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Explicit Dynamic Analysis of Shot peening on Aluminum Alloy Plate

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Abstract: Shot Peening allows metal parts to accept higher oads or to endure a longer fatigue life in service without failure. In usual applications shot peening can be done without changing the part design or its material. If you strike a part surface with a rounded object at a velocity, sufficient to leave an impression and continue until you completely cover (cold work) the entire surface then you will have peened that part. The reasons for this improvement were not then understood. Imparting residual compressive stresses in the surface layers of metallic components is one of the ways to improve their fatigue strength characteristics. Shot peening is employed for imparting residual stresses by means of cold work. Shot peening is a complex random process with many input variables. The material responses include residual stresses, cold work, surface roughness, micro-cracks and microstructure changes. To obtain the maximum fatigue strength, the designer needs to consider both favorable and detrimental aspects of these responses together. The prediction of the responses from the input parameters involves many methods spanning across multiple-disciplines such as plasticity, fracture, optimization etc.The goal of this paper is, first to describe the mechanical characteristics due to shot peening, then to list the main parameters, in order Explicit Dynamic Analysis Of Shot Peening On Aluminum Alloy Plates, finally to summarize the effects of the loading parameters on the improvement level.

Keywords: Aluminum Alloy Plates, Shot Peening, Structural Analysis, Cold working Process

I. INTRODUCTION

Shot Peening allows metal parts to accept higher loads or to endure a longer fatigue life in service without failure. In usual applications shot peening can be done without changing the part design or its material. If you strike a part surface with a rounded object at a velocity, sufficient to leave an impression and continue until you completely cover (cold work) the entire surface then you will have peened that part.

In modern usage peening is applied by throwing tiny cast steel balls or “shot” at high velocity hence the term “shot peening”.

Actually the effect of peening was discovered centuries ago by sword smiths and black smiths who found the peening the surface of a sword or wagon spring would greatly increase its resistance to breaking when bent or loaded repeatedly. The reasons for this improvement were not then understood. The round knob of the “ball peen” hammer was the smith’s tool for applying this process to cold (not hot) parts.

A. Shot Peening For Longer Fatigue Life

It is rare that we go from one place to another by road and not find a vehicle, either a lorry or a car broke down on the road due to fatigue failure of axle shaft or the spring and so on, thus creating obstacles in the flow of traffic and sometimes resulting in serious accidents. These fatigue failures can be reduced and are being almost eliminated in the Western countries by the adoption of shot peening process for increasing the fatigue life of various components subjected to fatigue stress.

Shot peening is just one of the applications of shot blasting for increasing the fatigue life of various components subject to fatigue stress. The reduced fatigue failures result in low maintenance and replacement cost for parts like springs, gears, axles and knuckle joints etc. As is well known, the part which h fails in fatigue, fails mainly due to its failure in tensile strength. Just as in pre-stressed concrete at the end of shot peening, the parts are left with residual compressive stress. When the component is subjected to the tensile load, a portion of the tensile stresses set by the load is neutralized by the residual compressive stresses left by the shot peening. Thus the effective load is greatly reduced, resulting in an increased fatigue life even to the extent of 1,500 per cent, or more. Manufacturers of swords and brass utensils are well known for their denting the surface of the swords or the utensils for better life by round-headed hammers called ball peen-hammers.

Today this is not done by hammers but by very fast moving metallic shots. Shot peening is a cold-working method accomplished by pelting the surface of a metal part with round metallic shot thrown at a relatively high velocity, by means of an Airless Wheelabrator Centrifugal wheel. Each shot acts as a tiny peen-hammer, making a small dent in the surface of the metal and stretching the surface radially as it hits. The impact of the shot causes a plastic flow of the surface fibres extending to a depth depending upon the degree of impact of the shot and the physical properties of the work. Depths varying from .005" to .030" are rather common, but values either higher or lower than this range can be practical. There is momentary rise of temperature of the surface due to transformation of energy, possibly enough to affect the plastic flow of surface fibres; however, the effect of shot peening is known as "cold working" to distinguish it from metal flow at high temperatures.

The fibres underneath the top layer, however, are not stretched to their yield point and, therefore, retain elasticity, the under fibres are, of course, bonded to the stretched surface layer and after the inner fibres force the outer fibres to return to a shorter length than that at which the stretched fibres would tend to remain, in the equilibrium which results, the surface fibres are in residual compression while the inner fibres are in tension.

The surface compression stress is several times greater than the tension stress in the interior of the section; so that when working stresses are applied that would ordinarily impose a tension stress on the surface, that tension is offset by the residual stress in the surface layer, and since as mentioned before the fatigue failures generally result form tensile stresses, not form compressive stress, the net result is considerably greater fatigue strength.

Shot peening is nowadays used with hundreds of different components some of which are given here. Railway leaf springs, automobile leaf springs, helical springs of all types, Gears of all types, axle bearings, crankshafts, pneumatic drills, milling cutters, connecting rods, cylinder blocks and value springs washers etc..

Most of the shot blasting equipment could be utilized for shot peening with the proper arrangement of the shot separator. Besides there are special shot peening machines to suit the specific requirement of particular sizes and shapes of the product and the quantity of the product to be shot peened.

II. LITERATURE SURVEY

M. Meo et al. Studied, Shot peening is a manufacturing process intended to give aircraft structures the final shape and to introduce a compressive residual state of stress inside the material in order to increase fatigue life. This paper presents the modeling and simulation of the residual stress field resulting from the shot peening process. The results achieved show that a significant decrease of welding induced tensile residual stress magnitude can be obtained. Good agreement between experimental and numerical results was achieved [1].

Y. H. Yang et al. Studied, The Key Laboratory of Contemporary Design & Integrated Manufacturing Technology, Ministry of Education, North western Polytechnical University, It is very significant to investigate the shot peening mechanism in ensuring a good resistance to fatigue and stress corrosion. This paper reviews the recent advancements in shot peening process. Emphasis is put on the application of numerical simulation techniques and finite element method in residual stress prediction during shot peening process. Different methods related to shot peening modelling and prediction of plastic deformation and surface integrity are reviewed. Some key issues such as algorithms and simulation procedures are discussed [2].

S.A. Meguid et al. Studied, Engineering Mechanics & Design Laboratory, Department of Mechanical and Industrial Engineering, University of Toronto,5 King+s College Road, Toronto, Ontario, M5S 3G8 Canada" Metal Improvement Company, 10 Forest Avenue, Paramus, New Jersey, 07652 USA This investigation is devoted to the modelling and simulation of the residual stress Held resulting from the shot-peening process. In this dynamic elasto-plastic analysis, single and twin spherical indentations were examined using the Þniteelement method. The contact between the shots and the target was modelled using contact elements of the penalty function type. Attention was devoted to three related issues. The Rust is concerned with the eject of the shot velocity, size and shape upon the plastic zone development and growth, and unloading residual stresses [3].

Andrew Levers et al. Studied, The shot peening process is largely used for the surface treatment of metallic components with the aim of increasing surface toughness and extending fatigue life. A secondary consequence of the process is that the residual stress distribution developed within the material may induce distortion of the component. This effect may therefore be used constructively in the straightening and forming of thin flexible metallic structures. In this paper, the various techniques available for modelling the effect of peening with finite elements are discussed. In particular, a method of simulating the effect of peening on large flexible panels is presented. Analyses are shown in which a novel loading is applied to finite element meshes in order to produce the desired residual stress distribution. Results from tests are compared to finite element analyses and preliminary results of large scale analyses are presented [4].

Royston et al. Studied, Shot peen forming is a production process used to create curved metal parts fiom sheet. It is commercially important despite the fact that its mechanisms are not fully understood; peen forming programmes are currently generated using experience and trial and error. The purpose of this work is to increase the predictability and range of application of the process by advancing its understanding. Finite element analysis proved to be a satisfactory procedure for studying shot peen forming. The stress distribution in a sheet arising from multiple indentations, as occur in shot peen forming, was modelled. [5].

Chang Feng Yao et al. Studied, to study the effect of different milled surfaces on shot peening surface integrity (roughness, residual stress, hardness, and microstructure), research on the change of surface integrity is carried out using the same shot peening process for different milling surfaces of 7055-T77 aluminum alloy. Surface integrity measurements, fatigue fracture analysis, and fatigue life tests are conducted to reveal the effect of surface integrity on crack initiation and fatigue life. The results show that shot peening can reduce the dispersion and instability of surface integrity brought by milling processing, although it increases the surface roughness; the maximum residual compressive stress and depth of residual stress layer increase significantly after shot peening, and the residual stress and hardening distribution are very good; larger surface roughness and irregular surface scratches of milling samples before shot peening easily lead to cracks and gouges produced on shot peening surface [6].

Baskaran Bhuvaraghana et al. Studied; Imparting residual compressive stresses in the surface layers of metallic components is one of the ways to improve their fatigue strength characteristics. Shot peening is employed for imparting residual stresses by means of cold work. Shot peening is a complex random process with many input variables. The material responses include residual stresses, cold work, surface roughness, micro-cracks and micro-structure changes. To obtain the maximum fatigue strength, the designer needs to consider both favorable and detrimental aspects of these responses together. The prediction of the responses from the input parameters involves many methods spanning across multiple-disciplines such as plasticity, fracture, optimization etc. The paper presents an overview of the studies that predict the various material responses and suggests a method based on continuum mechanics in order to optimize the fatigue 7strength of any material [7].

Grum, J. Uros et al. Studied, The objective of the present study was to investigate the effect of surface hardening by shotpeening(SP) on fatigue properties of high-strength aluminium alloy 7075-T651. The paper describes the effects of SP treatment by presenting analyses of surface roughness measurement, microhardness profiles, microstructure changes, residual stresses and material bending fatigue resistance. The obtained results show a favourable influence of SP treatment on fatigue properties as induced compressive residual stresses and hardened surface layer retarded the initiation of fatigue cracks. SP treatment nearly doubled the cycles to failure at the higher applied stresses when compared to the untreated specimens. The fatigue limit of the SP-treated specimens increased to 218 MPa at 107 cycles. The experimental data confirmed an increase of fatigue strength after SP treatment due to the compressive residual stress ability to influence fatigue crack nucleation. Increased resistance to plastic deformation and the residual stress profiles provided a corresponding fatigue crack closure [8].

M. Benedetti et al. Studied, The effect of different shot-peening treatments on the reverse and pulsating bending fatigue behaviour of Al 7075 T651 was studied. The fatigue improvements with respect to the unpeened condition and the influence of the peening intensity on fatigue were discussed accounting for the effects of surface modifications and residual stresses. In particular, the extent of the residual stress redistribution during loading was investigated by means of X-ray diffraction (XRD) measurements. No significant residualstress relaxation was observed in samples tested to a load level corresponding to the fatigue endurance at 5□106 cycles. Residual stress relaxation was observed only when the material plastic flow stress was achieved during the compressive part of the fatigue load cycle. Accordingly, shot peened samples with deep sub-superficial compressive residual stress peak showed a reversed fatigue endurance level corresponding to the condition of incipient plastic flow. This phenomenon was also accompanied by sub superficial fatigue crack initiation. On the contrary, samples tested at shorter fatigue lives or under pulsating loading conditions showed crack initiation close to the surface. The initial and the stabilised residual stress profiles were considered for

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discussing the improvement in the fatigue behaviour due to peening. For this purpose, a multiaxial fatigue criterion was adopted to account for the biaxial residual stress field. The fatigue life was quite accurately predicted as long as fatigue initiation occurs on the surface [9].

III. METHODOLOGY

Imparting residual compressive stresses in the surface layers of metallic components is one of the ways to improve their fatigue strength characteristics. Shot peening is employed for imparting residual stresses by means of cold work. Shot peening is a complex random process

This project work will relate to design of aluminium alloy plate, Optimization of stresses, and suggests a method based on continuum mechanics in order to optimize the fatigue strength of any material including:

1) Measurement of stress developed in aluminium alloy plate.
2) Development of finite element model using ANSYS software.
3) Fatigue analysis of aluminium alloy plate.

A. Explicit Dynamic Analysis Of Plate

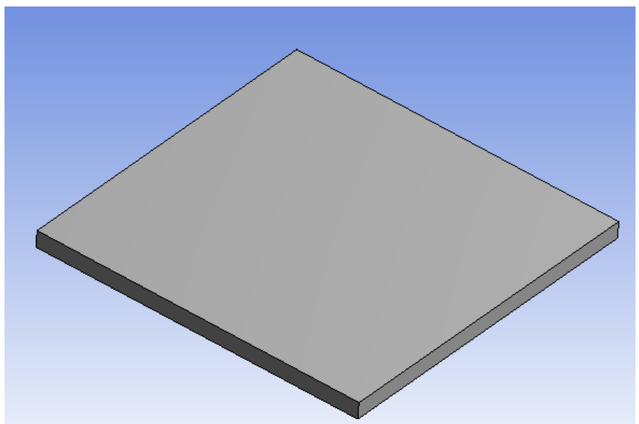

Figure No.1 Aluminium Plate

CATIA V5 is mechanical design software, addressing advanced process centric design requirements of the mechanical industry. With its feature based design solutions, CATIA proved to be highly productive for mechanical assemblies and drawing generation. CATIA V5 is totally compliant with windows presentation standards. CATIA V5 users' access the highest productivity for specific advanced processes with focused solutions like Sketcher, Part design, Assembly Design, Drafting.

Material for Aluminium Alloy Plate: A wrought plate of high-strength, precipitation hardened, aluminium alloy.

Aluminium Plate 100×100×5mm.

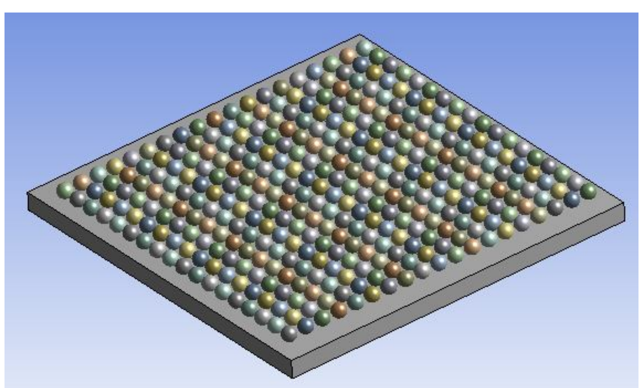

Figure No.2 Aluminium Plate with Steel balls

For above Figure No.2, Steel balls of 2mm Radius and around 342 numbers were impacted with velocity of 50 m/s.

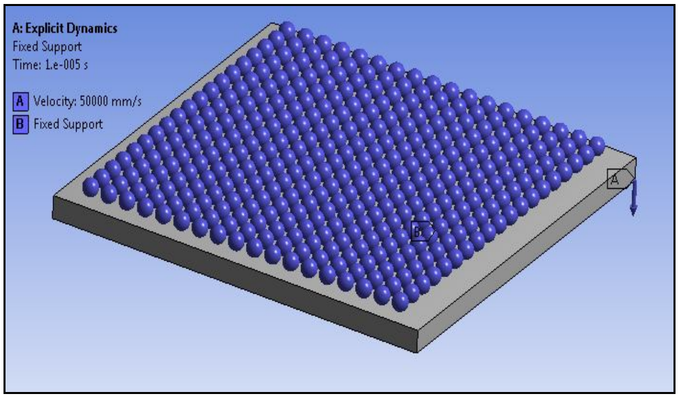

Figure No.3 Boundary Condition of Plate with Velocity and Base fixed support

For above Figure No.3, Velocity is 50m/s.

B. Explict Dynamics of Aluminium Plate:

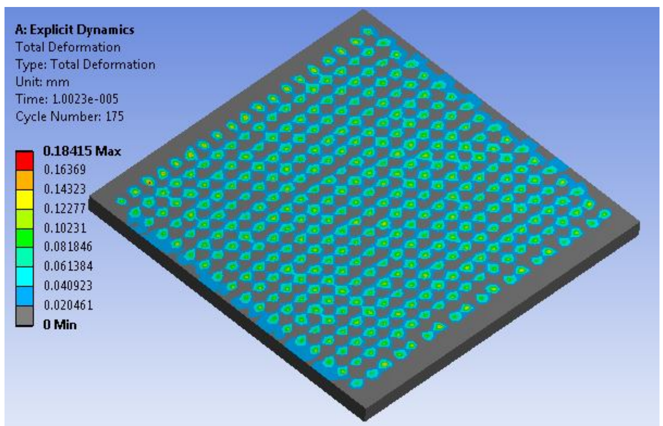

Figure No.4 Aluminium Plate with Deformation for Explict Dynamics

For Explict Dynamics of plate, total deformation is 0.1845 mm.

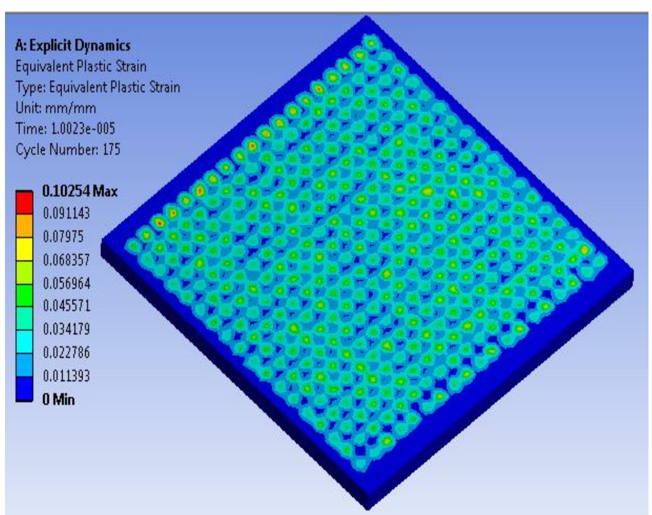

Figure No.5 Aluminium Plate with Equivalent Plastic Strain

For Explict Dynamics of plate, Equivalent Plastic Strain is 0.1025mm/mm.

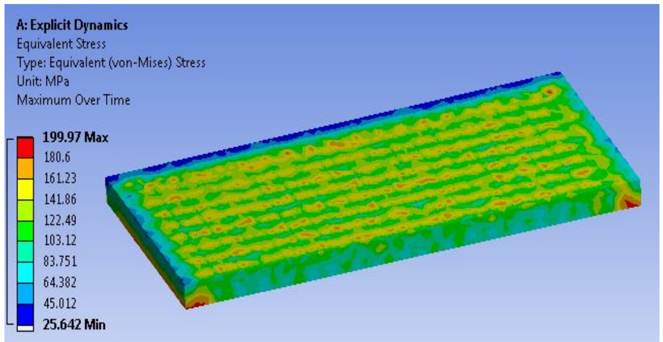

Figure No.6 Aluminium Plate with Equivalent Von-Mises (Residual) Stress

For above Figure No.6, Aluminium Plate with Equivalent Von-Mises Stress (Residual) is 199.97 MPa.

IV. CONCLUSIONS & DISCUSSIONS

1) Total deformation is 0.1845 mm.
2) Equivalent Plastic Strain is 0.1025mm/mm.
3) Equivalent Von-Mises (Residual) Stress is 199.97 MPa.

Hence, Explict Dynamics can be used to stimulate shot peening stress.
Experimentation will be the proposed work for the Shot peening on Aluminum Alloy Plate.

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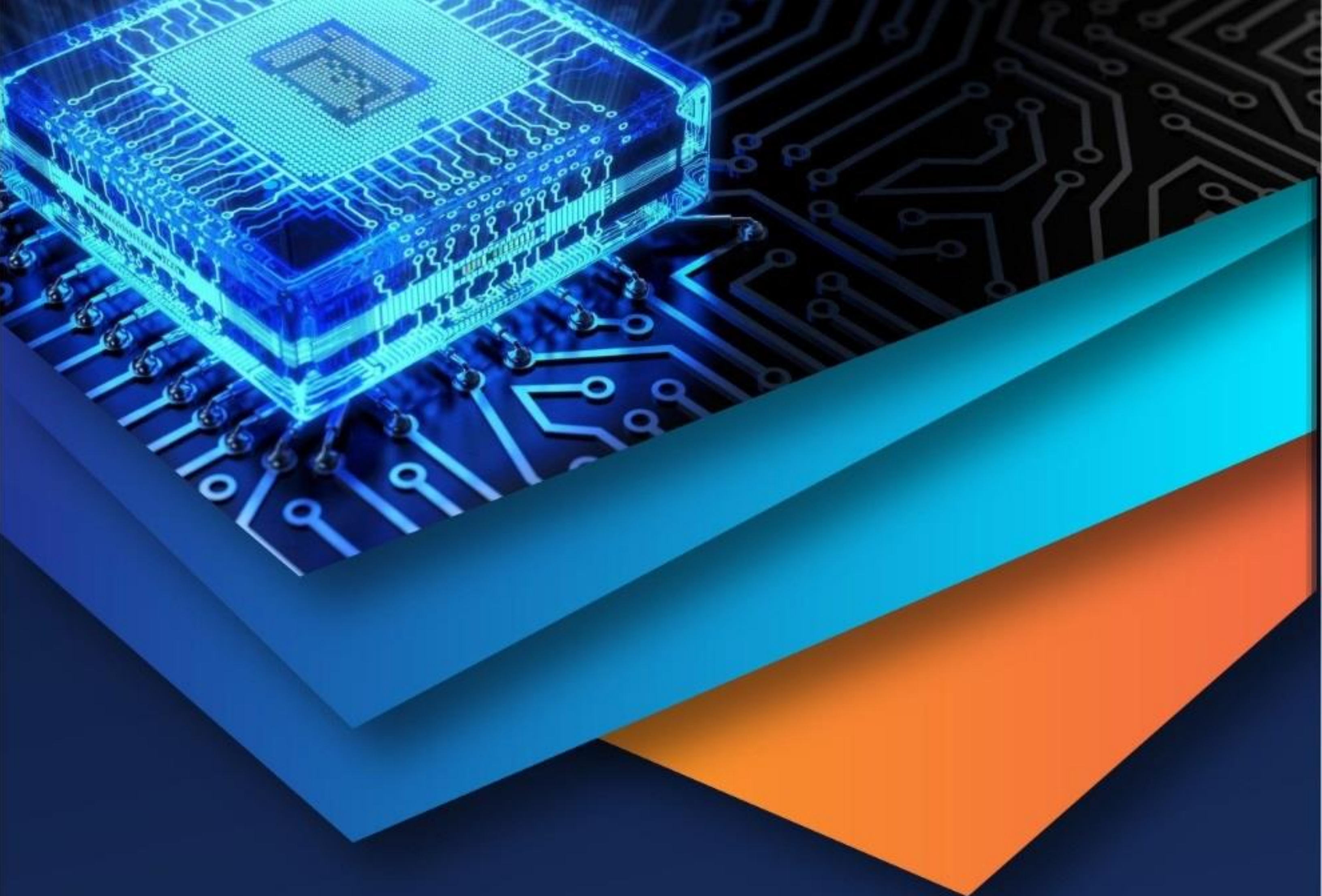

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