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Design Improvement of Base Plate of Fixture using FEA Analysis

Megha Mohite[1], Santosh Trimbake[2], Vinay Ugale[3]
[1, 2, 3]*Mechanical Department, College of Military Engineering, Pune*

Abstract: Fixture design is a highly complex and intuitive process. Fixture is a special purpose work holding device which improves the efficiency, method and class of doing work with repeatability and accuracy.
Proper fixture design could improve the quality of products and reduce the cost as well as the time required for manufacturing. In machining fixtures, minimizing workpiece deformation due to clamping and cutting forces is essential to maintain the machining accuracy, surface finish and overall quality of the machined component. This paper presents a case study of fixture which leads to poor surface finish on machined component because of deflection in fixture due to improper clamping of the base plate of fixture.
The fixture considered here is mechanical fixture for holding a job which undergoes the milling process. The analysis was carried for design improvement of base plate using FEA (Finite Element Analysis) which helps to obtain better clamping which further helped in achieving good surface finish.
Findings of this analysis showed that by improving the base plate design, directional deformation and overall Von-Mises stresses has reduced appreciably which helped to achieve desired surface finish and accuracy of the product.
Keywords: Fixture, Clamping, Base plate, Von Mises stress, FEA

I. INTRODUCTION

A fixture is a work-holding or support device used in the manufacturing industry [1]. Fixtures are used to securely locate (position in a specific location or orientation) and support the work, ensuring that all parts produced using the fixture will maintain conformity and interchangeability.
Using a fixture, improves the economy of production by allowing smooth operation and quick transition from part to part, reducing the requirement for skilled labour by simplifying how workpieces are mounted, and increasing conformity across a production run
Fixture is special purpose tool which are used to facilitate production (machining, assembling and inspection operations), when work piece is based on the concept of interchangeability according to which every part will be produced within an established tolerance [2].
Fixture eliminates the necessity of a special set up for each individual part. Fixtures have a much-wider scope of application. These work holders are designed for applications where the cutting tools cannot be guided as easily as a drill. Fixtures are used in most of the manufacturing operations such as machining, inspection, welding, assembly and etc. to found and secure designed position and direction of the workpiece as required by design descriptions [3].

II. PROBLEM DEFINITION

This paper presents a case study of milling fixture which was used for machining by clamping it on VMC (Vertical Milling Machine). Because of extra overhang length of the fixture body, preliminary design of fixture was not complying with the design requirement.
The fixture was acting like a cantilever because of the forces acting on its free end, resulting in the vibration which affects the surface finish as well as an accuracy of the product. One of the solutions to overcome with this problem is to modify the design of fixture. After studying the different causes responsible for poor surface finish and vibrations decision was made to improve the rigidity of fixture.
With increase in rigidity, it enables the fixture to sustain against the high forces acting upon free end of workpiece and reduce the vibrations which consequently helps for achieving the good surface finish. Therefore the final decision was considered to improve the rigidity of the fixture by improving the design of base plate.

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III. STUDY OF BASE PLATE OF EXISTING FIXTURE

Fig.1 shows the base plate of fixture which gets held in the collet of the machine. Base plate of fixture gets clamped directly on the machine table with the M10 size bolts which are 5 in number. As the shaft of base plate fixes inside the machine collet, the shaft has got defined as a fixed support.

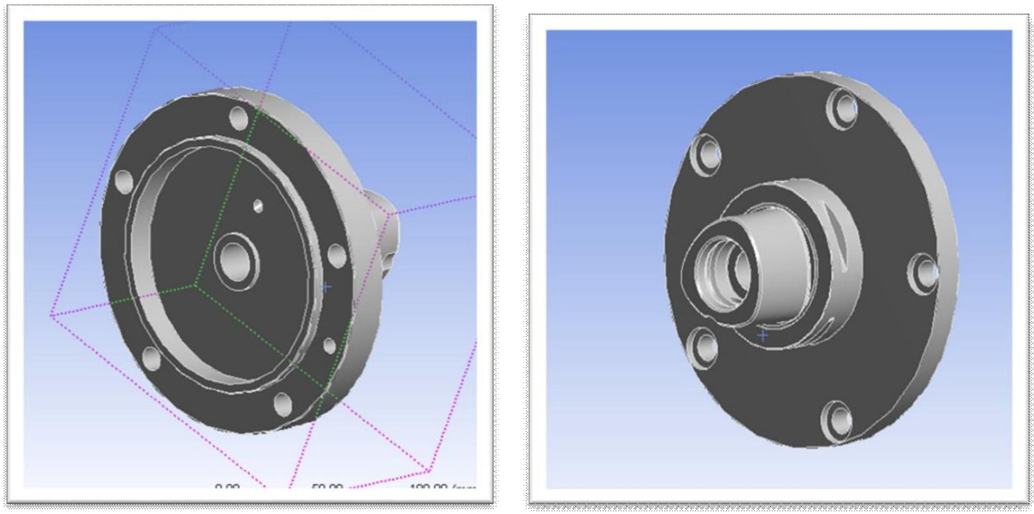

Fig.1- Base plate

A. Numerical Model Base Plate of Existing Fixture With ANSYS Software 13.0

Static Structural Non-Linear Analysis in ANSYS 13.0[4]

1) *Geometry Simplification*: To reduce the complexity of the finite element modeling minute details are neglected here.
2) *Meshing Strategy:* Base plate of fixture is complex to mesh with hexahedral elements so they are meshed with lower order tetrahedral elements. Finalization of element size is done on the basis of stress convergence. Same strategy has been adopted for modified fixture [5]. Fig.2 shows the original base plate of fixture whereas fig.3 shows the meshed model.
3) *Element Type:* SOLID185 is used for 3-D modeling of solid structures. It is defined by eight nodes having three degrees of freedom at each node: translations in the nodal x, y, and z directions. It allows for prism and tetrahedral degenerations when used in irregular regions. Same strategy has been adopted for modified fixture.
4) *Loading and Boundary Conditions:* Since the shaft of base plate fixes inside the machine collet, the shaft has got defined as a fixed support, which locks all degrees of freedom for that particular area and the maximum force acting on the fixture was taken as 1800N as shown in fig. 4. After meshing, boundary conditions and loads are applied on the nodes and then solver is set to obtain the solution. Further in Postprocessor results are analysed. Von-Mises Stress plots and Directional deformation plots are taken for visualization and interpretation of results.

Fig.2- Original model

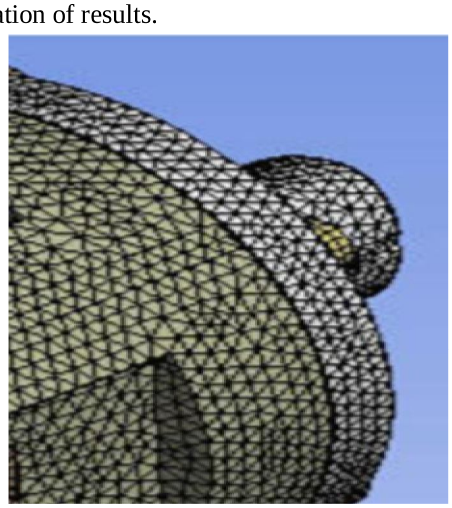

Fig.3-Meshed FEA model

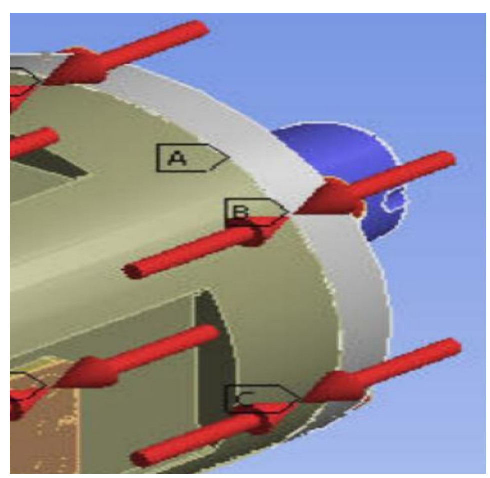

Fig.4-Loading and boundary conditions

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B. FEA Analysis of base plate of Existing Fixture

1) Von Mises stresses near bolt region are in the range of 195- 230 N/mm^2 after ignoring localized stresses. Overall von- Mises stresses in body are in the range of 0 – 148 N/mm^2 (Fig.5).
2) Referring to fig.6 directional deformation in original fixture was 6.97 µm.

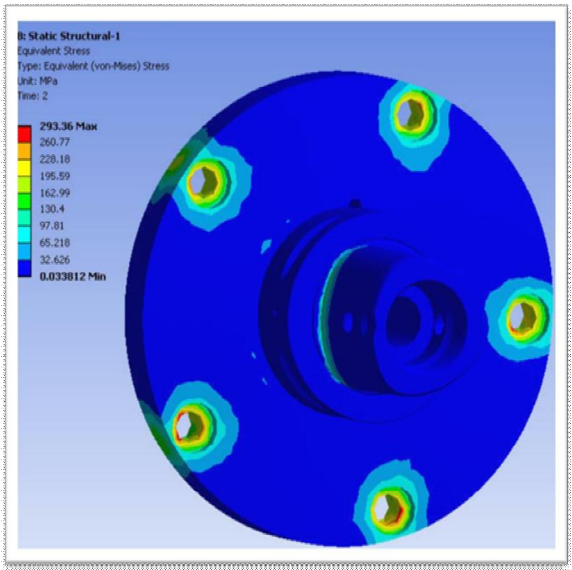

Fig.5-Von-mises stress plot

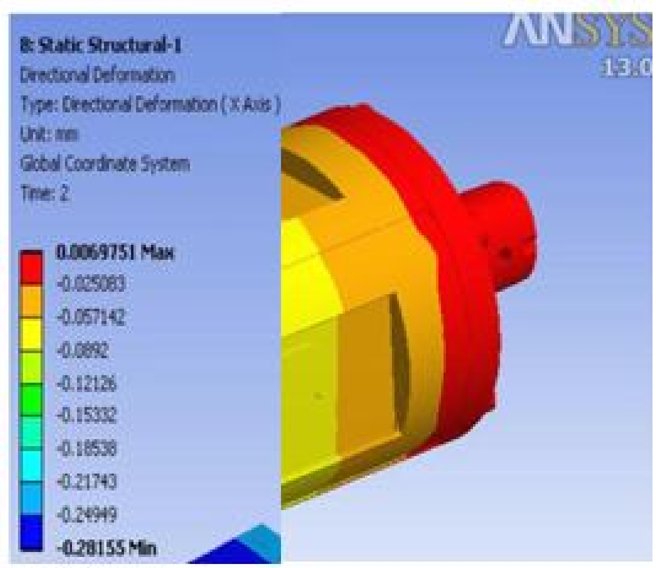

Fig.6- Directional deformation plot

IV. STUDY OF BASE PLATE OF MODIFIED FIXTURE

Based on analysis, the major factor affecting the deflection and stresses within the fixture was seen as the extra overhang length of the fixture body, which cannot be avoided. The second major cause of the deflection was the insufficient clamping and support of the baseplate, which is provided by clamping the protruded shaft, which was not able to sustain the loads acting on the fixture body. To overcome the above constraints there was a need to improve the fixture design. After the brainstorming sessions, it was concluded that there was the need to replace the protruded shaft by some other means to provide effective clamping to have less deflection of plate and overall fixture body. Thus direct clamping was provided to machine table so major factor affecting deflection (protruded shaft) in original model was minimized. Fig.7 and fig.8 shows the design of base plate of original fixture and modified fixture.

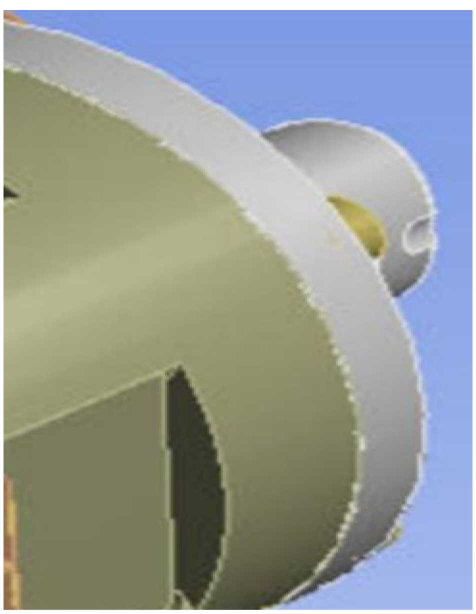

Fig.7-Original model

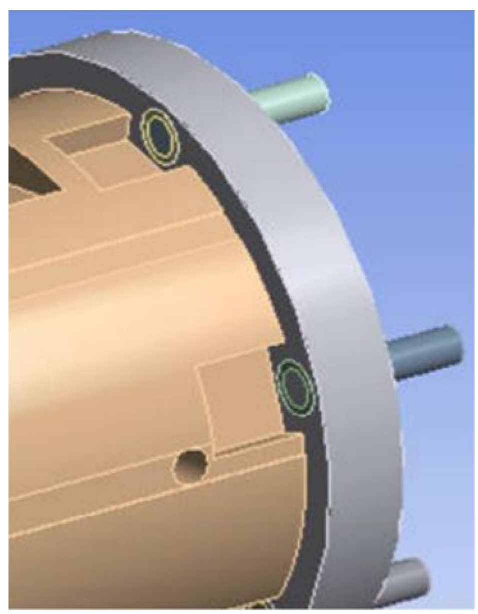

Fig.8 Modified design model

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A. Numerical Model of Base Plate of Modified Fixture With ANSYS Software 13.0

Static Structural Non-Linear Analysis in ANSYS 13.0[4]

1) *Loading and Boundary Conditions:* Since the base plate which gets clamped by bolting onto the machine table, thus the bolts were defined as a fixed support, which locks all degrees of freedom for that particular area. The red coloured cylindrical portion is allowed to displace along Z-direction only. The red indicated surface of the base plate is allowed to displace along X and Ydirection. The maximum force acting on the fixture is taken as 1800N. Fig.9 shows the meshed model of modified fixture design whereas fig.10 shows modified fixture with loading and boundary conditions.

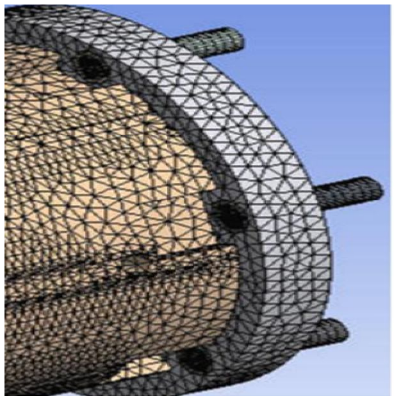

Fig.9-Meshed FEA model

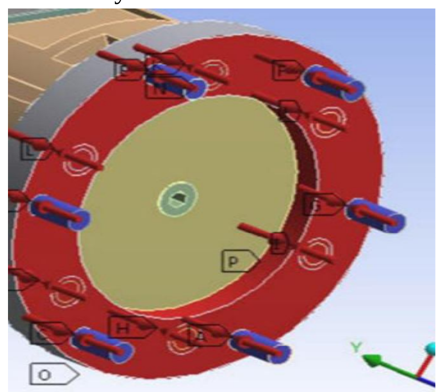

Fig.10-Loading and boundary conditions

B. FEA Analysis of base plate of Modified Fixture

1) Von Mises stresses near bolt region are in the range of 121 - 145 N/mm^2 after ignoring localized stresses. Overall von-Mises stresses in body are in the range of 0 - 95 N/mm^2 (Fig.5).
2) Referring to fig.6 directional deformation in original fixture was 6.97 µm.

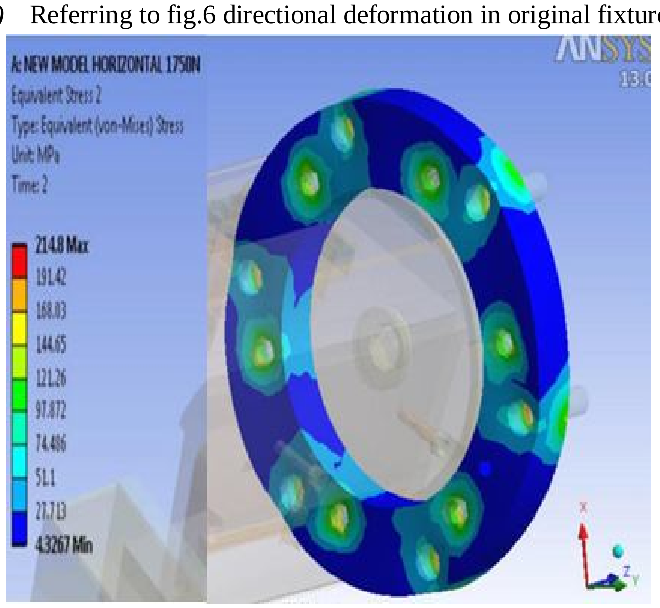

Fig.11-Von-Mises stress plot

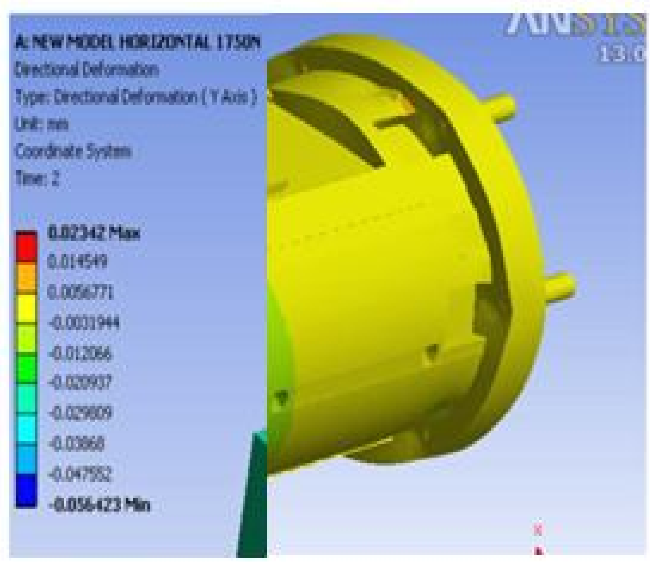

Fig.12-Directional deformation plot

V. RESULTS AND DISCUSSION

A. Overall Von- Mises stresses in original fixture were seen to be 148 N/mm^2. Stress got reduced by 35% to the value of 95N/mm^2 by virtue of design improvement as shown in fig.13.

B. Von-Mises stresses near bolt region are in the range of 195 – 230 N/mm^2 for original fixture design. With design improvement the stress level were reduced to 121 - 145 N/mm^2 after ignoring localized stresses as shown in fig.14.

C. Directional deformation was observed as 6.97 µm for original fixture design which was reduced to 3.19 µm in modified fixture design. Therefore overall reduction in directional deformation was 54% as shown in fig.15.

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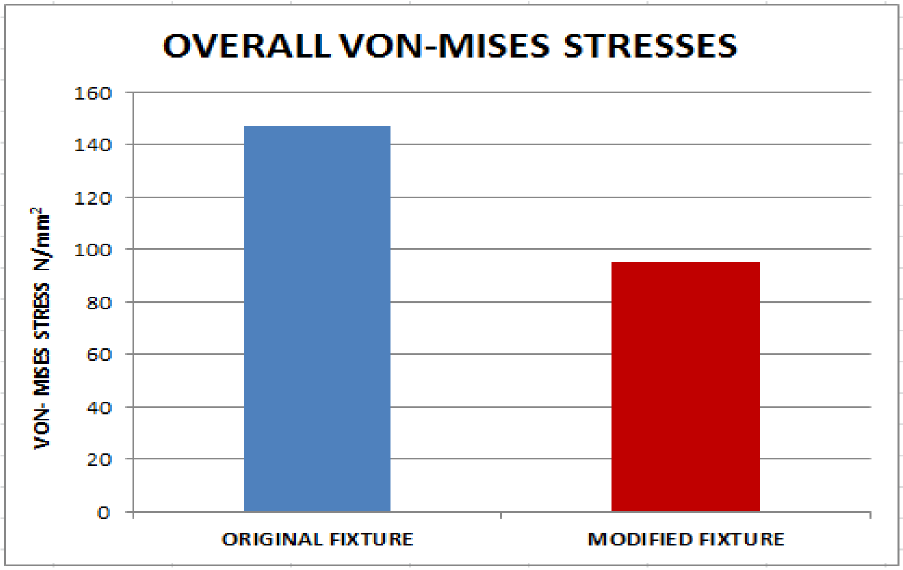

Fig.13- Overall Von-Mises stresses

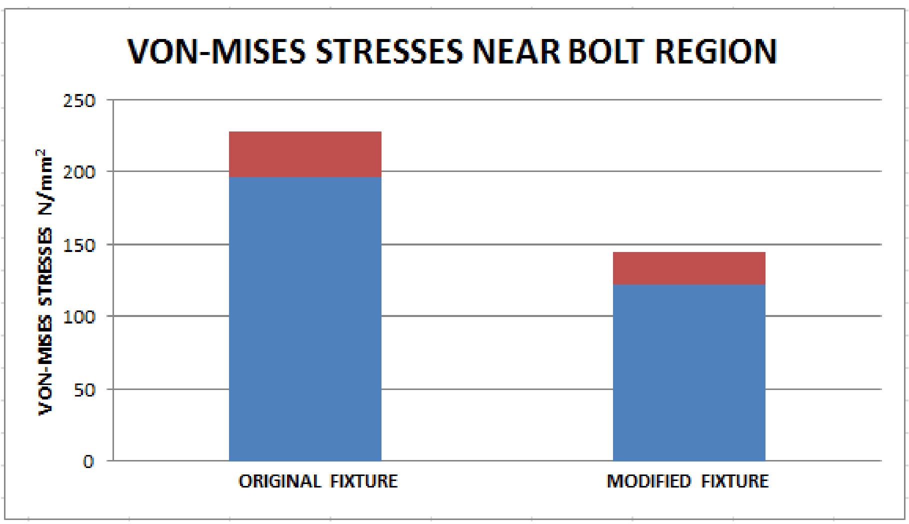

Fig.14- Von-Mises stresses near bolt region

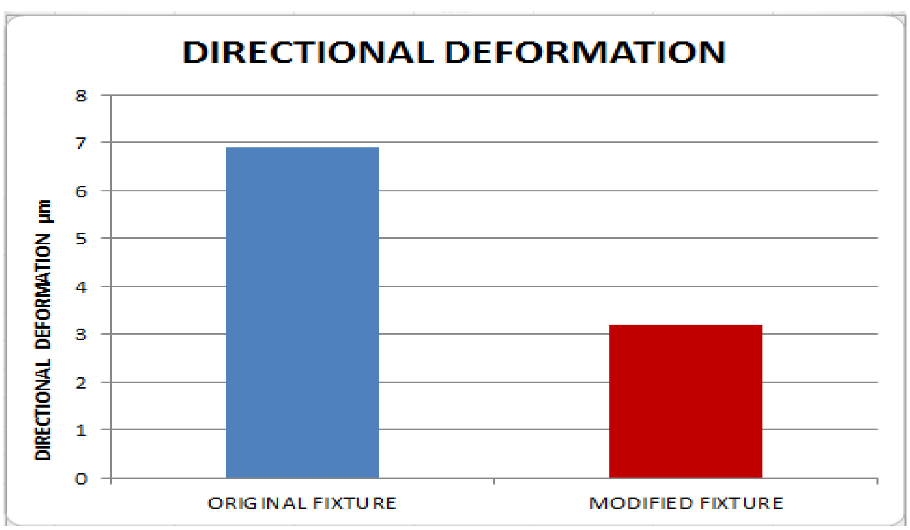

Fig.15- Directional deformation

VI. CONCLUSIONS

A. Based on the numerical analysis of base plate of original fixture, it was observed that the major cause of the stresses and deflection was the insufficient clamping and support of the baseplate, which was provided by clamping the protruded shaft, which was not able to sustain the loads acting on the fixture body.

B. Thus in modified fixture design direct clamping was provided to machine table so the major factor affecting stresses and deflection in original model was minimized.

C. With improvement in design, the reduction in overall Von-Mises stresses was found to be 35%, whereas near bolt region Von-Mises stresses reduced from 195– 230 N/mm^2 to 121 - 145 N/mm^2 after ignoring localized stresses.

D. Reduction in directional deformation was appreciable and was to the tune of 54%.

E. With enhancement in rigidity of the fixture, the vibrations are reduced which further helps for achieving the desirable surface finish.

F. With improvement in design, the quality of clamp has improved which also helped to reduce the machining time and cost of manufacturing which ultimately increases the productivity.

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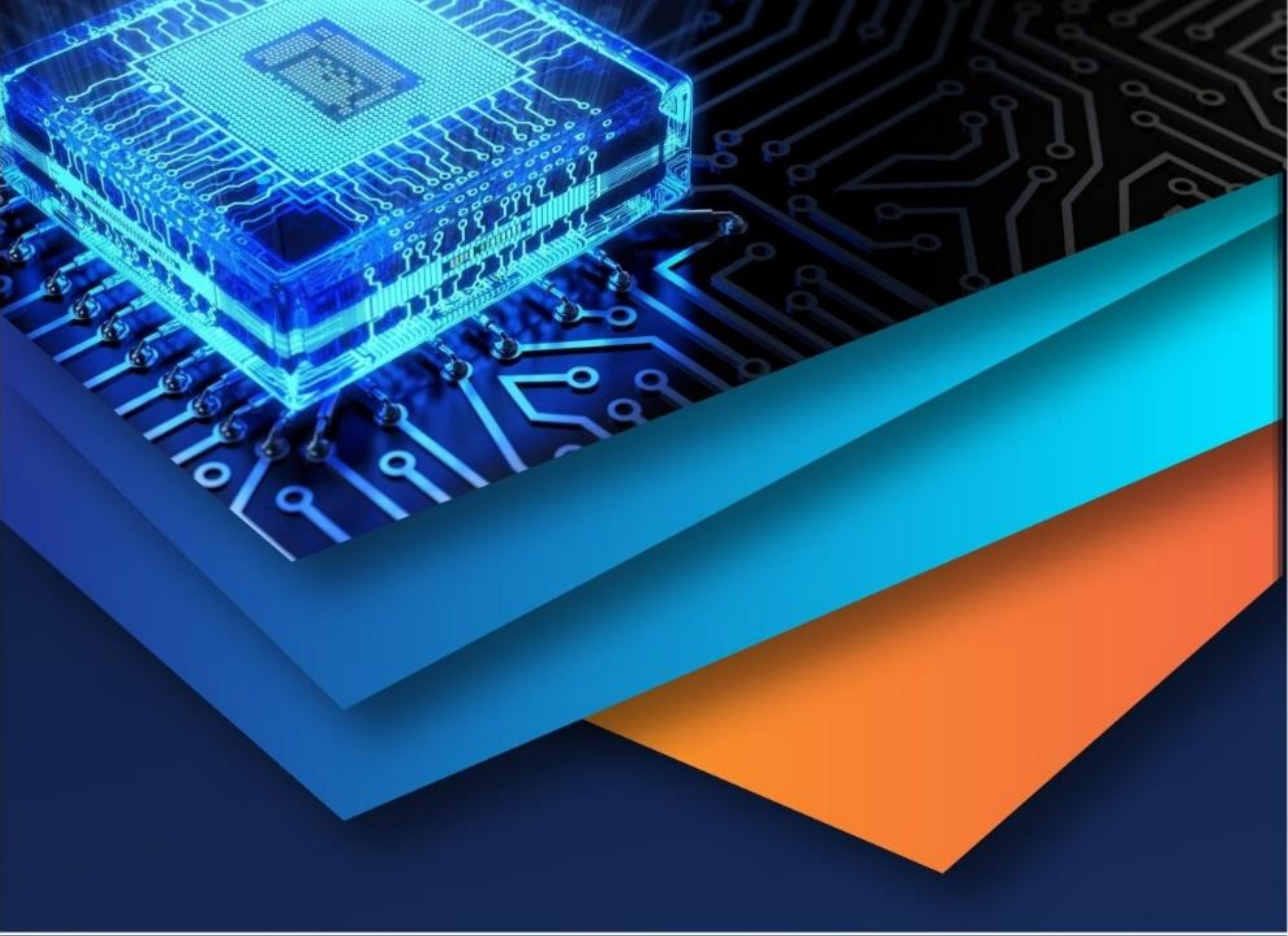

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