iJRASET
International Journal For Research in Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 8 **Issue:** VI **Month of publication:** June 2020

DOI: http://doi.org/10.22214/ijraset.2020.6056

www.ijraset.com

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International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429
Volume 8 Issue VI June 2020- Available at www.ijraset.com

Design and Analysis of Circular Runway for some Existing Airports in India

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Abstract: ***In India, there are a number of International and Domestic Airports which can be seen in all major cities of India. From all of this, Chhatrapati Shivaji International Airport (CSI) in Mumbai is the second busiest airport in India with 34.7million passengers in 2018. There are two runways at Chhatrapati Shivaji International Airport with flight movement from 76 to 96 hours. Another Airport is Netaji Subhas Chandra Bose Airport in Kolkata, which is the fifth busiest Airport in India with more congested passengers' traffic movement and flight delay due to busy runway. Circular Runway concept is a concept which has been in consideration for a long time. This concept is one of the best ways to resolve air traffic, provide more aircraft movement per hour and a safe landing and take-off operations in any condition. Circular Runway can reduce the chances of accidents and multiple operations can be resolved several times. This concept will be applied to existing airports in India and feasibility will be determined. It will help in forming the basis for construction of the Airport and solve problems which are currently being faced all over India. In this paper, we are going to design and analyses Circular Runway for particular existing airports (i.e. Chhatrapati Shivaji International Airport, Netaji Subhas Chandra Bose Airport, and Navi Mumbai Airport) and check the feasibility of construction of a new runway in India.***

Keywords: Circular Runway, International Civil Aviation Organizations, Federal Aviation Administration, Air Traffic Movement, Airport capacity.

I. INTRODUCTION

Circular Runway consists of an airport with circular shape, that fits for both seasonal and hub airports. This runway is used for take-off in any direction and landing from any direction and will allow aircraft to shorten their global trajectory through optimized departure and arrival routes and will offer the unique characteristic that the runway can be used under any wind condition and crosswind will not affect the procedure at a high level as it can bereduced.

The thought of looking forward to this topic of Circular Runway is that India is a developing country with a large population inbound and with a large tourism network. Chhatrapati Shivaji International Airport (CSI) in Mumbai is the Second busiest airport in India with 34.7 million passengers in 2018. The Netaji Subhas Chandra Bose airport (NSCB) handled almost 20 million passengers in financial year 2017-18 making it is the fifth-busiest airport in India in terms of passenger traffic and flight delay due to busy runway after airports at Delhi, Mumbai, Bangalore and Chennai. India is expected to welcome more millions of domestic and international passengers by 2020 as compared to past years. The traditional airport can be used at low- cost basis at places where the movement is very less but for hub airports it requires

more runways, which comes at the cost of a lot of areas, facilities, helps in saving fuels, aircraft maintenance, repairs and location distance from the city. To satisfy all the requirements we are going to apply the concept of circular runway to some existing airport and check if this concept is to become feasible. This concept will be applied to the airport with a large crowd like

Chhatrapati Shivaji International Airports, Netaji Subhas Chandra Bose Airport (Kolkata) and Navi Mumbai Airport. These airports are taken into consideration because they are facing many problems in present and past years and due to this there will be large impact on them in future.

Navi Mumbai Airport is taken into consideration because its work is still in progress. So to get an idea that this concept will go to work at this place rather than conventional runway that has been provided. The circular runway had never been implemented in India till now. It is an innovative concept for airport operations in the long term. Three different operational cases can be identified for aircraft landing on and taking- off from the circular runway. There is strong wind, low wind, and changing wind directions. By keeping these operational cases in mind, Circular Runwayhas to be provided in particular area.

ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429
Volume 8 Issue VI June 2020- Available at www.ijraset.com

II. OBJECTIVE

So the main objectives of implementing Circular Runway are as follow:

A. To apply the circular runway concept to particular existing airport in India, compare it with conventional runway airport and then to check the feasibility of the circular runway.
B. To allow the planes to take off from any point in the circle, so they could avoid damaging crosswinds that can shut down linear runways.
C. To find out the Radius of circular runway for safe operations and exact bank angle for safe ground rolling.

III. CONCPT OF CIRCULAR RUNWAY

A. Description

The circular runway is an innovative concept for airport operations in the long term future which is based on a radically new airport design encompassing a circular shape. In order to allow to sufficient number of landing and take-off at a time, the Circular Runway inner radius is set to some diameter according to existing Airport Design Analysis of Chhatrapati Shivaji International Airport, Netaji Subhas Chandra Bose Airport and Navi Mumbai Airport. The minimum length for circular runway is set to be almost three times more than straight runways, which is long enough to allow multiple simultaneous landing and take-off on the runway and to build the airport infrastructure inside the circular runway while keeping the airport compact. Due to higher centrifugal forces for a narrower runway, the runway width is set to 2.5 times of actual width (from International Civil Aviation Organisations) for avoidance of discomfort of passengers. To limit the effects of centrifugal forces, the outside of runway is banked with increasing angle.

B. Design

The taxiway system consists of an outer and an inner taxiway ring between the runway and the terminals area. The outer taxiway, operated in the same directions as the runway, is connected to runway access points through high-speed exit taxiways, where one aircraft can hold if needed. The inner taxiway is operated in the opposite direction to the outer one. Taxiways between the airport's buildings link the inner circular ring to the inner airfield area. The most important elements are the design of the infrastructure of the airport, and the access to the airport, including intermodal aspects. Access from the outside to the inside facilities is provided to employees and suppliers through tunnels passing under the runway, and to passengers through an APM (Automated People Mover) connecting the main terminal to the intermodal station located outside and to the parking lots that may be constructed under the runway.

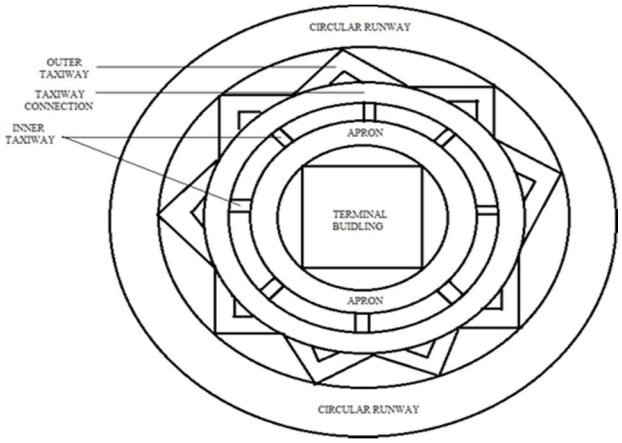

Figure No. 1(Airport Design)

C. Super Elevation and Centrifugal Force acting on Circular Runway

Super elevation on circular runway is very necessary because of risk of skit of back gear of aircraft due to its high speed and slight turn. But the necessary elevation on circular runway track should be considering the comfort level of passengers. When a plane will land or take-off on a circular runway due to its necessary high speed plane will face a centrifugal force which will try to deviate the plane, so the sliding will take place 0n back gear. To counter act this centrifugal force necessary elevation should be provided on track during the design and analysis of Circular Runway.

D. Modification in Aircraft

Some modification in Aircraft has to be carried out such as a double bubble fuselage, enabling a larger landing gear track and providing a certain lift, T-tail empennage, Engines should be provided in the rear part of the fuselage thus decreasing the risk of contact with the runway, and larger control surfaces to increase its maneuverability during low-speed phases.

IV. METHODOLOGY

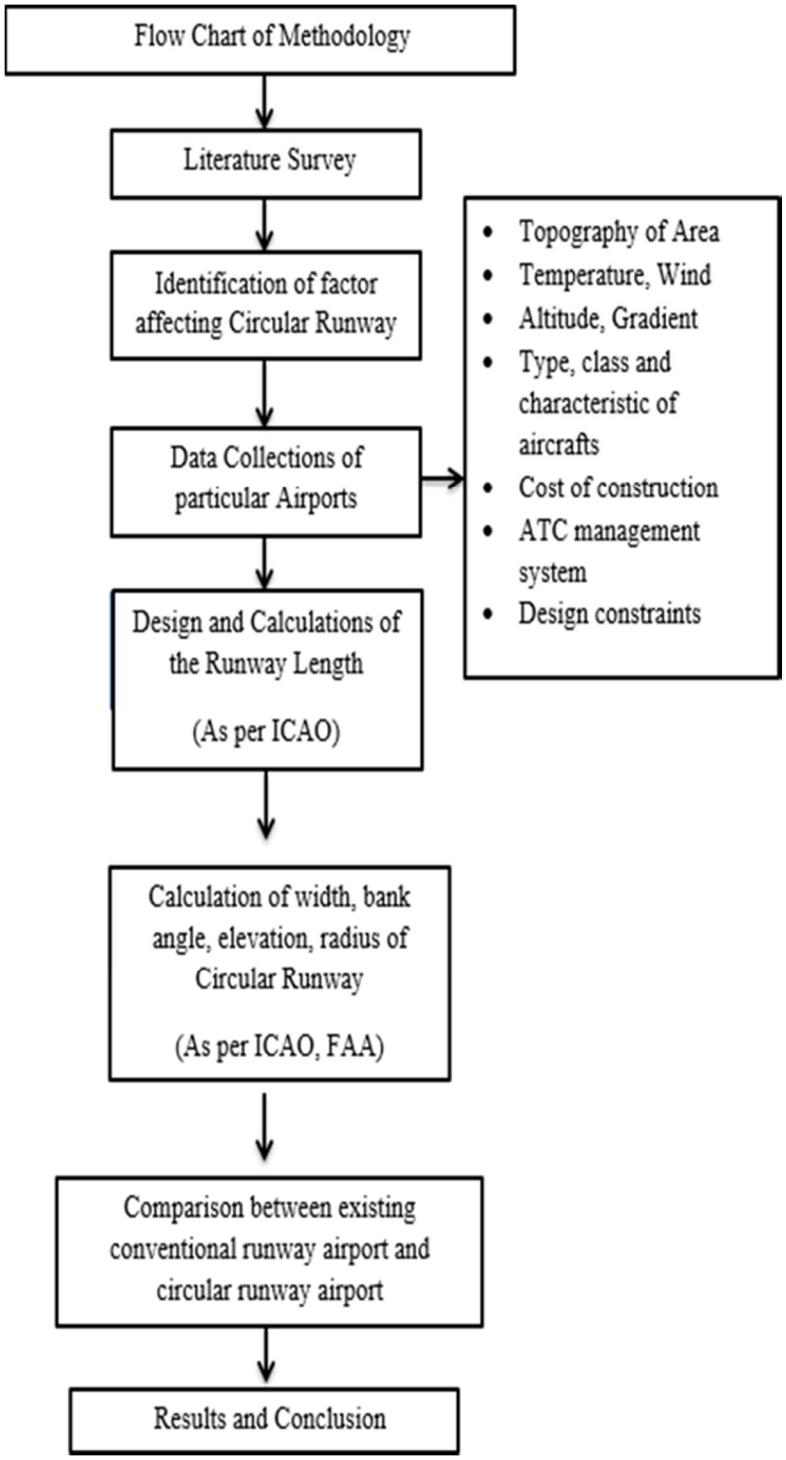

Figure No. 2

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V. DATA COLLECTION

The data for the existing airports (i.e. Chhatrapati Shivaji International Airport, Netaji Subhas Chandra Bose Airport and Navi Mumbai Airport) was collected from a particular airport area. The wind and temperature data are collected from the wind rose diagram and last year's temperature average. The table mentioned below shows the collected data of Kolkata Airport. In the same manner, the other 2 airport data were collected and analyses of circular runway for those airports were carried out.

A. Netaji Subhas Chandra Bose Airport

Table No.1

Wind Detail: (From Wind Rose Diagram)	N22°39.81' and E88°26.81' direction.
Temperature Detail: (Temperature Table) Monthly Mean Average daily Temperature (May 2019) (Ta) Monthly Mean of Maximum daily Temperature (May) (Tm)	35.87° C 36° C
Cross Wind Component for Airfield	10.3m/s
Runway Elevation at Aerodrome	6m
Friction	0.2-0.3
Runway Heading	007° to 187°.
Total Passengers Yearly	21,877,350.
Total Aircraft Movement	161,565.
Cargo Tonnage	163,233
International operators (Types of Aircraft)	A320, B737, A319, B777, ATR, B787, A350.
Domestic operators (Types of Aircraft)	ATR, A320, B787, B737, BQ4.
Area provided Detail	1,641 acres (664 ha)
Cost of Construction	2325 Crore.
Terminal Total Capacity	25 million passengers a year.
Runway Detail: Length & Wide: Runway1 Runway 2 Runway 1flights capacity Runway 2 flights capacity	Two Parallel Runways. 3,190m-long and 46m-wide. 3,627m-long and 46m-wide. 35 flight per hour. 15 light per hour.

B. Data Collected from International Civil Aviation Organisations Code

The following data are collected for the analysis of Circular Runway from International Civil Aviation Organizations Code, Annex-14.

Design Speed: An aircraft of larger size need minimum 285-290 km per hour, and smaller 155-160 km per hour.

Radius: An aircraft need minimum radius of 180 m for turning. Width: Width of runway varies from 55 m to 80 for small and bigger size of airport respectively.

Bank Angle: The minimum bank angle for aircraft is 6 degree and maximum recommended by ICAO is 60 degree.

Elevation: Elevation of runway should be such that the wings of craft should not be in touch with ground, minimum clearance should be 0.73m and maximum should be 5.

VI. DATA ANALYSIS

The project was to find the circular runway feasibility in the place of the particular existing runway and can it be implemented in our country. For which, data was required which can give a clear view. For comparing traditional runway design to the circular runway design for Navi Mumbai Airport, Netaji Subhas Chandra Bose Airport (Kolkata), Chhatrapati Shivaji International Airport (Mumbai), data was collected from various airports and after that the design of circular runway has been carried out by considering the following steps:

1) Runway Length Calculation

a) In Runway Length, first the Basic runway length was determined from the take-off performance charts. After getting value of Basic Runway Length, that value was added to the Actual Runway Length formulas. Actual Runway Length was calculated by using formula:

b) Elevation= [Take off run× .07 × Runway elevation/300] ….. (a)

c) Temperature (ART) = Ta + (Tm – Ta)/ 3 ….. (b)

d) Slope= [Take off run × % runway slope × .10] + Take off run…(c)

e) Tm, Ta and Elevation data was obtained from the data collected for existing airports.

f) After putting those data into the temperature, elevation and slope formula (a), (b) and (c) the Length of Existing Runway was determined.

g) For getting Movement of 2 or 3 aircraft at same time, length of circular runway = 2 or 3x Length existing of runway.

h) Width of Circular Runway: was decided from the Runway Width Table referred to from International Civil Aviation Organization Annex 14, (page 3-3) and multiplied by 2.5times of the selected Runway Width.

2) Radius of Circular Runway: Radius of runway should be such that the landing and taking-off operations should be done without any extra effort. So designing for the biggest aircraft boing 474, which need maximum speed for landing and take-off as 250 kmph. Formula applied for calculating the Radius of Circular Runway is Circumference= 2π x R (Radius).

3) Elevation of Circular Runway

a) To counter act this centrifugal force necessary elevation we are providing on track. Values of mass and speed are taken for Boeing 474 and 777.

b) Total Centrifugal force (Fc) = mV^2/R.

c) For reducing the effect of this force on plane we are providing necessary elevation using the formulae recommended by ICAO and FAA both i.e. (e+f = V2/125R).

d) According to Federal Aviation Administrations and International Civil Aviation Organisations the friction between tire and pavement should be between 0.15.

4) Bank Angle: For Boeing 474 or 777 which have the maximum landing and takeoff 69.4m/s or 73.61m/s. As we know the formula of bank angle, Bank Angle= [speed of aircraft / 10] + 7.

5) Total Area Covered = 3.14xRxR, (R=Outer Radius).

According to the above calculations steps and procedure, the result for the existing Airports came out to be:

A. Netaji Subhas Chandra Bose Airport

1) Runway Length Calculation

a) Basic Runway Length = 3100m.

b) Actual Runway Length = 3950m.

c) Movement of 2 aircraft at same time length of circular runway = 7900m.

d) Width of Circular Runway = 150m.

2) Radius of Circular Runway (R) = 1257.32m.

a) (External) Radius of circular runway= 1257.32 m ~1260 m.

b) (Internal) Radius of circular runway= 1260-150=1110m.

3) Elevation of Circular Runway

Values of mass and speed are taken for Boeing 777. (M= 23000Kg, V= 73.61m/sec)

a) Total Centrifugal force (Fc) = 100.82 KN

b) e = V^2 /125 R – f, e= 0.28.

As e= 0.28 is greater than e_{max}= 0.07 Therefore, provide super elevation (e) = 0.07.

f= v^2 / gR, f= 0.36

The value of (f) = 0.28 greater than the value for f= 0.15 Hence take (f) = 0.15

Allowable speed for maximum value of e= 0.07 and f=0.15

v_a = √ (0.22g x R) = √ (0.22 x 9.81 x 1260 = 52.147m/s = 188kmph.

i) As the allowable speed for specific circular runway= 188kmph which is less than aircraft take-off speed Boeing 777 selected which is the larger type aircraft available in NSCB Airport (Kolkata) proves out to be Not Safe against super elevation and centrifugal force.

ii) The minimum speed required for smaller size aircraft ranges between 155-160kmph as per ICAO and FAA recommendation which is less than the allowable speed calculated.

iii) Hence Circular Runway proves out to be safe against super elevation and centrifugal force for following Aircrafts: Smaller Sized General Aviation Aircraft, Turboprop powered passenger aircraft (Small) and Turboprop Powered Aircraft (Heavy) such as Beriev Be- 200, ATR-42, Antonov An-158, Beechcraft 200 Super king, British Aerospace BAe 146, Bombardier CRJ-100-200, Cessna 208, etc. After this some modifications in these Aircraft have to be carried out.

4) Bank Angle= [73.41 / 10] + 7= 14.36 degree.

5) Total Area Covered= 3.14x12600x1260 = 4985064 sqm.
= 1231.79 acres.

6) Minimum Distance Between two aircraft=120m.

B. Comparison Made Between Traditional Runway And Circular Runway As Per Following Parameters

Parameters	Conventional Runway	Circular Runway
Runway Length Available	3190m & 3627m	7900m and 1260m (Outer radius)
Width	46m and 46m	150m (2-3 Segments)
Aircraft movement at same time	1	2
Cost of Construction (Crore)	2325	3138.75
Area in (Acres)	1841	1231.79

Table No 2(Comparison of Netaji Subhas Chandra Bose Airport)

In the same manner, the other 2 Airport analyses were carried out according to the calculation steps and procedure and results were obtained. Comparison of remaining 2 Airports from the result obtained.

C. Comparison Made Between Traditional Runway And Circular Runway As Par Following Parameters

Parameters	Conventional Runway	Circular Runway
Runway Length Available	3660m & 2990m	7400m & 1180m (Outer radius)
Width	60m and 45m	150m (2-3 Segments)
Aircraft movement at same time	1	2
Cost of Construction (Crore)	10724	14477.4
Area in (Acres)	1850	1080.35

Table No. 3 (Comparison of Chhatrapati Shivaji International Airport).

D. Comparison Made Between Traditional Runway And Circular Runway As Per Following Parameters

Parameters	Conventional Runway	Circular Runway
Runway Length Available	3700m & 3700m	11550m &1840m (Outer radius)
Width	45m & 60m	150m (2-3 Segments)
Aircraft movement at same time	1	3
Cost of Construction (Crore)	9932	13408
Area in (Acres)	3300	2626.92

Table No. 4 (Comparison of Navi Mumbai Airport)

VII. CONCLUSION

Through our project analysis, it was concluded that the circular runway may be possible in India in some conditions and after some modification in Aircrafts. So the aircrafts will be able to fly in any direction, giving pilot greater control over where to fly, and where to avoid flying. This concept has not been implemented till now in India due to its non-executed trials and high requirements. The implementation requirements are as follows:

A. Area Required and Profit

1) The area covered at Navi Mumbai Airport is 3300 acres, Netaji Subhas Chandra Bose Airport (Kolkata) is 1841 acres at CSI Airport is 1850 acres.

2) Area required by Circular Runway at Navi Mumbai Airport is 2626.92 acres, Netaji Subhas Chandra Bose Airport (Kolkata) is 1231.79 and at CSI Airport (Mumbai) is 1080.35 acres.

3) Area profit at Navi Mumbai Airport is 673.08 acres, Netaji Subhas Chandra Bose Airport (Kolkata) is 609.21 acres and at CSI Airport (Mumbai) is 769.65 acres.

B. Aircraft Movement

1) The Aircraft movement at Netaji Subhas Chandra Bose Airport (Kolkata) is 280 aircraft per day (approx.) and at CSI is 900 aircraft per day.

2) The circular runway can provide 560 at Netaji Subhas Chandra Bose Airport (Kolkata) and 1800 at CSI aircraft movement per day.

C. Time Delay

Time delay at Netaji Subhas Chandra Bose Airport (Kolkata) is 10min (approx.) and CSI Airport (terminal 2) is around 6 min. at min traffic on other hand time delay on the Circular runway is very rare.

D. Other Requirements

1) Not safe against centrifugal force and super elevation.
2) Can be made feasible only against the use of particular size of Aircraft.
3) Require high capital investment.
4) The circular runway cannot be extended if demand grows.
5) The maintenance and repair could disrupt the whole runway movement.
6) It can only be applied to smaller airports but the cost will not be recovered by operating at maximum efficiency.

VIII. ACKNOWLEDGMENT

We hereby are grateful to be able to present our project on the topic “Circular Runway” and would like to extend our gratitude to the people who have helped and supported us through it.

We are highly obliged to express our heartfelt thanks for the initiation of the project by Asst. Prof. Sagar Butle (Project guide). It is with great pleasure that we express our gratitude for his guidance and advice without which this study would not had been possible. We thank him for his valuable suggestions and worthy counsel. His keen interest and untiring assistance enabled us to complete this project.

We are like to express sincere thanks to Asst. Prof. Rajesh Dubey, Head of Civil Engineering Department, DR. J.B Patil, Campus Director, UCOE, for allowing us to carry our project and provide us with all the facilities needed to complete our project.

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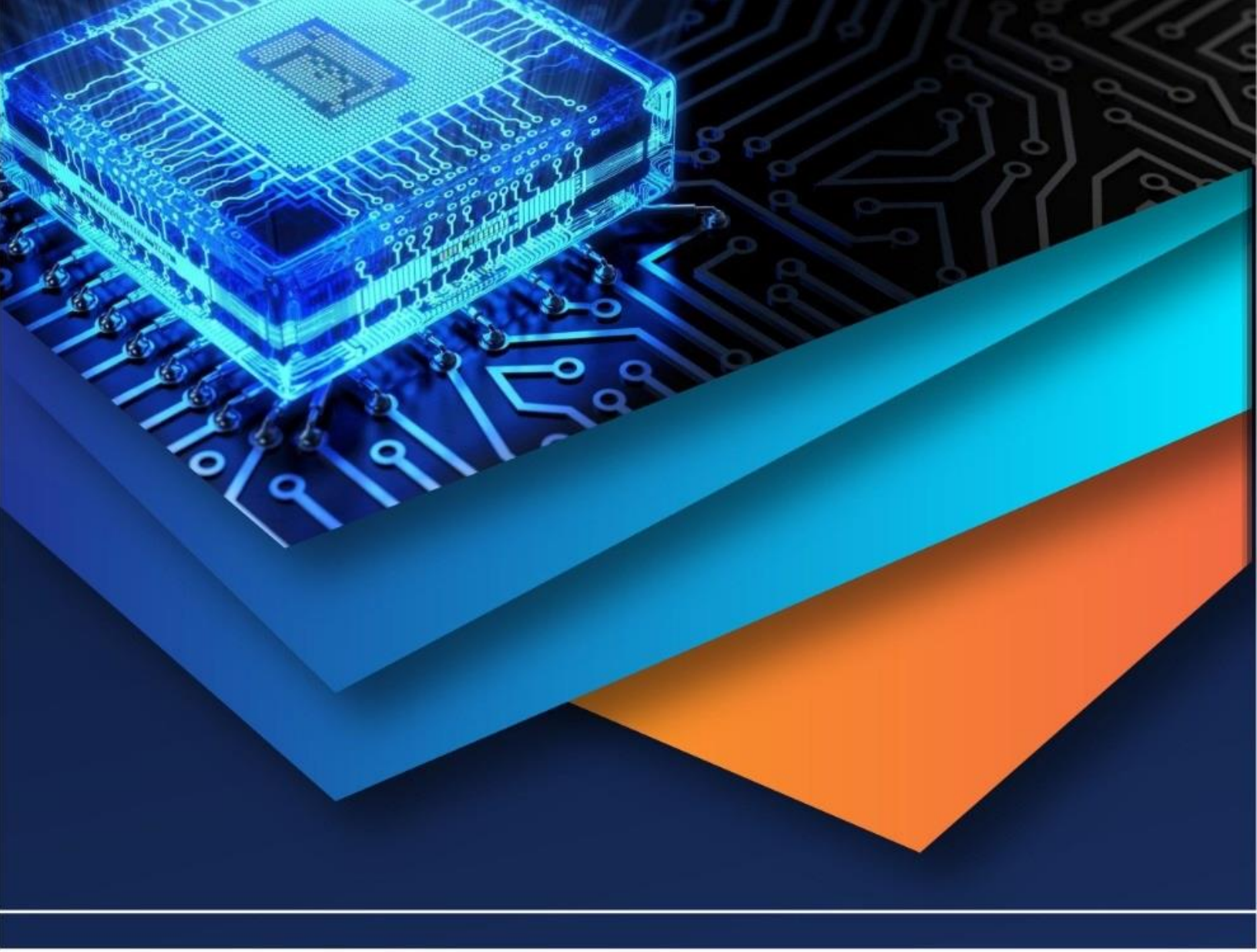

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