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Deformation and Stress Analysis of Sheet Hydroforming in Car Frame T-Joint

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Abstract: Hydroforming is a relatively new metal forming process that offers many advantages over traditional cold forming processes, including the ability to produce more complex components with fewer operations.
For certain geometries, hydroforming technology makes it lighter, stiffer, cheaper to manufacture, and requires less blanks, resulting in less material waste.
This paper focuses on the analysis of composite T-joints which are used in automobiles under various loads. It is modelled analysed using CATIA V5 and ANYSYS software's respectively.
There are several studies on design optimization of automotive T-joints. This paper depicts deformation and stress analysis of T-Joint, when made using sheet hydroforming.
Keyword: Hydroforming, Metal Forming, Cold Forming, T-Joint, Catia, Ansys

I. INTRODUCTION

Hydroforming is a nearly net shape metal forming process that uses fluid pressure instead of (or in combination) with traditional mechanical forces to create complex shapes.

The hydroforming process has several advantages over other forming processes and has helped to establish it in many specific applications.

The development of light weight vehicles is an increasing need due to the excessive consumption of fuel and hydroforming can solve this issue as it is faster manufacturing process than other conventional manufacturing process. The T-joint is the connection between the car's B-pillar and side sill, as shown in.

Not only does it play an important role in reducing weight, but it also improves vehicle rigidity in the event of a side collision or rollover accident, improving safety.

II. LITERATURE REVIEW

1) Aue-U-Lan, Y., Ngaile, G., & Altan, T. (2004). Optimizing tube hydroforming using process simulation and experimental verification. Journal of Materials Processing Technology, 146(1), 137-143. - Experimental and simulation results show that FE-based stress pathways can significantly reduce trial and error, increase productivity, and extend the THF function when moulding complex parts.
2) Bell, C., Corney, J., Zuelli, N., & Savings, D. (2020). A state-of-the-art review of hydroforming technology. International Journal of Material Forming, 13(5), 789- 828. - The paper concludes with a discussion of the future of hydroforming, including current state-of-the-art technologies, research directions, and process benefits that help predict new hydroforming technologies.
3) Zhang, S. H., Wang, Z. R., Xu, Y., Wang, Z. T., & Zhou, L. X. (2004). Recent developments in sheet hydroforming technology. Journal of Materials Processing Technology, 151(1-3), 237-241. - This paper summarizes the recent developments in seat hydroforming technology, analyses some important technical issues that need to be resolved for the development of seat hydroforming technology, and describes various seat hydroforming techniques.
4) Parsa, M. H., & Darbandi, P. (2008). Experimental and numerical analyses of sheet hydroforming process for production of an automobile body part. *Journal of materials processing technology*, *198*(1-3), 381-390. - An approach for substituting conventional manufacturing method of a three pieces shell fender by one piece has been proposed. This approach is based on sheet hydroforming process, which has many advantages over conventional stamping processes.

III. DESIGN

Figure 1 shows the T-joint, which is a typical and important structural intersection between the B-pillar and the rocker panel used in the car. In a side collision, an out-of-plane load can be applied to the T-joint.

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Figure 1: - Reference Part

For designing the part, we have used CATIA V5 software and the dimensions were referred from a research paper. Figure 2 shows the 3D Model of a Car frame T-Joint.

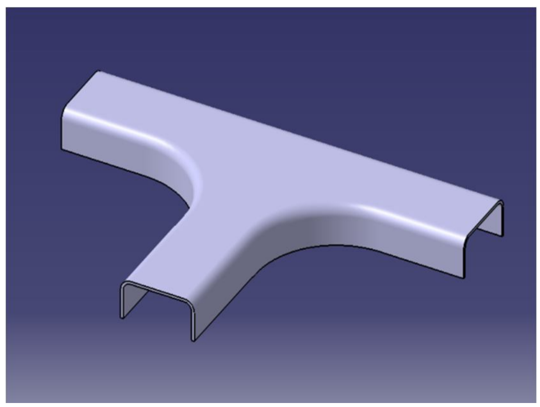

Figure 2: - Design made in CATIA V5

Drafting of the Car Frame T-Joint CAD Model is given below:

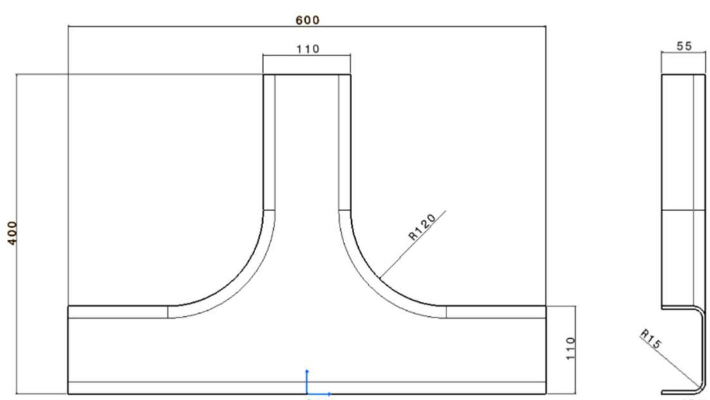

Figure 3: - Draft of the T-Joint

IV. ANALYSIS

For the simulation part we tried several different software like DYNAFORM, ABAQUS and ANSYS R22.

We considered 3 pressure values for the simulation of hydroforming process. As we have considered pressure sequencing hydroforming the pressure is to be applied in stages, so to apply the pressure in stages we considered 4 stages for every iteration.

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A. Set Parameters

1) Units

Unit System	Metric (m, kg, N, s, V, A) Degrees rad/s Celsius
Angle	Degrees
Rotational Velocity	rad/s
Temperature	Celsius

Table 1: - Set Parameters

2) Material

Blank – Structural Steel NL

Density	Specific Heat	Young's Modulus (Pa)	Poisson's Ratio	Bulk Modulus (Pa)	Shear Modulus (Pa)
7850 kg m^-3	434 J kg^-1 C^-1	2.e+011	0.3	1.6667e+011	7.6923e+010

Table 2: - Structural Steel NL Properties

3) Die – Structural Steel

Density	Coefficient of Thermal Expansion	Specific Heat	Thermal Conductivity	Resistivity
7850 kg m^-3	1.2e-005 C^-1	434 J kg^-1 C^-1	60.5 W m^-1 C^-1	1.7e-007-ohm m

Table 3: - Structural Steel Properties

B. First Iteration

1) Pressure Values in Steps

Steps	Time[s]	Pressure [Pa]
1	0.	0.
	1.	6.25e+007
2	2.	1.25e+008
3	3.	1875e+008
4	4.	2.5e+008

Table 4: - Pressure Values (First Iteration)

2) Total Deformation

Figure 4 shows the total deformation of the Blank with the pressure values given in Table 4. The total deformation of the Structural Steel NL blank was 0.08659 m.

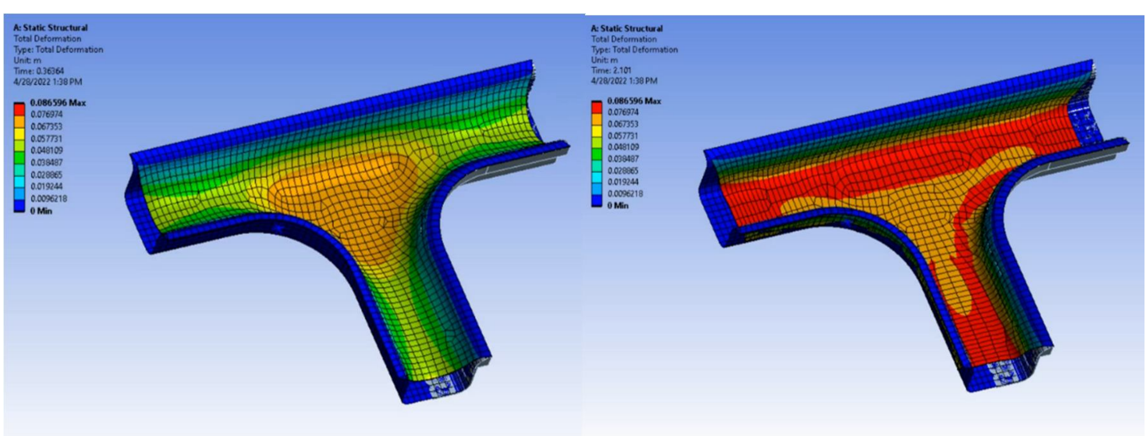

Figure 4: - Total Deformation (First Iteration)

3) Equivalent Stress

After meshing the Model, the boundary conditions were applied. The boundary conditions were applied by fixing the blank at the Die. Figure 5 shows the equivalent stress acted on the blades. The maximum equivalent stress acting on the Blank was 1.54e9 Pa

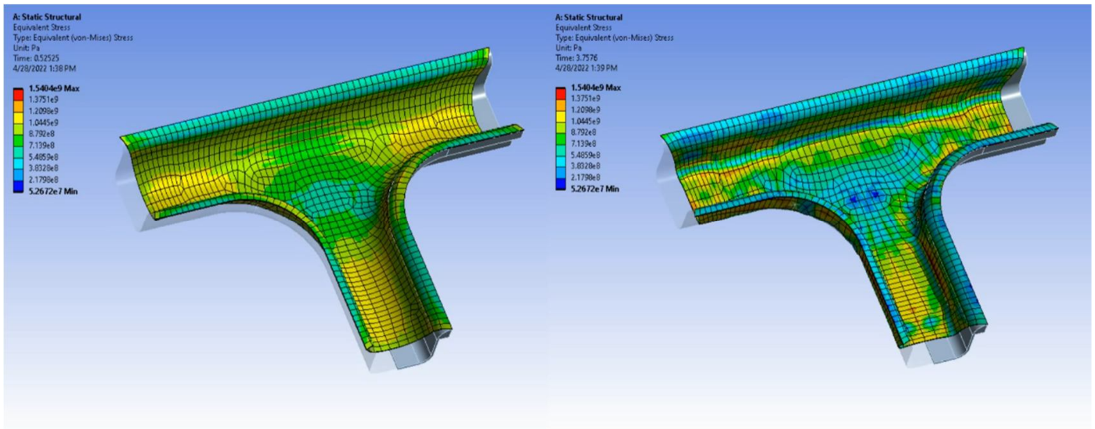

Figure 5: - Equivalent Stress (First Iteration)

C. Second Iteration

1) Pressure values in steps

Steps	Time[s]	Pressure [Pa]
1	0.	0.
	1.	5.e+007
2	2.	1.e+008
3	3.	1.5e+008
4	4.	2.e+008

Table 5: - Pressure Values (Second Iteration)

2) Total Deformation

Figure 6 shows the total deformation of the Blank with the pressure values given in Table 5. The total deformation of the Structural Steel NL blank was 0.08657 m.

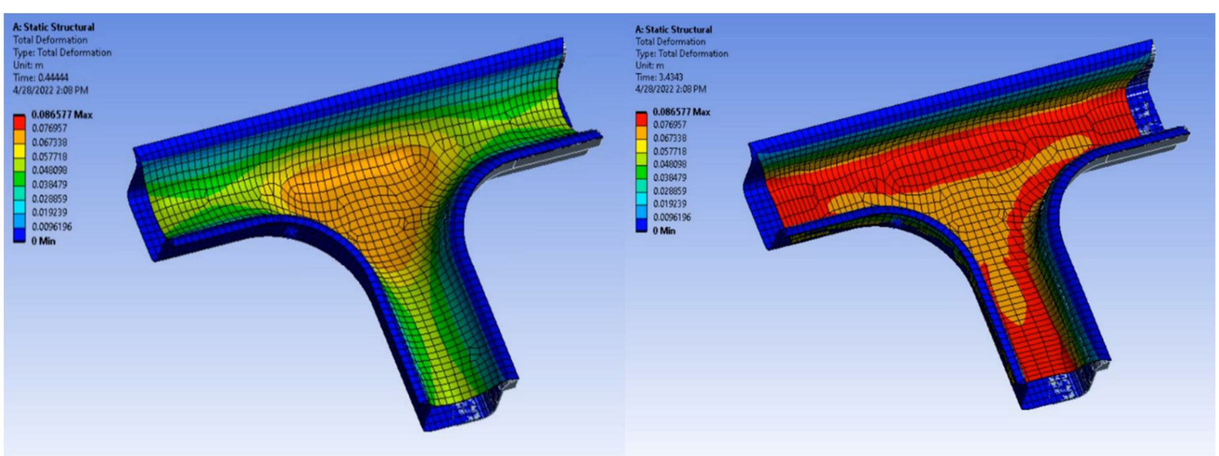

Figure 6: - Total Deformation (Second Iteration)

3) Equivalent Stress

Figure 7 shows the equivalent stress acted on the blades. The maximum equivalent stress acting on the Blank was 1.53e9 Pa.

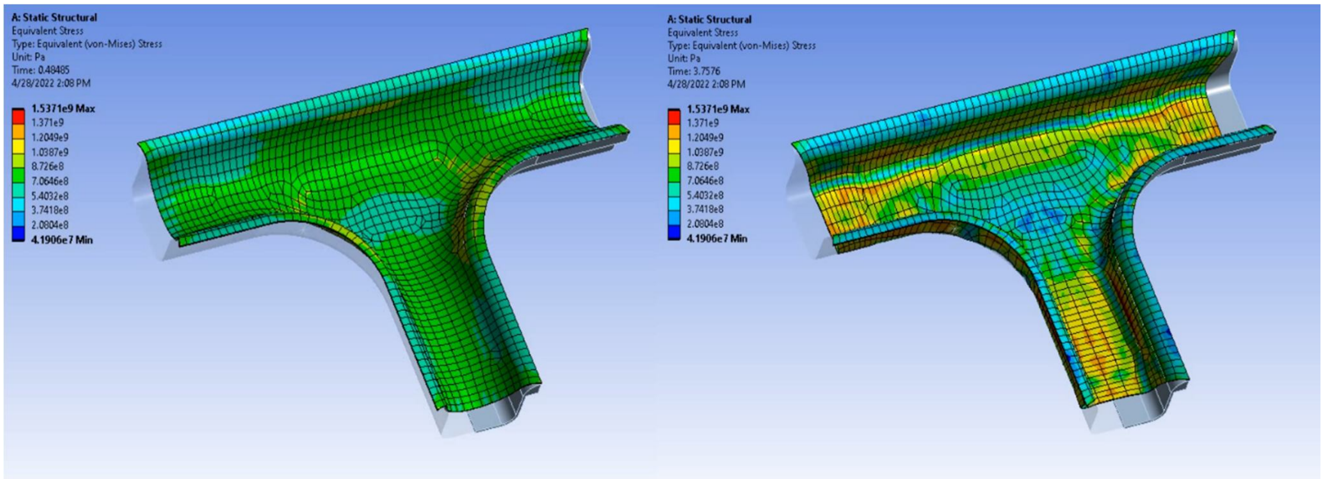

Figure 7: - Equivalent Stress (Second Iteration)

D. Third Iteration

1) Pressure Values in Steps

Steps	Time[s]	Pressure [Pa]
1	0.	0.
	1.	4.e+007
2	2.	8.e+007
3	3.	1.2e+008
4	4.	1.6e+008

Table 6: - Pressure Values (Third Iteration)

2) Total Deformation

Figure 8 shows the total deformation of the Blank with the pressure values given in Table 6. The total deformation of the Structural Steel NL blank was 0.08656 m.

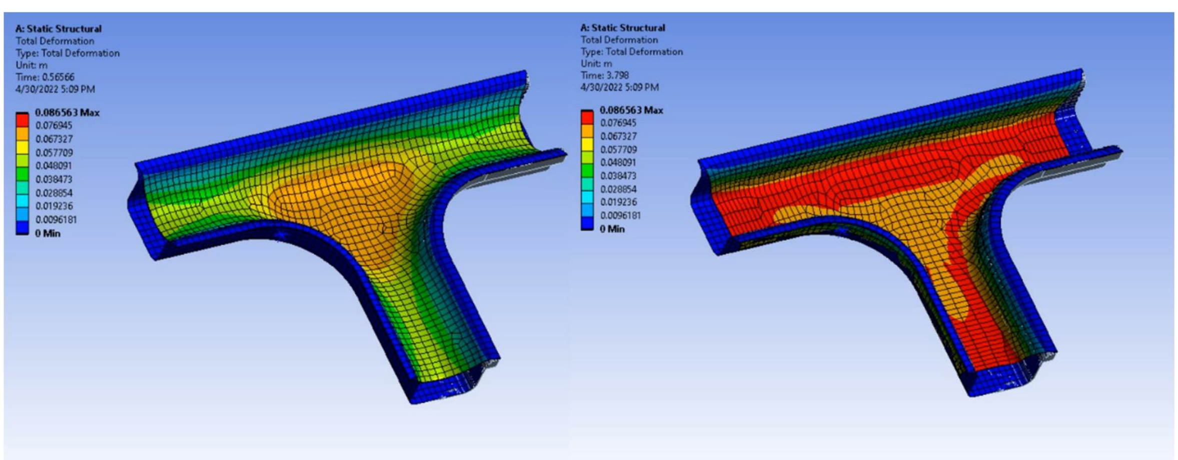

Figure 8: - Total Deformation (Third Iteration)

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3) Equivalent STRESS

Figure 9 shows the equivalent stress acted on the blades. The maximum equivalent stress acting on the Blank was 1.53e9 Pa.

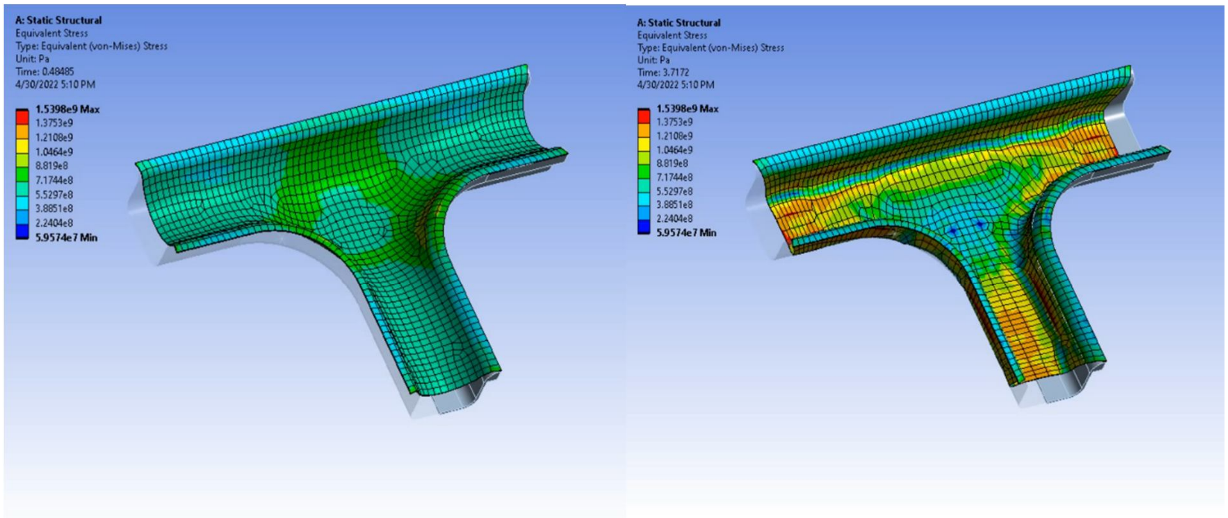

Figure 9: - Equivalent Stress (Third Iteration)

V. CONCLUSION

With the help of analysis done by the using Ansys, we can conclude that:

1) Uniform Stress distribution was observed in all iteration.
2) Third Iteration of 160 MPa is ideal fluid pressure to form T-Joint.
3) Material Thin-out was less in all iterations, although 160MPa iteration showed ideal deformation.
4) As hydroforming is faster and efficient process than other conventional forming processes, it can be a great alternative.
5) Hydroforming has zero carbon footprint and helps in weight reduction as welding is not involved in it.

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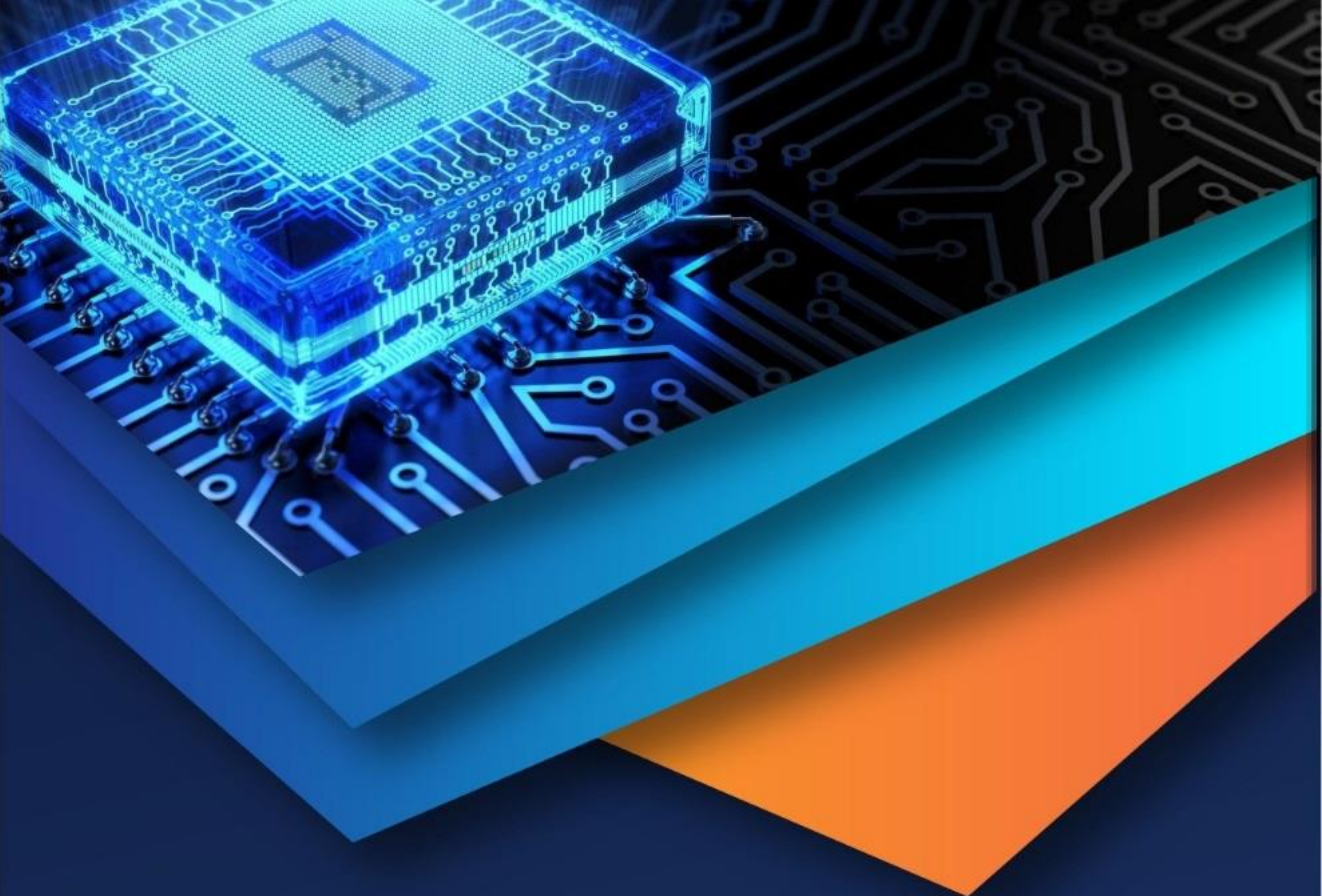

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