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Design and Fabrication of CNC Thermocol Cutting Machine

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Abstract: ***Traditional manual thermocol cutting often results in material waste and imprecise shapes. This project introduces a Thermocol Cutting Machine that uses a heated nichrome wire to cut thermocol (EPS) with high precision. Powered by an Arduino Uno, CNC shield, and stepper motors running GRBL firmware, it interprets G-code for smooth, accurate motion. The heated wire melts thermocol cleanly along the cutting path, producing burr-free edges. The machine supports complex patterns with minimal errors. Designed to be cost-effective and user-friendly, it suits industries, hobbyists, and educational use. This solution enhances cutting efficiency and reduces manual effort.***
Keywords: GRBL firmware, Thermocol Cutting Machine, CNC shield, G-code.

I. INTRODUCTION

Today the products of plastic are an important and integral part of everything in our life. The process of manufacturing the plastic foam is the casting and extruding, so the perfect way to cut these types of foam is hotwire cutting. This cutting can be performed with a source of heat, which is wire that change the physical properties of material until it can be cut with low cutting force [1]. There are several mechanisms for the cutting of plastic foam; they can be divided into three-basic modes or the mixing among them

Thermal cutting: In this mode, the plastic foam is vaporized or just melting in front of the wire cutter but without touching between them. See Figure 1.a.

Thermo-mechanical cutting: this mode is a mixing between the shearing force and the melting of material to perfume the cutting and the hot-tool in contact with the material. See Figure 1.b.

Mechanical cutting: this mode depends on the shearing because it happens when the temperature of tool is below the melting point of the foam [2].as shown in Figure 1.c

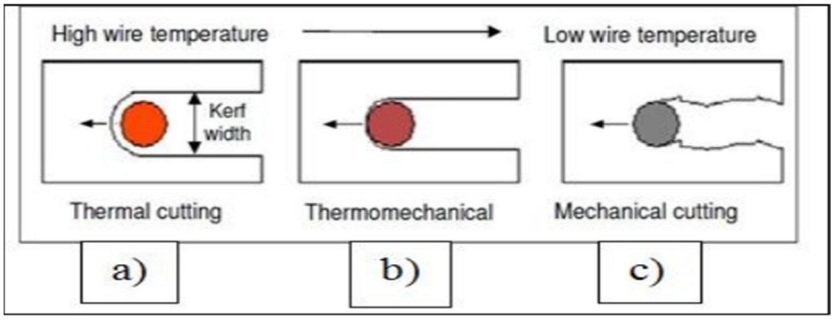

Fig. 1. Cutting mechanism [2].

Simply the principle work is an electrical power pass through wire then the wire is heated to desire temperature degree according to the input voltage through electrical resistance. When the wire contact the surface of foam, it melts the area surrounding it, the heat of the wire vaporises the foam creating a smooth surface Figure 2. Shows the wire is moving across the specimen of foam material.

The material to be cut is just soften under the point of melting because it is thermoplastic material, after that the cutting is done. The surface of the cut and kerf-width is affected by the changing of the velocity and the diameter of wire even if it was small [1].

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II. LITERATURE SURVEY

Many researchers have studied the cutting process of polymers and the effective parameters on it.

Harmanpreet & Manpreet Singh [3] studied the effect of parameters for the polymer cutting process on material removal rate and kerfwidth also the optimization of the machining process.

Ranjeet et al [4] maked investigation in ablation process for the Expanded Polystyrene (EPS) rapid prototyping to predict and calculate the kerfwidth and surface roughness (Ra) with mathematical model.

Kiril & Jesper [5] proposed a novel thermo-electro-mechanical model for hotwire cutting of EPS foam and predicts the stress, voltage and temperature of wire during cutting of EPS foam. In addition, find relation between kerfwidth and the cutting angle as measured from the horizontal direction.

Namrata & Sathyan [6] investigated the factors responsible for the bowing phenomenon via a series of experiments involving variations in current and wire feed rate, build more precise prototypes, kerf width is also examined, Further more finding noval way to predict the influence of gases in bowing has been analyzed and quantified.

Luka & Ivanovskis [7] developed a 4-axis numerically controlled hot-wire foam cutter suitable for flying aircraft modelling purposes. Numerically controlled foam cutter had to be able to cut intricate shapes out of foam material such as extruded polystyrene by using 3D virtual model, also find novel mathematical model to predict the kerfwidth, and empirical relationship is established to predict the surface roughness (Ra) of the sliced surface by performing regression analysis.

Ahn et al [8] studied the Influence of process parameters on the surface roughness in hotwire of variable lamination manufacturing (VLM-S) for EPS foam such as cutting angle and compositions of expandable polystyrene EPS, the apparatus is four-axis automatic cutter and the specimen is thin foam. While in my study, parameters differ and the device is 2D axis CNC. With any thickness of foam can be cut.

P. Gallina et al [9] studied the hot wire with 2D robotic system to cut polystyrene plates with accurate force control which is delayed reference control (DRC) with time delay: x d(t-T) ,T the time delay calculated online, while my study is about 2D CNC machine and different parameters to reach optimum conditions of cutting without considering of time. The objective of this paper is to obtain the optimum cutting conditions for hotwire cutting process, and study the effects of these parameters on the process.

III. SOFTWARE USED

A. GRBL Firmware

1) Step 1: Download GRBL firmware and extract it and copy the folder "grbl-master". Do not copy this folder to "Arduino library directory!"

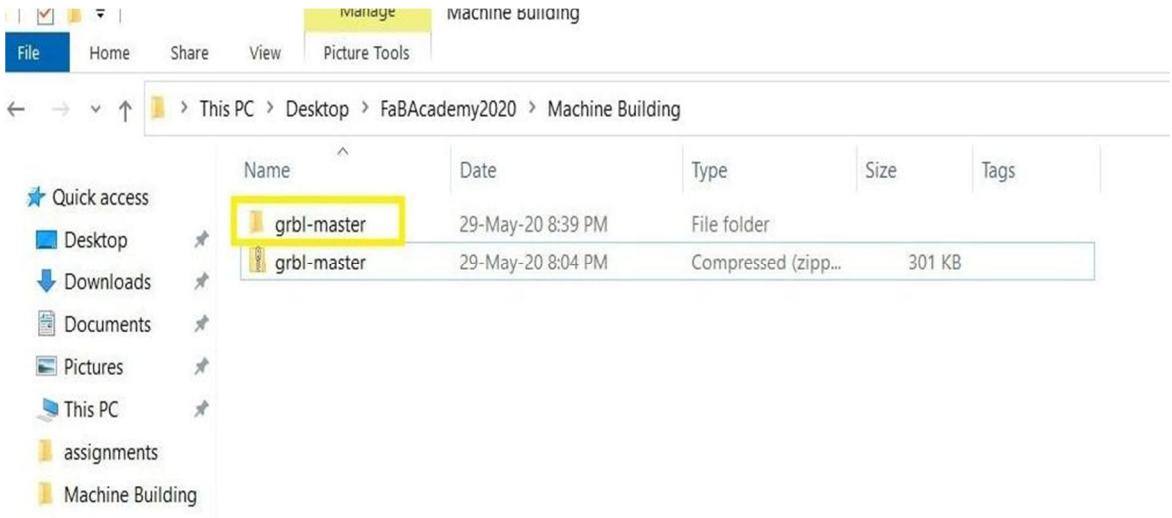


Fig. GRBL Master

2) Step 2: In Arduino IDE go to "Sketch > Include Library > Add .ZIP Library..." and from inside "grbl-master" folder locate "grbl" folder. Click open

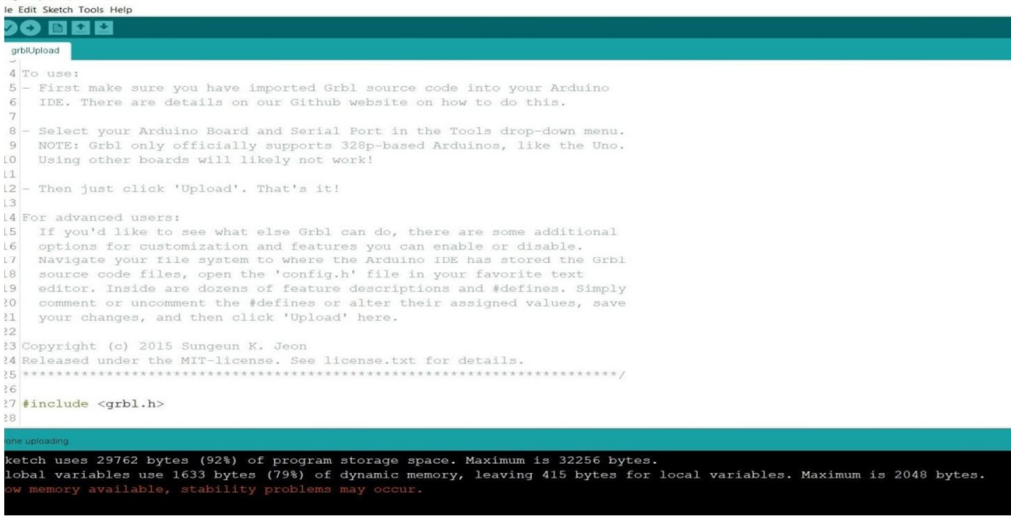


Fig. Code

B. GRBL Controller Software (g-code Sender)

This software will generate g-codes according to job and send those codes to Arduino board (which knows how to read g-codes now!). We will use Universal G-code Sender.

1) Step 1: Install JAVA Runtime Environment to your PC from here. The GRBL controller is a JAVA program and runtime environment should be installed. You may need to create an account.

2) Step 2: Go to download page and download 2.0 Platform version and extract the zip file. Inside extracted file open "ugs platform > bin" and run one of the executable files (ugsplatform64 in my case).

3) Step 3: Connect to Arduino board. Set baud rate to 115200 and the right COM port. Click on "Connect/Disconnect" button. In the console window you should see connection confirmation and defined settings.

4) Step 4: To configure the machine, we will use the built in setup wizard. Go to "Machine > Setup wizard..." A new window will appear which will confirm connection to GRBL.

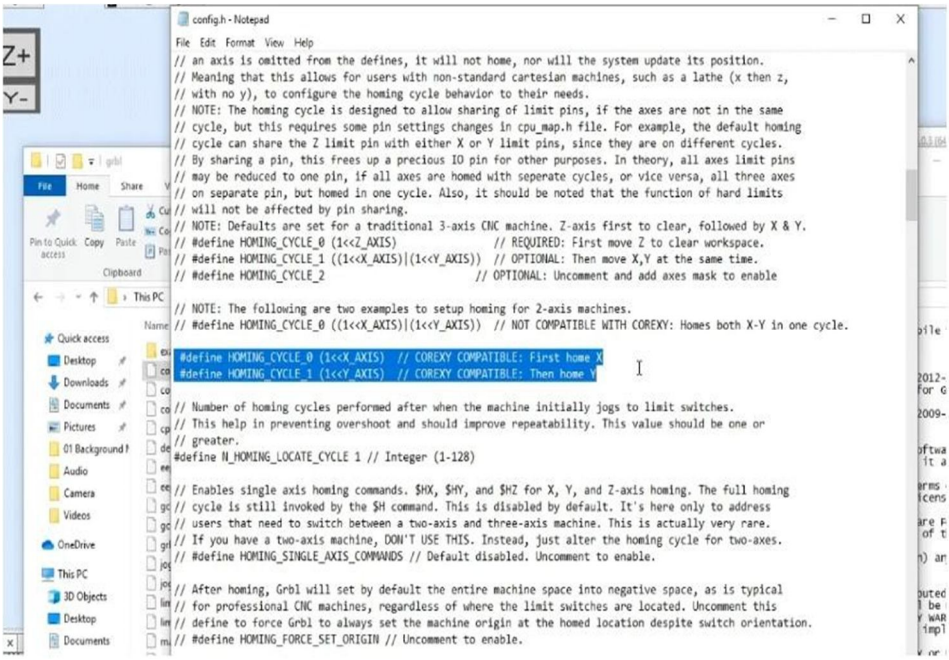
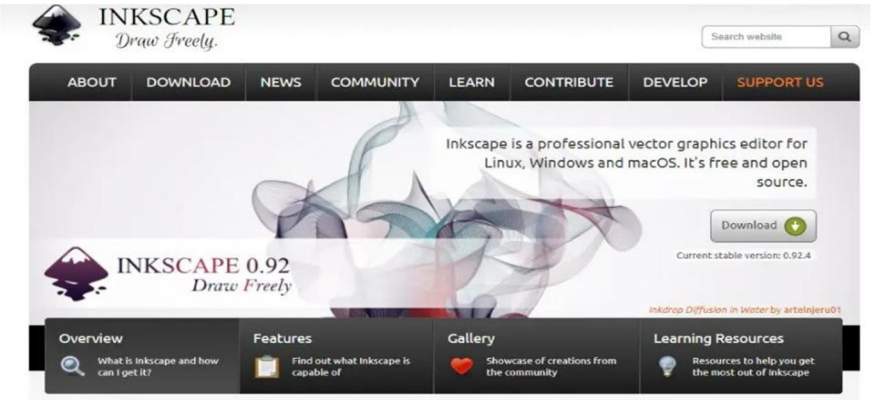


Fig: UGS

C. Generating G-code for the CNC Machine

For that purpose, we need vector graphics software, and again, I chose an open source one, and that's Inkscape. You can download it from its official website for free.



We can select a cylinder as the wire obviously has a cylindrical shape. Here we can change the parameters like diameter of the tool, I set it to 1mm, as well as the feed rate. The other parameters are not important at this time. Finally, now we can generate the G-code for this shape using the Path to G-code function. The G-code is simply a set of instructions that the GRBL or the Arduino can understand and according to them drive the stepper motors. So now, we can open the G-code in the Universal G-code sender program and through the Visualizer window we can see that path that the machine should go through.

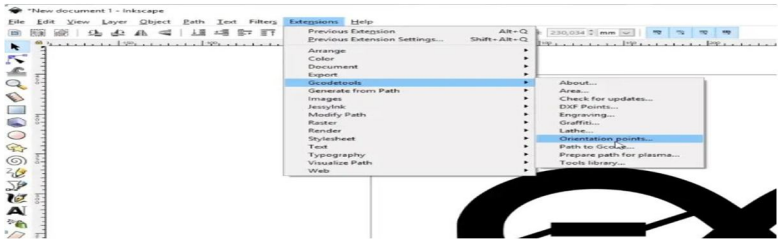


Fig. G-Code

IV. WORKING PRINCIPLE

A CNC hot wire foam cutting machine is a specialized device used to cut foam materials, such as expanded polystyrene (EPS) or polyurethane foam, into precise shapes and designs. The machine utilizes a heated wire or wires to melt through the foam, following a programmed path generated by computer numerical control (CNC).

A. Design and Programming

1) Begin by creating a design or model of the desired foam shape using CAD (Computer-Aided Design) software

2) Convert the design into a CNC-compatible file format, such as DXF or G code, which contains instructions for the machine's movements and wire paths.

3) Load the file into the CNC machine's control software.

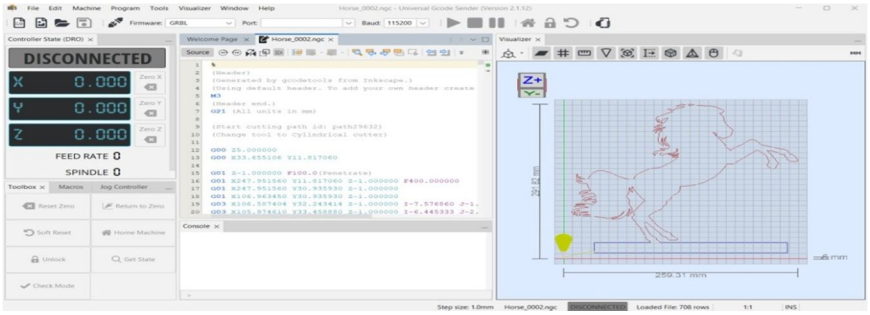


Fig. Code

B. Setup and Material Preparation:

- Prepare the foam material, ensuring it is securely positioned on the machine's worktable.
- Check and adjust the wire tension to ensure it is taut and properly aligned
- Set the appropriate cutting temperature based on the type and thickness of the foam material.

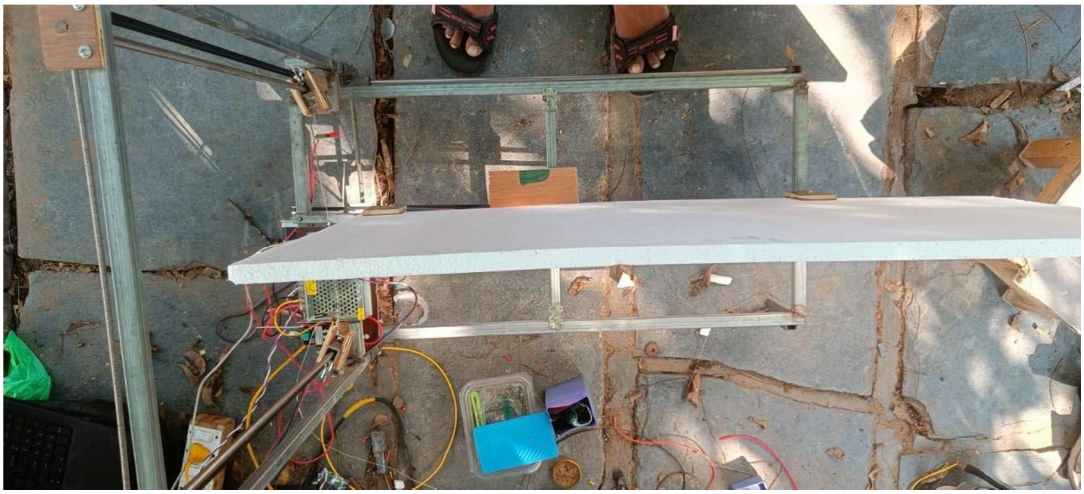


Fig Material

C. Machine Initialization

- Power on the CNC hot wire foam cutting machine Home
- The machine's axes, ensuring they are properly calibrated and aligned. Zero
- The machine's reference point to establish the starting position.

D. Tool path Execution

- Initiate the CNC program, which contains the instructions for the machine's movements and wire paths
- The machine's controller interprets the program and sends signals to the machine's motors to move the wire along the designated paths.
- The heated wire is typically connected to a power supply, which ensures the wire reaches and maintains the desired cutting temperature.
- As the machine executes the program, the wire is guided along the programmed path, melting through the foam material with controlled precision.
- The foam material is cut according to the programmed design and shape, following the wire's movements.

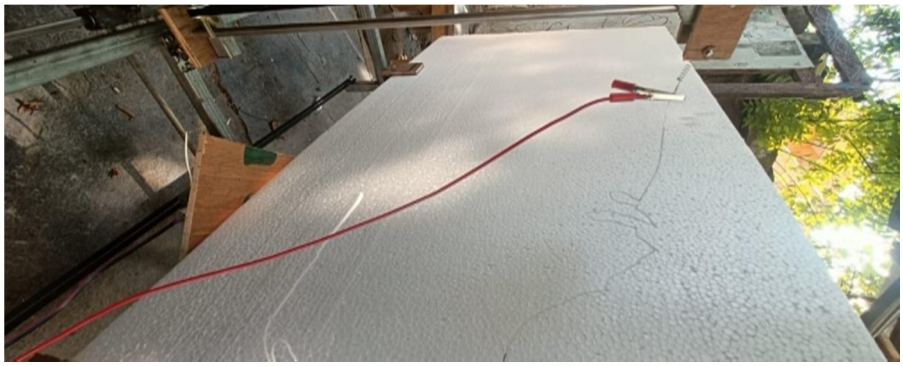


Fig. Alignment

E. Finishing and Quality Control

- Once the cutting process is complete, inspect the cut foam piece for accuracy and quality.
- Sand or smooth any rough edges or imperfections as needed.

Fig. Finish Model

F. Thermal Plastic Foam Cutting

The section starts with an overview of PFC or plastics foam cutting, followed by introductory points about polystyrene foams and their manufacture. This is served as an entrance towards the PFC process and an overview of the thermo mechanical mechanisms involved in the process.

Metal plastic ,wood	Starch Plaster	Metal Plastic	Plastic ,Paper	Build Material	Photo polymers	Plastics	Photo polymers	Starch Plaster
Complexity	Excellent	Fair	Very good	Fair	Good	Fair	Poor	Excellent
Accuracy	Excellent	Fair	Very good	Fair	Good	Fair	Excellent	Excellent
Cost	Very high	High	Mode rate	Low	Very high	Low	Low	Very high
Build size	Excel lent	Excellent	Good	Poor	Excellent	Poor	Excellent	Excellent
Speed	Aver age	Poor	Good	Very good	Average	Very good	Excellent	Average
SLA	FDM	Inkjet	3DP	SLS	LOM	SRP		FDM
Property	RP Process							RP Process

V. CONCLUSION

1) The hot wire CNC foam cutting machine is an excellent tool for a precise and efficient way of cutting foam material. This tool integrates heated wire movements controlled by a computer to perform accurate and intricate cuts on foam blocks or sheets.

2) The CNC hot wire foam cutting machine processes cuttings in an automated manner and hence the productivity level is very much increased while manual labor is reduced. The machine cuts complicated shapes and designs with high precision and thus ensures constant cutting results. It also has flexibility concerning customized cutting with respect to foam thicknesses and densities.

3) The different considerations required while selecting and assembling the key components of the machine such as the frame, stepper motors, hot wire system, control electronics, and so on must be deliberated upon throughout the project. The cutting paths designed for the machine must be programmed.

4) The safety measures implemented should guarantee safety to operators and safe operation of the machine. The machine must be maintained periodically with a calibration routine to enhance its performance and accuracy. Hot wire CNC foam cutting machines are widely adopted in many industries, including packaging, insulation, model making, signage, etc.; making it an economical option for the precision production of foam parts.

In summary, the hot wire CNC foam cutting machine is by far a great asset for the foam industry; properly assembled, programmed, and maintained-fine cutting operation in many industries. The machine offers precise cutting, automation, versatility, and customizing options.

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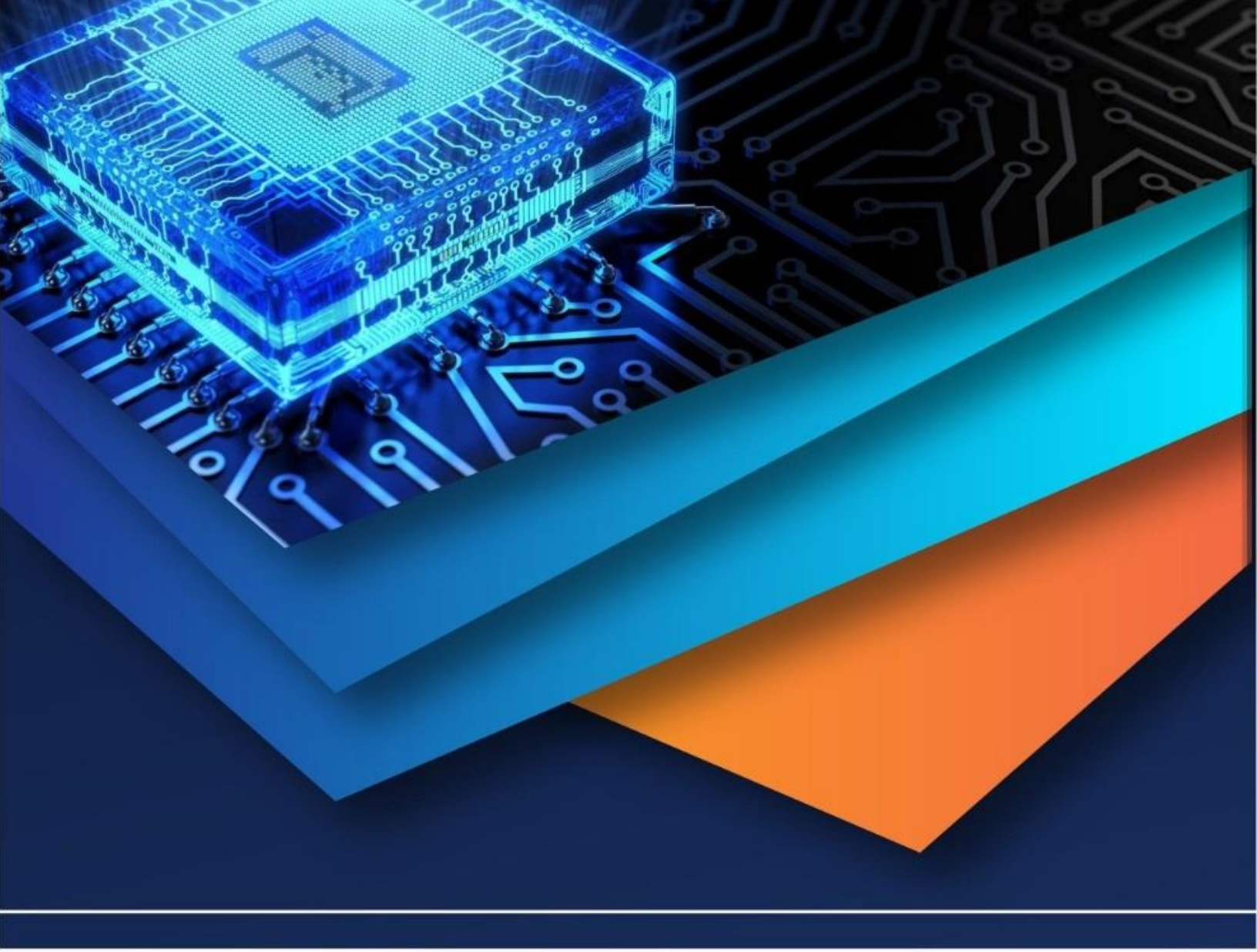

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