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Effect of Rolling and Galvanizing Process on Mechanical Properties of Mild Steel

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Abstract: Mild steel is an alloy with a very vast range of applications and it is important to study the physical properties, and mechanical properties of mild steel. In this study, the effects of hot-rolling, cold-rolling, and galvanization on factors such as microstructure, and mechanical properties of mild steel were studied. In this experiment, there were 3 sample (hot rolling, cold rolling and galvanized sample) are prepared. Microstructures of mild steel treated with these processes were characterized using optical microscope and XRD. The study suggests that the ferrite phase is observed which BCC form of iron is in both the cases of hot rolled and cold rolled steel. After galvanization process, the microstructure was found as the combination of ferrite and pearlite phase. The mechanical properties such as hardness and strength were found to increase slightly on hot-rolling and increase drastically on cold-rolling. Galvanization process leads to a reduction in tensile strength and a small increase in its toughness.

Keywords: Hot Rolling, Cold Rolling, Galvanizing, Hardness, Tensile Strength, Mild Steel with 0.04%C

I. INTRODUCTION

Rolling is one of the oldest processes known for reducing the cross section of a metal sheet. Rolling done above recrystallization temperature of a material is Hot-rolling and below that temperature is Cold-rolling. Hot-rolled and cold-rolled mild steels have a wide variety of applications, ranging from utensils to automobiles to construction of structures. Hot-rolled and Cold-rolled steels are preferred in most applications of mild steel due to their low yield strength, high tensile strength, high impact strength, and good plasticity. [1] Galvanization is done in these steels to prevent their corrosion, with hot-dip galvanization, involving dipping the steel in molten zinc at 460^{o}C, being the most common process used.

Understanding the physical, chemical, and mechanical properties of steel used in construction of a tool or equipment is necessary to predict its effectiveness and limits. Metal-forming processes such as rolling have a profound impact on the physical and mechanical properties of any material; with the microstructures and grains being rearranged during the process causing massive changes in the mechanical properties such as toughness, hardness, impact strength etc. [2] [3] Galvanization processes affect the physical, mechanical, and chemical properties of the material undergoing it, as, in addition to the microstructural changes leading to variations in mechanical properties, there is change in chemical properties such as corrosion resistance, reactivity with environment, etc. as well. [4] [5] [6]

In this work, we aim to study the effect of hot-rolling, cold-rolling, and hot-dip galvanization on the physical, chemical, and mechanical properties of mild steel with 0.04% carbon content. We aim to study the changes observed in microstructure of low carbon steel due to these processes using optical microscope, XRD and to correlate these changes with the changes in mechanical properties observed. In addition to this, we also intent to study the effect that hot-dip galvanization process has on the corrosion rate of the mild steel being studied, and the effect the process has on the reactivity of mild steel with process environment. [7]

II. EXPERIMENTAL

A. Material

Hot rolling and cold rolling is done on the low carbon steel and a zinc coating is pasted on cold rolled surface (after annealing process) by using hot dipping process to protect surface from corrosion. This is a continuous process because hot rolling, cold rolling and zinc coating is performed on a particular sample. There were three samples for experiment one is hot rolled steel sample, second is cold rolled steel sample and third one is zinc coated steel sample (by using galvanization process) and the composition of the particular sample is mentioned below-

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TABLE I
COMPOSITION of HOT ROLLED SAMPLE

%C	%Mn	%P	%S	%Si	%Al	%N	%B	%Cr	%Cu	Carbon Equivalent
0.04	0.111	0.005	0.005	0.013	0.031	0.0042	0.0025	0.007	0.002	0.0615

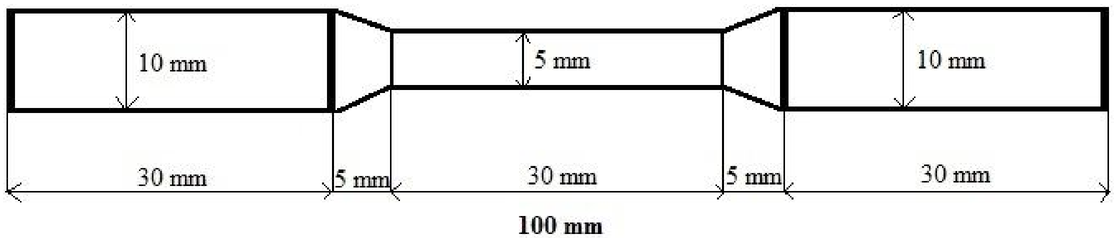

Fig. 1 Tensile test specimen for hot rolled, cold rolled and galvanized steel sample

B. Sample Preparation

Galvanized sample were prepared by pasting a zinc coating over the cold rolled sample and the schematic diagram of the process is given as follow-

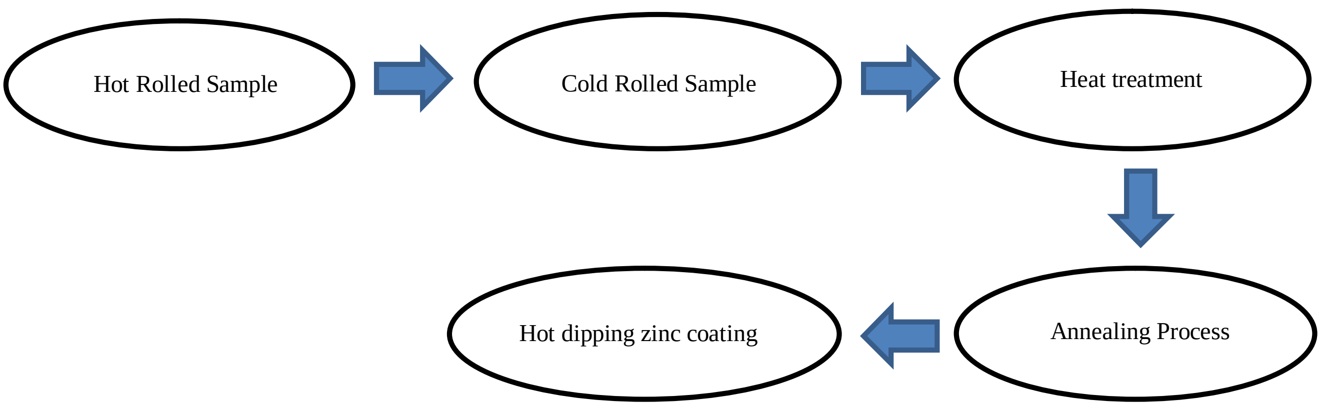

Fig. 2 Flow chart showing the sample preparation cycle

C. Methodology

The methodology followed for this experiment was-

1) Hot-rolled and cold-rolled samples were prepared by rolling (hot and cold) on low carbon steel
2) The microstructures of the hot-rolled and cold-rolled samples were observed with an optical microscope (manufactured by Nikon Microscopes) at 100x magnification after etching with Nittal (98 ml nitric acid in 5 ml ethanol)
3) The X-ray Diffraction study of these samples was done using X-Ray Diffractometer manufactured by Bruker
4) The hardness of the samples was studied using Rockwell Hardness Testing machine (manufactured by AFFRI System) at B-scale and tensile strengths were studied using Universal Testing Machine (manufactured by Tinius Olsen)
5) The cold-rolled sample was then made to undergo heat treatment at 800^{o}C for 30 minutes in a tubular furnace (manufactured by OTF-1200X)
6) Annealing of the sample was done inside the furnace with an approximate cooling rate of 2^{o}C per minute till a temperature 450^{o}C
7) The annealed sample was then coated with zinc, which was heated to 450^{o}C. This gives the hot-dip galvanized sample and this process is known as hot dipping coating process.
8) The microstructure, X-ray Diffraction pattern, Hardness, and Tensile strength of the galvanized sample were then obtained using the respective instruments.

After tensile test, all the samples with different elongation and thickness were observed. The elongation and thickness values are also mentioned in table II.

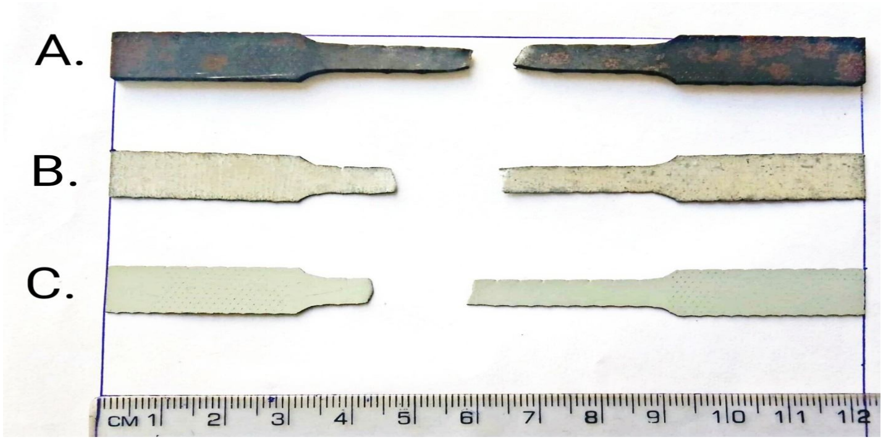

Fig. 3 Tensile specimens after tensile test of different samples i.e.; **A.** (HR Sample), **B.** (CR Sample) and **C.** (Galvanized Steel Sample)

III. RESULTS AND ANALYSIS

A. Microstructures

The microstructures of hot rolled, cold rolled and galvanized samples are mentioned here. All the images of microstructures were taken at 100x magnification.

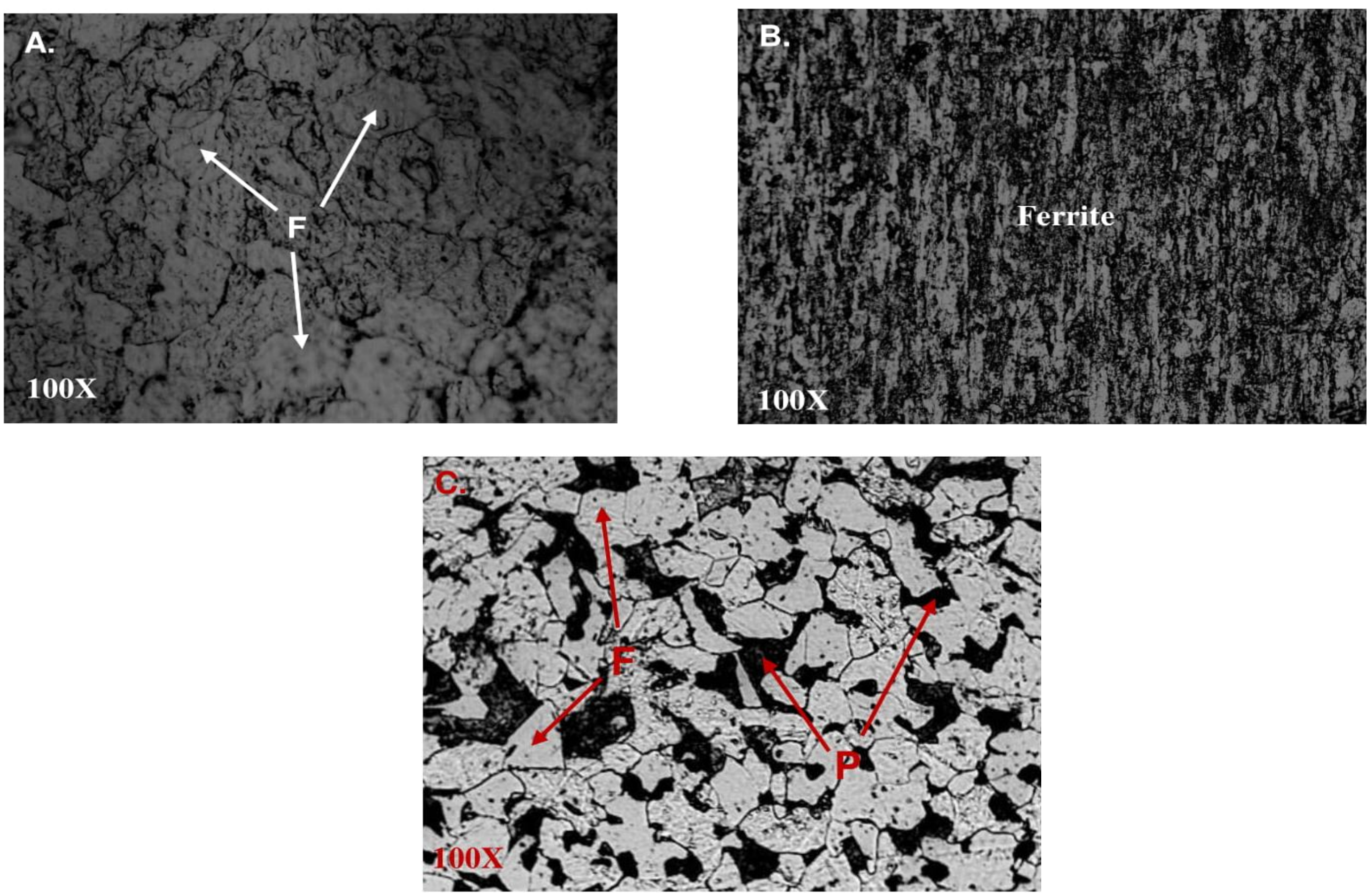

Fig. 4 Microstructures of different samples where- A. is hot rolled steel sample where F is ferrite phase, B. is cold rolled sample where elongated ferrite is observed and C. is galvanized sample where F is showing ferrite phase and P is showing pearlite phase

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B. Tensile Test

A table is shown below for compare the value of ultimate force, ultimate stress of each sample-

Table II comparision of ultimate stress and elongation for hr, cr and galvanized samples

Sample	Width (mm)	Thickness (mm)	Area (mm^2)	Ultimate Force (KN)	Ultimate Stress (MPa)	Elongation (%)
Hot Rolled Sample	6	2.50	15	4.07	272	14
Cold Rolled Sample	6	0.36	2.16	1.38	639	9
Galvanized Sample	6	0.38	2.28	0.605	265	8

C. X-Ray Diffraction

X-ray diffraction is a strategy utilized for deciding the nuclear and sub-atomic structure of a precious crystal, in which the crystalline atoms create a light emission X-ray beams to diffract into numerous particular bearings. By estimating the edges and powers of these diffracted beams, a crystallographer can create a three-dimensional photo of the thickness of electrons inside the crystal.

The graph between intensity count (y-axis) and 2 theta (x-axis) is shown below-

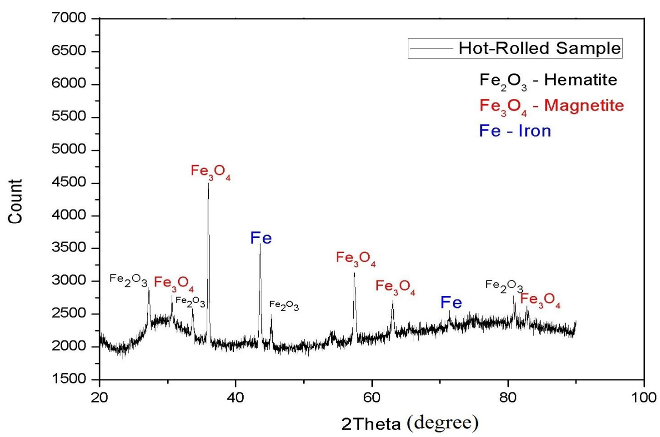

Fig. 5 XRD plot for Hot Rolled Sample where hematite and magnetite is observed

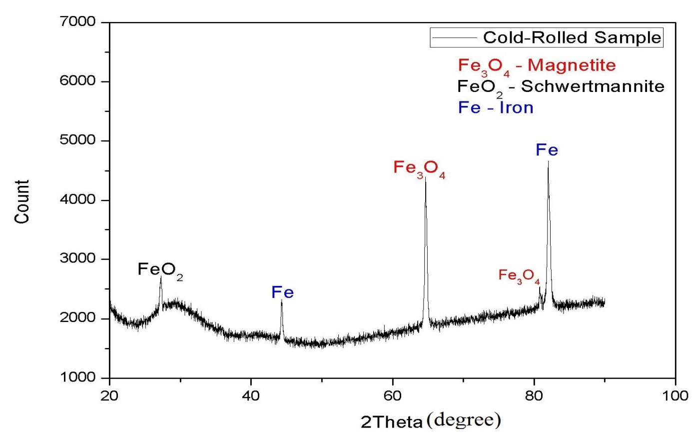

Fig. 6 XRD plot for Cold Rolled Sample where magnetite and iron is observed

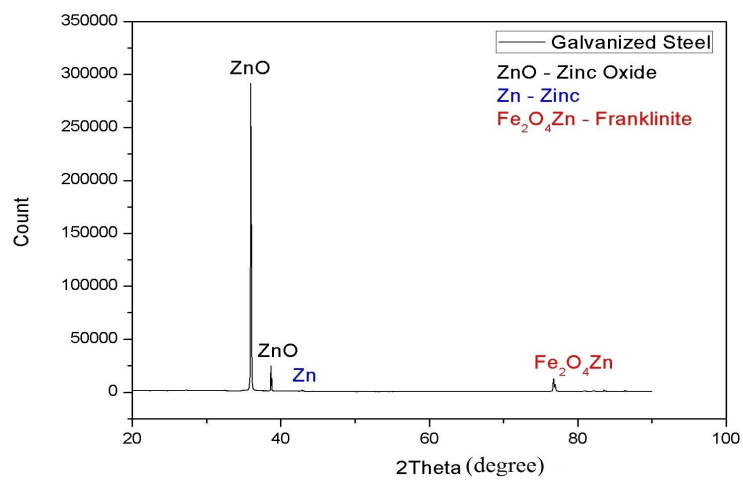

Fig. 7 XRD plot for Galvanized Sample where zinc oxide, franklinite and zinc (in small amount) is observed

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D. Hardness Test

The Rockwell scale is a hardness scale in view of space hardness of a material. The Rockwell test decides the hardness by estimating the depth of penetration of an indenter under a huge load contrasted with the entrance made by a preload.

There are various scales that use different loads or indenters to find out the hardness value. The result of hardness (by using Rockwell hardness machine) is a dimensionless value noted as HRB. The table for hardness values and corresponding graphical representation is given below-

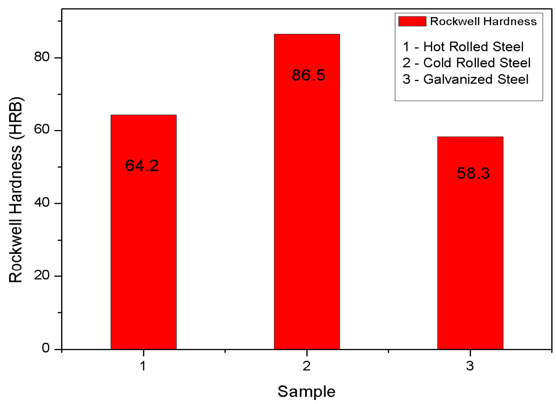

Fig. 8 Graphical representation of

Table III
Hardness values of different samples

Sample	Hardness (hrb)
Hot rolled steel sample	64.2
Cold rolled steel sample	86.5
Galvanized steel sample	58.3

IV. CONCLUSION

A. Through our study of the microstructures of cold rolling, hot rolling, and hot-dip galvanizing of mild steel, we have found that both hot and cold rolled mild steel samples display purely ferrite phase (BCC form of iron) and crystalline structure, which gives rise to their magnetic properties.

B. Galvanized sample, on the other hand, shows a combination of ferrite and pearlite phases, where pearlite is observed as a two phase layered structure of alternating layers of ferrite and cementite.

C. On the study of mechanical properties of the sample after these 3 operations, we have observed that the mechanical properties such as hardness and strength increase slightly on hot-rolling and increase drastically on cold-rolling. Galvanization is observed to have led to a reduction in tensile strength of the sample.

D. The usage of X-ray Diffraction to study the crystal structure of the samples after each process has helped us observe the presence of hematite and magnetite in hot-rolled sample, of magnetite and iron in cold-rolled sample, and of zinc oxide and zinc in galvanized sample.

E. In cold rolling process the reduction in thickness is due to dislocation movement and below recrystallization temperature the dislocations piling up to each other so the strength (UTS) and strain hardening were increased, so the hardness is more in case of cold rolling.

F. In case of zinc coated steel, the sample was gone through the heat treatment and annealing process, so recovery, recrystallization and grain growth were takes place and the ferrite and pearlite microstructure were observed and due to this strength and hardness were decreased.

G. The zinc coated steel is very useful for appliance purpose because the zinc oxide layer protects the surface from corrosion and oxidation.

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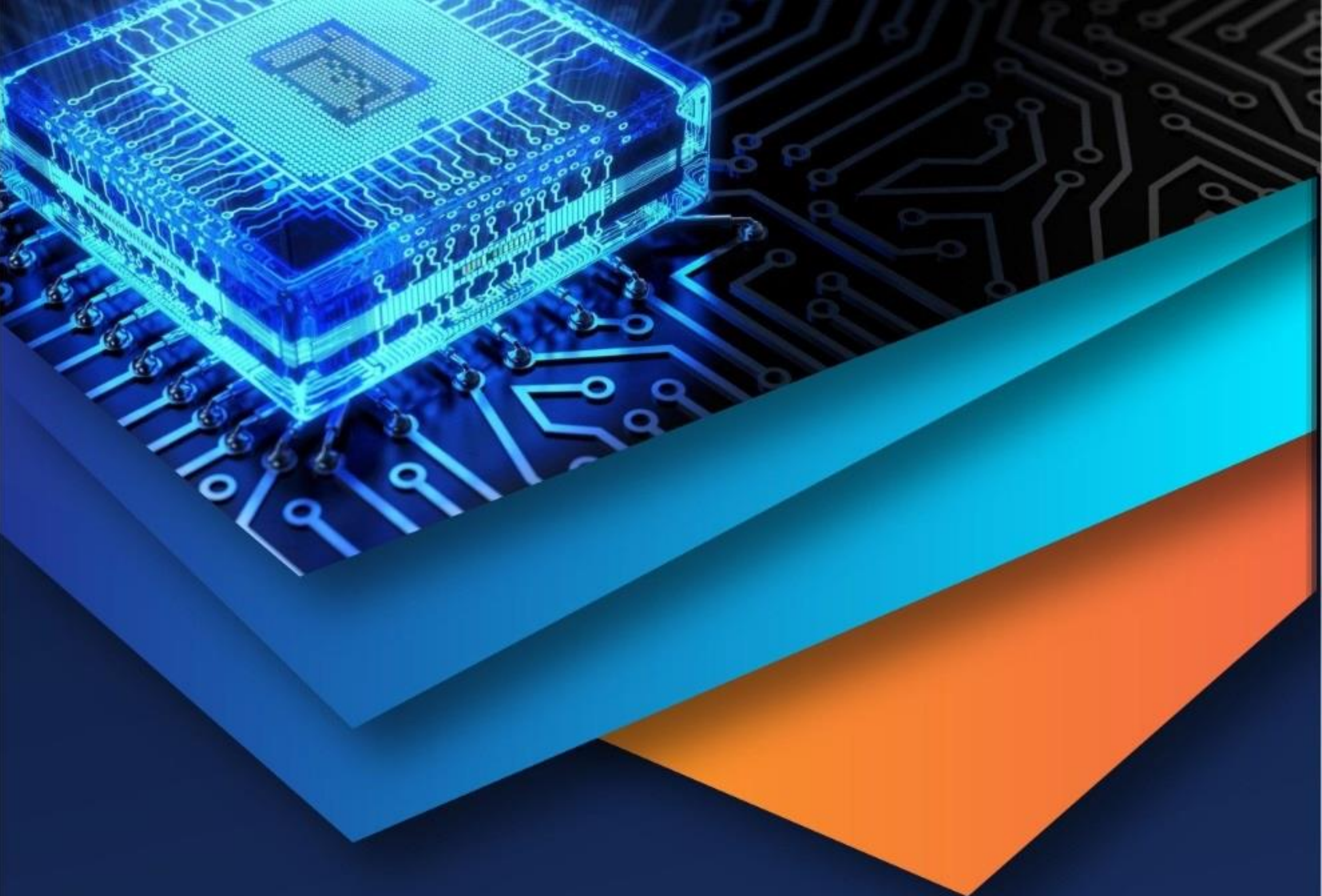

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