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Study of Wear Characteristics of Hardfaced Layers made by E430 and E410 Electrodes using SMAW Process

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Abstract: In this present investigation, multilayer hardfacing of mild steel is done by Shielded metal arc welding (SMAW) process by using two different electrodes in order to compare the performance of hardfaced layers. SMAW process is selected as the process is more versatile, an all-position process and most economical. In this study, it is also focused on the influence of chromium variations on wear, hardenability and the effect on microstructure, etc. The main aim of the hardfacing chosen here is, for repairing, improving or extending the service life of the industrial equipments made up of mild steel economically and to provide excellent wear resistance. Wear test and other tests were carried out and complemented by a detailed hardness survey. The wear behaviour of the hardfaced material was tested by using pin and disc machine. The effect of multilayer's and surface alloying on the hardness, microstructure and wear behaviour of mild steel was studied. It was found that triple layer hardfacing has good wear resistance properties, followed by single and double layer hardfacing. Among the two electrodes, the E430 electrode deposits are having good wear resistance than the E410 electrode deposits. It was also found that chromium supports the improvement of wear resistance.
Keywords: Hardfacing, multilayer's, E430, E410, wear resistance

I. INTRODUCTION

The deposition of surfacing layers by welding techniques, such as shield manual arc welding (SMAW), submerged arc welding (SAW), plasma arc welding (PAW) etc. have been used widely in many industries in order to improve the wear and corrosion resistance of the equipments [11]. Among weld metal deposition techniques, SMAW has been especially effective and more economical.

The surfacing is the process of altering the surface characteristics of a component to achieve an improvement in properties like wear resistance, resistance to corrosion etc, by depositing a coating or modifying the surface structure. In metallurgy, it is depositing filler metal on a metal surface by welding or spraying. Economical gains can be achieved by using surfacing process. Different types in surfacing process are cladding, hardfacing, build up, and buttering.

Hardfacing is a surface treatment to improve the surface properties of metals, in which a alloy metal having excellent resistance to wear is deposited onto surface of a substrate. It is mainly applied to parts exposed to various wear environments in order to protect them and extend their life [2].

In the present research work, a layer wise wear properties comparison of two different electrodes (viz. E430 and E410) was studied. During the past two decades, 13% chromium alloys were improved widely, 15-18% chromium as welded deposit for various applications in the industries has increased [14]. Most of the common hardfacing alloys are iron based, they contain more percentage of chromium. Over last 10 years wide range of 400 series alloys which contain 10-17% of chromium were developed for industrial components applications, which requires its alloys to possess mechanical properties of extreme values [17].

II. BASE METAL

Mild steel was selected as base material. Mild steel is typically used in manufacturing, industrial components like automobile parts, split tapered bush, flanges, nuts and bolts, etc. which undergo various wear deformations in their daily service. And it has good weldability, ductile and malleable properties. This study will help in improving the wear resistance of mild steel components, which have vast industrial applications.

III. HARDFACING ELECTRODES

Among many hardfacing alloys iron based alloys have been given the greatest tonnage. Hence, the type 400 series martensitic and ferritic stainless steels have been employed for hardfacing in the present work. Martensitic stainless steel containing about 11.515% chromium, offers some low friction coefficient which offers metal to metal sliding, rolling and corrosion resistance. It also imparts some considerable hardening characteristics to the deposits. The ferritic stainless steels are iron-chromium-carbon alloys with sufficient chromium (16-18%) which acts as ferrite stabilizer. Ferritic stainless steel is selected because at elevated temperatures it eliminates the formation of austenite and the ferrite is stable up to its melting point [16]. Hence E410 and E430 stainless steel electrodes have been used in this study.

TABLE 1
Chemical composition of electrodes

Chemical composition	**C%**	**M%**	**Si%**	**P%**	**S%**	**Cr%**	**Ni%**	**Mo %**	**Cu %**	**V%**
E410	0.072	0.62	0.26	0.018	0.018	13.36	0.39	0.1	0.05	0.002
E430	0.08	0.68	0.22	0.018	0.018	17.10	0.05	0.05	0.05	0.002

IV. EXPERIMENTATION

Trial runs were conducted for selecting the process parameters like current, speed of weld metal deposition, etc. Weld metal was deposited along the thickness side of the mild steel by single, double and triple layers by using two different electrodes (E430 and E410) separately. Wide range of parameters was applied during the trial runs. Number of specimens were prepared and examined visually and microhardness testing was conducted over selected samples.

According to the trial runs conducted, important process parameters i.e. welding current, voltage, weld metal deposition speed was selected to conduct the experiment. The hardfacing electrodes were deposited on the mild steel plate by using shielded metal arc welding. In this experiment six mild steel plates were used, these plates were divided into two batches, one batch of the plates were hardfaced with E430 electrodes and another batch of plates were hardfaced with E410 electrodes. In each batch weld metal was deposited in single, double and triple layers on base plates in flat position along the thickness side, by this dilution was minimized by increasing layers.

Constant process parameters were maintained throughout the hardfacing process. A good interpass temperature was maintained throughout the process to avoid cracking in the hardfaced layers. In order to remove unwanted slag after every weld pass cleaning and machining was done. After completion of weld depositions, each work piece was allowed to cool in air. The approximate thickness of each weld metal layer deposited on the base metal was 2.5 mm. Stringer bead technique without any transverse oscillation of the electrode was employed throughout the process which controls the dilution within the limits. Specimens were machined from the hardfaced layers for testing microhardness, microstructure, dilution and wear. Fig. 1 and Fig. 2 shows the weld metal deposition on the base plate.

Fig. 1 Sample specimen with three layers

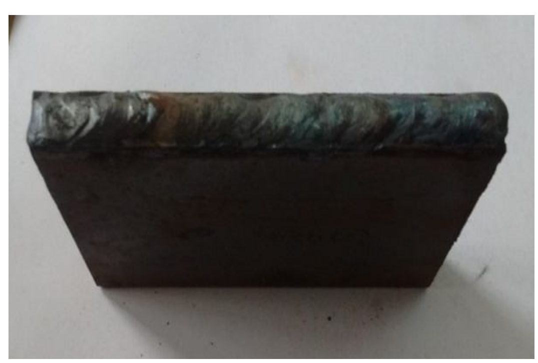

Fig. 2 Deposition of weld metal on base metal

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Volume 5 Issue VIII, August 2017- Available at www.ijraset.com

Process parameters for weld metal deposition
Current : 140 Amps
Voltage : 30-35 volts
Weld metal deposition speed: 2 mm/s
Machine used for welding : DC machine electrode positive

A. Microhardness Test

Hardness is the ability of the metal to resist penetration, abrasion wear or the absorption energy under impact load. Hardness measurements provide the information about the metallurgical changes caused by welding in the various regions. The hardness tests were carried out using Vickers hardness instrument with 500 gm load. Readings were taken along the cross section of weld metal. The average of these results was taken into consideration for further analysis. The microhardness readings were taken in a vertical direction from top of weld metal to base metal with 0.5 mm gap between each reading. Average values of the microhardness readings from top, middle of the weld metal and HAZ position were taken into consideration for analysis. The average microhardness of base metal is 139 VHN.

TABLE 2
Microhardness values (average) of hardfaced layers deposited by E430 electrode

Type of layer	Microhardness (VHN) Position (Top)	Microhardness (VHN) Position (Middle)	Microhardness (VHN) Position (HAZ)
Single layer	380	351	190
Double layer	433	400	190
Triple layer	451	434	184

TABLE 3
Microhardness values (average) of hardfaced layers deposited by E410 electrode

Type of layer	Microhardness (VHN) Position (Top)	Microhardness (VHN) Position (Middle)	Microhardness (VHN) Position (HAZ)
Single layer	368	330	183
Double layer	403	389	181
Triple layer	439	409	170

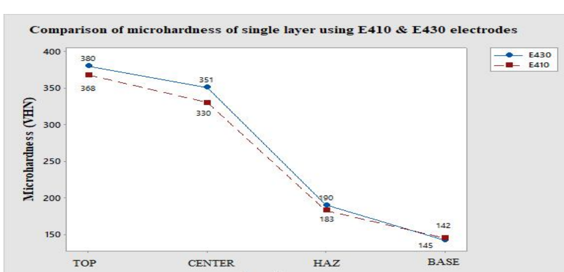

Fig. 3 Comparison of microhardness of single layer

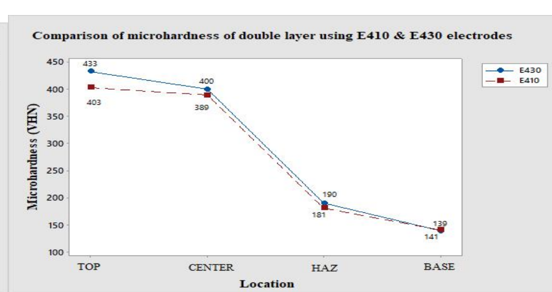

Fig. 4 Comparison of microhardness of double layer

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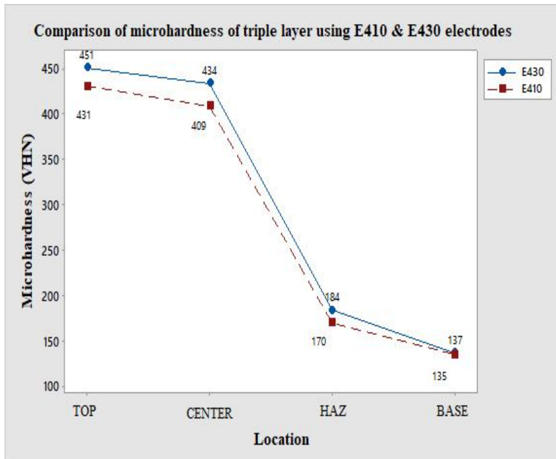

Fig. 5 Comparison of microhardness of triple layer

From the above graphs (Fig. 3, Fig. 4, Fig. 5) it is observed that the microhardness of weld metal deposited by E430 electrodes is slightly higher than E410 electrodes. And as compared to layers, with increase in layers microhardness is also increased. The microhardness at the top of the bead is higher compared to microhardness values at middle and heat affected zone position. The main reason is that cooling rate at the top of the bead is very high compared to middle and heat affected zone position and the microhardness is directly proportional to cooling at the point. By increasing the number of hardfaced layers, due to decrease in the dilution, the concentration of alloy elements in chemical composition of hardface layer is increased and increases the volume fraction of carbides with more uniform distribution in the matrix and the hardness is increased.

B. Dilution Test

Dilution is the ratio of the area of the fused base metal to the total area of the weld deposit. The proper amount of dilution is very necessary for hardfacing, if dilution is less that means the filler metal has not penetrated inside the base metal. On the other hand, if dilution is more that means more filler metal is penetrated into the base metal that means wastage of weld metal. The given table shows the dilution percentage for each weld metal layers deposited by using E410 and E430 electrodes.

TABLE 4Dilution percentage for hardfaced layers deposited by E410 electrode

Type of Layer	**Area of penetration (mm^2)**	**Area of reinforcement (mm^2)**	**Total area of weld metal deposited (mm^2)**	**Dilution percentage**
Single	8.43	23.86	32.29	26.11
Double	9.52	33.33	42.85	22.22
Triple	8.33	42.01	50.34	16.55

TABLE 5 Dilution percentage for hardfaced layers deposited by E430 electrode

Type of Layer	**Area of penetration (mm^2)**	**Area of reinforcement (mm^2)**	**Total area of weld metal deposited (mm^2)**	**Dilution percentage**
Single	5.93	21.50	27.43	21.62
Double	7.58	33.90	41.48	18.27
Triple	9.32	44.54	53.86	17.31

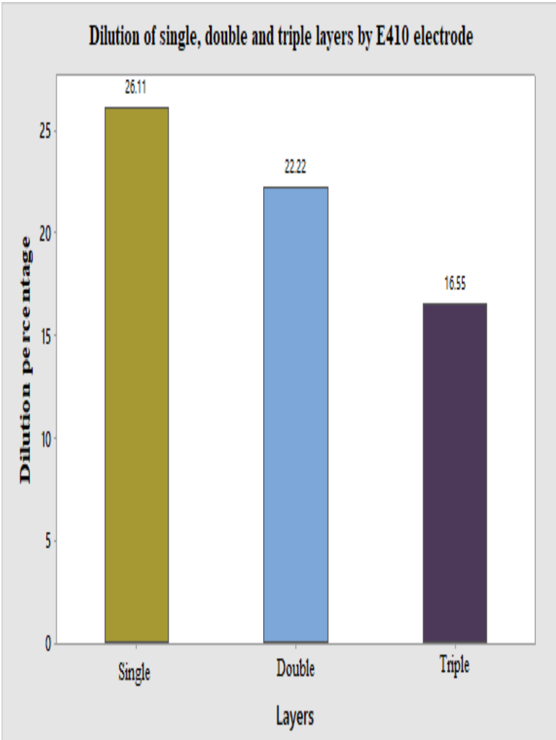

Fig. 6 Dilution of single, double and triple layers by E410 electrodes

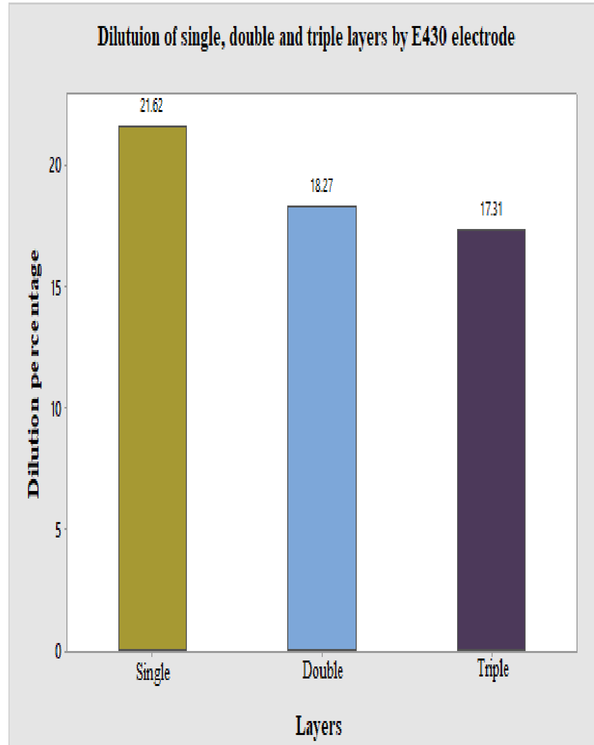

Fig. 7 Dilution of single, double and triple layers by E430 electrodes

From the above graphs it is observed that dilution is reduced as the number of layers is increased. And as it comes to electrode material E430 electrode deposits are having less dilution than the E410 electrode deposits except in the case of triple layer. The dilution basically depends upon heat input given.

C. Wear Test

For wear test, pin on disc apparatus was used. The wear test was conducted at room temperature. For wear test, cylindrical samples with a diameter of 8mm and a length of 30 mm were machined on a lathe. The tests were carried out at constant variables, i.e. the speed at 600 rpm, track diameter 60 mm, load 2 kg and time 10 min. Six hardfaced samples (three each from E430 and E410 electrode deposits) and one sample for base metal were used in this test. Before and after the test, all specimens were weighed using an electronic balance with an accuracy of ±0. 0001g. Loss in weight can be used for calculating the wear rate. The weight loss for 10 minutes was used for calculating wear rate for hour.

Calculation of wear rate

Weight loss of sample (mild steel) for 10 min = 0.0266 g

Weight loss for 1 min $= \frac{0.0266}{10}$

Weight loss for 60 min $= \frac{0.0266}{10} \times 60 = 0.1596$ g

Similarly, wear rate for all samples can be calculated by applying the following formula

Wear rate (g/hr) = loss of weight (g/10min) × 6

TABLE 6 Weight loss and wear rate

Type of electrode & material	**Type of layer**	**Initial weight (g)**	**Final weight (g)**	**Loss in weight (g)**	**Wear rate (g/hr)**
E410 electrode	Single	10.8851	10.8726	0.0125	0.075
	Double	10.8410	10.8312	0.0098	0.0588
	Triple	10.8434	10.8352	0.0082	0.0492
E430 electrode	Single	10.6855	10.6744	0.0111	0.0666
	Double	10.5656	10.5570	0.0086	0.0516
	Triple	10.3186	10.3133	0.0053	0.0318
Mild steel	-------------	11.2173	11.1907	0.0266	0.1596

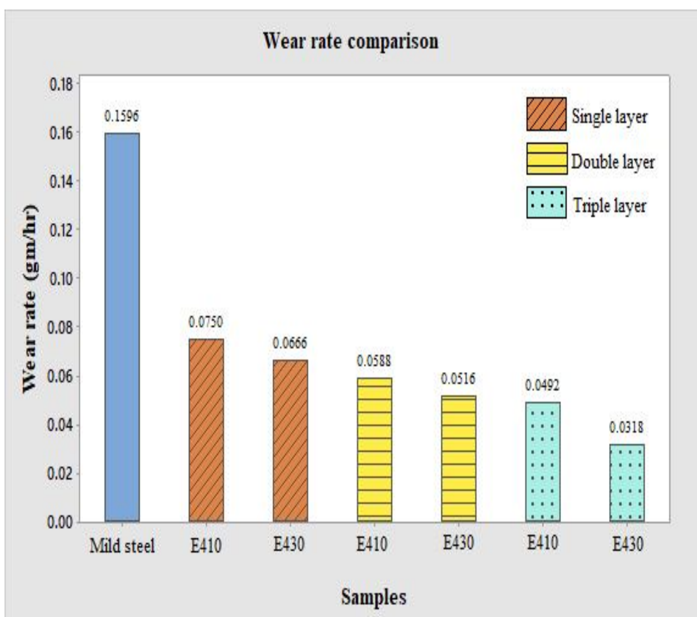

Fig. 8 Wear rate comparison

From the graph and results obtained from the Table. 6 shows that, wear rate is decreasing as layers increased and also that the hardfaced layers deposited by E430 electrode shows less wear rate than the hardfaced layers deposited by E410 electrodes. It can be said that wear resistance is improving as layers were increased. As it comes to electrodes E430 electrode deposits have good wear resistance properties than E410 electrode deposits because E430 electrodes have more percentage of chromium which helps in obtaining of less coefficient of friction than E410 electrodes.

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D. Microstructural Analysis

Microstructural studies reveal that how the deposited layers are responsible for enhanced microhardness values and thereby increasing the wear resistance.

Fig. 9 shows the microstructure of base metal, it is clear that base metal is composed of ferrite and pearlite structure which is responsible for low microhardness and less wear resistance.

Among all of the hardfaced layers, triple layer is showing good wear resistance properties so it was decided to capture the microstructure of triple layer only. The microstructure was captured after etching with nital. Fig. 10 shows the microstructure of hardfaced triple layer deposited by E410 electrode. Elongated grains, with martensite, low amounts of austenite and carbides were observed in E410 electrode deposites. Fig. 11 shows the microstructure of hardfaced triple layer deposited by E430 electrode. From Fig. 11 columnar structure with ferrites, carbides at the grain boundaries and small amounts of austenite is identified [15].

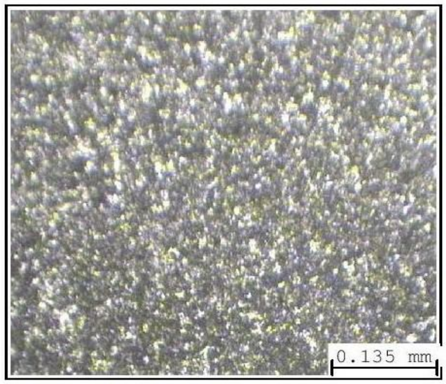

Fig. 9 Microstructure for base metal

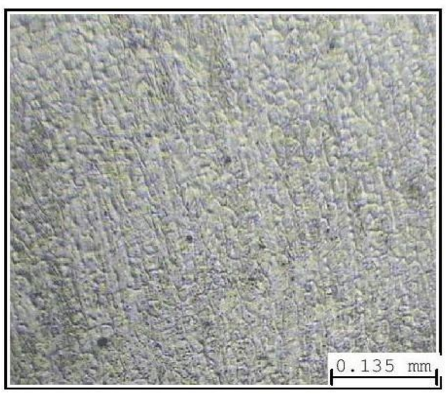

Fig. 10 Microstructure for E410 electrode weld metal

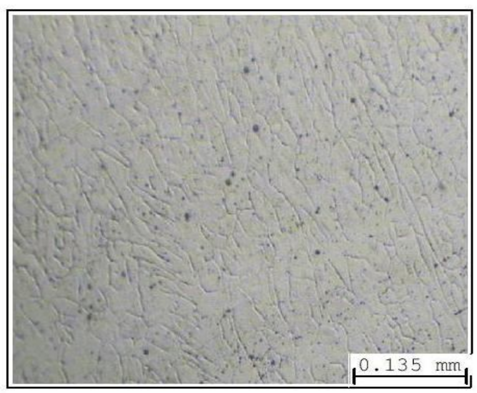

Fig. 11 Microstructure for E430 electrode weld metal

Due to the presence of ferritic structure, more percentage of chromium and carbides E430 weld metal is having more wear resistance than the E410 weld metal.

V. CONCLUSION

A. As layers increased, the wear resistance of the hardfaced layers increased, and hardness is also increased.

B. By using triple layer hardfacing with E430 electrode, the hardness can be increased upto 2.24 times more than base metal and with E410 electrode it can be achieved around 2.16 more than the base metal.

C. Wear rate was reduced upto 69.17% with triple layer hardfacing by E410 electrode and by using E430 electrode it can be reduced upto 80% as compared to mild steel wear rate.

D. Martensite, low amounts of austenite and carbides were observed in the E410 electrode deposits. Ferritic structure, more percentage of chromium, carbides and austenite were present in the E430 electrode deposits..

E. Dilution percentage is maintained within the tolerance limit.

F. E430 electrode with multilayer hardfacing can be recommended. As it has been observed that the wear resistance of triple layer deposited by E430 electrode is more, followed by single, double layer hardfacing and multilayer hardfacing by E410 electrode.

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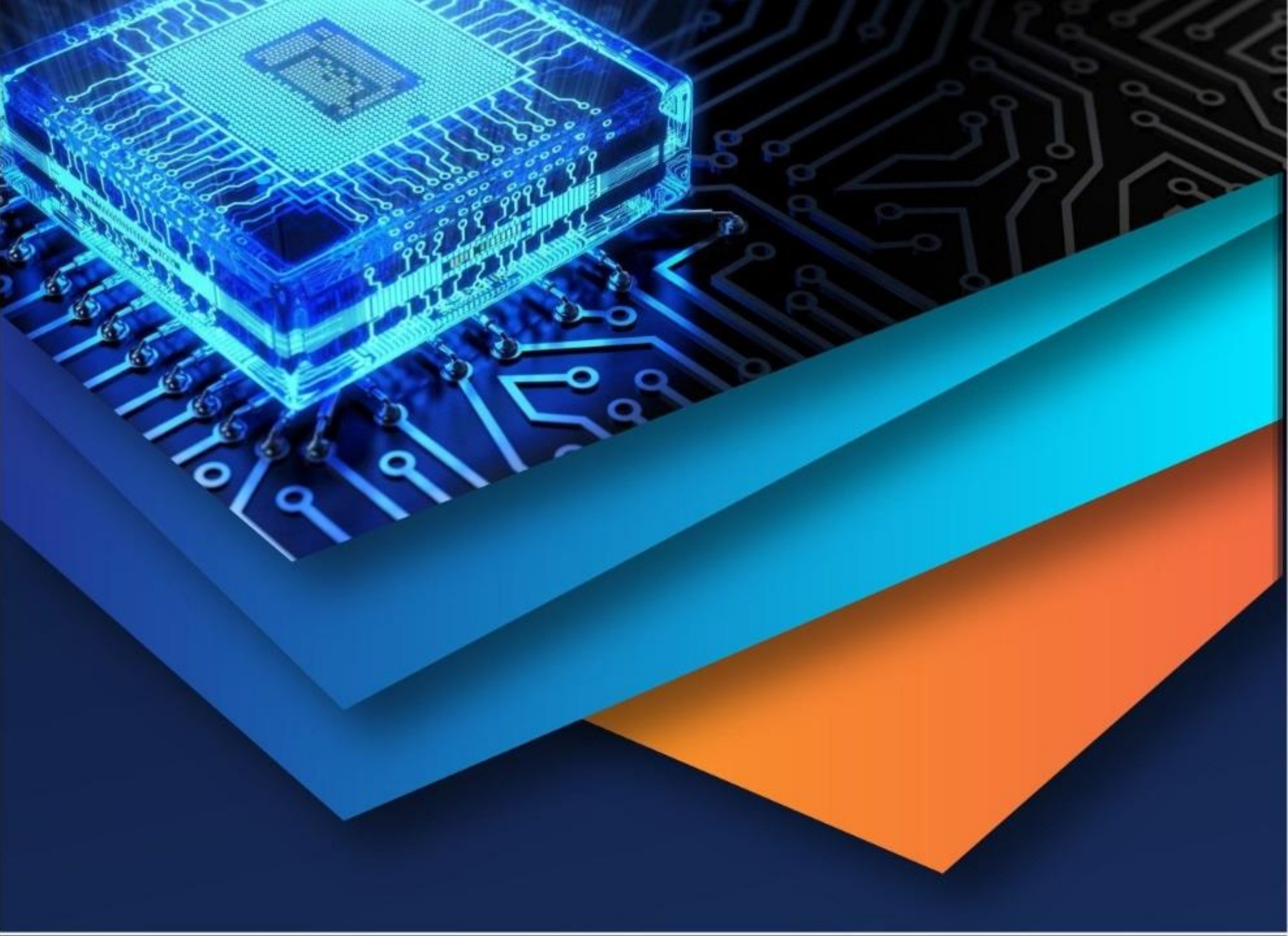

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