iJRASET
International Journal For Research in Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 4 **Issue:** V **Month of publication:** May 2016

DOI:

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International Journal for Research in Applied Science & Engineering Technology (IJRASET)

Design of Automated Coil Winding Machine

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Abstract*— The main objective of this project is to develop an automated winding machine to wind coils for motors and pumps that will greatly reduce an effort behind the manually operated machines and to implement the idea of automation in coil winding machine at minimum manufacturing cost that increases the productivity of automated machine. This machine is needed to wind coils of copper wires up to 18 Gauge. Currently, this process is done manually which is being automated. Automatic plants can work continuously and decreases the gap between the demand and supply. For such a machine there is no need of labour so there is no human error. Without human error, the quality of product is better and cost of production would definitely decreases. Today's fast growing industries requires an automated machine instead of manually operated machine.

Keywords—Aluminium former, Ball screw rod, PLC, Proximity Sensors, Servomotor.

I. INTRODUCTION

The entire world is rapidly switching to advanced technology like Automation. It is a process in which all the process is done by using different instruments i.e. less man power is involved. So human errors are reduced in this process and hence the system gains high accuracy. All the lengthy processes included in the conventional processes are eliminated in automation process. So time required for getting result is decreased in automation process. Automation gives effective work with less time & less manpower. Now a day, automation rapidly spreads all over sector for e.g. Agricultural, Industrial, Educational and Robotics etc.

Design of Automatic coil Winding Machine is one of the easiest ways to manufacture coil winding for all type of motors and pumps. It is an upgrade version of existing manual coil winding machine. The issues in present version of coil winding machine such as excessive tension in coil while winding, wastage of insulation material in existing controlling mechanism has been overcome in this proposed design of coil winding machine. That is achieved by the use of modern electronic circuits with monitoring devices.

II. BASIC BLOCK DIAGRAM

This machine consists of Servomotor with braking mechanism and AC motor. The Servomotor with braking mechanism is coupled with spindle shaft which can apply brake automatically in case of an emergency. The Servomotor is coupled with ball screw rod so that it can transmit the rotary motion into linear motion. The frame of this machine is simple in construction. The sliding rod is fixed in the ball screw rod shaft. The overall block diagram of coil winding machine is given in Fig.1.

This machine consists of 3 set of formers so that 3 sliding rods are used in this machine. An encoder is fixed with the servomotor. The spindle shaft is coupled with Servomotor with braking mechanism .Tailstock is the dead centre which is placed in the end through the centre axis of the machine. A pneumatic cylinder is attached with the tailstock. The control panel and start and stop push button is placed in the front view of the machine. The stop, halt and runs indication lights are fixed at the top of the machine.

The main advantage of this automated winding machine over manual winding is its better quality of winding and this is achieved only by the linier and rotary motion of the aluminium former and the liner motion is achieved by servomotor and rotary motion is achieved by AC motor .The variation in speed of AC motor and servo motor is controlled by AC drive and the change in frequency is controlled by variable frequency drive (VFD) to synchronize both motors. There is an incremental encoder used to count the pulse per revolution (ppr) and that synchronize the rotary motion of the ac motor with the linear motion of the servo motor. The servo motor will be provided with a UPS for backup memory during power off time .The entire unit is operated by interfacing with PLC. The SMPS is going to serve as the power supply unit for PLC and HMI. The HMI is the human machine interface which provides efficient monitoring and display of the machine operation.

Volume 4 Issue V, May 2016
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

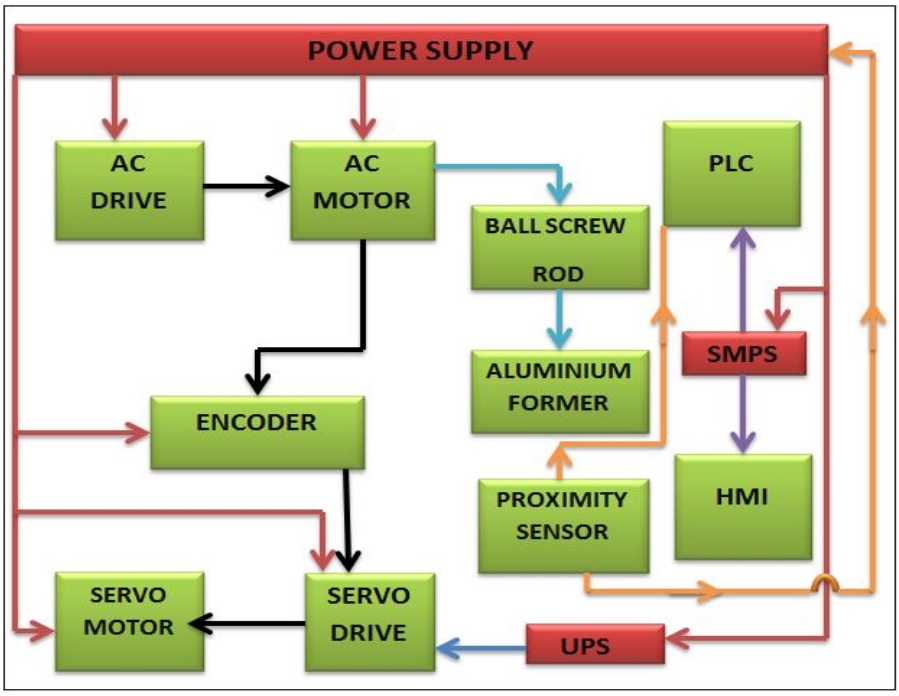

Fig.1 Overall block diagram of Coil Winding Machine

A. Main Component

1) Servomotor with braking system: Servomotors are generally characterized by a slim line design with a high power density, low inertia, and high efficiency. The servomotor with braking mechanism offer optimal drive behavior with high dynamic performance and accuracy and it is tailored for operation with servo drives. Servomotors have a sensor for angle and speed, whose signal is evaluated by the drive. This enables precise and dynamic control of the speed and position of the motor. The setting range for the speed and the achievable dynamics are considerably higher than when using a frequency inverter with a three-phase AC motor. Servomotors are also often equipped with a brake, in particular applications where gravity can cause the machine to move. The brake is a normally-ON device which will hold the position when the power supply of the drive is switched off. Servo motors with brakes are used in particular applications involving lifting and lowering, or for holding a position against a particular force. During operation the normally braking mode brings the stop is performed using the servo drive and is a wear-free process. The servomotor with braking mechanism ASD-B2 series is given in Fig.2.

Fig. 2. ASD-B2 Series Servomotor with braking mechanism

2) Servo Drive: ASDA-B2 series drives are open type servo drives and must be installed in an NEMA enclosure such as a protection control panel during operation to comply with the requirements of the international safety standards. They are

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ISSN: 2321-9653
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provided with precise feedback control and high-speed calculation function incorporating DSP (Digital Signal Processor) technology, and intended to drive three-phase permanent magnet synchronous motors (PMSM) to achieve precise positioning by means of accurate current output generated by IGBT (Insulated Gate Bipolar Transistor). The ASDA-B2 series servo drive is given in the Fig.3.

ASDA-B2 series drives can be used in industrial applications and for installation in an enclosure that do not exceed the specifications defined for the ASDA-B2 series (Drives, cables and motors are for use in a suitable enclosure with a minimum of a UL50 type 1 or NEMA 250 Type 1 rating).

Fig. 3 ASDA-B2 Series Servo Drive

3) *Proximity Sensors:* A sensor is an object whose purpose is to detect events or changes in its environment, and then provide a corresponding output. A sensor is a type of transducer with various types of output. The commonly used transducer have electrical or optical signal outputs. The purpose of using proximity sensor is to find wither the coil is continuously running or not and the output signal form the proximity sensor is given to the PLC ladder logic. The image of proximity sensor is given in Fig.4.

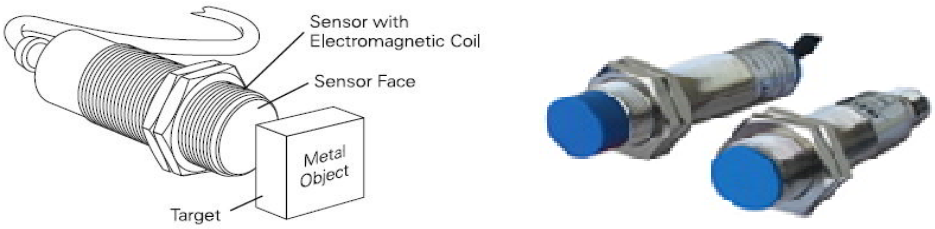

Fig. 4 Proximity Sensors

4) Ball Screw Rod: A ball screw is a mechanical linear actuator that translates rotational motion to linear motion with little friction. A threaded shaft provides a helical raceway for ball bearings which act as a precision screw and withstand high thrust loads, with minimum internal friction. The ball screw rod are made of close tolerances and are therefore suitable for use in situations where high precision is necessary. The image of ball screw rod is given in Fig.5.

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Fig. 5 Ball Screw Rod

4) *Aluminum Former:* Former is in elliptical shape which is used to turn the copper coil for stators. This former consist of starting and running stage. It consist of several grooves which the coils are turned into the grooves. This is an aluminum metal which is used to worn coils in it. This former helps to separate the turns of the windings in separate bars grooves. Formers are separated into 2 equal half's. This helps the worned coils take out easier. This is having a slot inside which will be inserted into a square rod. This type of formers are widely used in many other winding industries The Design of the aluminium former is given in Fig.6.

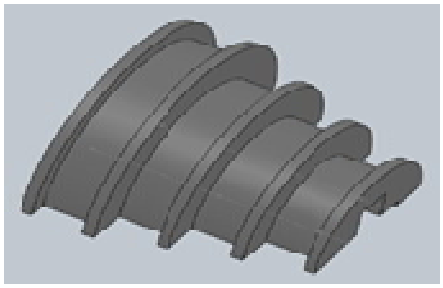

Fig. 6 Aluminium Former

5) *AC Drive VFD-E Series:* A variable-frequency drive (VFD) (also termed adjustable-frequency drive, variable-speed drive, AC drive, micro drive or inverter drive) is a type of adjustable-speed drive used in electro-mechanical drive systems to control AC motor speed and torque by varying motor input frequency and voltage. The Delta's VFD-E series AC Drive is shown in the Fig.7.

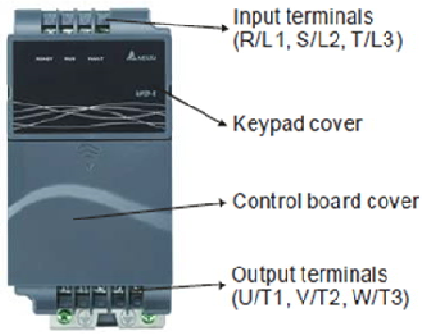

Fig. 7 Delta's VFD-E series AC Drive

VFDs are used in applications ranging from small appliances to the largest of mine mill drives and compressors. However, around 25% of the world's electrical energy is consumed by electric motors in industrial applications, which are especially conducive for energy savings using VFDs in centrifugal load service, and VFDs' global market penetration for all applications is still relatively small. That lack of penetration highlights significant energy efficiency improvement opportunities for retrofitted and new VFD installations.

Over the last four decades, power electronics technology has reduced VFD cost and size and has improved performance through

advances in semiconductor switching devices, drive topologies, simulation and control techniques, and control hardware and software. VFDs are available in a number of different low- and medium-voltage AC-AC and DC-AC topologies.

6) *AC motor:* An AC motor is an electric motor driven by an alternating current (AC). The AC motor commonly consists of two basic parts, an outside stationary stator having coils supplied with alternating current to produce a rotating magnetic field, and an inside rotor attached to the output shaft producing a second rotating magnetic field. This output shaft is connected with the ball screw rod which is going to convert the rotary motion to a linear motion. In automated coil winding machine 0.5 HP AC motor is implemented with the speed of 1440 rpm and this speed is controlled by AC drive.

7) *Encoder:* In this automated coil winding machine incremental encoders are used. An incremental encoder can be used in positioning and motor speed feedback applications which includes servo/light-, industrial- or heavy-duty applications.

An incremental encoder provides excellent speed and distance feedback and, since there are few sensors involved, the systems are both simple and inexpensive. An incremental encoder is limited by only providing change information, so the encoder requires a reference device to calculate motion.

An incremental encoder provides a specified amount of pulses in one rotation of the encoder. The output can be a single line of pulses (an “A” channel) or two lines of pulses (an “A” and “B” channel) that are offset in order to determine rotation. This phasing between the two signals is called quadrature.

The typical assembly of an incremental encoder consists of a spindle assembly, PCB, and cover. The PCB contains a sensor array that creates just two primary signals for the purpose of position and speed. Optionally, additional signals can be provided:

An index or ‘Z’ channel can be provided as one pulse per revolution signal for homing and pulse count verification on the A and/or B channels. This index can be gated to either A or B in their various states. It can also be un-gated and vary in width. Commutation (U, V, W) channels can also be provided on some encoders. These signals are aligned to the commutation windings found on servomotors. They also ensure that the drive or amplifier for those motors apply current to each winding in the correct sequence and at the correct level. The incremental encoder used in our project is shown in the Fig.8.

Fig. 8 Incremental Encoder

8) *Uninterruptible Power Supply:* An uninterruptible power supply, also uninterruptible power source, UPS or battery/flywheel back up, is an electrical apparatus that provides emergency power to a load when the input power source, typically mains power, fails. A UPS differs from an auxiliary or emergency power system or standby generator in that it will provide near-instantaneous protection from input power interruptions, by supplying energy stored in batteries, super capacitors, or flywheels. The on-battery runtime of most uninterruptible power sources is relatively short (only a few minutes) but sufficient to start a standby power source or properly shut down the protected equipment. A UPS is typically used to protect hardware such as computers, data centers, telecommunication equipment or other electrical equipment where an unexpected power disruption could cause injuries, fatalities, serious business disruption or data loss. UPS units range in size from units designed to protect a single computer without a video monitor (around 200 volt-ampere rating) to large units powering entire data centers or buildings.

9) *Switched Mode Power Supply:* A switched-mode power supply (switching-mode power supply, switch-mode power supply, switched power supply, SMPS, or switcher) is an electronic power supply that incorporates a switching regulator to convert electrical power efficiently. Like other power supplies, an SMPS transfers power from a source, like mains power, to a load, such as a personal computer, while converting voltage and current characteristics. Unlike a linear power supply, the pass transistor of a switching-mode supply continually switches between low-dissipation, full-on and full-off states, and spends very

Volume 4 Issue V, May 2016
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

little time in the high dissipation transitions, which minimizes wasted energy. Ideally, a switched-mode power supply dissipates no power. Voltage regulation is achieved by varying the ratio of on-to-off time. In contrast, a linear power supply regulates the output voltage by continually dissipating power in the pass transistor. This higher power conversion efficiency is an important advantage of a switched-mode power supply. Switched-mode power supplies may also be substantially smaller and lighter than a linear supply due to the smaller transformer size and weight. DVPPS series is only used for Delta DVP series. DVPPS series is separated from the PLC MPU for better space utilization and easier installation. The SMPS delta 2 A DVP PS02 is shown in the Fig. 9.

Fig. 9 SMPS Delta 2A DVP PS02

10) *PLC (Programmable Logic Controller):* A programmable logic controller, PLC, or programmable controller is a digital computer used for automation of typically industrial electromechanical processes, such as control of machinery on factory assembly lines, amusement rides, or light fixtures and in this automated coil winding machine the PLC is used to program the machine the ladder logic helps to wound the coils in the aluminium former.

PLCs are used in most of the automation industries. PLCs are designed for multiple arrangements of digital and analog inputs and outputs, extended temperature ranges, immunity to electrical noise, and resistance to vibration and impact. Programs to control machine operation are typically stored in battery-backed-up or non-volatile memory. Here we use Delta PLC 12As 211T. The programmable logic controller is given in the Fig.10.

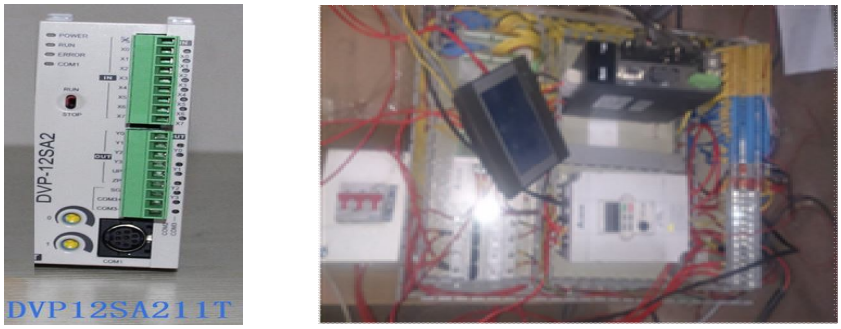

Fig. 10 Programmable Logic Controller

The 2nd generation DVP-SA2 series slim type PLC offers bigger program capacity and executing efficiency, offering 100 kHz high-speed output and counting functions. It is extendable with DVP-S series left-side and right-side extension modules.

11) *Human Machine Interface:* Human Machine Interface is an interface in a manufacturing or process control system. It provides a graphics-based visualization of an industrial control and monitoring system. Previously called an "MMI" (man machine interface), an HMI typically resides in an office-based Windows computer that communicates with a specialized computer in the plant such as a programmable automation controller (PAC), programmable logic controller (PLC) or distributed control system (DCS)

Features of HMI Delta DOP-B03S211

a) Energy Saving And Environmental Automation
b) A Wide Range Of Options
c) Powerful Controller Drives Support
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12) *Power supply:* The machine is working on single phase 230V AC, 50 Hz supply and the machine devise like AC Drive-E series/Three Phase/0.4KW/0.5 HP, Servomotor –A2 SERIES/WITH BRAKE/400 W/3000RPM/TORQUE-1.27NMSMPS-2AMPS, ENCODER-1024 PPR, UPS-600VA are used and the SMPS converts the 230 V in to 24 V DC which is applied to PLC and HMI unit.

B. Working

The input power supply for the automated coil winding machine is single phase 230 V AC, 50HZ supply. The quality of winging is achieved only by the liner and rotary motion of the aluminium former. The liner motion is achieved by servomotor and rotary motion is achieved by AC motor and the ball screw mechanism is implemented in the machine .The incremental encoder is used in between the servo drive and AC drive it count the pulse (ppr) and it provides a loop control in between the drives. The proximity sensor is used to monitor the continuous running of coils in between the spool and the aluminium former. The entire machine operation is programed by PLC ladder logic and for better monitoring HMI is implemented. The input AC power supply is converted to DC 24 V by the SMPS and the SMPS provides power supply to the PLC and HMI unit. The Auto CAD design of the developed automated coil winding machine is shown in the Fig.11. The developed automated coil winding machine have some advantages as followers.

1) Reduction in operating costs as compare to manual operated machine.
2) Fully automatic system so that quality production achieved in less time.
3) Efficiency & Maintenance easy.
4) Affordable price.
5) Simple control.
6) It can be manufactured on large scale.
7) It will provide economical constant over current version of coil winding machine.
8) Reduce insulation paper and coil wastages.
9) Accuracy and control.

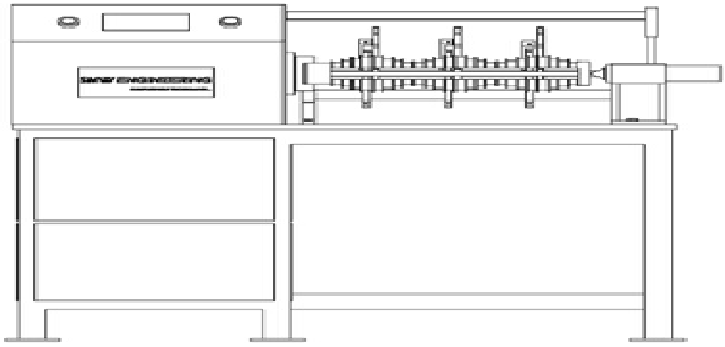

Fig. 11 Auto CAD Design of the Automated Coil Winding Machine

III. CONCLUSION

The automated coil winding machine eliminates over lapping of coils, reduce the overall time taken to wind coils and also it reduces man power involved in winding coils. The HMI provides user friendly environment of high security settings with alarm systems. The overall cost for this machine is around 5 Lakhs. The developed automated coil winding machine is used for winding coil for monoblock pumps and it can be used to wound stator windings for all type of motors and pumps by changing the structure of aluminium former.

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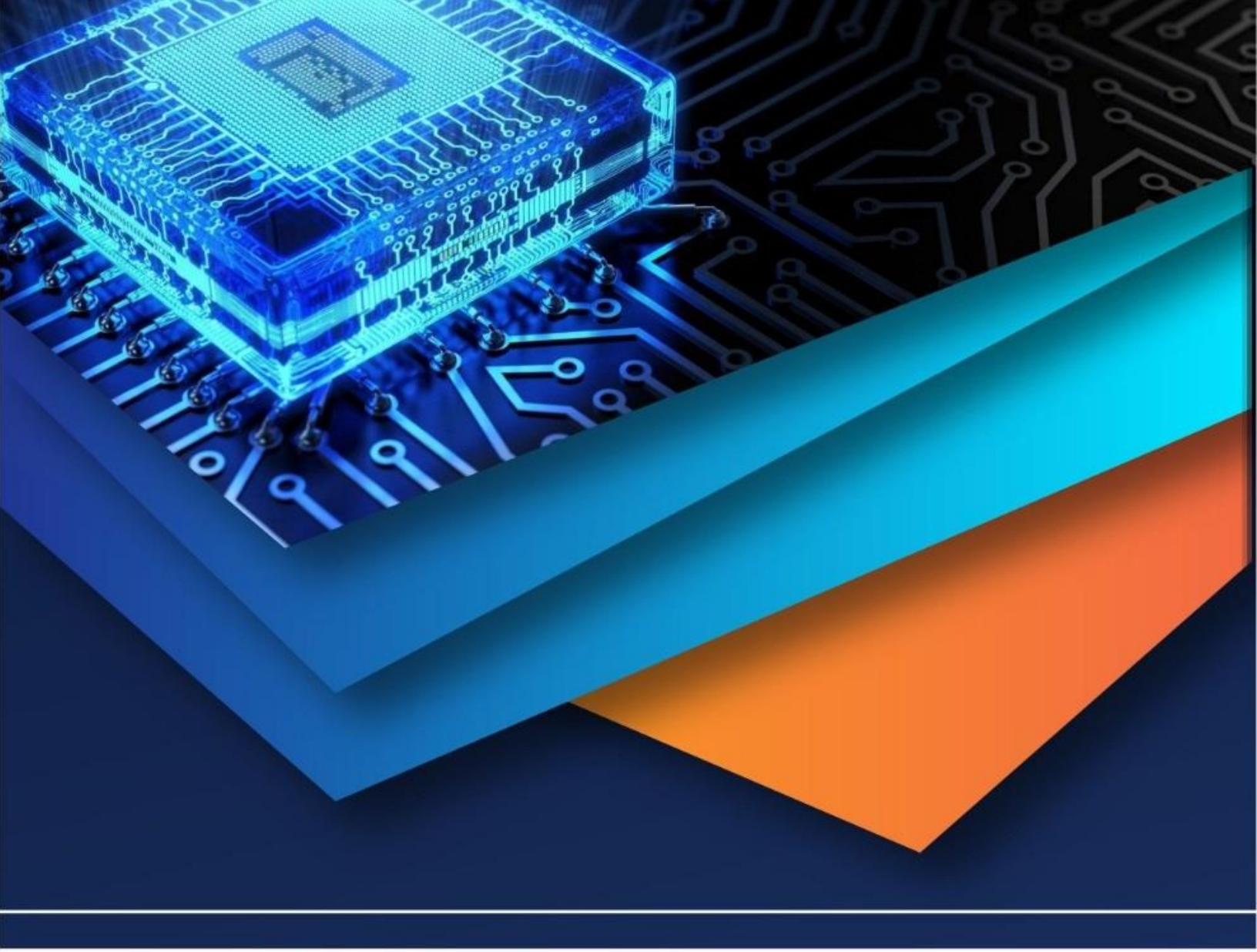

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