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Design and Fabrication of Jigs and Fixture for Radial Drilling Machine in Automotive Industry to Improve Productivity

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Abstract: ***This final year paper report is about the design and Fabrication of jigs and fixtures for manufacturing process. For this project, it is focus on the perspective of the job handling to produce the part. Improvement that is trying to do is by replace the manual handling for the process by designing the jigs and fixture for this process. The objectives of this project are to investigate the collected data and analyse the design of jig and fixture to ease work handling. The methodology adopted for problem identification in connecting rod line are Root cause analysis for quality-related problems is a key and necessary step in the operations of manufacturing processes, especially in high-throughput automated processes. The design of jig and fixtures is using CATIA V5 software. Jigs and fixtures are specially designed so that large numbers of components can be machined and to ensure interchangeability of components. To reducing the setup, loading, unloading and machining time during drilling, reaming, Tapping and chamfering operation. The jigs and Fixture is successfully designed and implemented for the radial drilling machine for line balancing of existing connecting production line and it help to ease the handling of the job. It will make easy, quick and consistently accurate locating, supporting and clamping the blank in alignment of the cutting tool. Guidance to the cutting tool like drill, reamer, tap etc. Increase in productivity and maintain product quality consistently. It will reduce operator's labour and skill requirement, Also reduce measurement and its cost. After the implementation of jigs and fixture on Radial drilling machine the non-productive time (loading and unloading) was reduced from 78 seconds to 52 Seconds and machine setup time reduced to 120 to 96 seconds also machining time reduced to 38 to 30 seconds due to increase in spindle speed where the difference of 58 seconds is converted as the productive time and this will help to overcome the problem of bottleneck in existing connecting rod production line, productivity will be improved and this also helps to good will of the company.***

Keywords: Drilling, jigs and fixture, root cause analysis, connecting rod etc

I. INTRODUCTION

A radial drilling machine or radial arm press is a geared drill head that is mounted on an arm assembly that can be moved around to the extent of its arm reach. The most important components are the arm, column, and the drill head. The drill head of the radial drilling machine can be moved, adjusted in height, and rotated. Aside from its compact design, the radial drill press is capable of positioning its drill head to the work piece through this radial arm mechanism. The tasks that a radial drilling machine can do include boring holes, countersinking, and grinding off small particles in masonry works.

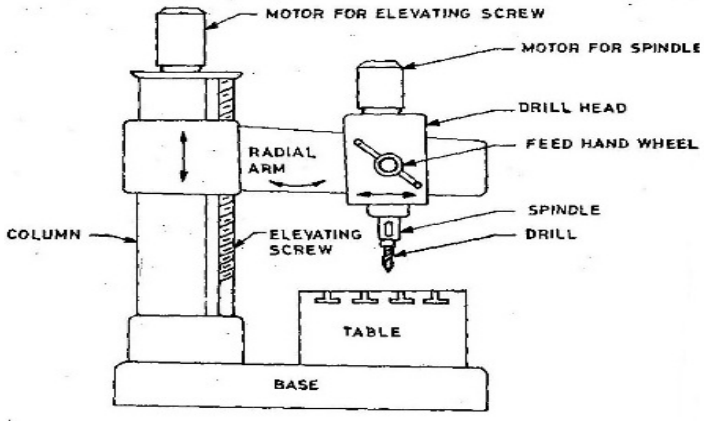

Fig 1 Radial drilling machine

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A. Jigs and Fixtures

A jig is a type of custom-made tool used to control the location and motion of parts or other tools. A jig is often confused with a fixture, a fixture holds the work piece in a fixed location. A device that does both functions (holding the work piece and guiding a tool) is called a jig. Drilling Jigs are used to machine holes in mechanical products to obtain positional accuracy of the holes. A fixture's primary purpose is to create a secure mounting point for a work piece. It allows support during operation and increases accuracy, precision and reliability in the finished parts. It also serves to reduce working time by allowing quick set-up, and by smoothing the transition from part to part.

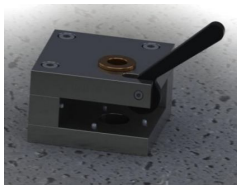

Fig 2. Drilling Jig

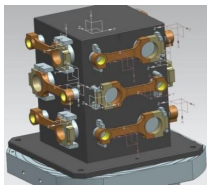

Fig 3. fixture

B. Connecting rod Manufacturing Line

Connecting Rod is most Critical Part of Engine as it is subjected to dynamic load in operation. The material, machining operations, dimensional tolerances, geometrical tolerances and surface finish requirement are very stringent. In addition to this maintaining Center distance between small and big end bores, Bend and twist of connecting rod within specified limits is also critical. Normally connecting rods are forged and the material used is typically mild and medium carbon steel. The end where the rod is connected to the crosshead on crank-pin has bearings which are made up of white metal working surface and shims are used to make the necessary adjustment. There are four bolts at each connection point which help for assembly and removal of connecting rod and are tightened to their required torque using hydraulic jack. The layout of connecting rod manufacturing line involves about 25 operations carried-out on 15 machines consisting mainly SPM, CNC Machines and General Purpose Machines. There is also backtracking of components in the lay-out for few operations. The tolerances required are very close and operations in each stage are closely controlled.

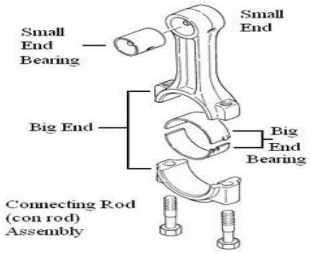

Fig 4. Parts of connecting rod

Kataria Mahendra B.et.al [1]Suggested that Jig is device which is used to hold the workpiece or fix the work piece and guide the cutting tool. The purpose of the jigs is to provide strength, holding, accuracy and interchangeability in the manufacturing of product. The objective of this project is to design and development of drill jig. We found that there is problem in auto part which required three holes of diameter 8.05mm at 120°with the help of drilling manually. It is time consuming process. Also skills and accuracy is required. So with the use of jig time consumption for drilling three holes is less. Drilling jigs make possible the drilling of holes at higher speed with greater accuracy and with less skilled worker and after the implementation, Jigs and fixtures eliminate the individual marking, positioning, and frequent checking. This reduces operation time increases productivity, facilitate uniform quality in manufacture labour effort reduces and substantial saving in labor cost.

ABHIJIT TAGADE.et.al [2] This project is proposed method to design modified angle jig for the drilling holes on given component. Thus, the time required for the production of component should be decreased to as small as possible with the help of these jig. The marking time, loading and unloading time can be get minimize with reduction in rejection, and cost effectiveness tool. In this paper we starts from basic conceptual design of jig and comes up with this model which can satisfy theoretical concepts of jig design. The 3D model design done on Solidworks & 2D drafting carried on using Auto-CAD

Sathish Kumar.et.al [3] In this project, preventive maintenance and a breakdown reduction methodology is adopted to improve the machine performance. Root cause analysis is conducted to find the root cause of breakdowns and some parallel improvement opportunities were also identified for implementation so as to reduce the downtime. The project thus aims to minimize downtime,

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maximize availability, minimize maintenance cost and maximize profit. The use of root cause analysis helped to identify the correct causes of failures by which the suitable counter measures are developed and implemented. The process measurable such as Availability, MTBF, and MTTR are calculated before and after the implementation Breakdowns such as Rollers problem, Spout unit problem, Impeller problem in Disa Shot Blast Machine is completely eliminated.

Burra Venkata.et.al [4]first main focus of this Project is to check the stress distribution on the tail wing during the face milling process by simulating the CAD model of the tail wing by applying cutting forces which are estimated using Merchant circle diagram and evaluating its design strength by factor of safety which is found to be suggesting the operation could be performed with given cutting parameters. The second focus is about the jig-fixture assembly designed for the milling operation on tail wing. This part of thesis precisely aims on verifying the design strength of the base plate of the assembly by estimating and applying the forces on the base plate during its transportation.

II. OBJECTIVES AND SCOPE

The main objective of the study is to improve the productivity of the firm's engine connecting rod manufacturing line. To attain this main objective, the following incidental objectives are sought to be achieved.

A. To analyze root causes of bottlenecks in the manufacturing line.
B. Adopting new generation tools like horizontal machining centers.
C. Design of Jigs and fixture for eliminating the time consuming problems while machining.
D. Review of general inspection methods for maintaining better quality

The scope of the above activity is relevant to the Mechanical Engineering and offers an opportunity for in-depth study of existing system to arrive at the root cause and evolve solutions to address the need for production, quality and resource optimization.

III. METHODOLOGY

A detailed study on the project is also done through the direct interaction with the employees and by timely studying the happening of the company.

A. Root Cause Analysis

To meet up the high changing market demands along with high quality at comparable prices, one shall have to identify quickly the root causes of problems by reviewing an event, with the goals of determining what has happened, why it has happened and what can be done to reduce the likelihood of recurrence. Root-cause identification for quality and productivity related problems are key issues for manufacturing processes. It has been a very challenging engineering problem particularly in a multistage manufacturing, where maximum number of processes and activities are performed. However, it may also be implemented with ease in each and every individual set up and activities in any manufacturing process. There are varieties of problems related to product quality and productivity in industries due to varying degrees of abnormality and inefficiency which ultimately causes rejection. Root-cause identification for quality-related problems is a key and necessary step in the operations of manufacturing processes, especially in high-throughput automated processes.

B. Cycle Time Calculation

It's the time period required to complete one cycle of an operation or complete function, job, task from start to finish. Cycle time is used in differentiating total duration of a process form it's run time. Cycle time taken for each and every machine using the stop watch to identify the bottle neck operation in the cell.

OpnNo	Process description	Setup Time in sec	Loading and unloading Time in sec	Machining Time in sec	Cycle Time in sec
1	Shot Peening Machine	40	35	20	95
2	Surface Grinding-Top And Bottom Grinding	120	62	30	212
3	Boring And Slitting Machine	121	49	24	194

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	-Small And Soft Boring-Big End Slitting				
4	BTW-Cnc Boring And Milling Machine-Big End Boring-Side And Bolt Seat Milling	173	86	42	299
5	Lathe-Small And Rough Boring	45	14	14	73
6	ELECTRONIC SPM	-	-	-	-
7	4-Spindle Machine-Radial -Drilling, Reaming, Tapping And Chamfering	120	78	38	236
8	HMT-RM62 Radial Drilling Machine-Tapping Of Bolt Hole	30	24	12	66
9	Notch Milling Machine-Notch Milling Of Rod End Cap	62	25	12	99
10	WIDAM – Single Spindle Gun Drilling Machine-Gun Drlling Of Oil Hole In Rod	60	35	17	112
11	GMT- Lapping Machine-Lapping Of Joint Faces In Rod End Cap	31	20	10	61
12	WIDAM – 2 Spindle Fine Boring Machine – Spm-Finish Boring Of Big And Small Ends- Big End Chamfering-Soft Bore	330	115	55	500
13	MICO- Weighing And Balancing SPM -Manual Work	-	-	-	-
14	V58-50 Single Spindle Honing Machine-Honing Of Big End Bore	75	31	15	121

Table 1. Cycle time Calculation

C. Study on Backtracking In Engine Connecting Rod Manufacturing Line

Fig 5 shows the layout design of engine connecting rod manufacturing line indicating the presence of backtracking. The upward flow of material in any production line is called backtracking. According to the Cycle time calculation in a connecting rod line SPM 4 spindle machine Consuming more time while machine setup, loading and unloading condition hence its necessary to design new jigs and fixture to eliminate problem associated with the radial drilling machine and by avoiding the unnecessary movement of material increases overall cycle time as shown in the figure thus there is a need for improvement in overall cycle time.

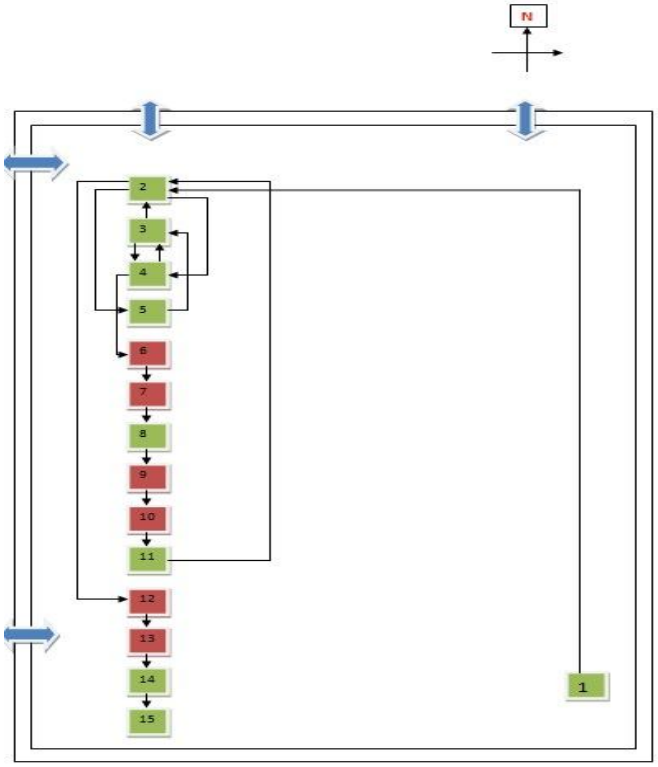

Fig 5. Layout of connecting rod manufacturing line

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IV. DESIGN AND DEVELOPMENT OF JIGS AND FIXTURE

1) Design of jigs and fixture should be such that there will not be any damage on part during loading /unloading and clamping / unclamping.
2) Fool proofing of part loading to be considered to avoid wrong loading of part direction and wrong part on loading stations.
3) Part should be easily located and fixture should have proper bottom rest face.
4) Rest pads and locating pins should be replaceable. It should be possible to replace without affecting the alignment.
5) Rest pads and locating pins should be hardened and ground. Sufficient chamfer should be provided for locating pins to facilitate easy and damage free component entry.

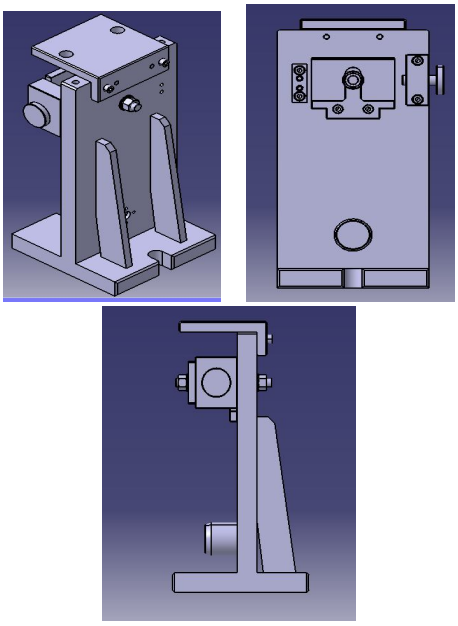
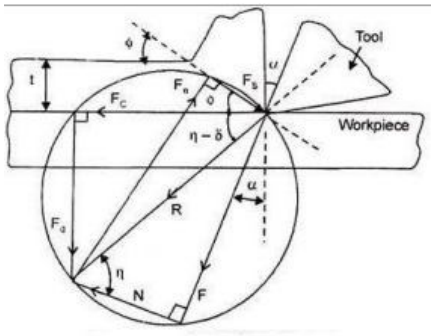


Fig 6. CAD model of Jigs and fixture

A. *Design Process*

Merchant circle diagram is used to analyze the forces acting in metal cutting. The analysis of three forces system, which balance each other for cutting to occur. Each system is a triangle of forces



Assumptions made in drawing Merchant's circle

1) Shear surface is a plane extending upwards from the cutting edge.
2) The tool is perfectly sharp and there is no contact along the clearance force.
3) The cutting edge is a straight line extending perpendicular to the direction of motion and generates a plane surface as the work moves past it.
4) The chip doesn't flow to either side that is chip width is constant.
5) The depth of cut remains constant.
6) Width of the too, is greater than that of the work.
7) Work moves with uniform velocity relative tool tip.
8) No built up edge is formed.

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Let
α = Rake angle
Ø = shear angle
B = friction angle
Fc=Horizontal cutting force
Ft=Vertical thrust force
Fs=Shear force along shear plane
Ff=Frictional force along tool face
Fn=Force normal to Ff
Fns=Force normal to Fs
μ=Co-efficient of friction
R=Resultant force

B. Design Calculations

1) Cutting Speed (Vc) - rate at which the outside or periphery of the tool moves in relation to the work being drilled.

$$Vc = \frac{Dc * \pi * n}{1000}$$

$$Vc = \frac{18.5 * \pi * 1375}{1000}$$

V_C = 80 m/min

2) Penetration rate (Vf) - is the speed at which a **drill** bit breaks the rock under it to deepen the borehole.

V_f = fn * n
V_f = 0.2 * 1375
V_f = 0.275 m/min

3) Metal removal rate (Q) - it's the volume of the material removed by the drill bit**.**

$$Q = \frac{DC * fn * Vc}{4}$$

$$Q = \frac{18.5 * 0.2 * 80}{4}$$

Q = 7.4 Cm3/min

4) Net Power (Pc)

$$Pc = \frac{fn * Vc * Dc * Kt}{240 * 103}$$

$$Pc = \frac{0.2 * 80 * 13.5 * 3100}{240 * 103}$$

Pc = 3.82 Kw

5) Torque (Mc)

$$Mc = \frac{Pc * 30 * 103}{\pi * n}$$

$$Mc = \frac{3.82 * 30 * 103}{\pi * 1375}$$

Mc = 265.49 N-M

6) Feed Force calculation

$$F_f = \frac{0.5 * Kt * Dc * fn * Sin Kr}{2}$$

$$F_f = \frac{0.5 * 3100 * 18.5 * 0.2 * Sin 125}{2}$$

F_f = 2348.91N

Feed force applied must be approximately equal to 2350N

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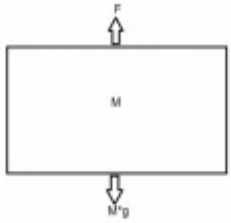
7) Parameters of an Drilling operation

Parameters	Value
Cutting Speed Vc (m/min)	80
Diameter of drill Dc(mm)	18.5
Feed fn (mm/rev)	0.2
Spindle speed n(rpm)	1375
Machine efficiency	0.85
Specific Cutting force Kc(Mpa)	3100
Main cutting edge Kr(degree)	125^0

Table 2. Parameters of Drilling operation

To lift the entire assembly equal amount of force must be applied in the opposite direction according to Newton's law.



To lift the mass of the assembly, $F \geq M * g$
M is the mass of the entire assembly, i.e., combined weight of the Top plate, Truss structure and Base plate.

Component	Mass (Kg)
Jigs and Fixture structure	60
Top Plate	80
Base Plate	150

Table 3. Details of a Mass assembly

Therefore, the entire mass of the assembly is 290 Kg.
There holding force of the component assembly
290 * 9.81 = 2844.9N
Holding force of the component assembly approximately equal to 2850N
Holding force of the component assembly 2850N is greater than applied Feed force 2350N therefore Jigs and fixture in safer condition and design is accepted.

V. RESULT AND DISCUSSION

Jigs and fixtures are manufacturing tools that are employed to produce interchangeable and identical components. They are unique tool-guiding and work-holding devices designed specifically for machining and assembling large number of parts. In the existing production line radial drilling machine under bottle neck condition and consuming more production time of about 236 seconds and leading to decreases in productivity. therefore it provides a opportunity to design and fabricate Jigs and Fixture in order to rigidly clamp the Connecting rod during Drilling, Reaming, Tapping and chamfering operation also faster loading and unloading of connecting rod.

A. Assembly of Jigs and fixture

The assembly of jigs and fixture is mainly consists of L-plate structure, cylinder locator, rest pad, clamping screw, special washer, jig-plate and jig-bush etc in order to clamp the connecting rod during machining operations like drilling, reaming, chamfering and tapping operations, overall weight of the jigs and fixture is 60kg.

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Fig 7. Assembly of Jigs and fixture

B. Mounting of Jigs and fixture on Radial Drilling Machine

The assembly of Jigs and fixture on top of the Radial Drilling Machine is as shown in the figure here on top of the base-plate and machine bed, Jigs and fixture is mounted and overall weight of the assembly is 290kg and holding force of an assembly 2850N.

Fig 8. Mounting of Jigs and fixture on Radial Drilling machine

C. Machining of connecting rod on Jigs and fixture in Radial Drilling Machine

mounting and clamping of Connecting on jigs and fixture in order to perform machining operations like drilling, reaming, chamfering and tapping operation. In The proposed jigs and fixture setup time, loading and unloading time required is considerably reduced also machining time is reduced with increasing spindle speed due to proper holding force. Time required for setup, loading and unloading and machining operations is listed in the below table

Fig 9. Machining of connecting rod on Jigs and fixture in Radial drilling machine

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Sl no	Operations	Time consumed Before implementation of jigs and fixture in sec	Time consumed After implementation of jigs and fixture in sec
1	Machine-Setup	120	96
2	Loading and unloading	78	52
3	Machining operations	38	30
		236	178

Table 4. Time consumed before and after implementation of jigs and fixture

From the above table it shows that After the implementation of jigs and fixture on radial drilling machine the non-productive time (loading and unloading) was reduced from 78 seconds to 52 seconds and machine setup time reduced to 120 to 96 seconds also machining time reduced to 38 to 30 seconds due to increase in spindle speed where the difference of 58 seconds is converted as the productive time and this will help to overcome the problem of bottleneck in existing connecting rod production line, productivity will be improved and this also helps to good will of the company.

VI. CONCLUSION

The jigs and Fixture is successfully designed and implemented for the SPM 4-spindle machine for line balancing of existing connecting production line and it help to ease the handling of the job by reducing the setup, loading, unloading and machining time during drilling, reaming, Tapping and chamfering operation. It will make easy, quick and consistently accurate locating, supporting and clamping the blank in alignment of the cutting tool. Guidance to the cutting tool like drill, reamer, tap etc. Increase in productivity and maintain product quality consistently. It will reduce operator's labour and skill requirement, Also reduce measurement and its cost. Enhancing technological capacity of the machine tools. Reduction of overall machining cost and also increases in interchangeability.

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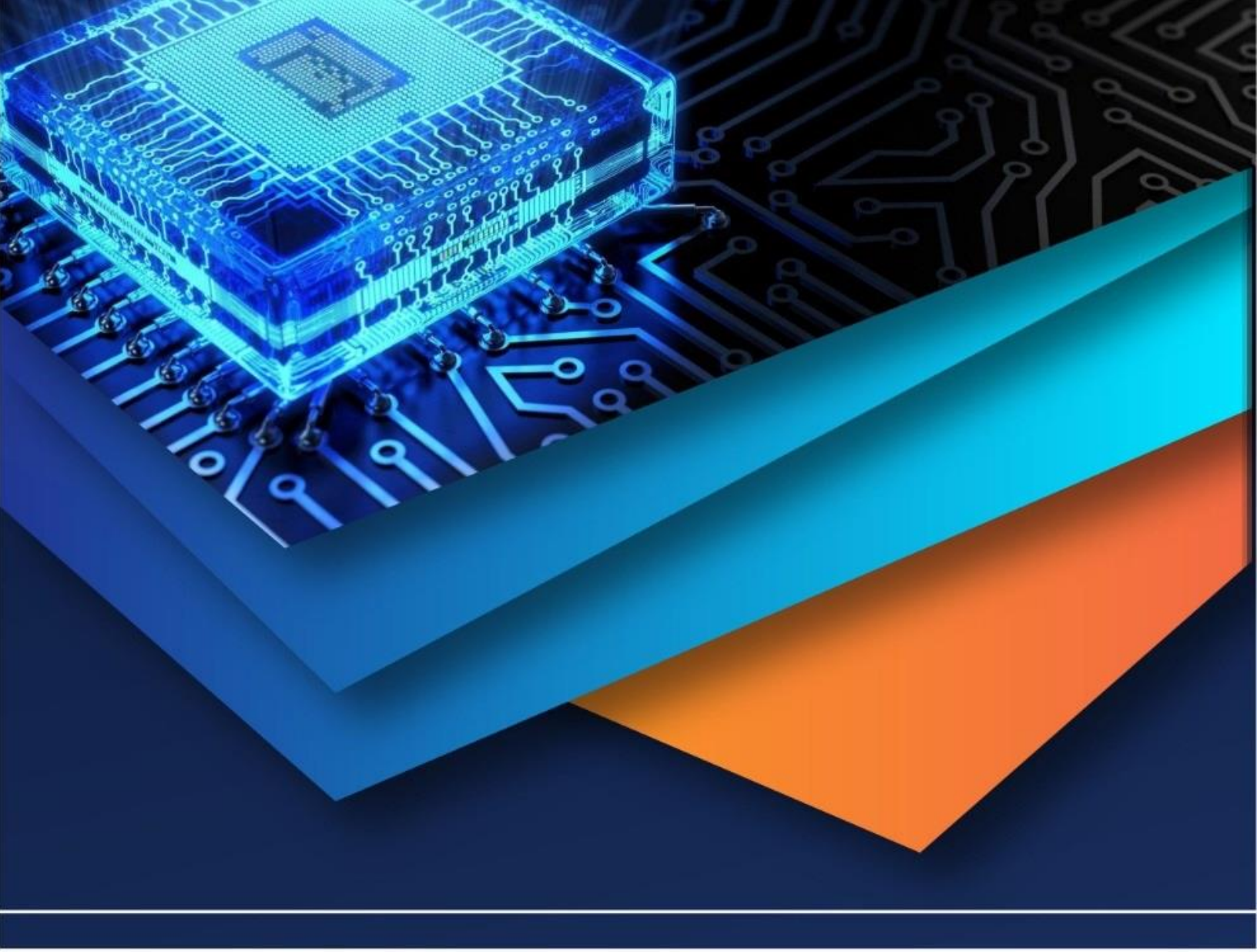

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