Mechanical Engineering
ANIL NEERUKONDA INSTITUTE OF TECHNOLOGY & SCIENCES
Sangivalasa-531 162 VISAKHAPATNAM Dist. A.P.

DECLARATION

We hereby declare that the work described in this project work, entitled **SIMULATION STUDIES ON INFLUENCE OF SHOT PEENING PROCESS PARAMETERS ON GENERATION OF SURFACE COMPRESSIVE RESIDUAL STRESS** which is submitted by us in partial fulfillment for the award of **Bachelor of Technology (B.Tech.)** in the Department of Mechanical Engineering to the **Anill Neerukonda Institute of Technology and Science**, affiliated to Andhra University, Visakhapathnam, Andhra Pradesh, is the result of work done by us under the guidance of ***P. Siva. V.N.B. Gupta (M.Tech,Ph.D)*** Assistant Professor

The work is original and has not been submitted for any Degree of this or any other university.

Place:

Date:

Signatures of Students:

P.MURTHY (Regd.No.318126520L25)

K.D.V.S.HARSHA (Regd.No.317126520139)

B. TEJA (Regd.No. 318126520L28)

P.SANTOSH KUMAR (Regd.No.317126520162)

K.JYOTEESH (Regd.No.317126520144)

ACKNOWLEDGEMENT

It is our privilege to express our glad and deep sense of gratitude to **P.SIVA.V.N.B.GUPTA (M.Tech,Ph.D),** Assistant Professor in the department of mechanical engineering, for his encouragement, guidance and co-operation in completing this project. Through this we want to convey our sincere thanks to them for inspiring assistance during this project.

We are deeply indebted to our head of department **Dr.B.Naga Raju (B.E,M.Tech,M.E,Ph.D,MISTE,MIE)**, for being instrumental in the completion of our main project with his complete guidance.

We also express our proud gratitude to our honorable Principal, **Prof.T.V.Hanumantha Rao (M.Tech,Ph.D,F.I.E)**, for his encouragement and facilities provided during the course of project

We express our heartful gratitude to all lab technicians, who helped us in all aspects of the lab work.

We thank one and all who have rendered help to us directly or indirectly in the completion of this work.

BY

P.MURTHY (Regd.No.318126520L25)

K.D.V.S.HARSHA (Regd.No.317126520139)

B. TEJA (Regd.No. 318126520L28)

P.SANTOSH KUMAR (Regd.No.317126520162)

K.JYOTEESH (Regd.No.317126520144)

ABSTRACT

residual stresses produced during shot peening. Towards this goal, the finite element package ABAQUS The present work was to determine the effect of residual stresses produced during shot peening operation. In order to basically understand the influence of various shot peening process parameters on the mechanism of residual stress generation, there is a need to develop numerical models that are capable of accurately predicting 6.9 software package has been employed to clarify and for better understanding of the effect of several key parameters such as shot velocity, shot size, shot material to determine optimum peening process parameters for fatigue life enhancement. The geometry of the target plate is assumed to be a deformable plate with 2×2 mm dimensions. Also, for simplicity, shot is assumed to be fully spherical, discrete and deformable with a mass positioned at its centre. The material models used was an aeronautical-based Ti 6Al-4V & 6061-T6 Aluminium alloys as deformable plate and Alumina (Al_2O_3), Cast steel as shot materials. Situations of single shot impacts were studied; specifically of interest was the magnitude of the residual stress on the surface, as well as the magnitude of the maximum compressive residual stress developed beneath the surface of the target. Other values of interest included the depth of the compressive layer and the magnitude of the maximum tensile residual stress. The model is first validated by comparison of residual stress profiles obtained by various simulation techniques published in the literature. The present work also indicates that the proposed finite element analysis is capable for investigating the influence of various parameters on the shot peening process and this process can successfully be simulated by the finite element package ABAQUS.

CONTENTS

CHAPTER 1

INTRODUCTION

CHAPTER 2

LITERATURE REVIEW

CHAPTER 3

SIMULATION PROCEDURE

LIST OF TABLES

LIST OF FIGURES

CHAPTER-1

INTRODUCTION

1.1 SHOT PEENING

Shot peening is used in numerous engineering applications. It is a cold-work process in which a stream of spherical shot is blasted against an engineering component. Each shot impacts on the target surface, causing plastic deformation. After contact between the shot and the component ceased, a high compressive residual stress is generated at the surface of the component. Compressive residual stress in the surface layers of the component greatly improves the fatigue strength. It is therefore very useful to be able to predict the pattern and magnitude of the residual stress distribution near the surface after shot peening. Shot peening is a very complex process to model numerically, involving dynamic analysis of fast moving shot impacting on a metallic component which can often has complex geometry. There are a significant number of parameters involved in shot peening which need to be controlled and regulated in order to produce a more beneficial compressive residual stress distribution within the component. These parameters can be categorized into three groups relating to the shot, the component and the process. The shot parameters include size, density, shape, impact velocity, rotary inertia, incident angle and hardness. The component parameters include geometry, initial yield stress, work-hardening characteristics and hardness. The process parameters include mass flow rate, air pressure, angle of attack, distance between nozzle and component and percentage coverage. In order to control the resulting residual stress pattern in peened components, it would be highly beneficial to establish quantitative relationship between these parameters and residual stress characteristics.

This section provides a brief description of the shot peening operation including the many parameters that are involved. Information is also provided regarding the measurement of peening intensities, as well as, the role that shot peening plays in the formation of residual stresses in the penned component. Shot peening is a surface strain hardening process that is used mainly in the manufacture of mechanical components[1,2].Strain hardening can be described as a process in which a ductile metal will become harder and stronger as it is plastically deformed. This process is also referred to as work hardening or cold working since the temperature at which it usually takes place is well below the absolute melting temperature of the material being worked on. In order to explain the fundamental principle behind strain hardening one must look at the dislocation-dislocation strain field interactions. Cold working causes the dislocation density in the material to increase resulting in a decrease in the average distance between the dislocations. The movement of a dislocation is hampered by the presence of other dislocations because of the repulsive interaction that occurs between them. As a result the stress required to further deform the ductile metal increases [1]. Overall, shot peening has been proven to markedly improve the fatigue life of a component. This is accomplished by impinging the surface of the component with many small spherical shots. Typical shot materials include hardened cast-steel, conditioned cut-wire, glass, or ceramic beads. Shot velocities can range from 45m/s to 125m/s. The size of the beads can vary from 0.1mm to 2mm in diameter [2]. "After contact between the shot and the target material has ceased, the elastically stressed region tends to recover to the fully unloaded state, while the plastically deformed region sustains some permanent deformation" [3].

1.2 RESIDUAL STRESSES

The primary focus of this research is to estimate the residual stresses resulting from shot peening Ti-6Al-4V. It is necessary to first present a brief background on such subjects as residual stress, shot peening, and fatigue. In this section a brief description of what residual stresses are and how they are introduced will be presented. Residual stresses are stresses that remain in a solid material after the original cause of the stresses has been removed. Residual stress may be desirable or undesirable. For example, laser peening imparts deep beneficial compressive residual stresses into metal components such as turbine engine fan blades, and it is used in toughened glass to allow for large, thin, crack- and scratch-resistant glass displays on smart phones. However, unintended residual stress in a designed structure may cause it to fail prematurely. "Residual stresses are one of the most important parameters that characterize the near surface layer of any mechanical component, which plays a crucial role in controlling its performance [4]. A residual stress is one that remains in a body even when all external loads have been removed and is the result of a non-uniform plastic deformation. Such stresses are generally the result of a previous thermal or mechanical load applied to the body or of a phase transformation that occurs within the body itself [4]. An example of a thermal load would be one that is applied during a heat treatment process, while mechanical loading can occur during finish machining, bending, or shot peening operations.

1.3 FATIGUE

According to Callister[5], fatigue can be defined as “failure, at relatively low stress levels, of structures that are subjected to fluctuating and cyclic stresses.” Under such cyclical loading conditions components have a tendency to fail at stress magnitudes that are well below the material’s understood tensile or yield strength for static loading conditions. As the name itself implies fatigue failures tend to occur over a rather lengthy period of time. As the driving factor behind approximately 90% of all metallic failures, fatigue is the single largest cause of failure in metals. Because very little plastic deformation is associated with fatigue failure it tends to be brittle by nature and is brought on by the generation and propagation of cracks through the material. At the present time “controversy exists in the shot peening and fatigue community as to whether the major benefits of shot peening should be ascribed to the compressive residual stresses or to the micro structural changes and/or deformation which occur over the same region and influence crack initiation”[6]. Niku-Lari found that for materials which posses “low characteristics” the resulting increase in the endurance limit due to the shot peening operation is primarily caused by the “superficial strain hardening and the residual stresses” while for high strength materials the increase in fatigue life has been found to be caused by the residual stresses[7]. It is widely accepted that compressive residual stresses improve the overall fatigue life of a component, however, what is not known is the exact impact that these stresses have[8].Amongst researchers there seems to be an increased interest in developing models capable of incorporating residual stress values into fatigue life calculations[6].

“The difficulties in controlling the parameters of the strain hardening operation by shot peening very often lead its users to treat it only as an extra safety factor, without taking the residual stresses due to the shot peening into account when calculating the required dimensions of the part”[7]. In the United States and France component developers tend to follow the previously stated approach, however, in England, Germany, China, and Japan engineers take residual stresses due to shot peening, in the stabilized condition, into account in their fatigue life calculations [7].

Fatigue is the weakening of a material caused by repeatedly applied loads. It is the progressive and localized structural damage that occurs when a material is subjected to cyclic loading. The nominal maximum stress values that cause such damage may be much less than the strength of the material typically quoted as the ultimate tensile stress limit, or the yield stress limit.

Fatigue occurs when a material is subjected to repeated loading and unloading. If the loads are above a certain threshold, microscopic cracks will begin to form at the stress concentrators such as the surface, persistent slip bands (PSBs), and grain interfaces. Eventually a crack will reach a critical size, the crack will propagate suddenly, and the structure will fracture. The shape of the structure will significantly affect the fatigue life; square holes or sharp corners will lead to elevated local stresses where fatigue cracks can initiate. Round holes and smooth transitions or fillets will therefore increase the fatigue strength of the structure.

1.4 TARGET MATERIALS

1.4.1 Ti-6Al-4V

Titanium has become a prominent material in many industries including aerospace, automotive, biomedical, and many more owing to its above average strength to weight ratio. Titanium alloys are currently being used to construct everything from bike frames and tennis rackets to airframes and automotive components. The most widely used titanium alloy is Ti-6Al-4V or Ti64 as it is commonly called, which accounts for 45% of total titanium production and can found in all of the aforementioned industries [8]. As the name suggests this alloy is comprised of 6-wt% aluminium and 4-wt% vanadium. Due to its wide usage it is important that as much information as possible be gathered about this particular alpha-beta alloy, and in particular the effects that the various processing techniques have on the final properties of the material. “Titanium is a material generally utilized for parts requiring the greatest reliability and therefore the surface roughness and any damage to the sub-surface layers (including residual stress) must be controlled”[9]. The main focus of this research will be the residual stresses formed during shot peening of Ti-6Al-4V.

The existence of the α/β transformation means that a variety of microstructures and property combinations can be achieved in the alloy through thermo mechanical processing thus permitting the adaptation of properties to specific applications. The need to weld the alloy for certain engine components can expose the alloy locally to non-optimum thermal cycles and it is therefore of importance to gain an understanding of the kinetics involved in the phase transformations during heating and cooling. Moreover, for the purpose of modeling and computer simulations of heat treatments and welding processes, Quantitative descriptions of the transformations are necessary

1.4.2 Aluminium6061

Aluminium has become a prominent material in aerospace, nuclear industries have developed a large range of super alloy and heat resistance materials mnemonics like ceramics and composite materials. With the vast and rapid progress in science and technology, modern industry has introduced a new generation of composite materials having low density and very light weight with high strength, hardness and stiffness to meet the current needs of modern technology and the challenges against liberalization and global competitiveness in market .it has numerous benefits like formability, weld ability, corrosion resistance and low cost. Aluminium 6061 is used as matrix material for the fabrication of Al-e-glass-fly ash hybrid composite material. Some of the mechanical properties have been evaluated and compared with Al6061 alloy. Significant improvement in tensile properties, compressive strength and hardness are noticeable as the wt % of the fly ash increases. The microstructures of the composites were studied to know the dispersion of the fly ash and e-glass fiber in matrix. It has been observed that addition of fly ash significantly improves ultimate tensile strength along with compressive strength and hardness properties as compared with that of unreinforced matrix.

Annealed 6061 (6061-O temper) has maximum tensile strength no more than 18,000 psi (125 MPa), and maximum yield strength no more than 8,000 psi (55 MPa). The material has elongation (stretch before ultimate failure) of 25–30%. T4 temper 6061 has an ultimate tensile strength of at least 30,000 psi (207 MPa) and yield strength of at least 16,000 psi (110MPa). It has elongation of 16%. T6 temper 6061 has an ultimate tensile strength of at least 42,000 psi (300MPa) and yield strength of at least 35,000 psi (241MPa). More typical values are 45,000 psi (310MPa) and 40,000 psi (275MPa), respectively. In thicknesses of 0.250 inch (6.35 mm) or less, it has elongation of 8% or more; in thicker sections, it has elongation of 10%. T651 temper has similar mechanical properties. The typical value for thermal conductivity for 6061-T6 at 77°F is around 152 W/m K. A material data sheet defines the fatigue limit under cyclic load as 14,000 psi (100MPa) for 500,000,000 completely reversed cycles using a standard RR Moore test machine and specimen. Note that aluminium does not exhibit a well defined "knee" on its S-n graph, so there is some debate as to how many cycles equates to "infinite life". Also note the actual value of fatigue limit for an application can be dramatically affected by the conventional de-rating factors of loading, gradient, and surface finish.

1.5 SHOT MATERIALS

1.5.1 Aluminium oxide

Aluminium is very strong, light, and durable. Aluminium Oxide is a form of aluminium. Aluminium is an extremely reactive substance so it is scarcely found in nature. Therefore, it is usually found in the form of Alumina. Alumina is formed in nature when aluminium reacts with oxygen in moist air to form a thin, whitish coating on Aluminium metal of Bauxite .Aluminium oxide is a chemical compound of aluminium and oxygen with the chemical formula Al_2O_3. It is the most commonly occurring of several aluminium oxides, and specifically identified as aluminium(III) oxide. It is commonly called alumina, and may also be called al oxide, Alluminiumoxite, or alundum depending on particular forms or applications. It commonly occurs in its crystalline polymorphic phase α-Al_2O_3, in which it composes the mineral corundum, varieties of which form the precious gemstones ruby and sapphire. Al_2O_3 is significant in its use to produce aluminium metal, as an abrasive owing to its hardness, and as a refractory material owing to its high melting point.

The most common form of crystalline aluminium oxide is known as corundum, which is the thermodynamically stable form .The oxygen ions nearly form a hexagonal close-packed structure with aluminium ions filling two-thirds of the octahedral interstices. Each Al^{3+} centre is octahedral. In terms of its crystallography, corundum adopts a trigonal Bravias lattice with a space group of

R-3c (number 167 in the International Tables). The primitive cell contains two formula units of aluminium oxide.

Aluminium oxide also exists in other phases, including the cubic γ and η phases, the monoclinic θ phase, the hexagonal χ phase, the orthorhombic κ phase and the δ phase that can be tetragonal or orthorhombic .Each has a unique crystal structure and properties. Cubic γ-Al_2O_3 has important technical applications. The so-called β-Al_2O_3 proved to be $NaAl_{11}O_{17}$.Molten aluminium oxide near the melting temperature is roughly 2/3 tetrahedral (i.e.2/3 of the Al are surrounded by 4 oxygen neighbors), and 1/3 5-coordinated, very little (<5%) octahedral Al-O is present .Around 80% of the oxygen atoms are shared among three or more Al-O polyhedral, and the majority of inter-polyhedral connections are corner-sharing, with the remaining 10–20% being edge-sharing. The breakdown of octahedral upon melting is accompanied by a relatively large volume increase (~20%), the density of the liquid close to its melting point is 2.93 g/cm^3.

1.5.2 Cast steel

Cast steel is a type of metal created by heating iron using a crucible container. Its creation was due to a revolutionary process invented by an Englishman, Benjamin Huntsman, the 1751. Cast steel allowed for a more uniform composition of, and fewer impurities in, steel than any previous manufacturing process. Since it is made in a crucible, cast steel is often called crucible steel. Steel is made by combining iron with carbon or other alloys. Iron is a soft metal, so not ideal for many construction purposes. The creation of steel removes many of the impurities in iron, which allows steel to be harder and more durable. The better the steel, the more iron impurities that are removed. Early steel was made by adding small amounts of carbon to iron. For example, blister steel was made by repeatedly heating wrought iron and charcoal together in a kiln the charcoal's carbon transferred to the steel by the process of diffusion. Cast steel was the first type of steel that allowed alloys to be added to the iron. Prior to this method, manufacturers had not been able to get steel hot enough to melt. By heating blister steel in a clay crucible placed directly into a fire, Huntsma allowed the metal to reach up to 2900°F (1600°C). Melting allowed other elements, such as nickel, to be mixed into the metal, thus strengthening the steel. Over the centuries, improvements in the crucible process have been made, though the steel is still heated by fire and inside clay, pot-shaped crucible that can be sealed. Modern cast steel is use in engines and machines, as well as ship building. It tends to be more expensive than other types of metals used for similar projects .Cast steel has a rough finish. It often has surface holes created by gas bubbling during the heating process. An elastic metal, this type of steel is very tough, having four times the tensile strength of cast iron. Tensile strength is how much pressure, created by pulling, an object can withstand before it breaks .One concern when using cast steel is whether the surface holes extend into the interior of the metal. If so, these holes could create weaknesses that affect the soundness of the steel. Measuring the volume of water that can be poured into the holes will give a good indication of whether the holes extend far into the metal.

1.6 Abaqus

- Abaqus FEA **(**formerly **ABAQUS**) is a software suite for finite element analysisandcomputer-aided engineering, originally released in 1978. The name and logo of this software are based on the abacus calculation tool. The Abaqus product suite consists of five core software products:
- Abaqus/CAE or "**C**omplete **A**baqus**E**nvironment" (a backronym with an obvious root in **C**omputer-**A**ided **E**ngineering). It is a software application used for both the modeling and analysis of mechanical components and assemblies (pre-processing) and visualizing the finite element analysis result. A subset of Abaqus/CAE including only the post-processing module can be launched independently in the Abaqus/Viewer product.
- Abaqus/Standard, a general-purpose Finite-Element analyzer that employs implicit integration scheme (traditional).
- Abaqus/Explicit, a special-purpose Finite-Element analyzer that employs explicit integration scheme to solve highly nonlinear systems with many complex contacts under transient loads.
- Abaqus/CFD, a **C**omputational **F**luid **D**ynamics software application which provides advanced computational fluid dynamics capabilities with extensive support for pre-processing and post processing provided in Abaqus/CAE.

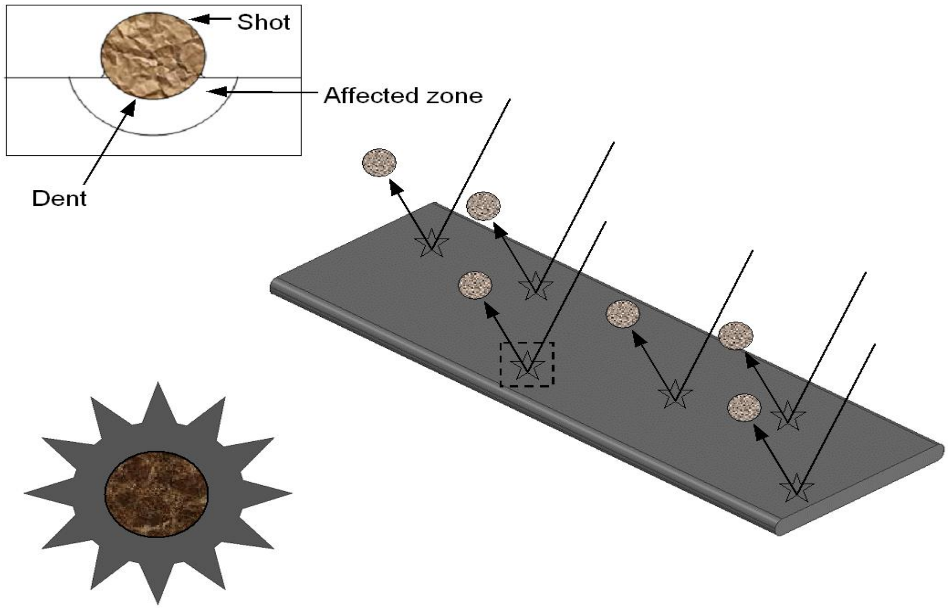

Figure1.1: Schematic representation of short peening

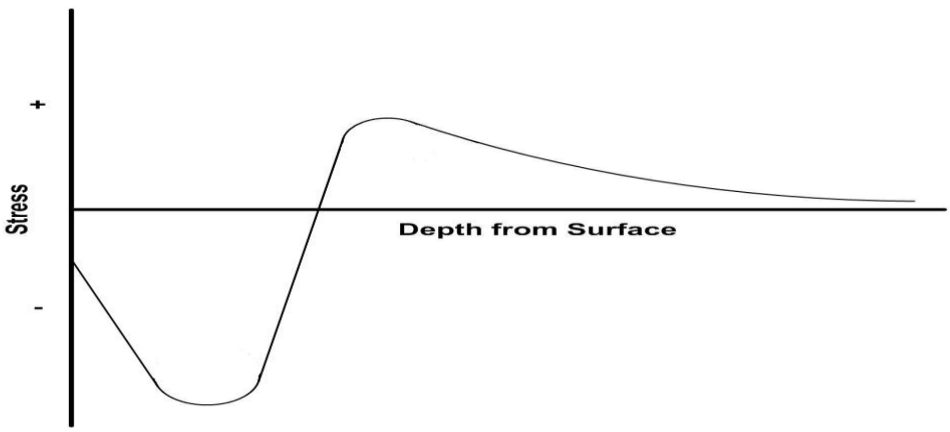

Figure 1.2: Shown here is a typical residual stress profile that would result from a peening operation.

CHAPTER 2

LITERATURE REVIEW

The shot peening process is significantly complex the system is dynamic and includes contact mechanics. Study of contact problems of the elastic and elastic-plastic materials resulting from the loading of circular contact area of a sphere with a plane (or more generally between two spheres) was presented by Hertz [11]. Li, et al. [12] proposed a simplified analytical model for calculating the compressive residual stress field due to the shot peening process which cannot take the velocity of the shot into account and, in addition, depends on empirical parameters to develop a theoretical model. Hardy et al. [13] was the first to solve the contact problem of a rigid sphere indenting an elastic–perfect plastic half-space using the FE method. The first FE analysis of shot peening using the commercial FE program was presented by Edberg et al. [14]. Meguid et al. [15] used the ANASYS computer program and developed a three-dimensional finite element model of dynamic elasto-plastic analysis, single and twin spherical indentations using rigid spherical shots and metallic targets. He examined the effects of shot velocity, size and shape, and target characteristics on residual stress distribution in the target. Their results indicated that the effects of shot parameters were more profound than the strain-hardening rate of the target. M. Frija et al. [16] published a numerical simulation of the shot peening process using a finite element method and obtained the residual stress, the plastic deformation profiles and the surface damage. In their model, the shot was supposed to be a rigid sphere. The mechanical behavior of the subjected material was assumed to be elastic plastic coupled with damage, using an integrated form of the Lemaitre and Chaboche model [17]. The shot peening loading was simulated by a static indentation, obtained by an energetic equivalence with the dynamic impact. Al-Hassam et al. [18] presented a numerical simulation of single shot impact on a component and examined single shot impacting with an oblique angle but very limited results were presented and their results verified the significant role played by non-linear work hardening and strain rate dependency of the target on residual stress profile and extent of surface hardening.

Majzoobi et al. [19] have investigated multiple shot impacts and the effect of the shot velocity on the residual stress profile by using LS-DYNA code. Their results showed that, residual stress distribution was highly dependent on impact velocity and multiplicity.

CHAPTER 3

SIMULATION PROCEDURE

We are going to study the compressive residual stress generated due to shot peening by using simulation procedure .The simulation procedure we have adopted is ABAQUS .Here we are going to compare the different parameters like velocity, size and compressive residual stress generated by taking Aluminium 6061 and Ti-6Al-4V as target material and Cast steel, Aluminium oxide as shot materials. The simulation procedure consists of the number of steps which are discussed below. For the Explanation of the procedure we have considered Aluminum6061 as target material and Cast steel as the shot material.

3.1 CREATING THE MODEL GEOMETRY

- Go to the Start Menu and open Abaqus CAE. Here you will observe a model tree on the left side of the home screen. Model tree consists of steps involved in the analysis like Part, Materials, assembly step, job etc. ABAQUS home screen is shown in figure 3.1
- As our analysis is shot peening the geometric model of part consists of the two parts Target and Shot material. For this select the part in the model tree.
- Enter the new nameas the target, under the modelling space select axis-symmetric, under the type select the Deformable and under the base feature select the shell then press continue then draw a rectangle with required dimensions. Thus target part has been completed
- The same procedure has been adopted for the design of the shot. Initially the selected size of the shot is 425µm as shown in figure 3.2

3.2 DEFINING MATERIAL PROPERTIES

- Next step in the procedure is defining the material properties for this select the materials in the model tree. As shown in the figure 3.3 assign the required properties for the materials here we had taken Aluminium 6061 as target material and cast steel as target material.
- Plasticity parameters here we have taken are Johnson-Cook parameters .The Johnson-Cook parameters and mechanical properties we have taken are given in the below table 3.1 and table 3.2
- Next we have to give the material properties of the cast steel .Elasticity and plasticity properties of cast steel are given in the below table 3.3 and table 3.4.

3.3 CREATING SECTIONS AND SECTION ASSIGNMENT

- In this step the sections must be created and the materials to the section are assigned. For this select the section dialogue box name as the section-1 for the target material and section -2 for the shot material. After that materials are assigned for the sections assignment as shown in figure 3.4
- Now the solid section has been created, it can be assigned to the geometry for this select the section assignment and assign the section-1 and section-2 as shown in the figure 3.5

3.4 ASSEMBLY

- In this we have to do the assembly of the target and shot for this first Instances must be created for target and shot. Then by using the translate instance assembly of the target and part done as shown in figure 3.6.
- After the assembly the meshing is done as shown in the figure 3.7. After that the type of the elements must be selected.

3.5 CREATING A STEP

- The step is where the user defines the different fields like velocities, interactions and boundary conditions. In the step there are two stages initial and impact .First interactions are created. In the interactions the selected method is Dynamic explicit, surface-surface-contact (Explicit) and give mechanical method as penalty contact type.
- In the first step as we are going to vary the velocities select the velocities in the predefined fields as v_1=0 and v_2=25m/s as shown in the below figure3.8.
- In the impact field select the field output what we required as stress and strains etc. Then apply the boundary conditions as U1=0 and UR3=0.Applying of boundary conditions are shown in the figure 3.9

3.6 CREATING JOB

- The job must be created for the analysis as shown in the figure3.10.The name of the job we have given is shot then submit the job for the analysis.

3.7 RESULTS

- The results of the residual stresses are taken in the X-axis, X direction in this the shot didn't show any effect on the target material the deformable shape of the target material is as shown in the figure.
- Same procedure is adopted with different velocities like 23m/s, 45m/s, 65m/s, 85m/s and 105m/s.

3.8 CHANGING THE SHOT SIZE AND SHOT MATERIAL

By using the same procedure what we have explained above we most change the size of the shot as 225µm, 425 µm, 625 µm, 825 µm and 1025 µm. Then the values of the residual stress are tabulated until we get the constant stress values. Then by changing the shot material as Al_2o_3 by taking 65m/s as velocity and 425 µm as shot size. The mechanical properties we have considered for Al_2o_3 are given in the below table

3.9 CHANGING THE TARGET MATERIAL

- Now we changed the target material as Ti-6Al-4V and the shot material is cast steel the mechanical properties of the Ti-6Al-4V are given in the below table
- Then in the predefined fields we had changed the velocity of the shot as 25m/s, 45m/s, 65m/s, 85m/s, and 105m/s. Then the residual stress values are tabulated.
- Then the model is done by changing the size of the shot as 225µm, 425 µm, 625 µm, 825 µm, 1025 µm.
- After that we have changed the shot material i.e., we had taken Al_2o_3 as the shot material and the simulation procedure is repeated. Thus we had done the simulation procedure for shot peening by changing the different target and shot materials and we had tabulated the residual stress generated by shot peening.

TABLES

Table 3.1 Mechanical properties of Aluminium 6061

Property	Values	Units
Density	2700	Kg/m^3
Young's Modulus	70	GPa
Poisson's Ratio	0.33	-

Table 3.2 Johnson-cook Parameters of Aluminium 6061

Material	A (MPa)	B (MPa)	n	m	Melting Temperature (K)	Transition Temperature (K)
Aluminium 6061	324	114	0.42	1.34	853	298

Table 3.3 Mechanical Properties of Cast Steel

Property	Values	Units
Density	7638	Kg/m^3
Young's Modulus	200	GPa
Poisson's Ratio	0.256	-

Table 3.4 Johnson-cook Parameters of Cast Steel

Material	A (MPa)	B (MPa)	n	m	Melting Temperature (K)	Transition Temperature (K)
Cast Steel	792	510	0.014	1.03	1793	298

Table 3.5 Mechanical Properties of Al_2O_3

Property	Values	Units
Density	3840	Kg/m^3
Young's Modulus	300	GPa
Poisson's Ratio	0.21	-

Table 3.6 Johnson-cook Parameters of Al_2O_3

Material	A (MPa)	B (MPa)	n	m	Melting Temperature (K)	Transition Temperature (K)
Al_2O_3	880	450	0.64	0.6	2298	298

Table 3.7 Mechanical Properties of Ti-6Al-4V

Property	Values	Units
Density	4430	Kg/m^3
Young's Modulus	114	GPa
Poisson's Ratio	0.324	-

Table 3.8 Johnson-cook Parameters for Ti-6Al-4V

Material	A (MPa)	B (MPa)	n	m	Melting Temperature (K)	Transition Temperature (K)
Ti-6Al-4V	1098	1092	0.93	1.1	1878	298

FIGURES

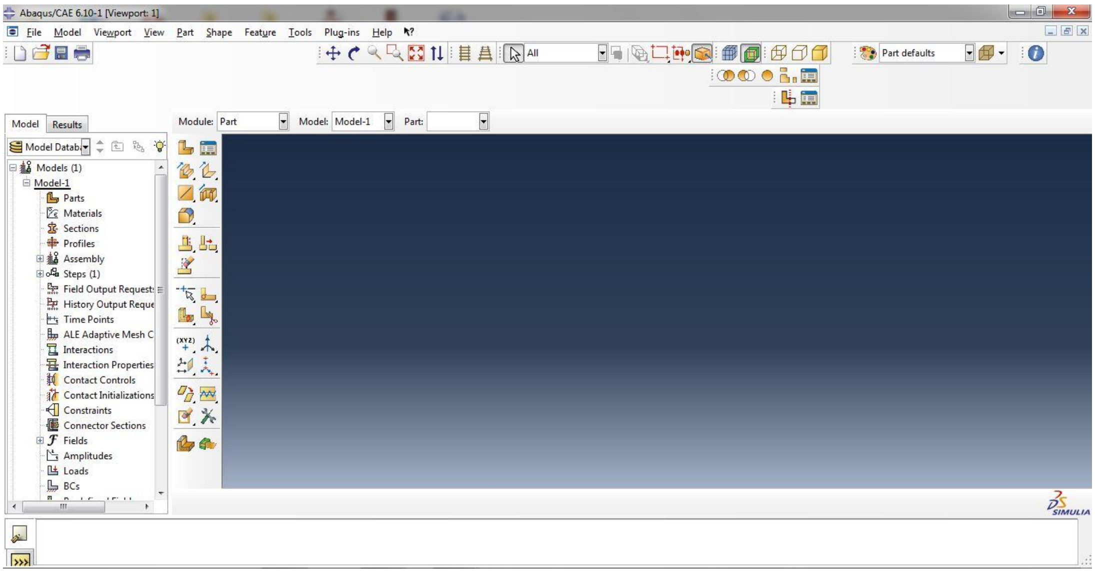

Figure 3.1 Abaqus home screen

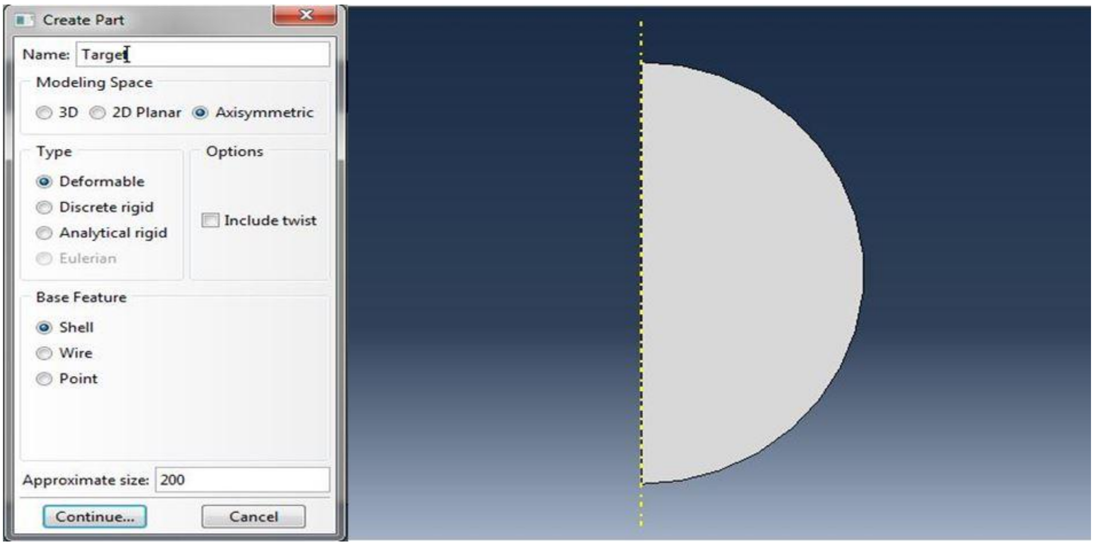

Figure 3.2 Creating part

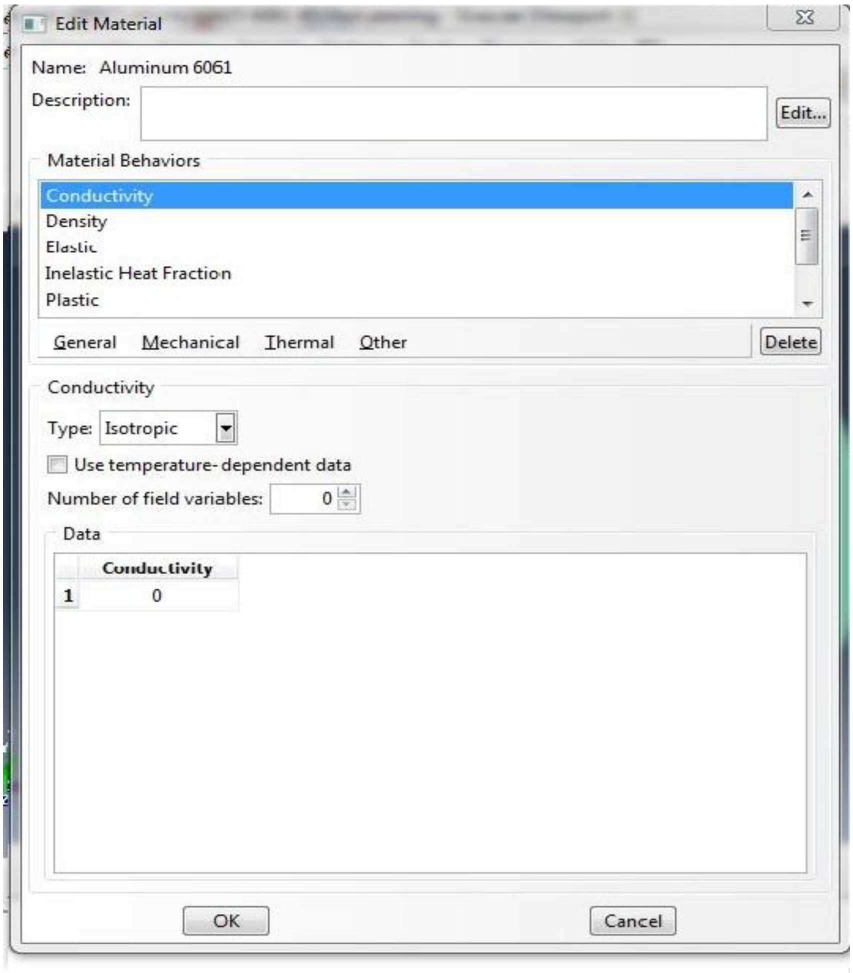

Figure 3.3 Defining material properties

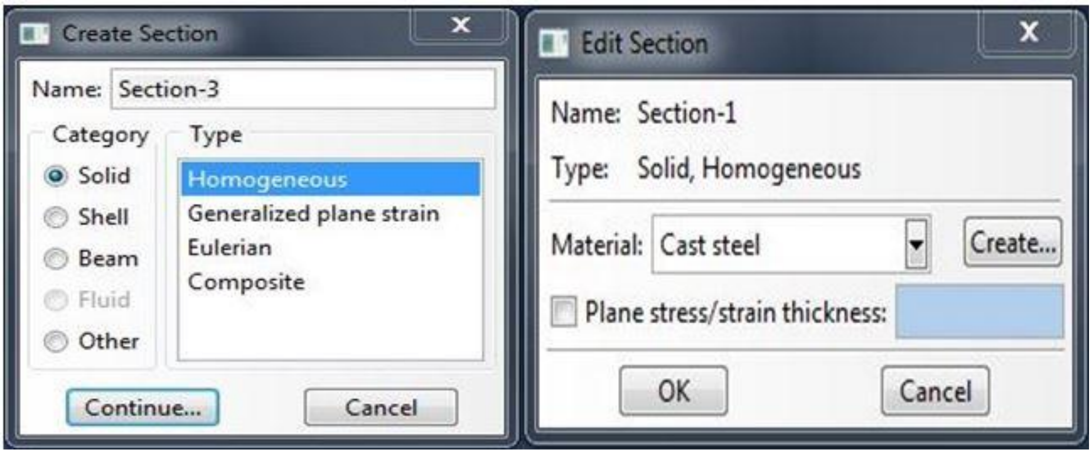

Figure 3.4 Creating Sections

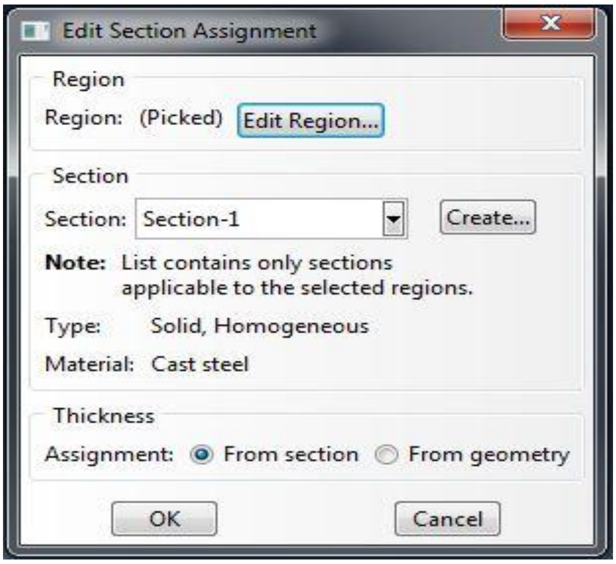

Figure 3.5 Section assignment

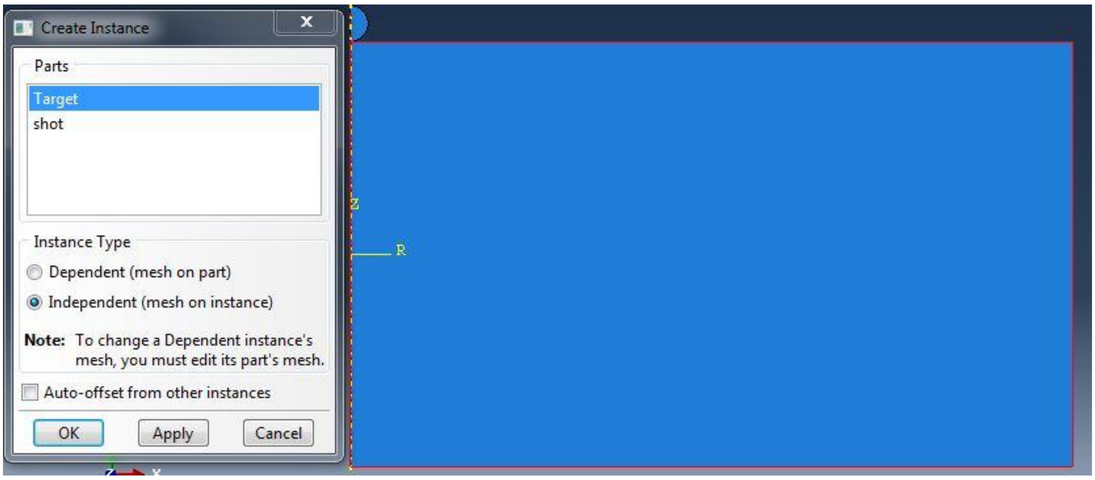

Figure 3.6 Creating instances and assembly of shot and target

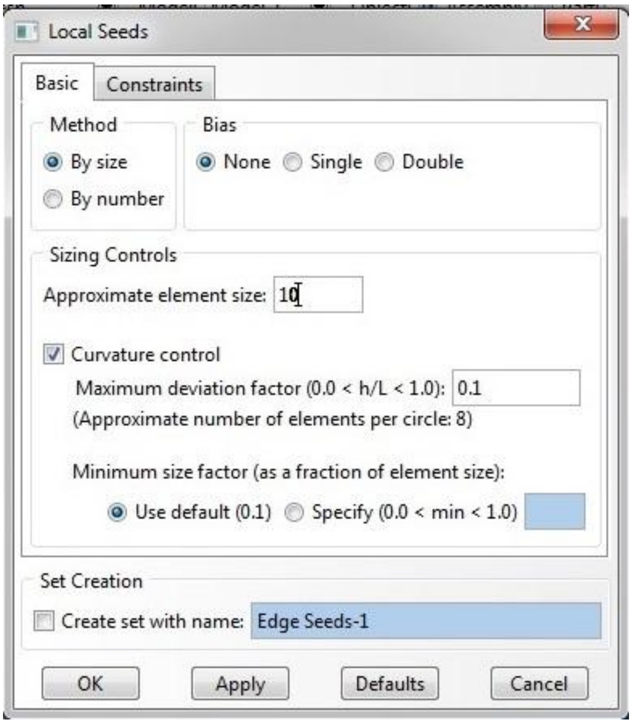

Figure 3.7 Meshing of materials

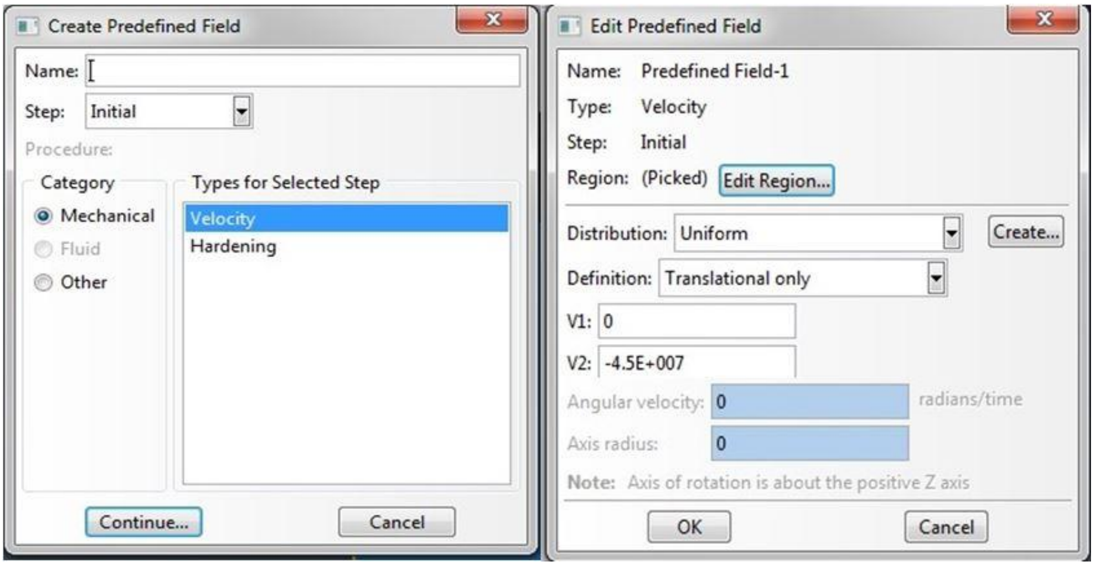

Figure 3.8 Creating predefined field

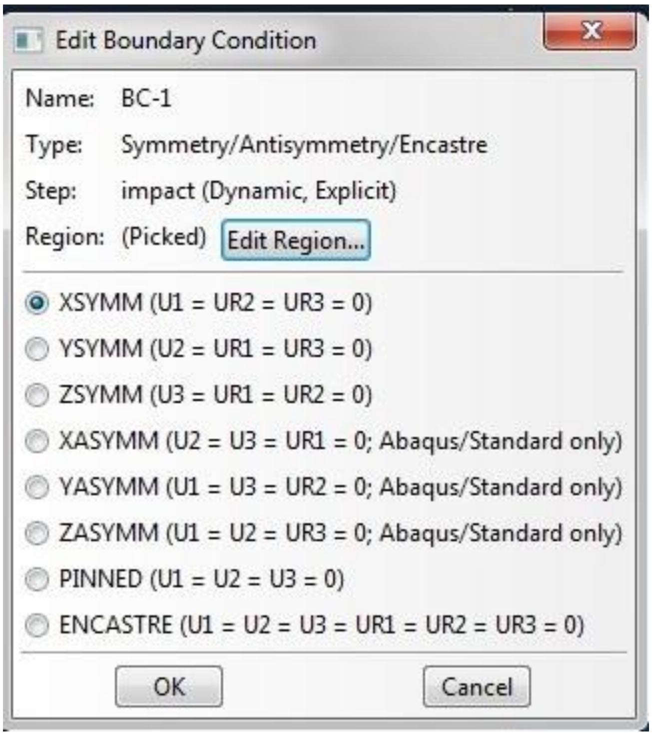

Figure 3.9 Applying boundary conditions

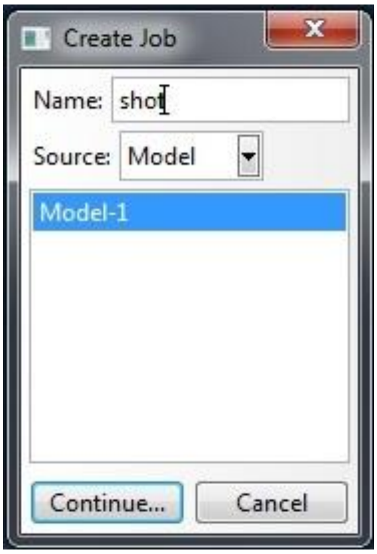

Figure 3.10 creating job

CHAPTER-4

RESULTS AND DISCUSSIONS

The results of the various parameters like size, velocity and residual stress of the Aluminium6061 and Ti-6Al-4v as target and Al_2O_3,cast steel as shot materials are discussed below

4.1 RESULTS AND DISCUSSIONS FOR TI-6AL-4V

4.1.1 Effect of Velocity

- The velocity comparison graph for the Ti-6Al-4V as target material and cast steel as the shot material is shown in the below figure 4.1.
- Form the above graph we can conclude that as the velocity of the shot increases the depth of the maximum compressive residual stress increases, magnitude of the compressive residual stress and depth of the compressive residual stress has been increased.
- The figure 4.2 shows deformations occurred due to the change in the velocities of the shot.
- Figure 4.3 is graph of maximum magnitude of the compressive residual stress (MPa) and velocity m/s we can conclude that with the increase in the velocity the magnitude of the compressive residual stress varies polynomial.
- From the figure 4.4 a graph is drawn for depth of maximum compressive residual stress and velocity of shot .From this we can conclude that the depth of maximum compressive residual stress increases linearly with the increasing the velocity.
- The above graph figure 4.5 is drawn for the Depth of compressive residual stress and the velocity. This graph has given the linear relationship. That is as the velocity increases the depth of the compressive residual stress increases

4.1.2 Effect of shot size

- In the above column we have studied the effect of velocity of the shot on the target material now we are going to study the effect of the size on the target material
- Figure 4.6 shows the deformation of target materials by varying the shot materials.

- The graph figure 4.7 is shot size comparison graph which is drawn is for the compressive residual stress and the depth of the target from this we can conclude that the depth of compressive residual stress, depth of maximum compressive residual stress and the magnitude of the compressive residual stress has been increased.
- Figure 4.8 is the graph drawn for the maximum magnitude of compressive residual stress and shot size. As the shot size has increased the maximum magnitude of the compressive residual stress has also been increased linearly.
- The above graph figure 4.9 is drawn for the shot size (µm) and the depth of the compressive residual stress. As the size of shot has been increased depth of the compressive residual stress also increased linearly.

4.1.3 Effect of shot materials

- The next result we had studied is by taking Ti-6Al-4V as the target material, cast steel and Al_2O_3 as the shot materials.
- Figure 4.10 is a bar graph drawn between shot materials and depth of compressive residual. From this graph we can conclude that the depth of compressive residual stress is more for the Al_2O_3 than the cast steel shot material
- Figure 4.11is a bar chart drawn for the shot materials and the depth of the maximum compressive residual stress. Depth of maximum compressive stress is more for the alumina than the cast steel because alumina is the harder material than the cast steel.
- Figure 4.12 is the next results we had plotted, is a bar chart against shot material and Maximum magnitude of compressive residual stress. From this we had observed that alumina has the more magnitude of compressive residual stress than the cast steel.

4.2 RESULTS AND DISCUSSIONS FOR ALUMINIUM6061

4.2.1 Effect of velocity

- Up to now we have discussed the results of Ti-6al-4V and cast steel as the target and shot materials now we are going to discuss the results of Aluminium6061 and cast steel as target and shot materials.
- Figure 4.13 represents deformation of target material Aluminium6061 with different velocities of shot material.

- Figure 4.14 is a graph drawn between residual stress and depth of target material. From this graph we concluded that maximum depth of compressive residual stress decreases with increase in velocity and magnitude of compressive residual stress and depth of compressive residual stress increases with increase in velocity.
- Figure 4.15 is drawn for the Velocity and the depth of compressive residual stress. This gives a result that as the velocity increases depth of compressive residual stress increases polynomial

4.2.2 Effect of shot size

- Now we are going to study the effect of shot size on Aluminum6061. Figure 4.16 represents the deformation of target material by varying different shot materials.
- Figure 4.17 shows the comparison of different shot sizes. The effect of shot size is studied for the target material as Aluminum6061 as the depth increases the magnitude of compressive residual stress and depth of compressive residual stress also increases. But the maximum size of the shot can be 825 µm after that the curve will follow the irregular shape.
- Figure 4.18 is a graph drawn between shot size and maximum magnitude of compressive residual stress. From this we can conclude that as shot size increases maximum magnitude of compressive residual stress also increases parabolic.
- From the graph figure 4.19 is drawn for depth of maximum compressive residual stress and the shot size .From this as the shot size increases depth of maximum compressive stress also increases polynomial.
- Figure 4.20 is a graph drawn between the shot size and depth of compressive residual stress .As the shot size is increased depth of compressive residual stress also increases.

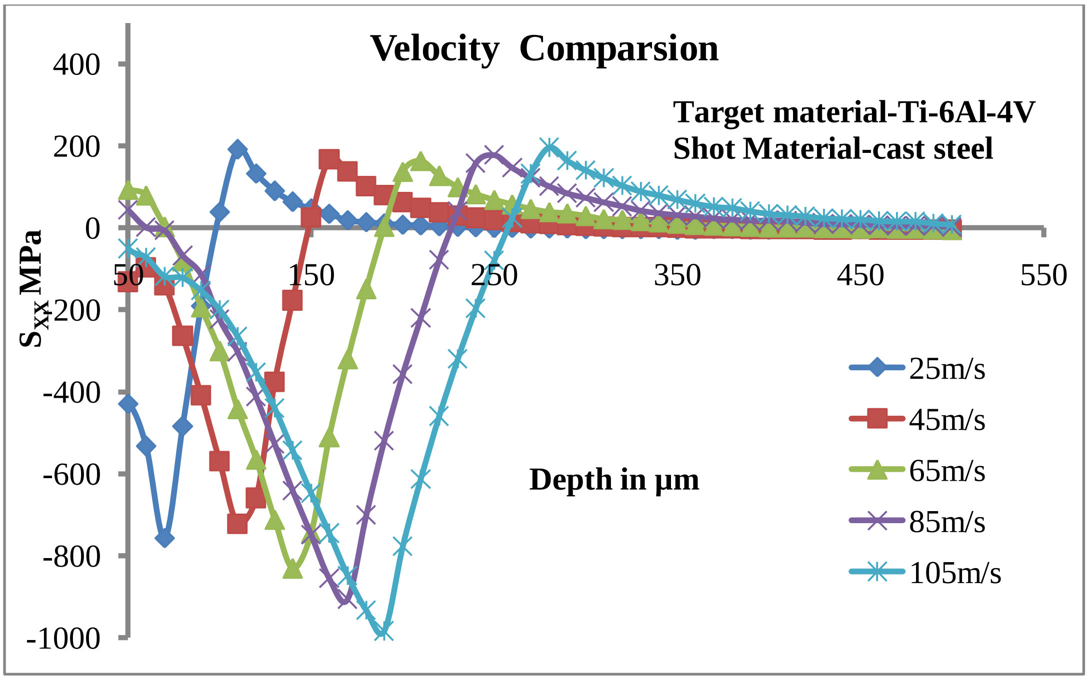

Figure 4.1 Velocity comparison for Ti-6Al-4v as target material and cast steel as shot material

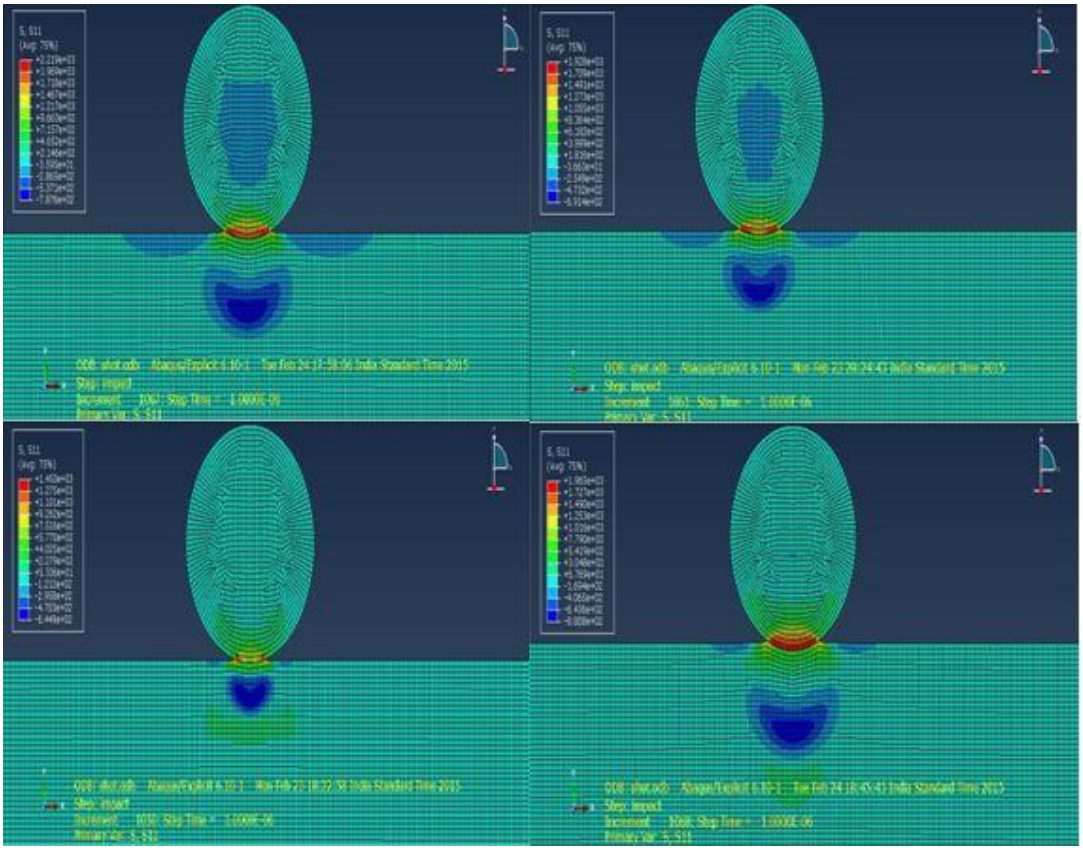

Figure 4.2 : Compressions of different velocities

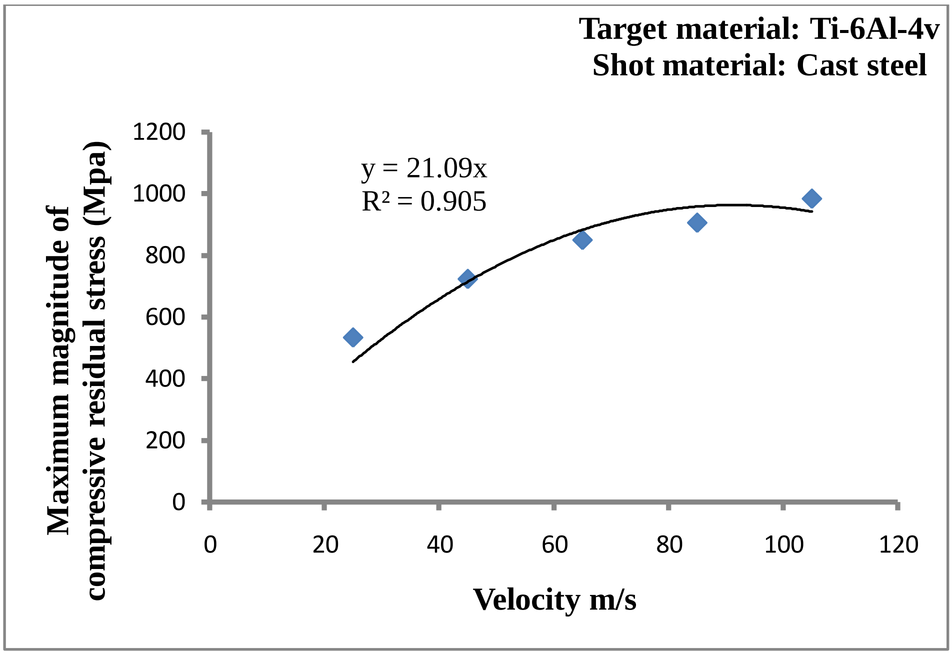

Figure 4.3 Comparison of velocity and maximum magnitude of compressive residual stress

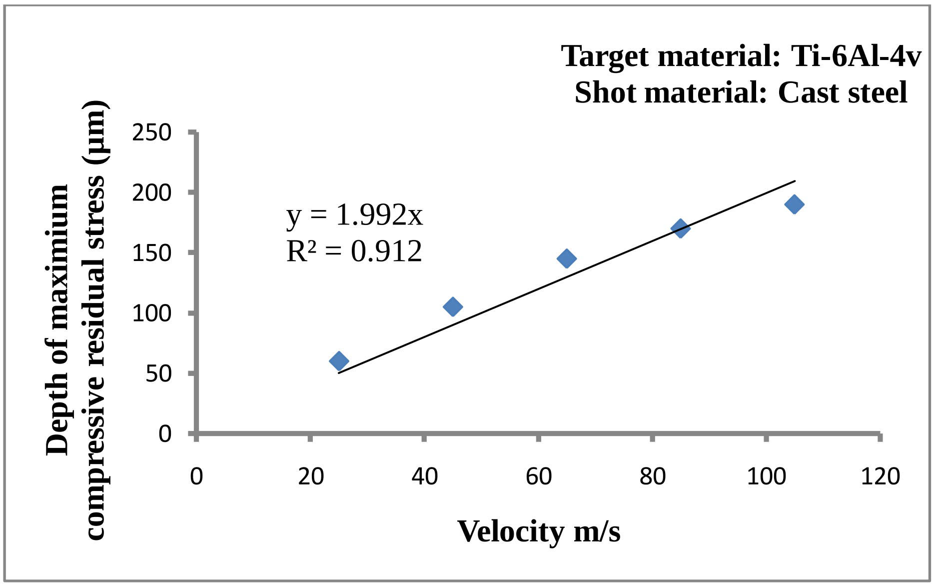

Figure 4.4 Comparison of velocity and depth of maximum compressive residual stress

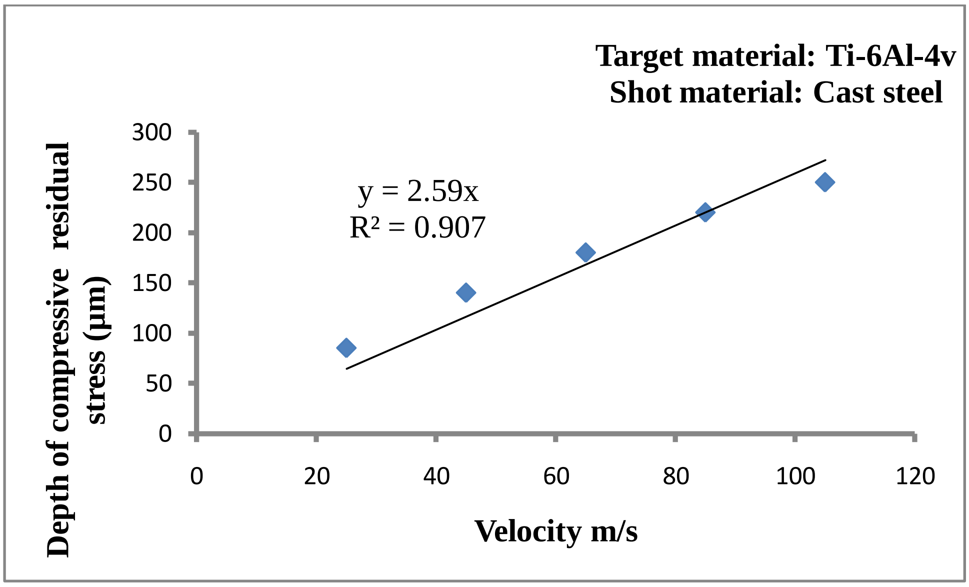

Figure 4.5 Comparison of velocity and depth of compressive residual stress

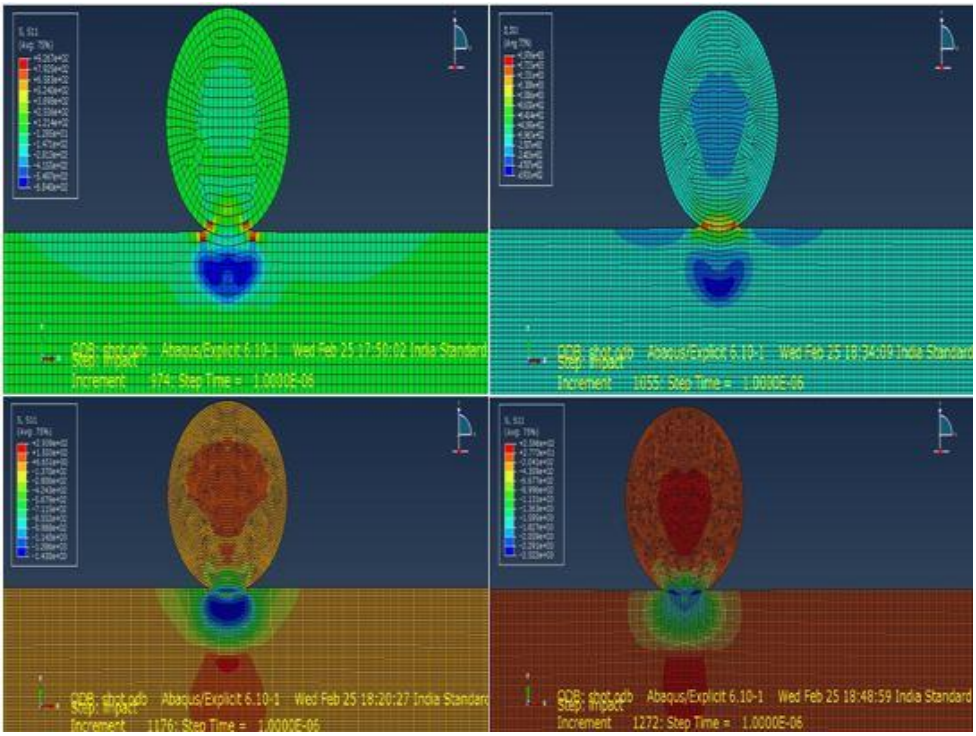

Figure 4.6 Effect of different shot sizes

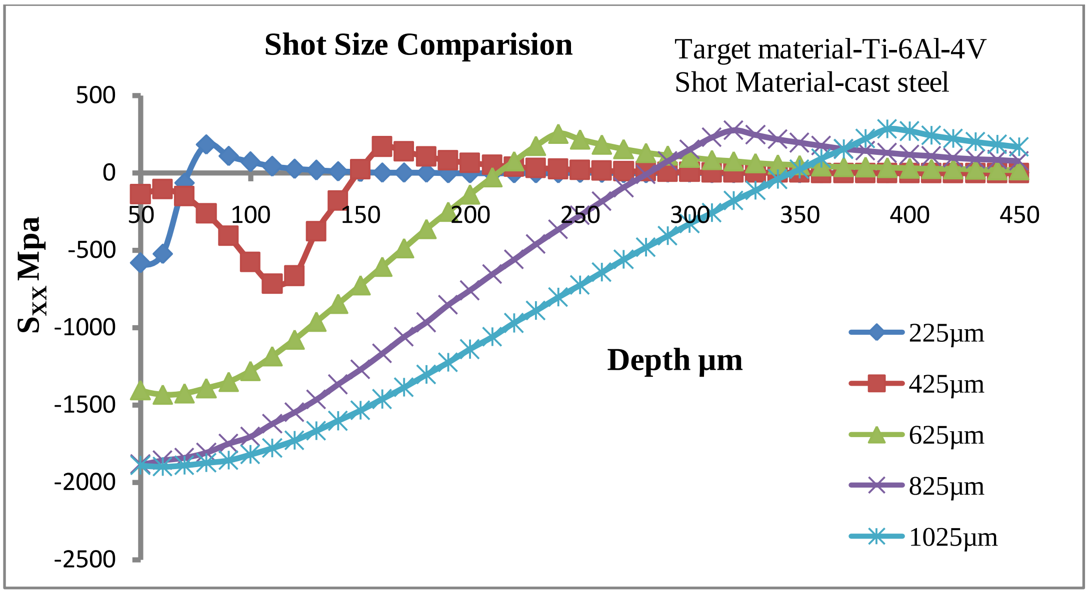

Figure 4.7 Comparison of different shot sizes by taking Ti-6Al-4V as target material and cast steel as shot material

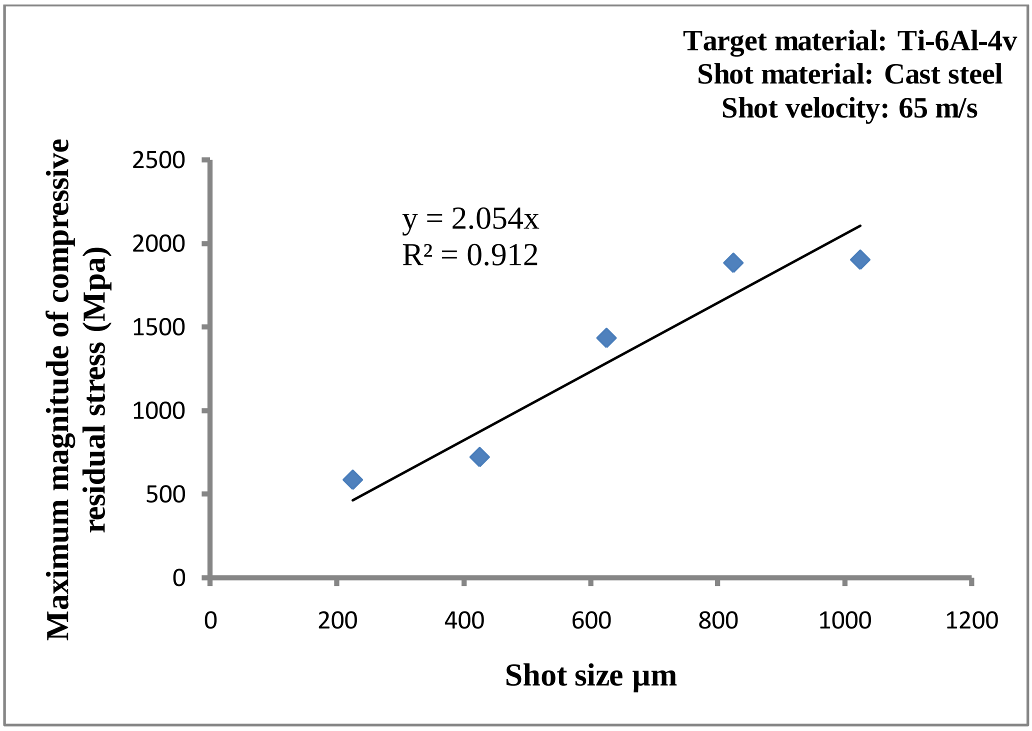

Figure 4.8 Comparison of shot size and maximum magnitude of compressive residual stress

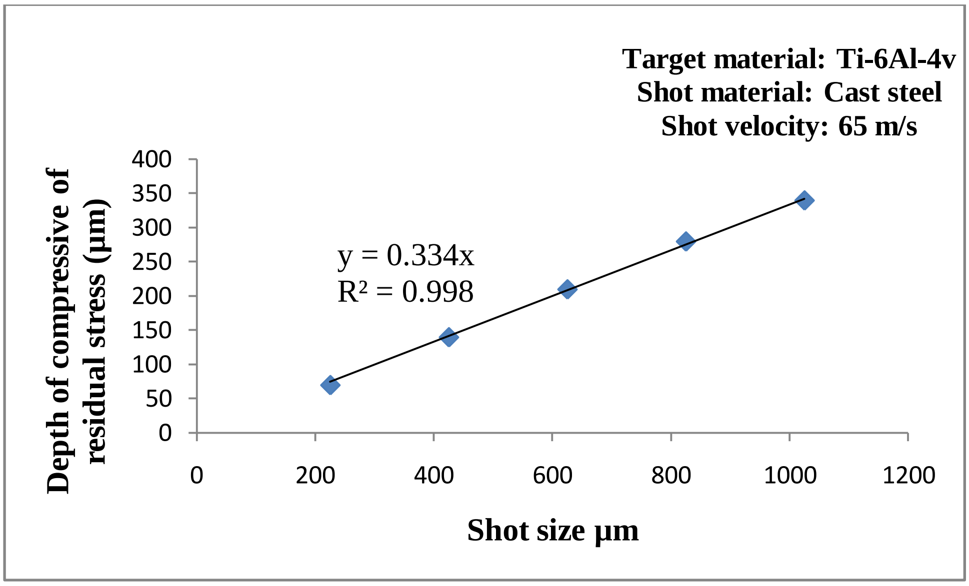

Figure 4.9 Comparison of shot size and depth of compressive residual stress

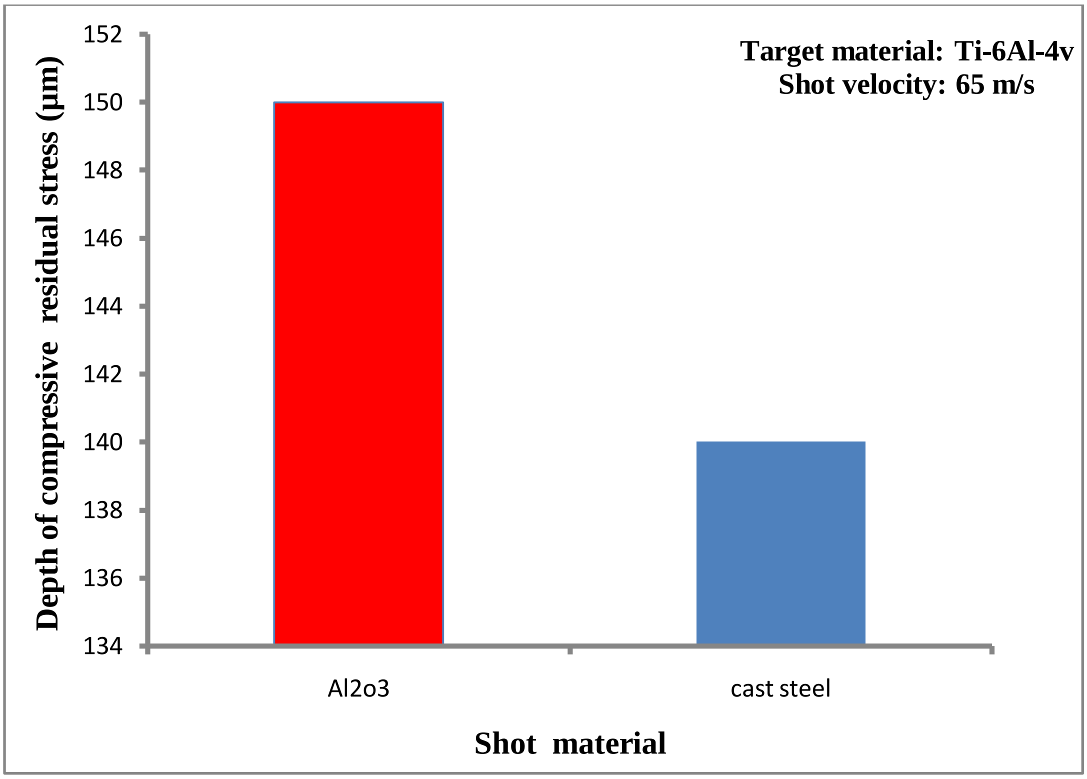

Figure 4.10 Comparison of shot materials and depth of compressive residual stress

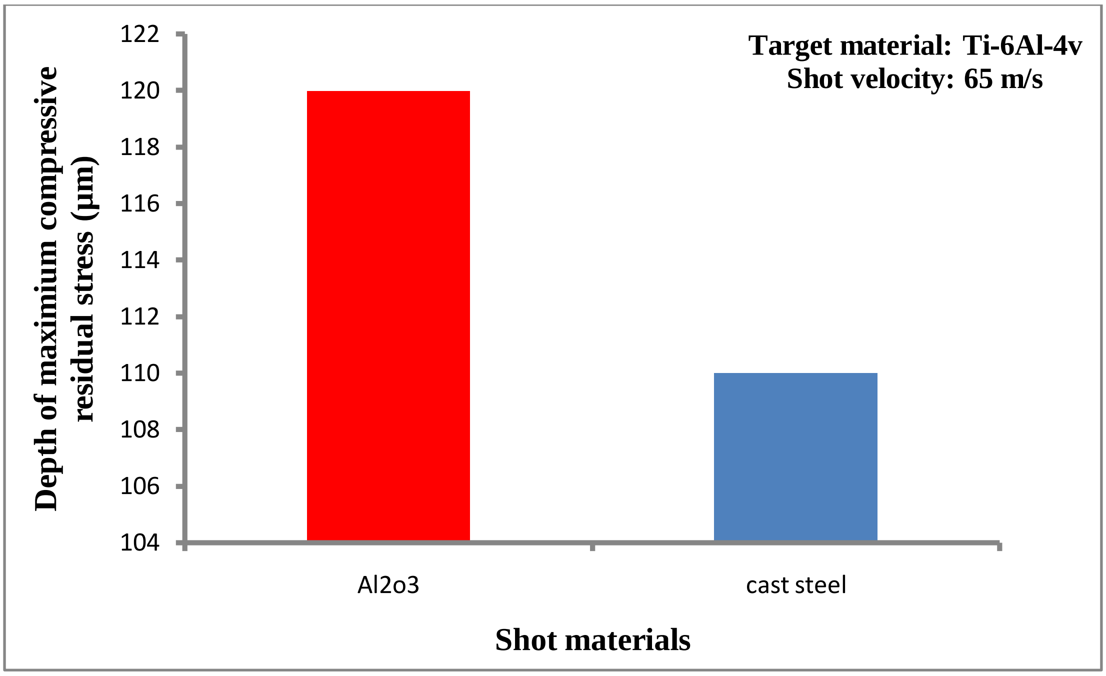

Figure 4.11 Comparison of shot materials and depth of maximum compressive residual stress

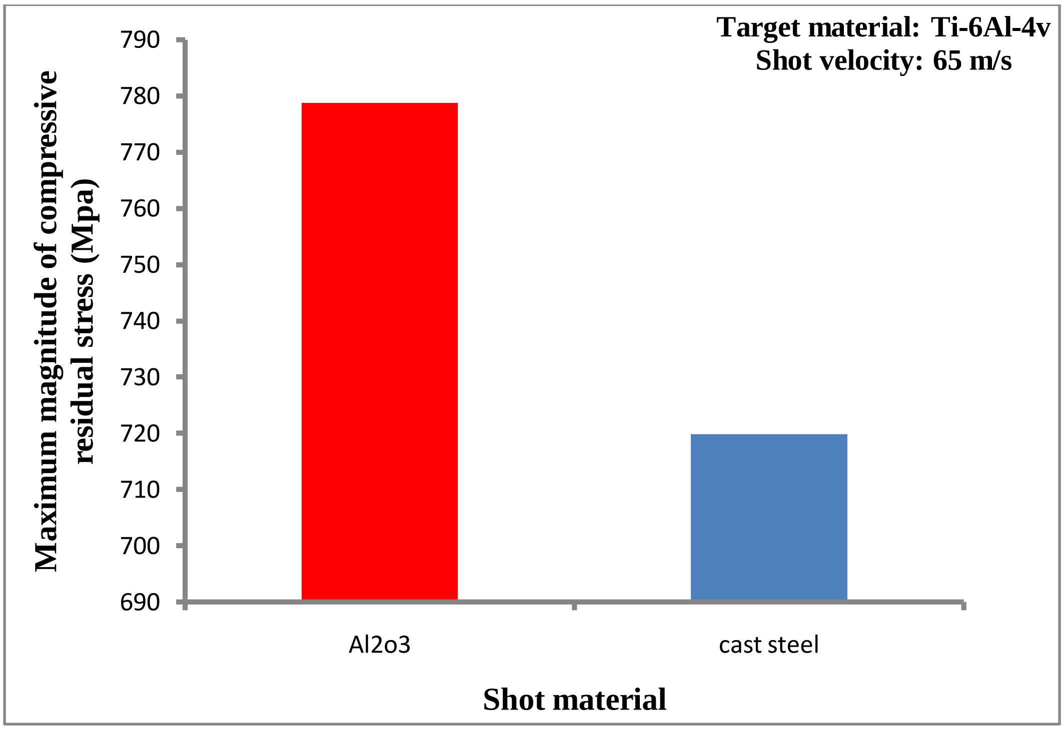

Figure 4.12 Comparison of shot materials and maximum magnitude of compressive residual stress

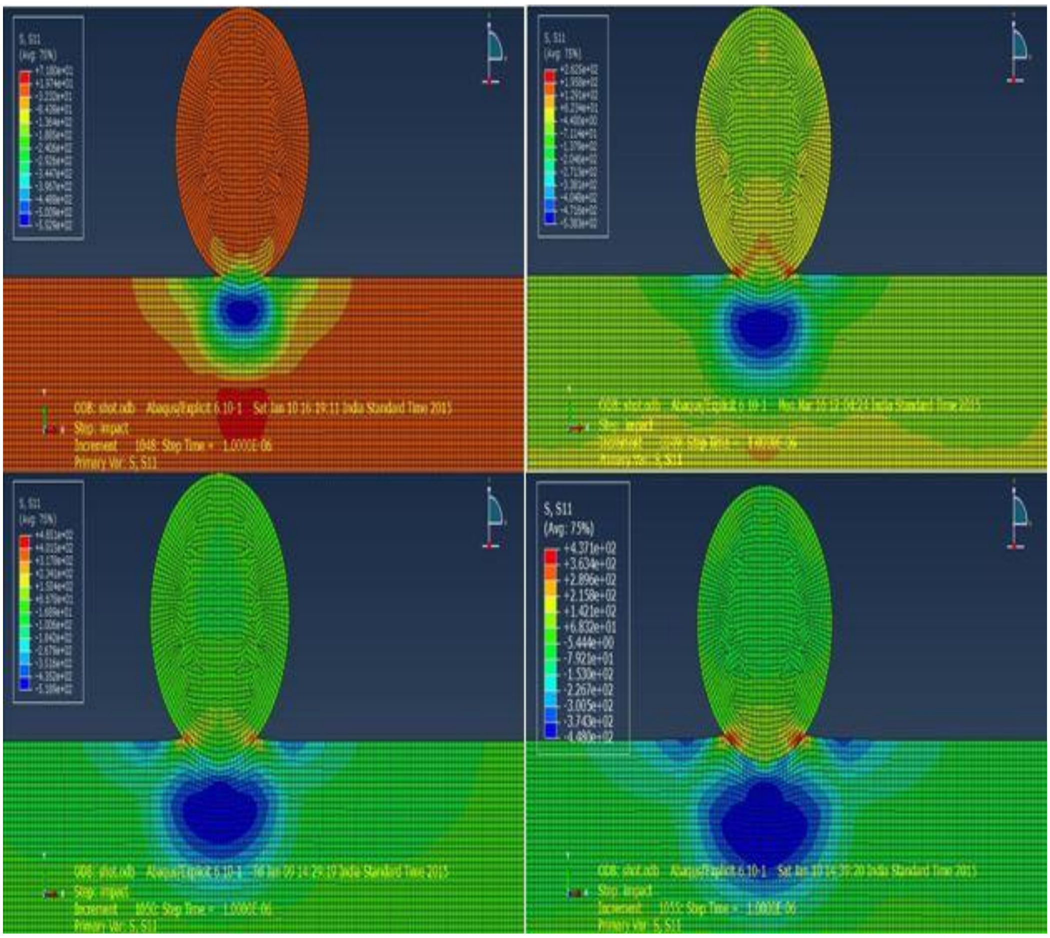

Figure 4.13 Effect on target material Al6061 due different velocities of shot

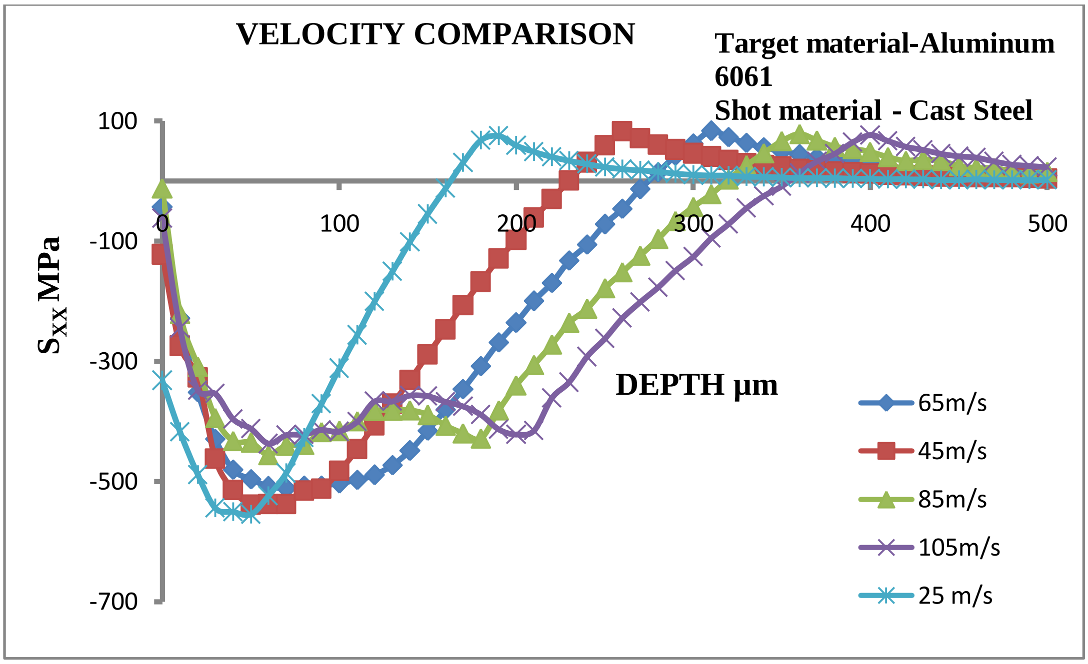

Figure 4.14 Comparison of velocities by taking Al6061 as a target material and cast steel as a shot material

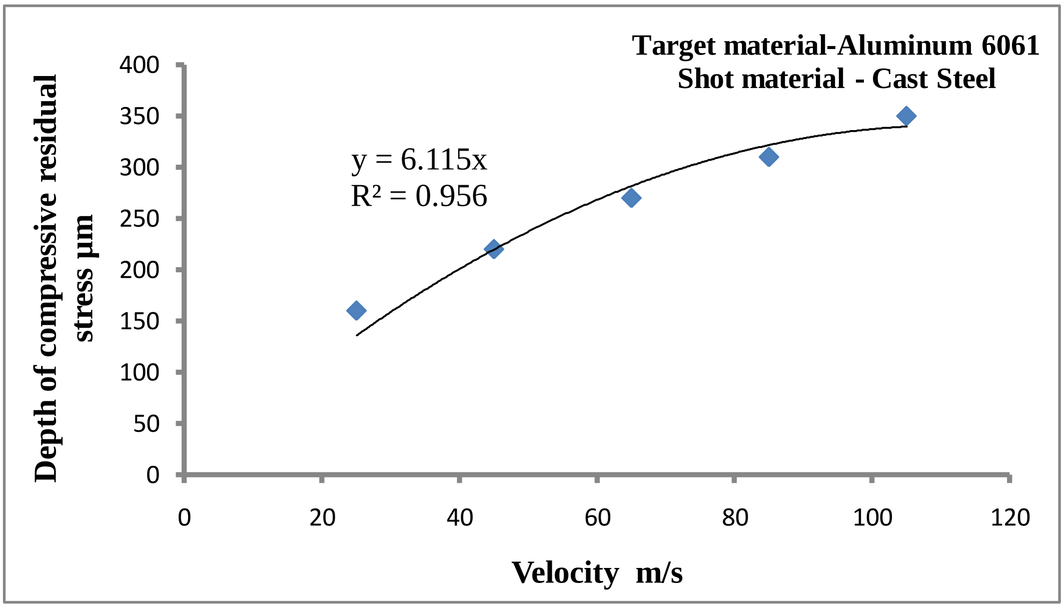

Figure 4.15 Comparison of velocity of shot and depth of compressive residual stress for al6061

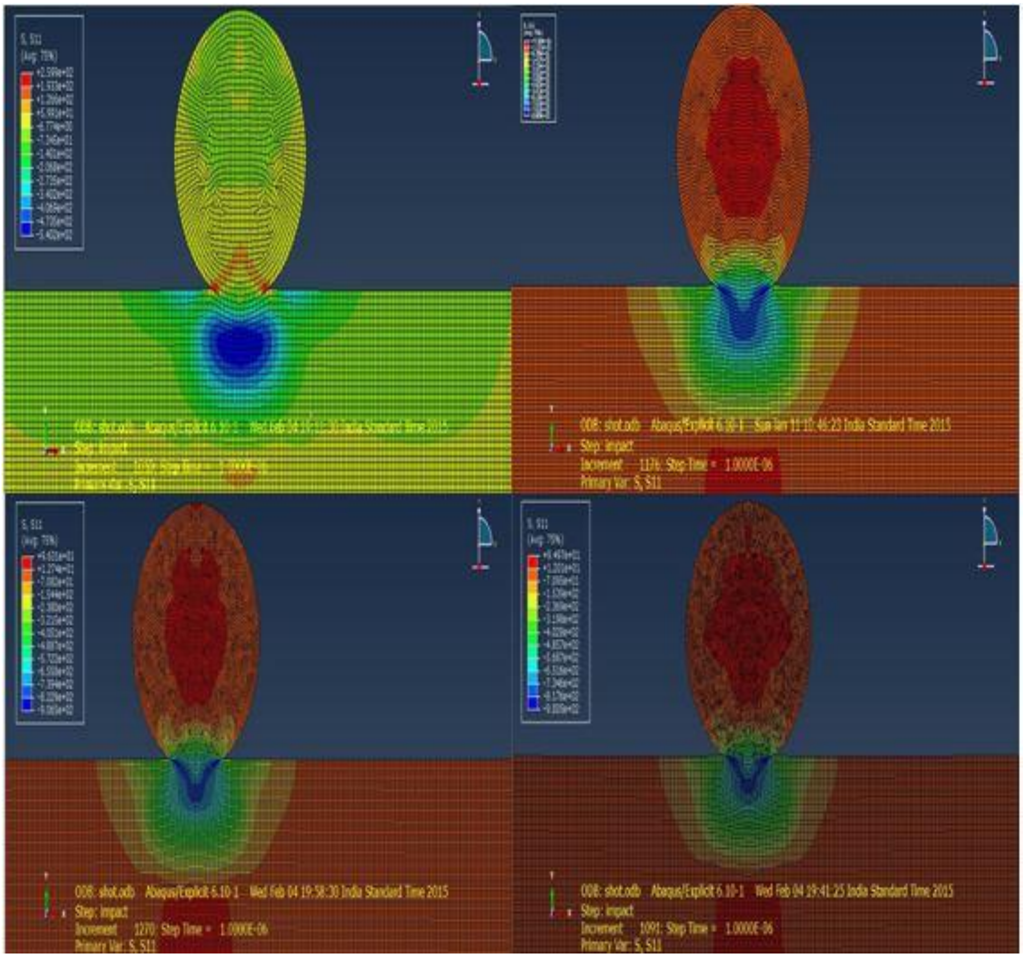

Figure 4.16 Effect on target material Al6061 due different shot sizes

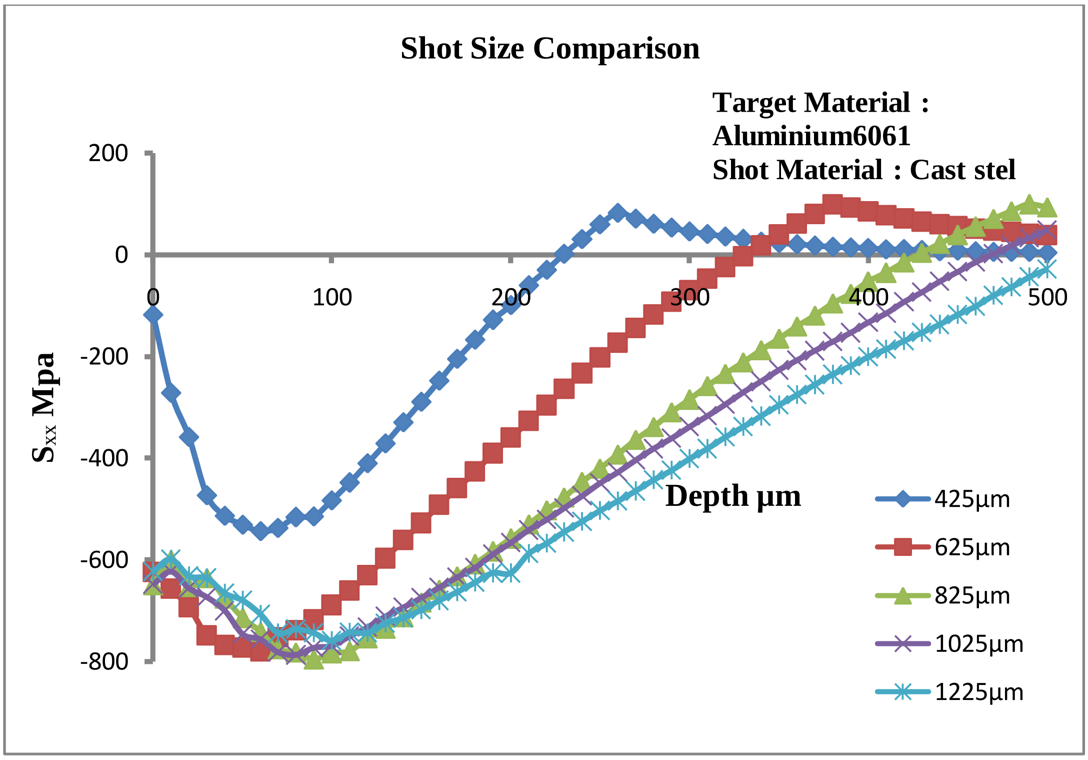

Figure 4.17 Different shot size comparison for aluminium 6061 as target material and cast steel as target material

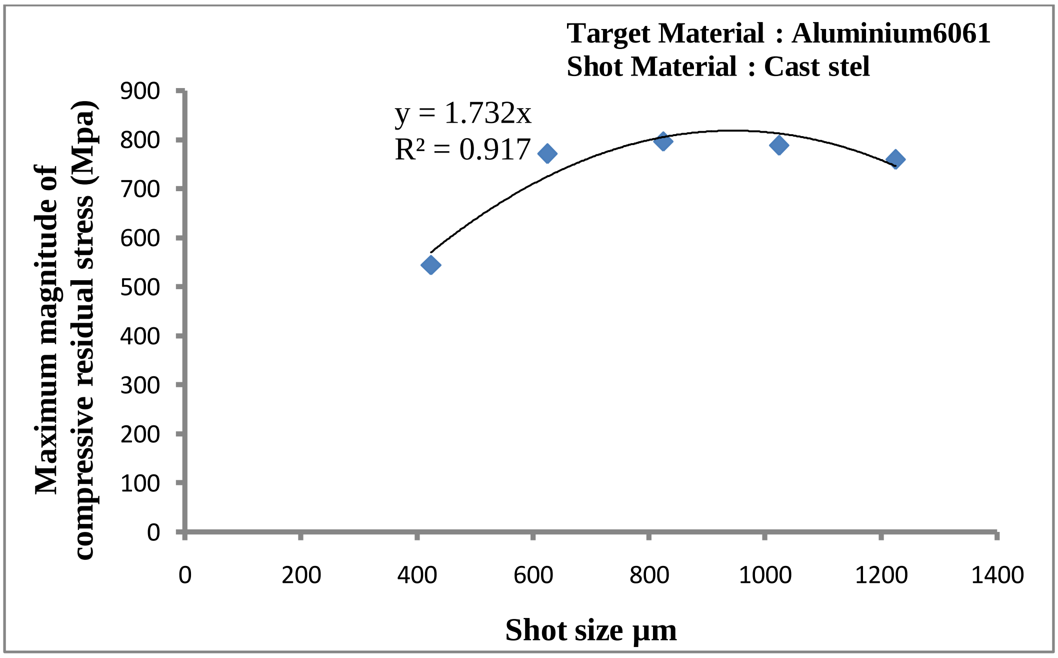

Figure4.18 comparison of shot size and maximum magnitude of compressive residual stress

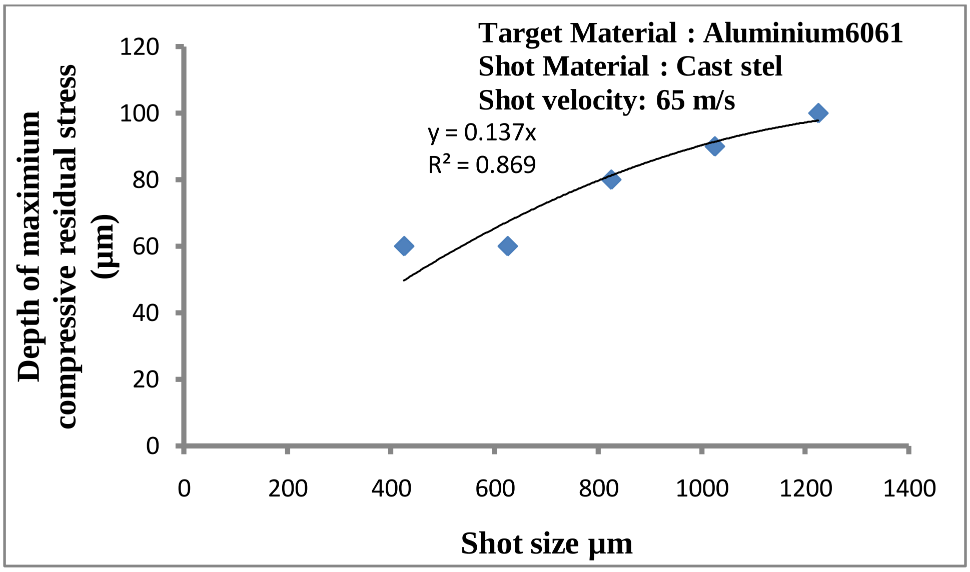

Figure 4.19 comparison of shot size and depth of maximum compressive stress

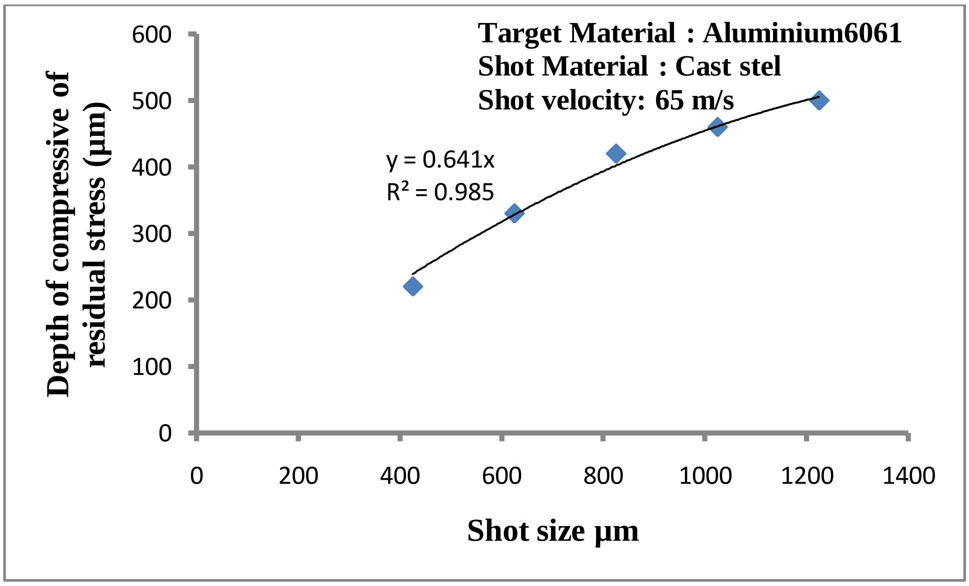

Figure 4.20 comparison of shot size and depth compressive residual stress

CHAPTER-5

CONCLUSIONS & FUTURE SCOPE

5.1 CONCLUSIONS

- The results of the simulation showed that an increase in shot velocity and shot size largely increases the magnitude and depth of the residual stress field created in both the target materials.
- The penetration depth of compressive residual stress increases with an increase in shot velocity and shot size in both the target materials.
- Hardness of shot material is one of the important parameter we observed, by fixed the all parameters like target material, shot velocity & shot size, except the shot material. The shot material of higher hardness given higher magnitude and depth of residual stress.
- The magnitude of surface compressive residual stress increases with an increase in shot size in both the target materials. Whereas shot velocity is not a significant parameter for surface compressive residual stress.
- Using Al_2O_3 as a shot material results in a faster rate of strain hardening of target materials when compared to steel shot. The overall depth of the compressive layer is greater when Al_2O_3 is used as a shot material compared to steel.
- The generation maximum magnitude of compressive residual stress is a polynomial function of shot velocity. Where as it is a linear function of shot size.
- The present work also indicates that the proposed finite element analysis is useful for the investigation of the influence of various parameters on the shot peening process. This process can successfully be simulated by the finite element package ABAQUS.

5.2 FUTURE SCOPE

In this present work, effect of some shot peening process parameters on residual stress is inquired. The future research can try to find the effect of other shot peening process parameters like coefficient of friction between the shot and target material, attack angle, multiplicity of shot, etc.

There is no practical experiment work done in this thesis work. In the future research, several shoot peening experiments are highly required, and it is necessary to compare the simulation result with the experiment results to adjust the model setting, also adjust the coefficient of empirical equations.

REFERENCES

[1] Callister Jr., W., 2003, Materials Science and Engineering: An Introduction, 6 th Ed.,John Wiley & Sons, Inc., New York.

[2]Niku-Lari,A.,1996,“An Overview of Shot Peening,” Trans. International Conference on Shot Peening and Blast Cleaning.

[3] Meguid, S., 2007, “Development and Validation of Novel FE Model for 3D Analysis of Peening of Strain-Rate Sensitive Materials,” Trans. Journal of EngineeringMaterials and Technology, vol :129 , pp. 271-283.

[4]Nasr, M., 2007, “A modified time-efficient FE approach for predicting machining-induced residual stresses,” Trans. Finite Elements in Analysis and Design,Vol: 44 , pp.149-161.

[5] Callister Jr., W., 2003, Materials Science and Engineering: An Introduction , 6th Ed., John Wiley & Sons, Inc., New York.

[6]James,M.,2007, “Residual stresses and fatigue performance,” Trans. Engineering Failure Analysis, vol:14 , pp. 384-395.

[7]Niku-Lari, A.,1996, “An Overview of Shot Peening,” Trans. International Conference on Shot Peening and Blast Cleaning.

[8] Ezugwu, E., 1995, “Titanium alloys and their machinability – a review,” Trans. Journal of Materials Processing Technology,Vol: 68 , pp. 262-274.

[9] Machado, A., 1990, “Machining of titanium and its alloys – a review,” Trans. IMechE, Vol: 204 , pp. 53-60

[10] Hertz H. UberdieBeruhrung fester elastischerKorper (On the contact of elastic solids). J ReineAngewandteMathematik 1882; Vol:92:PP.156–71.

[11] Li J etal.Mechanical approach to the residual stress field induced by shot peening. Mater SciEng 1991;vol:A147:PP-167–73.

[12] Hardy C, Baronet CN, Tordion GV. The elasto-plastic indentation of a half-space by a rigid sphere.Int J Numer Methods Eng 1971;vol:3:PP-451–62.

[13] Edberg J, Lindgren L, Mori K. Shot peening simulated by two different finite element formulations. In: Shen S, Dawson E, editors. Simulation of materials processing: theory, methods and applications –NUMIFORM95; 1995. p. 425–30.

[14] S.A. Meguid, G. Shagal, J.C. Stranart, J. Daly, Three-dimensional dynamic finite element analysis of shot-peening induced residual stresses, Finite Element Anal. Des. 31 (1999) pp.179–191.

[15] Frija M, Hassine T, Fathallah R, Bouraoui C, Dogui A. Finite element modeling of shot peening process: prediction of the compressive residual stresses, the plastic deformations and the surface integrity. Mater SciEngA 2006; 426:pp.173–180.

[16] J. Lemaˆıtre, J.L. Chaboche, *M*´ecanique des mat´eriauxsolides, Dunod, 2`eme Edition, ISBN 2 10 005662X, 2002.

[17] Al-Hassani STS, Kormi K, Webb DC. Numerical simulation of multiple shot impacts. In: Proceedings of ICSP-7, Warsaw, Poland, 1999. p. 217–27.

[18] Majzoobi, G.H., Azizi, R., AlaviNia, A., 2005. A three-dimensional simulation of shot-peening process using multiple shot impacts. J. Mater. Process. Technol. Pp.164–165, 1226–1234.

.