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Study of Stress Concentration Factor under Cyclic Loads for different Reduction Methods

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Abstract*: The present problem deals with investigation of variation of stress concentration factor under cyclic loading for different reduction methods. Three-dimensional finite element analysis based on theory of stress is used for the solution of transient structural problems. The present analysis is carried out in two phases. In the first phase, static analysis of stress concentration factor for reduction method is specially and generally completely reversed bending stress is subjected to cyclic loads has been presented. The present analysis includes the reduction of the stress concentration factor with fully reversed bending loads. The effect of reduction method on the stress concentration factor under cyclic loads in various parts like simple, fillet, notch and undercut is taken to reduce the stress. It is found that fillet has reduced stress concentration factor with Kt=1.37 when compared to the other reduction methods.
***Keywords*: Stress concentration, FEM, Reduction methods, Cyclic loading, Fillet**

I. INTRODUCTION

A. Stress Concentration

Stress concentration is defined as the localization of high stresses due to the irregularities present in the component and abrupt changes of the cross-section. In order to consider the effect of stress concentration and find out localized stresses, a factor called stress concentration factor is used.

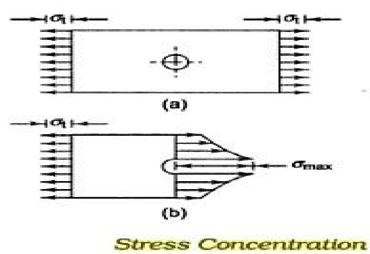

Fig 1: Stress Concentration

B. Reduction Method

Although, it is not possible to completely eliminate the effect of stress concentration. There are methods to reduce stress concentration. This is achieved by providing specific geometric shape to the component. In order to know the change of cross-section or at the discontinuity and reduce the stress concentration, understanding of flow analogy is useful. Numbers of methods are available to reduce stress concentration in machine parts.

Some of them are as follows:

Provide a fillet radius so that the cross-section may change gradually. Sometimes an elliptical fillet is also used. If a notch is unavoidable it is better to provide a number of small notches are rather than a long one. This reduces the stress concentration to a large extent. If a projection is unavoidable from design considerations it is preferable to provide a narrow notch than a wide notch. Stress relieving groove are sometimes provided.

These are demonstrated in

Force flow around a sharp corner Force flow around a corner with fillet:

Low stress concentration. Force flow around a large notch Force flow around a number of small

Notches: Low stress concentration.

In practice, reduction of stress concentration is achieved by following methods

1) *Addition Notches and Holes in Tension Member: A* flat plate with a V-notch subjected to tensile force are (a) it is observed that a single notch results in a high degree of stress concentration. The severity of stress concentration is reduced by three methods 1.Use of multiple notches; 2.Drilling additional holes; and 3.Removal of material. These method of removing undesired material is called the principle minimization of the material. In these three methods, the sharp bending of force flow line is reduced and it follows a smooth curve.
2) *Fillet Radius, Undercutting and Notch for Member in Bending:* A bar of circular cross-section with a shoulder and subjected to bending moment. Ball bearings, gears or pulleys are seated against the shoulder. The shoulder creates change in cross section of the shaft, that results in stress concentration. There are the three methods to reduce stress concentration (a) use of fillet radius (b) under cutting and (c) additional notch. This results in gradual transition from a small diameter to a large diameter. The fillet radius should be as large as possible in order to reduce stress concentration. In practice, fillet radius is limited by the design of mating components. The fillet radius can be increased by under cutting the shoulder. A notch results in stress concentration an additional notch is effective way to reduce stress concentration.
3) *Drilling Additional Holes for Shaft:* A transmission shaft with a keyway. Keyway is a Discontinuity and results in stress concentration at the corners of the keyway and reduces torsional shear strength. Stress concentration should be used when a shaft with keyway is combined bending and torsional moments. In addition to giving fillet radius at the inner corner of the keyway, there is another method of drilling two symmetrical holes on the sides of keyway. These holes press the force flow lines and minimize their bending of the keyway.
4) *Reduction of Stress Concentration in Threaded Members:* A threaded component is observed that the force flow line is bent as it passes from shank portion to threaded portion of the component. This results in stress concentration in the transition plane. A small undercut is taken between shank and the threaded portion of the component and fillet radius is provided for this undercut. This reduces bending of the force flow the line and reduces stress concentration. If the force flow line is almost straight and there is no stress concentration. However, it can be greatly reduced by selecting the correct geometric shape by the designer. Stress concentration have been solved by removing material instead of adding additional notches, holes and undercuts are used to reduces in the stress concentration.

II. METHODOLOGY

A. Simulation For Static Loading

In static method, first we have to open ANSYS WORKBENCH software then double click on transient structure in menu bar. After the dial box will open double click on geometry then ANSYS file is open. Take the dimensions in millimeter then work sheet will open select XY plane then click on face look eye. Select sketching click on draw take line and draw the lines with vertical and horizontal line by picking the points one by one at end point joining in it. Take constrains to select horizontal and vertical lines in straightway. Select dimensions to identify the lines which are drawn with reference of XY plane. Select modify to give the dimensions on vertical and horizontal lines as V1 = 175 mm, V2 = 100 mm, H1 = 30 mm and H2 = 15 mm then the sketch will form. Select the sketch1 on XY plane and click the sketch plane to select. Select axis then click on vertical line after click on generate to revolute and update to solve the sketch as extrude it. Finally save the file with name as fillet part.

B. Simulation For Dynamic Loading

Go to transient structural after one box will open double click on model then the model part will come on work sheet which we drawn in geometry part. That model is taken to mesh click on mesh tool bar then the details of mesh table will come select sizing the mesh. Select the on curvature, relevant size is fine, smoothing is high and minimum Size is 0.001mm is taken. After select the body to mesh then the meshing is completed. After Mesh the time Vs load should apply on the model part. Select the analysis settings on tool bar then the supports are taken for fixed support. While clicking on bottom part of the model is apply to fix at one part. After the loading is given at face part of the model by selecting force then the tabular form will come. Select the number of steps is 5,Current step is 1, Automated Time is off, time in sub steps, no of sub steps is 5, time integration is off and Time is taken as t_1 = 0.003sec and force is taken on x- component as F_1 = -10000 then the face part is clicked to apply load.

Similarly the time and load is changed in 5 steps. In second step, Time integration is on at next steps also as take time t_2 =0.006sec and force F_2 = 10000. In third step, take time t_3 = 0.009sec and force F_3 = - 10000. In fourth step, take time t_4 = 0.12sec and force F_4 = 10000. In fifth step, take time t_5 = 0.15sec and force F_5 = -10000.Select solution to find the values at min, max. Click on right click to insert stress tools as total deformation, Strain with equivalent elastic strain, Stress with equivalent stress and energy in strain.

Insert fatigue tools as Life, Damage, Safety factor, Biaxiatly Indication, equivalent alternating stress and fatigue sensitivity. To solve the solution select right click and solve the entire model to solve it. Finally the model is solved then the results will come in graphs and tabular values.

III.MODELLING AND ANALYSIS

A. Modeling Procedure

1) Setting The Units
2) Sketching And Dimensioning
3) Adding Constrains
4) Geometry Sketch Selection
5) Revolving The Sketch To Generate Stepped Shaft:
6) Fillet Radius To Blend

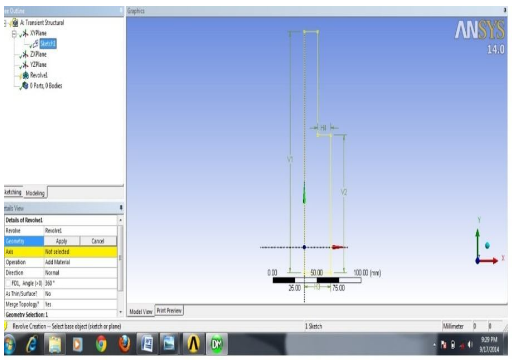

Fig.2 The Geometry Sketch Selection

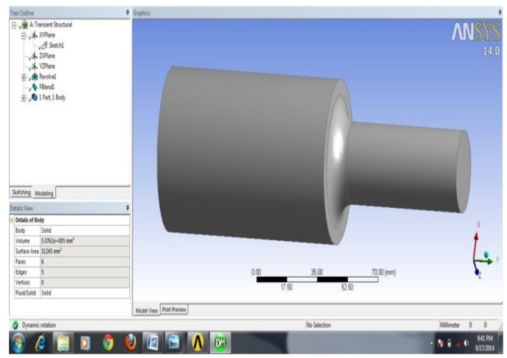

Fig. 3 Revolving The Sketch To Generate Stepped Shaft

B. Dynamic Analysis

Specifying the details of mesh, It is done with sizing as use advanced size fuction is on curvature, Relevance center is fine,smoothing is high and min size is 0.001mm on it. The meshing is done on model with transient structural on ANSYS work bench by selecting the total body with given sizing dimension of mesh is updated to it. Type of element selected is 4 noded tetrahydron element and the total no of elements 3,72,091 with the number of nodes 514673. After meshing is completed the support load is taken to fix the model at one end is fixed on transient structural using ANSYS work bench on selecting the back side part then it is taken as fixed support.

Table I load Vs time

Tabular Data

	Steps	Time [s]	X [N]	Y [N]	Z [N]
1	1	0.	0.	= 0.	= 0.
2	1	3.e-003	-10000	0.	0.
3	2	6.e-002	10000	= 0.	= 0.
4	3	9.e-002	-10000	= 0.	= 0.
5	4	0.12	10000	= 0.	= 0.
6	5	0.15	-10000	= 0.	= 0.
*					

Table shows that the data is given with Time Vs Force is applied and taken in 5 steps as

T_1 = 0.003sec F_1 = -10000N.
T_2 = 0.006sec F_2 = 10000N.
T_3 = 0.009sec F_3 = -10000N.
T_4 = 0.12sec F_4 = 10000N.
T_5 = 0.15sec F_5 = -10000N. respectively.

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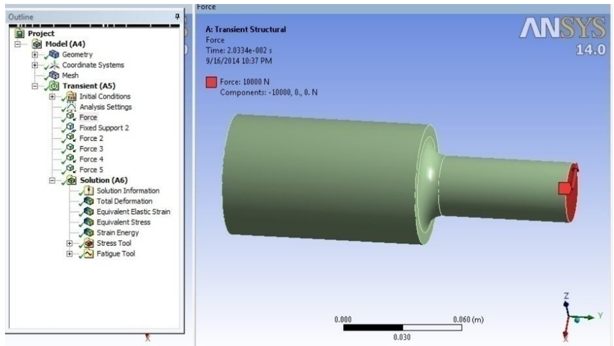

Fig.4 Forces Applied At Face For Fillet

IV. RESULTS AND DISCUSSION

The figure 5 shows about total deformation for fillet is taken to observe the maximum value is 0.00037297 mm and minimum value is 0. The figure 6 shows about equivalent elastic strain for fillet is taken to observe the maximum value is 0.0015098 MPa and minimum value is 2.4062e-6 MPa. The figure 7 shows about equivalent stress for fillet is taken to observe the maximum value is 266.85 Mpa and minimum value is 0.9518 Mpa. Figure 8 shows About life for fillet is taken to observe the maximum value is 1e6 Mpa and minimum value is 6464.3 Mpa. The figure 9 shows about fatigue sensitivity is taken to observe the maximum value is 1.13e5 Mpa and minimum value is 2.7e3 Mpa.

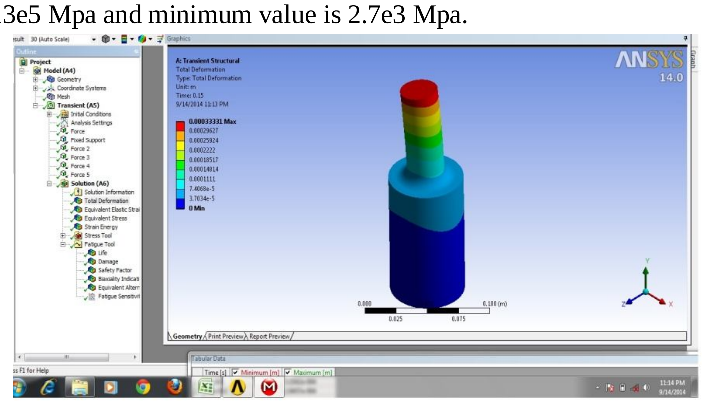

Fig. 5 The Total Deformation For Fillet

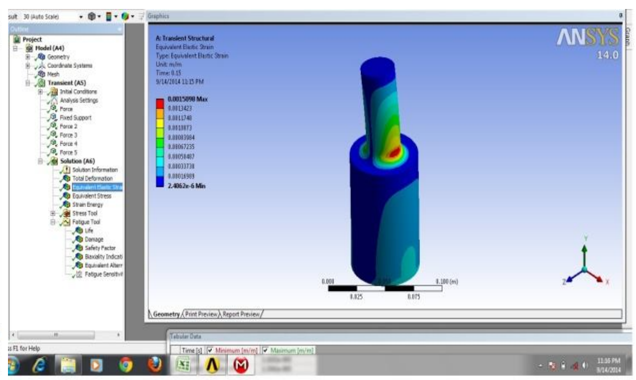

Fig. 6 The Equivalent Elastic Strain For Fillet

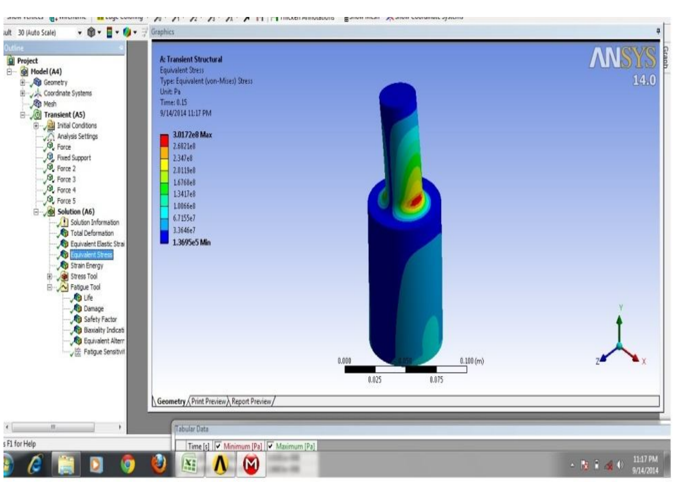

Fig. 7 the equivalent stress for fillet

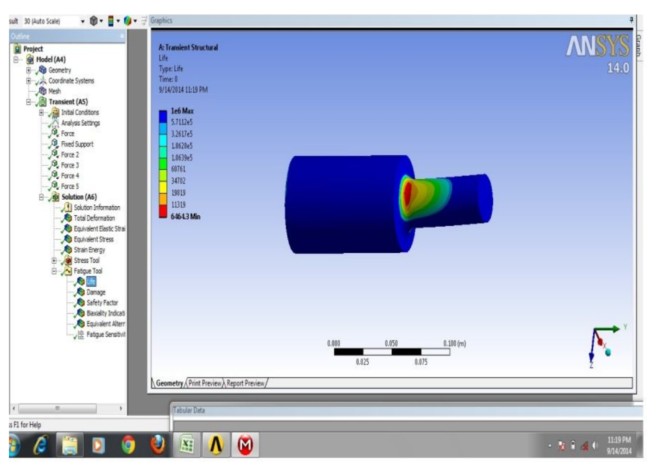

Fig. 8 the life for fillet

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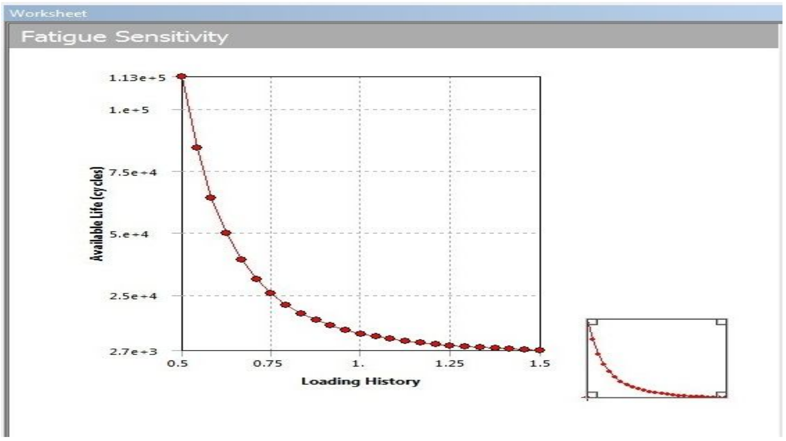
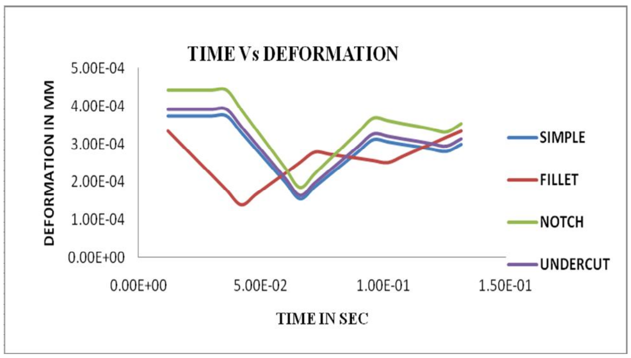


Fig. 9 Fatigue Sensitivity For Fillet



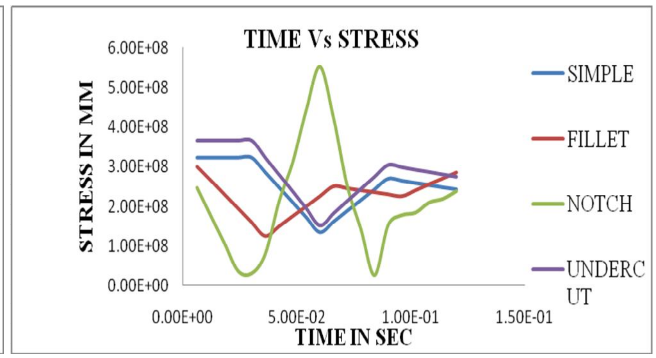
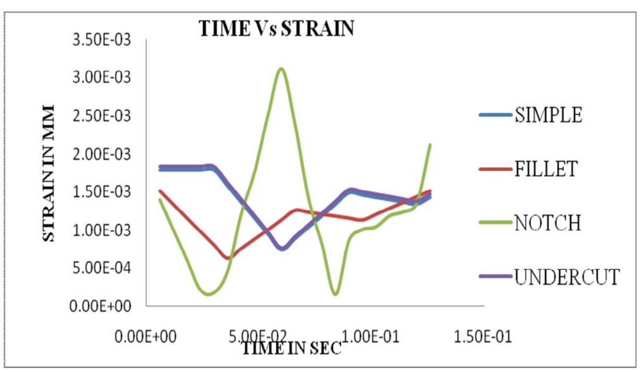


Fig.10 The Comparison Of Time Vs Deformation For Each Part   Fig. 11 the comparison of time Vs stress for each part Page Layout

This Fig.10 shows that the comparison of time Vs deformation for simple, fillet, notch and undercut on observing the graph notch is increased and fillet is decreased in it. Fig.11 shows that the comparison of time Vs stress for simple, fillet, notch and undercut on observing the graph notch is critically decreased and undercut is increased in it. This Fig.12 shows that the comparison of time Vs strain for simple, fillet, notch and undercut on observing the graph notch is critically decreased and undercut is increased in it.



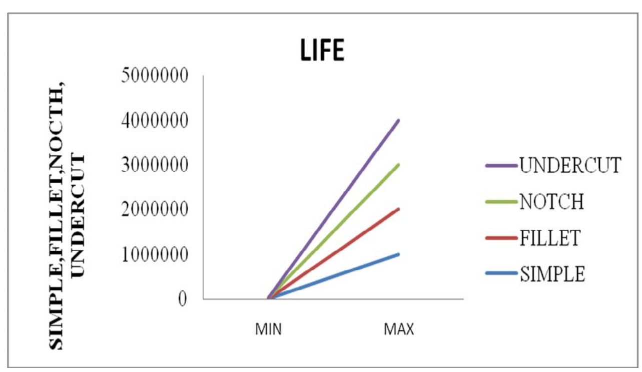


Fig.12 Comparison Of Time Vs Strain For Each Part   Fig.13 comparison of time Vs life for each part

V. CONCLUSION

In this project convergent test has been carried out with the variation of element sizes starting from 5 mm to 1mm and it is found that 2 mm sized elements are optimal and selected for meshing. For different reduction methods of stress concentration effect has been analyzed using standard stepped bar. From the analysis it is concluded that reduction method called making a fillet at the stress concentration area is more effective to reduce the same. The stress concentration factor is calculated $K_t = \sigma\ max/\sigma_o = 1.37$

value is for fillet part that the stress is reduced when compared to simple, notch and undercut parts. The Fatigue tools for Life, safety factor is more and fatigue sensitivity is less for undercut part when compared to other parts.

Calculation for stress concentration factor K_t is done by taking the values of maximum stress on each part like simple, fillet, notch and undercut. Such that by using different reduction method under cyclic loads is applied with respect to time on modelling the parts. Finally the stress concentration factor is calculated and is less stress for fillet was observed and tested when compared to other parts.

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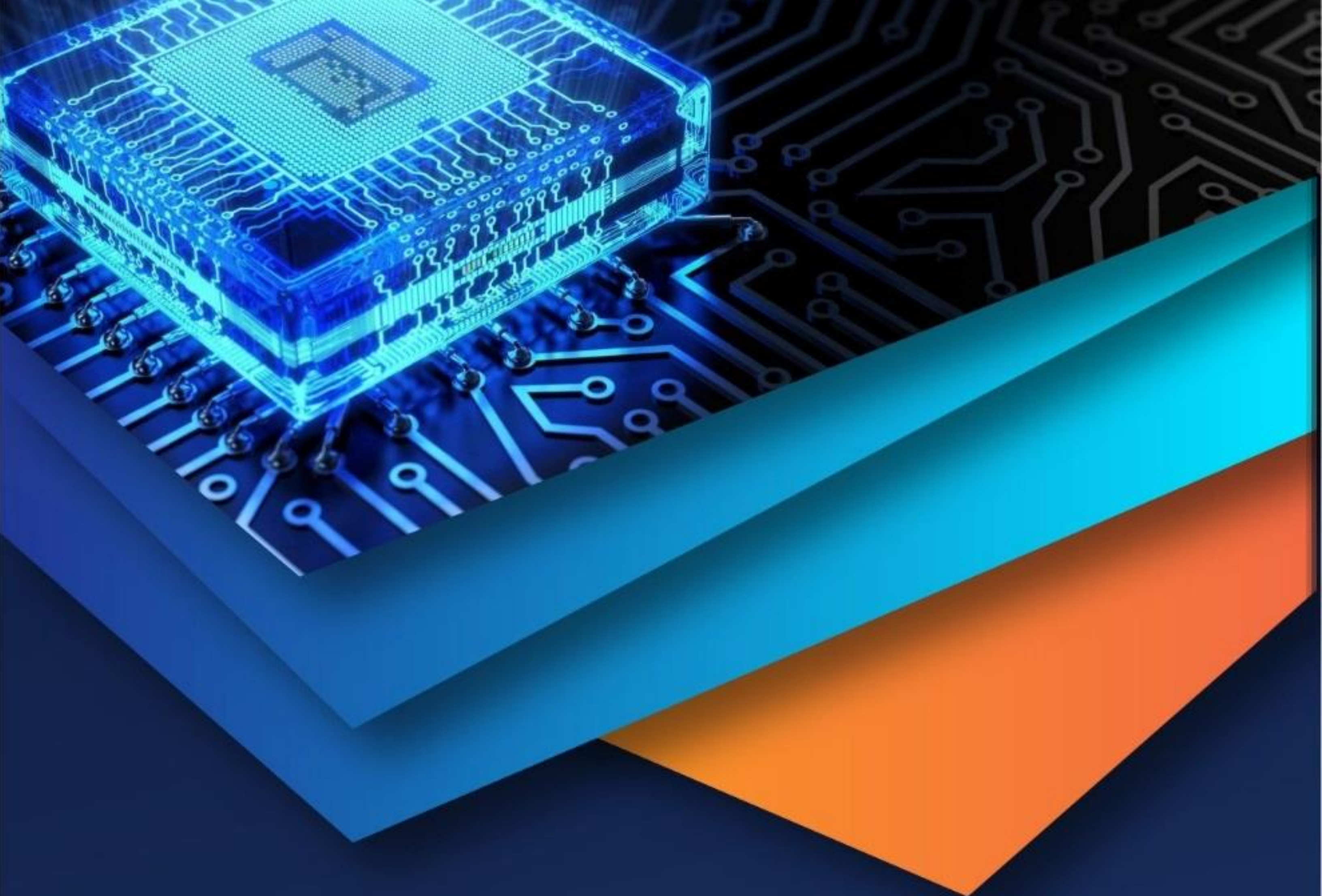

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