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Performance Analysis of a Venturi Water Pump With Different Parts Variation

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Abstract: The aim of the study is to determine the effects of varying the size of a specific part of Venturi water pump to the discharge volume flow rate and discharge head. A simulated design was fabricated as reference for the part variations. Tests were conducted on an experimental set-up where compressed air is supplied to a submerged Venturi water pump with a modified part. Discharge volume flow rates and heads were then measured and compared to the reference design test results. The obtained results demonstrated that when the chest diameter is increased the discharge volume flow rate also increased but the discharge head decreased. The effects were opposite when increasing both the pitot tube and throat lengths as the discharge flow rate decreased while the head increased. However, the results were fluctuating when changing the converging angle. Results presented in this paper can be of real use in the design and fabrication of Venturi water pumps for different applications. Further study should be made on variations of the converging angle to compare its discharge effect.
***Keywords*: Venturi water pump, chest diameter, pitot tube length, converging angle, throat length.**

I. INTRODUCTION

Venturi water pump has been widely used in the production and daily life due to its simple structure, reliable, and low-cost way to produce vacuum and considered an alternative to mechanical vacuum pumps.[1],[2] The efficiency of Venturi water pump is usually lower than that of conventional pumps but these accessories have some advantages over conventional pumps [3].

This water pump is based on the Venturi principle. The Venturi effect is the result of Bernoulli's principle of fluid dynamics, that is when the fluid is passing through the pipe and the pipe suddenly gets smaller, the fluid has to speed up to for the fluid behind it to keep moving at the same speed. It takes energy to accelerate, and the energy for the increased in speed comes from the force of pressure on the fluid. Since the energy is being used, the pressure has to decrease as the fluid accelerates. A decrease in pressure creates vacuum. The more speed the fluid has before it travels through the smaller section pipe, the faster it will have to go it once it enters, the pressure will drop, the greater the vacuum effect will be.[4]-[7]

In terms of design, a Venturi water pump is a pumping device that uses an air compressor to supply pressure to converging suction which can create vacuum. The pressure difference creates a vacuum at suction where placed in water then this device is called a "water vacuum pump." Basic vacuum pump components are shown in Figure 1.[8],[9]

In this paper, the researchers made different variations of those components considering that it can have an effect on the discharge performance of the device. A reference design was made so that for every component that was modified, all other parts were held fixed. This way the researchers were able to determine the relation of each altered component to the discharge condition namely: volume flow rate and head.

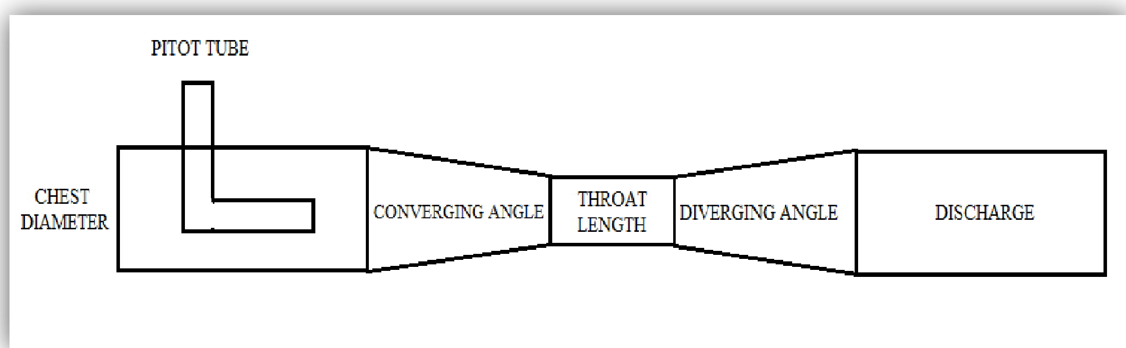

Figure1. Venturi Water Pump Parts

II. NUMERICAL METHOD

Flow Simulation using Solidworks software of the Venturi water pump was conducted before the fabrication of the device. Throughout simulations, symmetry is considered to reduce computational time and expenses. This is to ensure that the fabricated Venturi water pump will function as desired without the need of re-fabricating, thereby, minimizing cost.

During simulation, since simulating two fluids with different phases were not compatible to finish the calculation, the researchers came up with an idea of creating new fluid. Since air is more dominant, the researcher decided to create new fluid with a gas phase but its properties are the same with the water. Figure 2 shows the results of the simulation of the reference design.[10],[11]

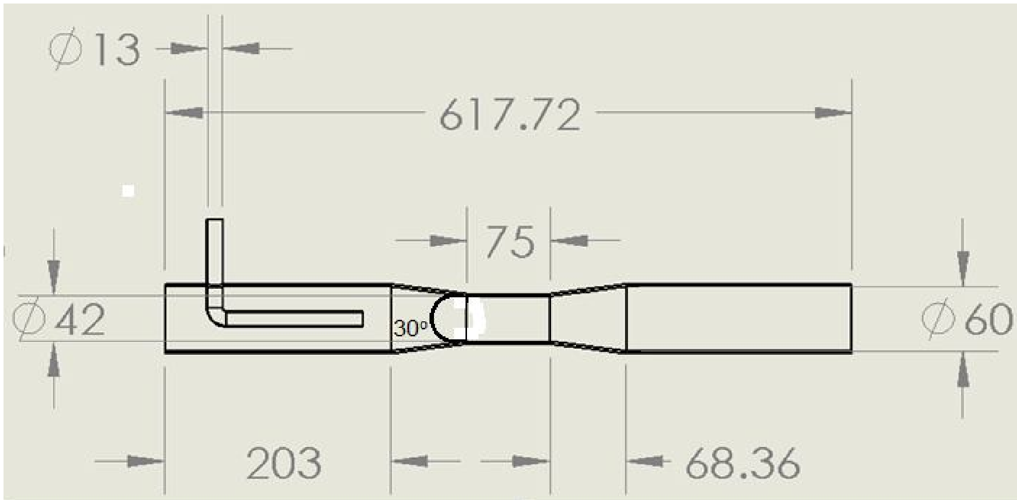

Figure2. Reference Design

Name	Current Value	Progress	Criterion	Averaged Value
SG Av Total Pressure 1	101364 Pa	Achieved (IT = 156)	24.894 Pa	101367 Pa
SG Av Velocity 1	8.56674 m/s	Achieved (IT = 184)	0.717555 m/s	8.96347 m/s
SG Volume FLow Rate	0.000563811 m^3/s	Achieved (IT = 167)	7.09819e-006 m^3/s	0.000562069 m^3/s

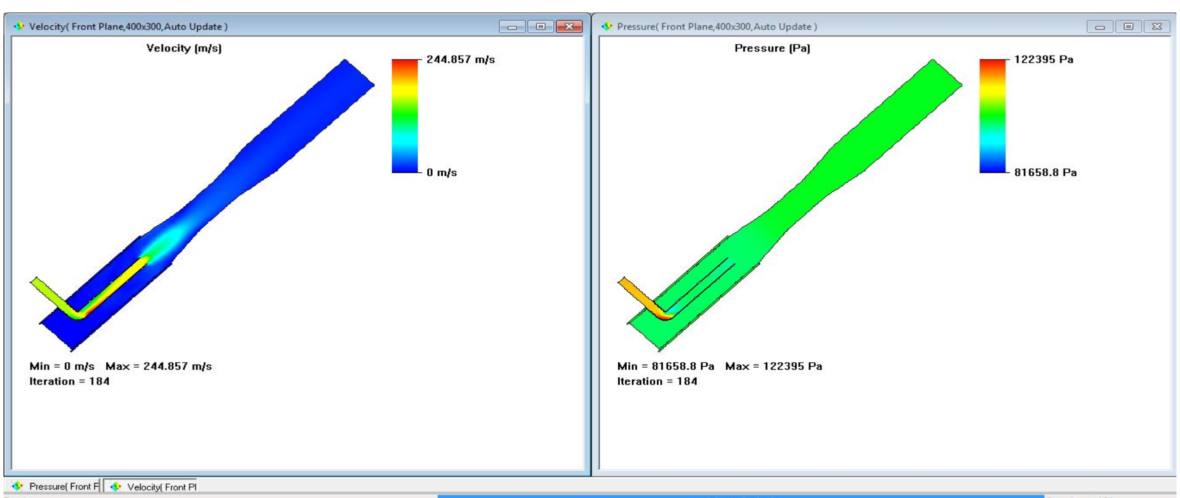

Figure3. Simulation results

Based on the result of simulation: (Figure 3)
Velocity = 8.96347 meter per second
Volume = 0.00056209 cubic meter per second

$$= 0.00056209 \frac{m^3}{seconds} \times \frac{1000li}{1m^3} \times \frac{60seconds}{1min}$$
$$= 33.7254 \frac{liters}{min}$$

Pressure = 101367 Pascals

III. EXPERIMENTAL METHOD

The four (4) parts of the Venturi water pump that are included in this study are the following: throat length, pitot tube length, chest diameter, and converging angle. Each part, except for the chest diameter, has four (4) variations on its dimension based from the reference design. See Table1.(NOTE: For each part variation, the other parts of the Venturi water pump are held fixed.)

The experimental set up is shown in Figure4. Compressed air from the compressor serves as the primary fluid entering the pitot tube and suddenly creates vacuum pressure as it passes the constriction. This vacuum pressure leads the water out the Venturi water pump, which is inclined at 45 degrees. The rectangular tank, where the pump was placed, has a base dimension of 600mm x 170mm and is elevated 20 inches above the ground. A ruler is attached to the side of the tank to measure and verify the initial and final volumes of the water for 15 seconds of operation. The discharge volume flow rate is then determined and calculated. A pole with a measuring tape attached to it was used to determine the discharge head of the Venturi water pump.

Table1. Variations For Each Part

Modified Part	Variation 1	Variation 2	Reference	Variation 3	Variation 4
Chest Diameter	-	50.8 mm	63.5 mm	70.6 mm	-
Converging Angle	22^o	26^o	30^o	34^o	38^o
Pitot Tube Length	123 mm	128 mm	133 mm	138 mm	143 mm
Throat Length	25 mm	50 mm	75 mm	100 mm	125 mm

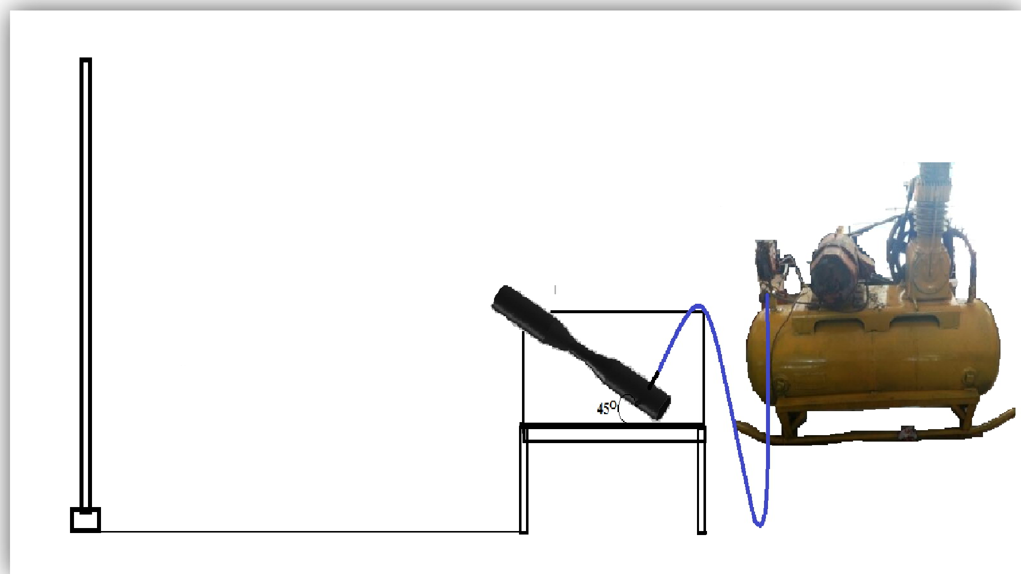

Figure4. Experimental Set-up

IV. RESULTS AND DISCUSSION

The discharge volume flow rate and head measured during the experiment are shown in Tables 2 and 3.

Table2. Volume Flow Rate Test Results

Modified Part	Volume Flow Rate (liters/min)				
	Variation1	Variation 2	Reference	Variation 3	Variation 4
Chest Diameter	-----	28.152	30.192	32.64	-----
Pitot Tube Length	33.456	31.824	30.192	23.664	20.400
Converging Angle	28.360	35.360	30.192	22.294	24.480
Throat Length	34.680	33.456	30.192	29.376	22.848

Table3. Discharge head test results

Modified Part	Discharge Head (inches)				
	Variation1	Variation 2	Reference	Variation 3	Variation 4
Chest Diameter	-----	115	111	103	-----
Pitot Tube Length	104	108	111	124	128
Converging Angle	117	107	111	125	116
Throat Length	103	110	111	121	132

A. Effects of Chest Diameter

As shown in the Figure5, the red curve represents the relationship between the chest diameter and volume flow rate while the blue curve represents the chest diameter and discharge head. The two curves tend to have opposing results when the chest diameter is enlarged. It can be seen that the largest chest diameter gave the highest value of volume flow rate (32.64 l/min) but attained the lowest discharge head (103 inches). In other words, as the chest diameter increases, the discharge volume flow rate of the pump also increases, but its discharge head decreases.

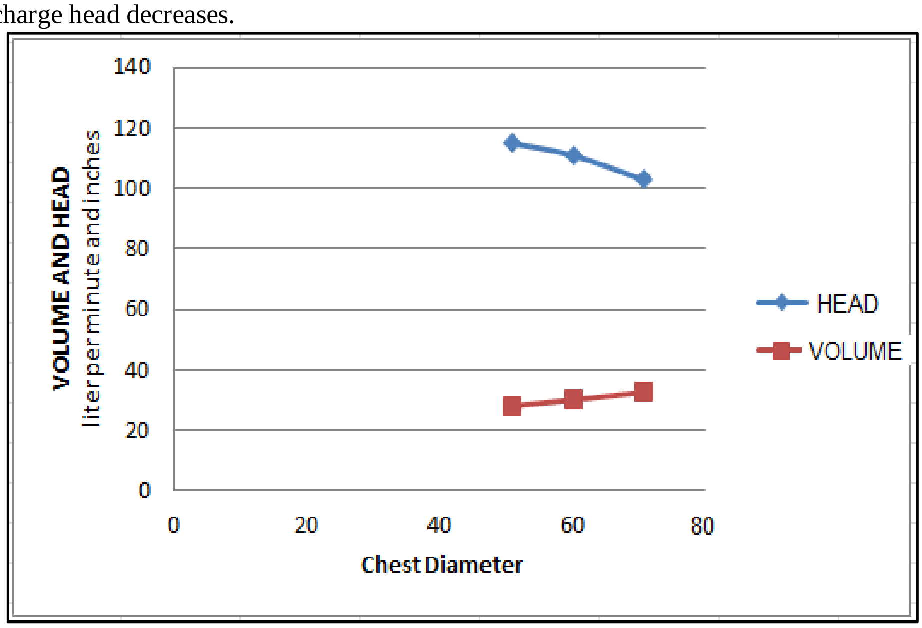

Figure5. Volume Flow Rate and Head vs Chest Diameter

B. *Effects of Pitot Tube Length*

In Figure6, the graph shows the relationship between the pitot tube length and the discharge head and volume flow rate. In terms of the volume flow rate, the shortest pitot length gave the largest value at 33.456 l/min, while the longest pitot length gave the smallest value at 20.4 l/min. On the other hand, it can be seen that the shortest pitot length attained the lowest discharge head at 104 inches, while the longest pitot length attained the highest value at 128 inches. In other words, as the pitot tube length is increased, the discharge volume flow rate tends to decrease but the discharge head tends to increase.

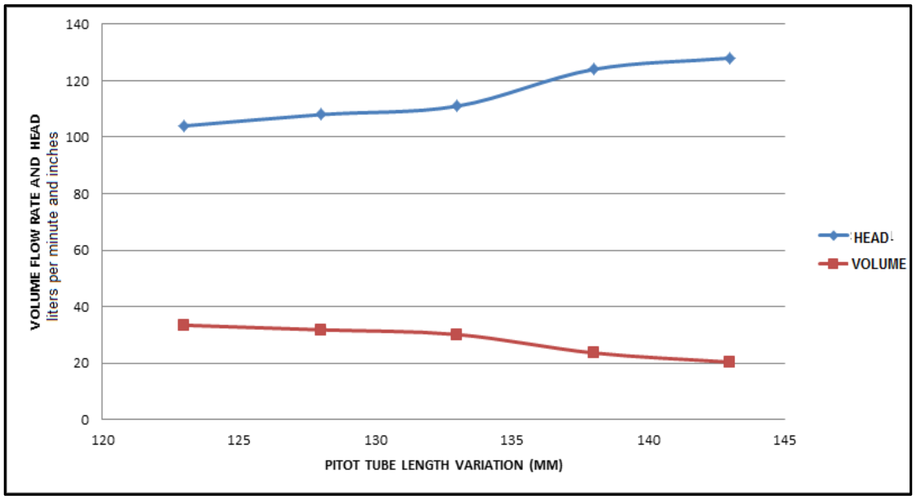

Figure6. Volume Flow Rate and Head vs Pitot Tube

C. *Effects of Converging Angle*

Figure7 shows that the device with the largest volume flow rate of 35.36 l/min was at 26^{o} converging angle. In contrast, less than or equal to 22^{o} of converging angle is less efficient because the attained result of 28.56 l/min is lower than that of the reference design at 30.192 l/min. Moreover, greater than or equal to 34^{o} of converging angle produces fluctuating results with lesser volume flow rates compared to that of the reference design. In the highest head obtained was 125 m at 34^{o} angle. Based on the 30^{o} reference angle, when the angle decreases to 26^{o}, the head obtained also decreases. However, when it decreases to much lower angle at 22^{o}, the head increases. On the other hand, when the angle increases to 38^{o}, the head decreases.

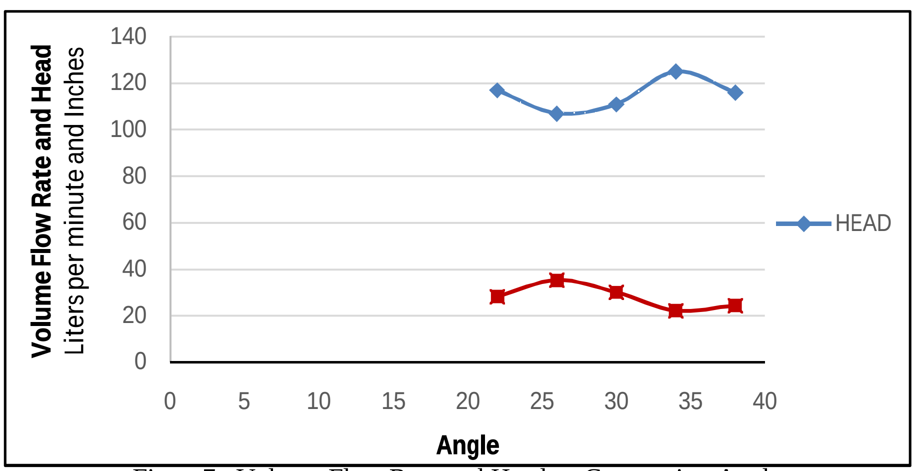

Figure7. Volume Flow Rate and Head vs Converging Angle

D. *Effects of Throat Length*

In Figure8, the 25mm throat length produces the lowest discharge head of 103 inches while the 125mm throat length reaches the highest discharge head of 132 inches. It means that increasing the throat length will decrease the discharge volume flow rate but will increase its discharge head. On the contrary, decreasing the throat length will increase the discharge flow rate but will decrease the discharge head.

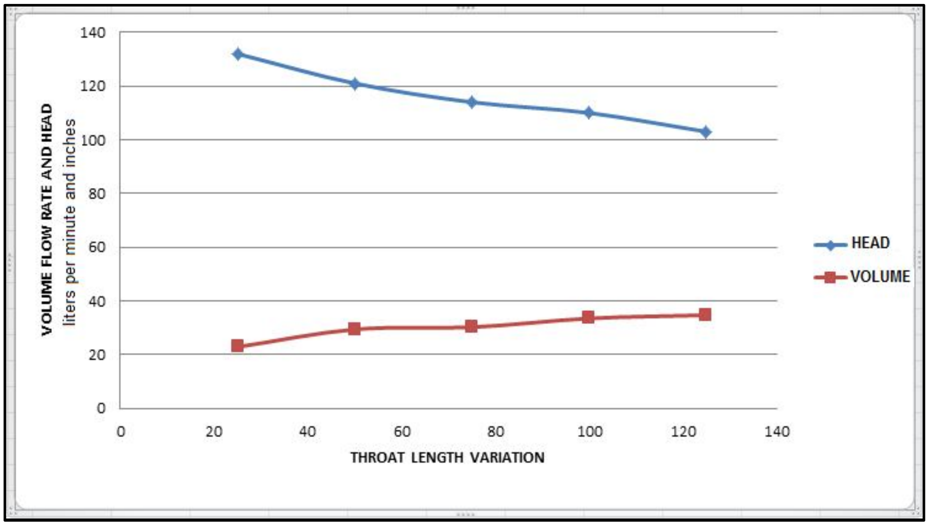

Figure8. Volume Flow Rate and Head vs Throat length

V. CONCLUSION

Experimental results yield the following conclusions when varying the dimensions of a specific part of a Venturi water pump:

A. as the chest diameter increases, discharge volume flow rate also increases but the discharge head decreases, and vice versa.
B. if the pitot tube length is increased, the discharge head also increases but the discharge flow rate decreases, and vice versa.
C. when the converging angle lessens to 26^o the volume flow is larger than the reference design because of the long narrow section which gives smoother flow of the water but angles less than 26^o gives lower volume flow because the pitot tube outlet in the compressed air is far from the suction area; when the converging angles are greater than the reference design, the volume flow is lower than the reference design because the vacuum water collides at the inlet of the throat diameter which causes the water to back flow.
D. when the throat length the higher is increased, its discharge head also increases but the discharge volume flow rate is decreased.

VI. ACKNOWLEDGMENT

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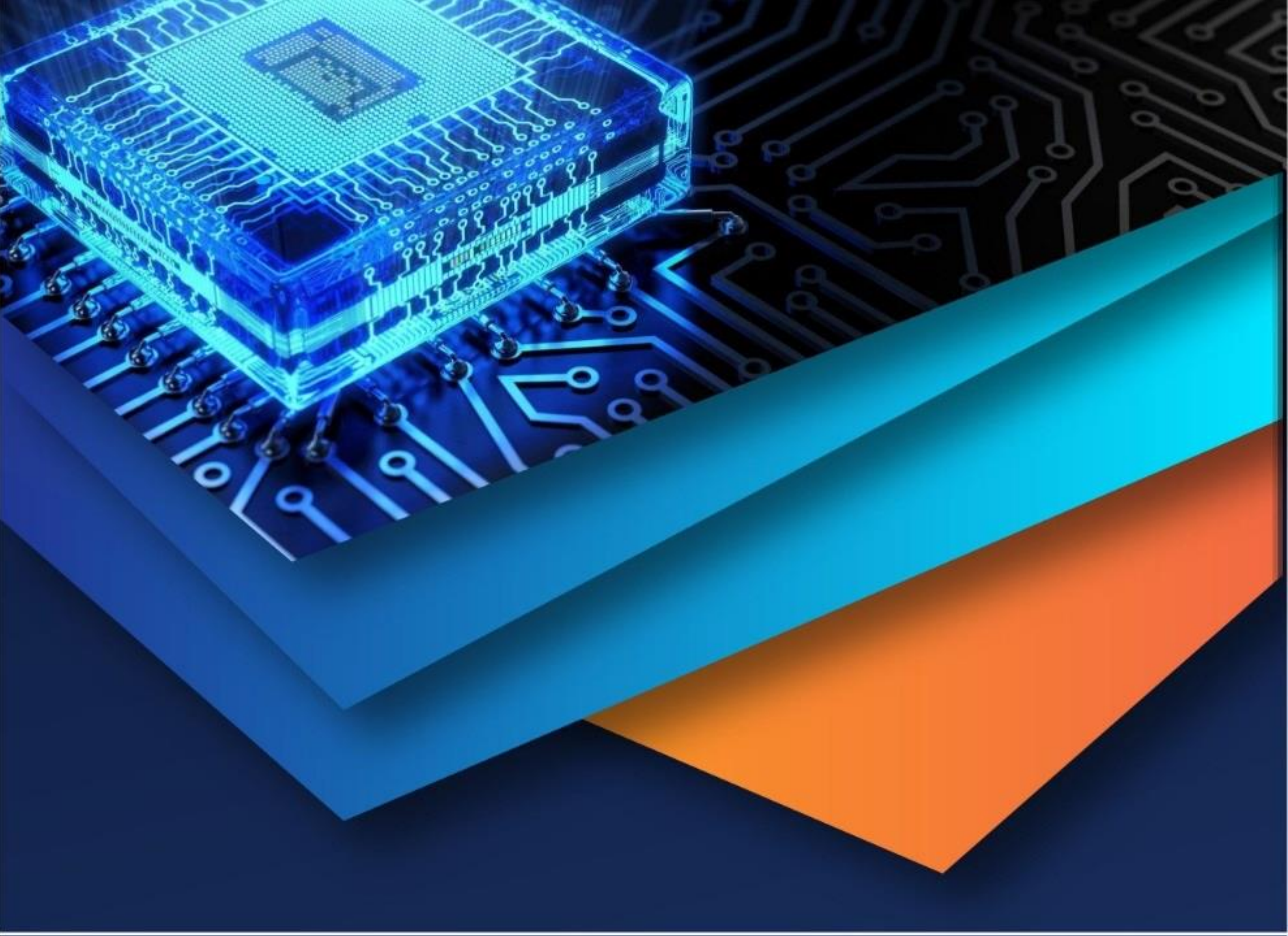

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