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An Approach for Transmission Loss Validation and Measurement of Various Reactive Mufflers with FEA Acoustic Module

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Abstract— In this paper the details of measurement of the Acoustic Transmission Loss of various Expansion Chamber is shown by using Finite element Analysis (FEM) is explained. For this purpose evaluation of transmission loss of different cross-sections by keeping constant volume of expansion chamber is explained. Also the design validation has been done with existing result to show the validity of results. After the validation process results are compared to observe the effect of changing in the cross-section of muffler.
Keywords—Expansion chamber muffler, Transmission loss

I. INTRODUCTION

Noise is a unwanted sound. Noise is the wrong sound in the wrong place and at wrong time. Noise is known to cause annoyance, may lead to hearing impairment and may interfere in speech communications. The response of human ear to the sound pressure is roughly logarithmic. Thus the logarithmic scale for the measurement of sound pressure appears logical and such a scale is known as Decibel. These include the noise reduction (NR), the insertion loss (IL) and the transmission loss (TL). Noise Reduction (NR) is defined as the sound pressure level difference between two points in a system. Insertion loss (IL) is the loss of signal power resulting from the insertion of a device in a transmission line [2]. Transmission loss (TL) is the accumulated decrease in acoustic intensity as an acoustic pressure wave propagates outwards from a source.

Absorptive filter have absorptive material lined on the inside of the ducts. The linings absorb acoustic energy and convert them to heat. It does not alter the sound produced by the source [3]. To design a complete muffler is a very complex task because every element of it is selected by considering its acoustic performance and its effect on the complete system of simple expansion chamber muffler for predicting the acoustic performance of muffler. The acoustic wave Propagates outwards from the source the intensity of the signal is reduced with increasing range due to: Spreading and attenuation.. Transmission loss (TL) of a silencer is predicted by Transfer Matrix method. TL for Five muffler configurations of different dimensions, with same volume has been analyzed. The influence of different structure dimensions of the simple expansion chamber muffler on its acoustic performance was studied.

A muffler is an important noise control element for reduction of machinery exhaust noise, fan noise and other noise sources involving flow of a gas. Basically, muffler is designed for two reasons: 1) High noise attenuation performance, a basic necessity of a muffler. 2) Minimum back pressure, it represents the extra static pressure acted by the muffler on the engine. Mufflers are of two types: the reactive type and absorptive type. Reactive mufflers work on the principle of impedance mismatch by use of sudden changes in the area of cross-section, perforated elements, resonators etc.

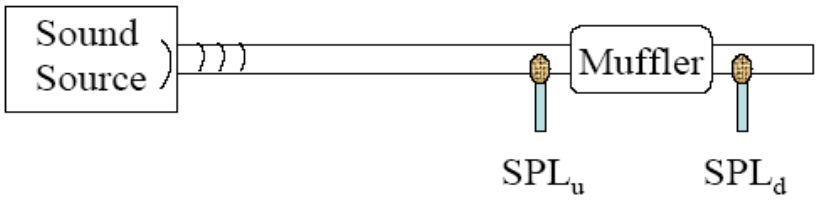


Fig. 1 Concept of Transmission Loss

II. MATHEMATICAL FORMULA FOR TRANSMISSION LOSS MEASUREMENT

The attenuation in acoustic intensity as an acoustic pressure plane wave propagates outwards from a source is known as Transmission loss [2].

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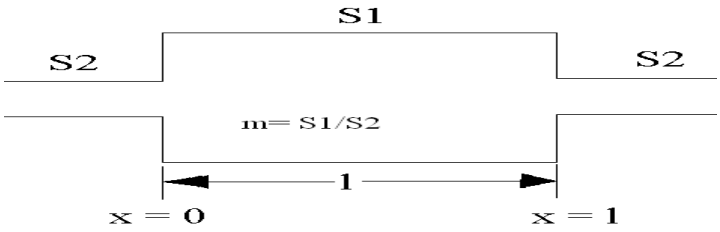


Fig. 2 Single Expansion Chamber

Where :
m = Expansion Ratio (Area Ratio)
L= length of Expansion Chamber
K= Wave no.= ω/c = 2πf/c
TL= Transmission loss [2]

$$TL = 10\,log_{10}[1 + \frac{1}{4}\left(m - \frac{1}{m}\right)^2 sin^2\,kl]$$

…….[eq. 1]

III.OBJECTIVES AND MODELLING

To validate the transmission loss measurement with existing system with the FEA result. Also to see the effect of transmission loss with various shape of cross sections by keeping volume constant. Abdullah A. Dhaiban, M-Emad S. Soliman, and M.G. El-Sebaie used a simple circular expansion chamber having dimension radius of the pipe is 0.6 m (60 mm) while for the simple elliptical expansion chamber is 0.42 m (420 mm) long while the pipes are 0.05 m (50 mm) long and the ovality ratio is 2.15. The dimensions are shown in Figure 3 [1].

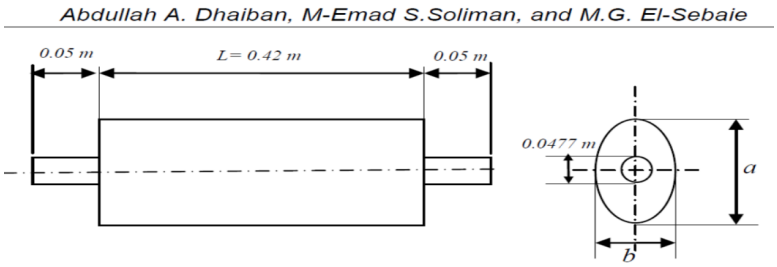


Fig.3 Existing geometry of a simple elliptic expansion chamber [1]

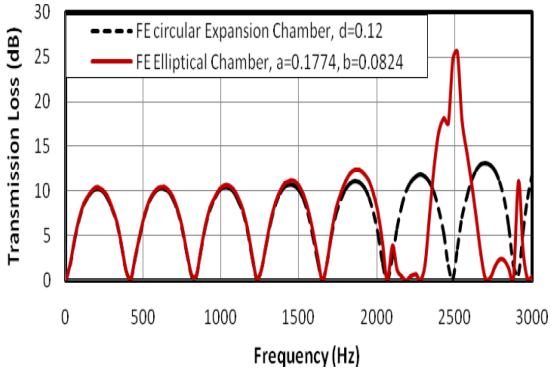


Fig. 4 Existing Results of Transmission loss of muffler [1]

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A. Transmission Loss Measurement by FEA Acoustic Module with reference of Abdullah A. Dhaiban et. al.:

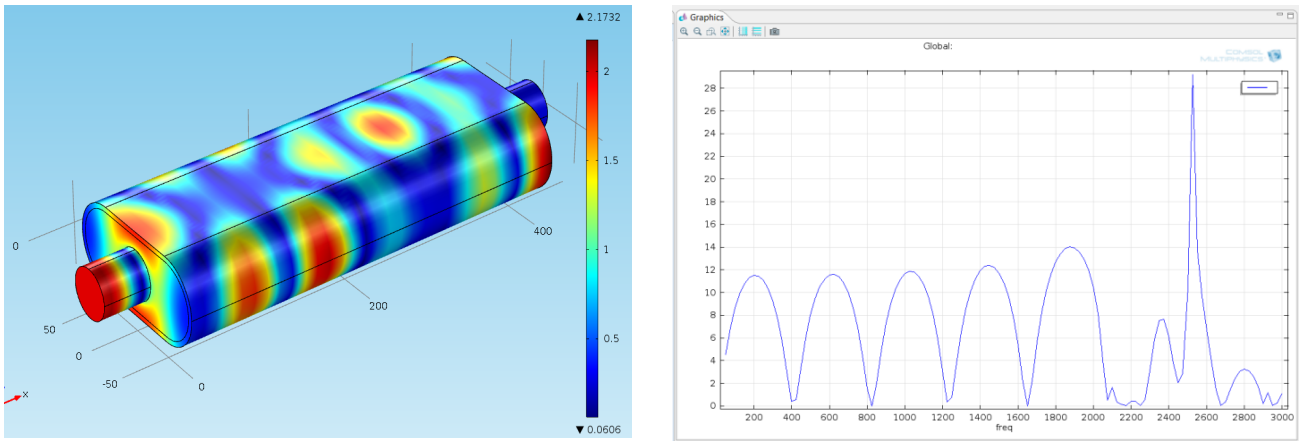


Fig. 5 Existing ResultsTransmission loss of muffler

B. Transmission Loss measurement compared with FEA with existing same dimensions

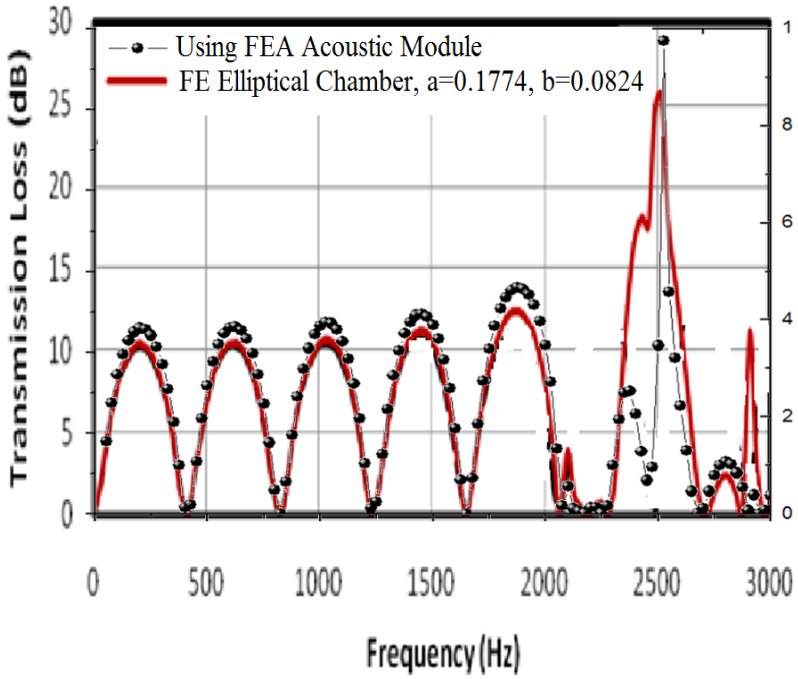


Fig. 6 Result comparison for Transmission loss of muffler with existing result

C. Boundary conditions

In the designing of the expansion chamber following boundary conditions are adopted:-

1) Volume of the expansion chamber is kept constant i.e., 6636500 mm^3 for all the modeling and designing work.
2) Modeling of various types of expansion chamber with keeping the length of expansion chamber as constant i.e., 211 mm.

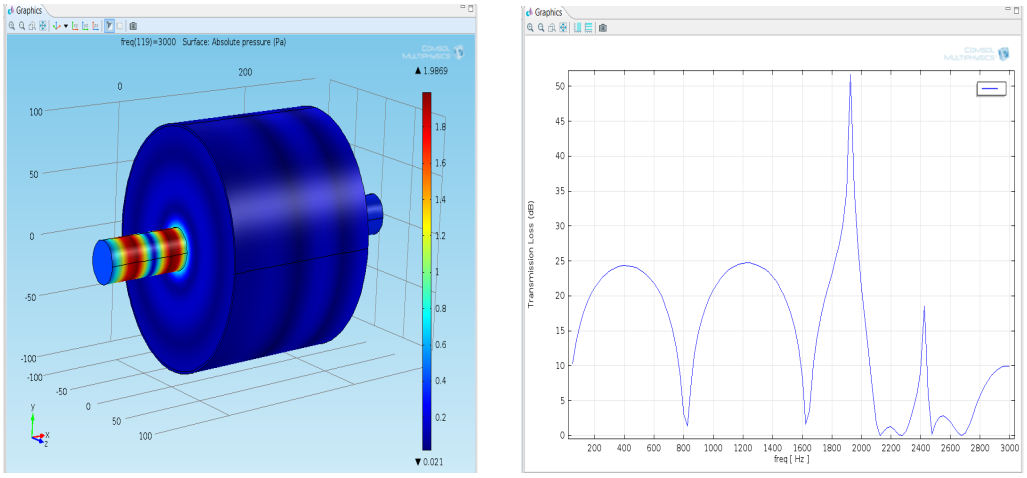
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TABLE I
MODELING OF TYPES OF EXPASION CHAMBER

S.No.	Types Of Expansion Chamber Having Length 211mm	Cross Section Dimensions With constant volume 6636500 mm^3
1	Circular	Radius = 100 mm.
2	Elliptical	Major & Minor Radius: 166mm X 60 mm
3	Rectangular	307.17 mm X 102.39 mm
4	Square	177 X 177 mm

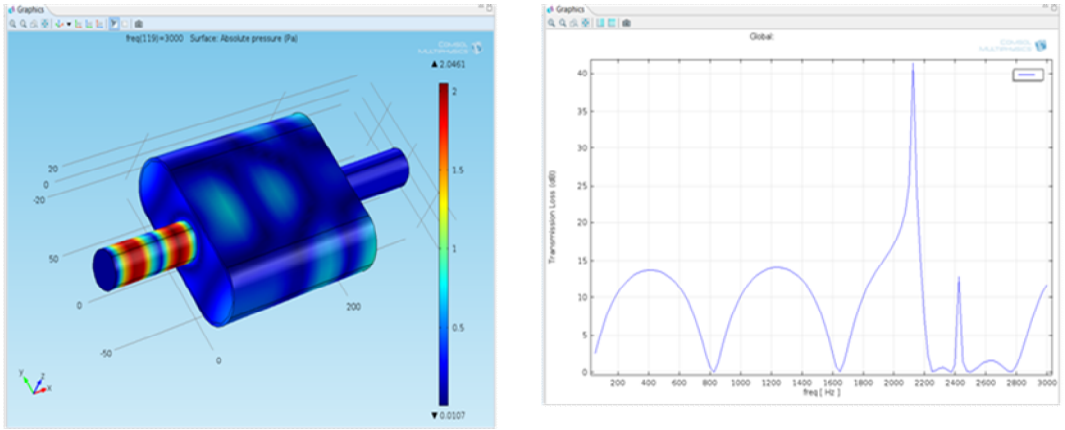
D. Circular Expansion Chamber with radius 100 mm (Cross section)



(a) (b)

Figure 7: Analysis of circular expansion chamber (a) Absolute pressure (b)Transmission loss

E. Elliptical Expansion Chamber with Major & Minor Radius : 166 mm X 60mm (Cross section)



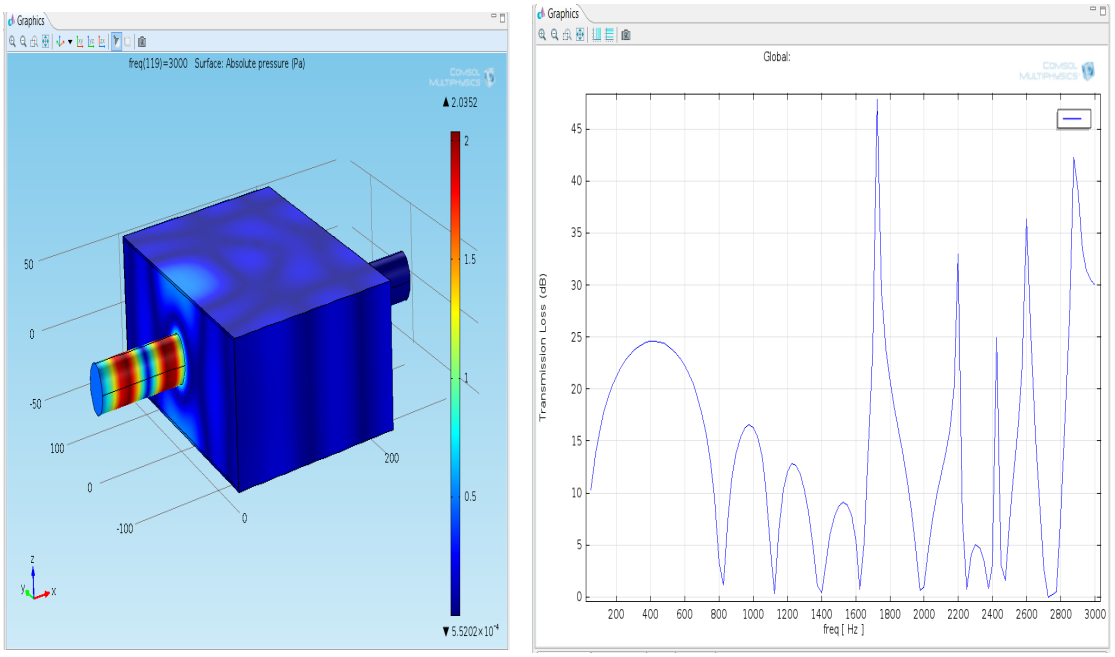
(a) (b)

Figure 8: Analysis of elliptical expansion chamber (a) Absolute pressure (b)Transmission loss

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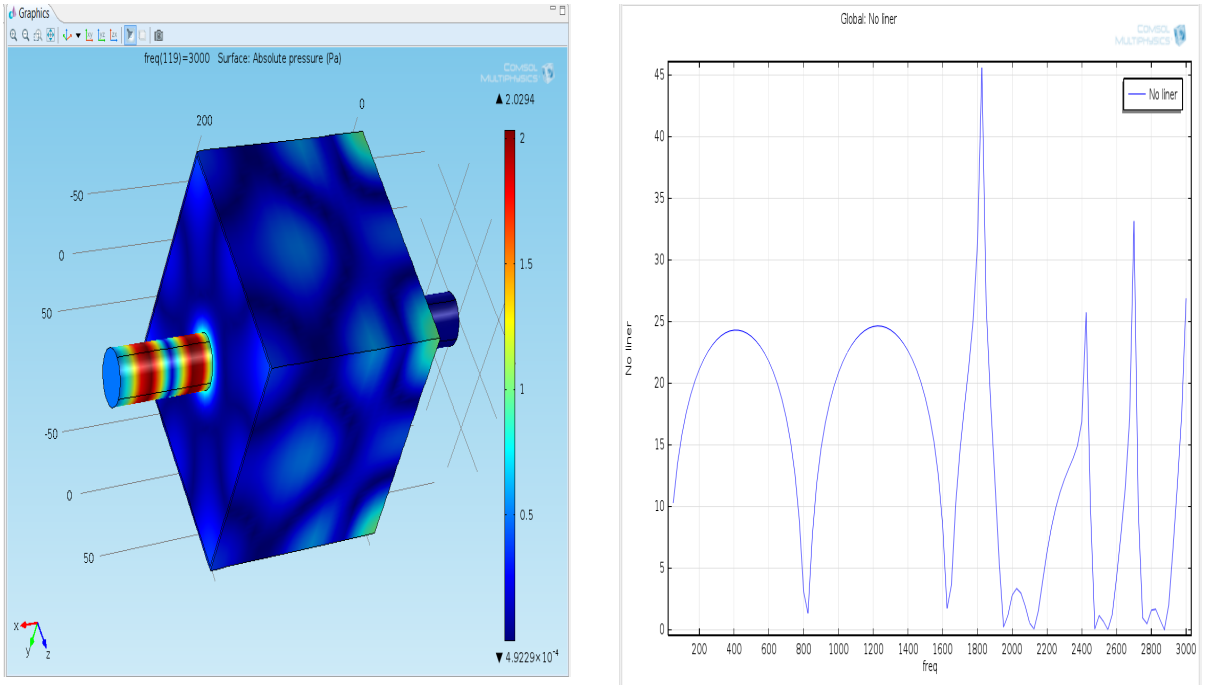
F. Rectangular Expansion Chamber with 307.17 mm X 102.39 mm (Cross section)



(a) (b)

Figure 9 : Analysis of rectangular expansion chamber (a) Absolute pressure (b)Transmission loss

G. Square Expansion Chamber with 177 mm X 177 mm (Cross section)



(a) (b)

Figure 10 : Analysis of square expansion chamber (a) Absolute pressure (b)Transmission loss

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IV. RESULTS

S.No.	Types of Expansion Chamber Having Length 211mm	Dimensions of Cross Section	Average Transmission Loss in (dB) for Constant Volume 6636500 mm^3	Average Acoustic Pressure (Pa)
1	Circular	Radius = 100 mm.	15.02617	1.98
2	Elliptical	Major & Minor Radius: 166mm X 60 mm	8.690717	2.03
3	Rectangular	307.17 mm X 102.3 mm	14.5414	2.04
4	Square	177 mm X 177 mm	15.01246	2.5

H. Graph of Transmission Loss With Various Cross Section

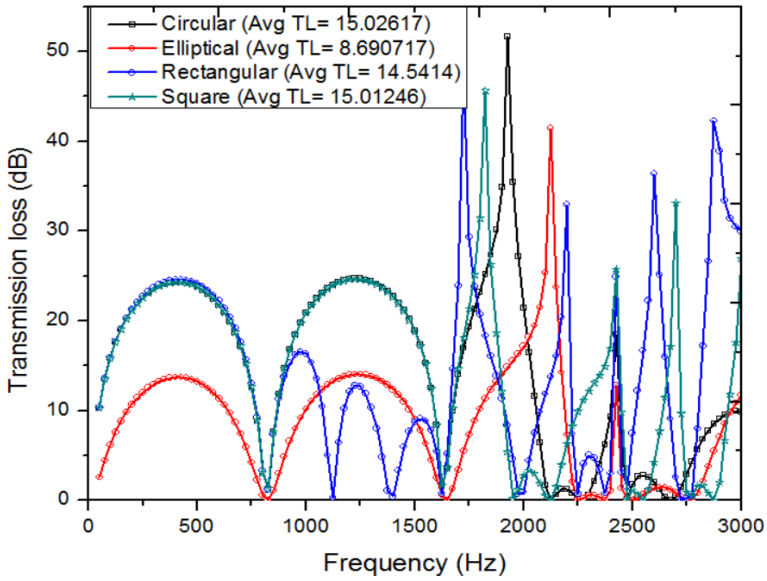


Figure 11: Transmission Loss for various cross section

V. CONCLUSIONS

The following conclusions are made with FEA results:

A. The analysis result is matched with existing result.

B. By taking the various cross section of muffler FEA result shows that the Transmission Loss for circular cross-section is showing maximum attenuation as compared with others cross-section having same volume.

C. Minimum Back pressure is achieved in case of circular cross section of muffler.

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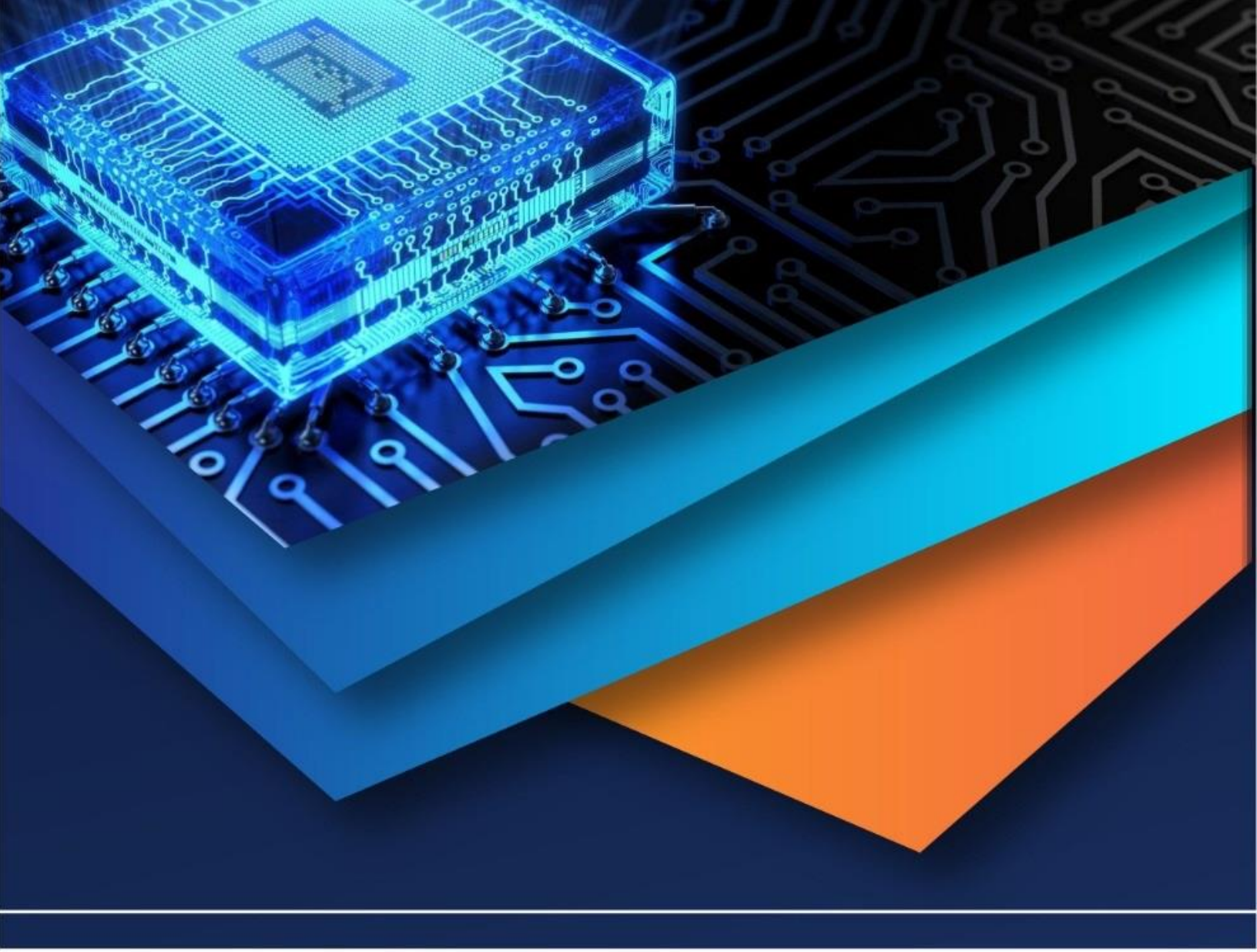
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