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Maglev Technology and the World Scenario

S. Anurag[1], Tanish Aggarwal[2], J. P. Kesari[3]
[1, 2]*Department of Applied Physics, Delhi Technological University*
[3]*Department of Mechanical Engineering, Delhi Technological University*

Abstract: In this growing world when cities and towns continue to become more crowded , the modes of transportation that are currently available to us will not be able to handle the demands of these overpopulated areas. This problem can be solved by the concept of electromagnetism.
Electromagnets and superconducting magnets have allowed us to create a magnetic levitating train nicknamed "Maglev" which reduces friction between track and train by floating over it instead of directly being in contact. This has a lot of potentials to create trains that require a high initial investment but later on low maintenance and helps in fast transportation thus saving time.
The magnetic levitation system used by these trains play an important role in suspending the Maglev train stably and following the track quickly with the adequate gap from the side walls thus highly reducing chances of damage. This paper gives an idea about the tech aspects of maglev projects worldwide such as Germany, Japan, and USA and also discusses about various idea to bring Maglev trains in developing countries like India.
Keywords: Maglev, superconducting magnets, magnetic levitation, Transrapid, lateral guidance, linear induction morot, frictionless travel.

I. INTRODUCTION

A. Objectives

This paper presents an outline of worldwide developments in the field of Maglev and also covers some technical issues related to them.[3] We will also discuss about the technology incorporated in Maglev and will look at the feasibility of Maglev in India. In this paper, there are some specific considerations as if Maglev systems, which is referring to industrial or commercial Maglev and Maglev projects, which is referring to studies, R&D developments, which have not reached, at that time, an industrial or commercial level [8],[9].

B. High Speed Ground Transportation

During this time of industrialization and rapid growth of technology ,per capita income and population has also increased drastically all this has combined the growth, by a factor of 7.4, which has translated into a nearly proportional increase in passenger mobility , so in order to fulfil these sustainable objectives ,there are necessitates to improve transport in a drastic way with regards to environmental impacts, societal effects (noise, pollution, congestion) and economical cost (in particular in terms of beneficial operations and infrastructure amortization, which necessitates the reduction of operational and maintenance costs) [1].
Lopez-Ruiz indicates that in 2050, France and other industrialized countries should decrease their CO2 emissions of 75% compared to today's values. *Absorbing increased mobility, r educing environmental impacts* and i*ncreasing sustainability of transport* are the three challenges of future transport. This can only be feasible with the invention of new sustainable innovative transport systems and services his can only be feasible with the invention of new sustainable innovative transport systems and services.
Today mainly, Magnetic Levitated (MAGLEV) systems are considered as industrial solutions. Both industrial Maglev for low speed (≤150 km/h) as Urban Maglev and high speed (≥400 km/h) Maglev are seen on the worldwide market.

Various solutions are considered mainly depending on the speed of the transportation system and on the mechanical air gap between the vehicle and the track. Super-speed maglev systems are limited to two industrial types:

1) The German and Chinese Transrapid systems:
2) The superconducting JR type (Japan MLX).

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II. MAGLEV TECHNOLOGY (BASIC IDEA OF MAGLEV)

A. *Basic Idea of Maglev*

Maglev technology comprises of a system in which the vehicle runs levitated from the guide way by employing electromagnetic forces between superconducting magnets on board the vehicle and coils on the ground. It is analogous to running a bullet train in the conditions that there exist zero or negligible friction between the train and the track. The magnetic levitation is achieved with the use of an *electrodynamic suspension system* (EDS).

Electromagnetic Suspension works on the fundamental principle of magnets that it's like poles are repelling and unlike the poles are attractive. EMS does this in a controlled manner this means that that the magnetic area is transient or managed.

1) *Frictionless Travel:* Friction less travel helping in improved speeds of train leading to faster transportation. Also, as there is no contact between train and track, it will lead to less mechanical wear and tear of parts, thus making them more durable, even more than airplane sometimes.
2) *Energy Efficient:* Maglev does not consume oil but instead uses electricity to function, which can be produced from other renewable or non-renewable resources. When traveling at 500kph in the open atmosphere, Maglev consumes only 0.4 mega joules per passenger mile, compared to 4 mega joules per passenger mile of oil fuel for a 32-kilometers-per-gallon car that carries 2 people at 96kph.
3) *Quality of Life:* The quality of life will improve as an outcome of the construction of Maglev trains. In the course of time Airports have been becoming more and more congested ever since the events of September 11, 2001 (9/11 attacks). People have to now wait for a very long time in order to board their planes, due to increment in the security. This is not the comfortable way for people to travel. Although planes are still the fastest way to travel, compared to the other transportation options that exist at this time, Maglevs can play a significant role to ease this problem. Since they have the ability to travel up to 500 km/h, people will be able to travel long distances on land in a relatively short amount of time.

Fig.1 Japanese Maglev train

B. *Lateral Guidance System.*

The Lateral guidance systems have the work to make sure the train stay on the track and have negligible chances of derailing. It stabilizes the movement of the train from moving left or right on the train track by using the system of electromagnets which are placed in the undercarriage of the Maglev train [8]. The placement of the electromagnets in combination with a computer control system make sure that the train does not deviate more than around 10mm from the actual train track [3].

1) *Japanese:* The lateral guidance system used in the Japanese electrodynamic suspension system can use one “set of four superconducting magnets” to control lateral guidance from the magnetic propulsion of the zero flux coils located on the guideways of the track [6]. The Coils are used frequently in the design of Maglev trains. The Japanese Lateral Guidance system also uses a semi-active suspension system. This system dampens the effect of the side-to-side vibrations of the train car and allows quite comfortable train rides [8].This stable lateral motion caused from the magnetic propulsion is a joint operation from the acceleration sensor, control device, to the actual air spring that dampens the lateral motion of the train car [9],[3]. The lateral guidance system which used in the Japanese electrodynamic suspension system uses one “set of four superconducting magnets” to control the lateral guidance from the magnetic propulsion of the zero flux coils which are located on the guideways of the track [6]. The Coils are used frequently in the design of MagLev trains. The Japanese Lateral Guidance system also uses a semi-active suspension system [8].This system dampens the effect of the side-to-side vibrations of the train car and allows quite comfortable train rides. This stable lateral motion caused from the magnetic propulsion is a joint operation from the acceleration sensor, control device, to the actual air spring that dampens the lateral motion of the train car [9].

2) *German:* The lateral guidance system found in the German transrapid system is similar to the Japanese model. In a combination of attraction and repulsion, the Maglev train is able to remain centered on the railway.[6] Once again levitation coils are used to control lateral movement in the German Maglev suspension system. The levitation coils are connected on both sides of the guideway and have opposite poles [8]. The opposite poles of the guideway cause a repulsive force on one side of the train while creating an attractive force on the other side of the train [3]. The location of the electromagnets on the Transrapid system is located in a different side of the guideways. To obtain electromagnetic suspension, the Transrapid system uses the attractive forces between iron-core electromagnets and ferromagnetic rails [9].

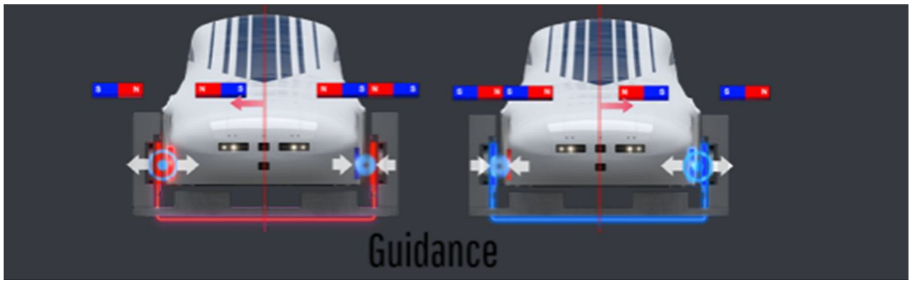

Fig.2 Guidance mechanism of Maglev to make it stable on the track

C. Principle of Propulsion

Propulsion is the force that moves the train in forward direction. Maglev uses an electric linear motor for this task. A normal electric rotary motor uses the concept magnetism to create torque and rotate an axle. It has the stator which is stationary that surrounds a rotating piece called rotor [8].The stator is used to generate a rotating magnetic field. This field induces a spinning force on the rotor, which causes it to rotate [9]. The stator is laid flat and the rotor rests above it [3]. Instead of a rotating magnetic field, the stator generates a field that travels down its length. Similarly, instead of a rotating force, the rotor experiences a linear force that pulls it down the stator. Thus, an electric linear motor directly produces motion in a straight line [3]. However, this motor can only produce a force while the rotor is above the stator [8],[3].

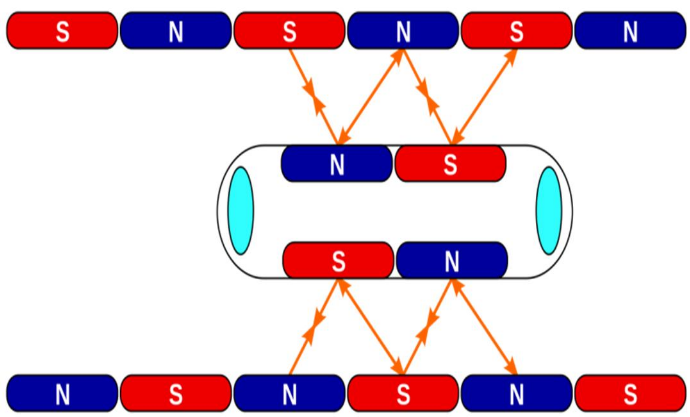

Fig.3 Principle of propulsion, a mechanism needed to increase speed on track

D. Principle of Levitation

Two types of levitation technologies are:

1) *Electromagnetic suspension (EMS)*: It uses attracting force of electromagnets placed on guideway as well as on train to achieve levitation. The advantage is that it is simple to implement and maintains the levitation even at zero speed [5]. The downside is that it is a bit unstable and at high speeds it becomes difficult to maintain the correct distance between train and guideway [8].For this reason it requires a feedback control system to keep in check the stability of the train[9].
2) *Electrodynamics suspension (EDS)*: In contrast to EMS, it uses repulsive force between magnets placed on the train and guide way to achieve levitation [5]. While the train is moving, magnets move past each other to generate the repulsive force [8]. The plus point is that this system is stable at high speeds as well. But the drawback is that it needs some speed to achieve levitation which makes the system complex and costly to implement [9].

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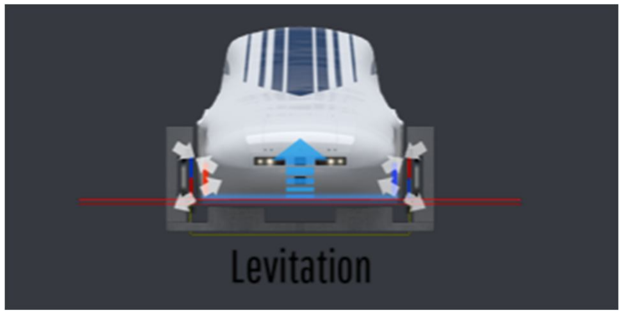

Fig.4 Principle of levitation, a mechanism to lift the train on the track.

III. WORLDWIDE SCENARIOS

We are going to have a glimpse of advancements in Maglev technology in recent years in four different countries:

A. Spain Project

The initiation of maglev commenced in the autumn of 2010, the island's President established the Maglev Tenerife Planning Consortium, which comprised of Consulting Engineers Dipl.-Ing. H. Vössing Ltd. (IBV) and the Institute of Railway Engineering Ltd. (IFB), to examine the high-speed magnetic levitation railway as an alternative for a North-South link on Tenerife (one of the islands in Spain) in a feasibility study [4].

Even though this was a great initiative in implementing the technology of Maglev, but still the operational Transrapid concept, even today, assumes a constant length of the high-speed maglev trains for the entire service period of 17 hours. The frequency of services is defined differently for the peak and off-peak service periods. An operational top speed of 270 km/h is achieved on the Southern route, and 230 km/h on the Northern route. Since the guide way distance between stops on the Southern route is roughly 40 km [4].The problem arises here as higher speeds do not result in any operational advantage on the other route sections but cause significantly higher traction energy costs. A total of 16 trains are required. These include three trains as an operational reserve or as a maintenance reserve. In the context of the feasibility study, 6 route variants, the total investment is between 3 and 3.55 billion EUR [4].

B. Switzerland Swiss-metro Maglev Project

Swiss Metro is a high speed and high frequency passenger transport system which is independent of built-up areas and surface obstructions such as topography as it is functional as the super underground railway, meets the requirements that are arising at the dawn of the third millennium. The advantages of this system consists of the following traits ,that it fits in with existing or projected railway networks, provides a credible response to the foreseeable increase in mobility and contributes actively to the transfer of private/road traffic to public/rail traffic It is a fully underground network which has the following as the main objectives [4].

1) An entirely underground infrastructure, comprising two tunnels of 5 m interior diameter, driven through the bedrock at a depth varying between 60 and 300 m according to the topography, as well as stations in the center of towns connected to the public urban and regional surface transport networks [4].
2) A reduction of the pressure in the tunnels (partial vacuum corresponding to the pressure at about 10000 Pa in order to save the energy necessary for the propulsion of the pressurized vehicles [4].
3) A propulsion system of the vehicle made of linear electric motors, allowing speeds in the order of 500 km/h [4].

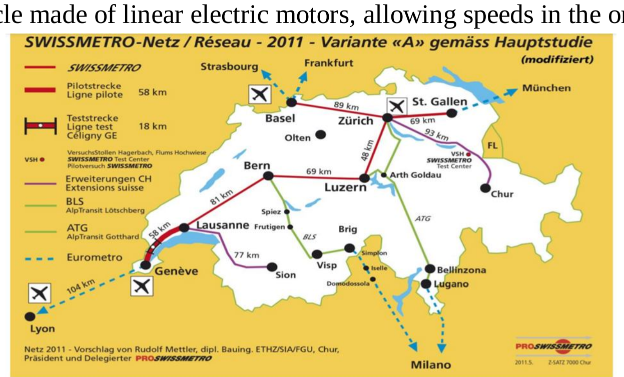

Fig.5 Map depicting the Switzerland Swiss-metro Maglev route

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C. China

China started investing in Maglev way back since the arrival of the German Transrapid and they expressed their interest in the German Maglev technology. After statistical gathering and analyzing, a contract was reached on January 23, 2001 between Shanghai and *TransRapid International* to build a line between Shanghai and its airport. And then Shanghai Maglev demonstration line from Pudong airport to downtown Shanghai started its trial operation on a single track at the beginning of 2003, began shuttle running on the double track in September of 2003 and completed the test and acceptance at the end of 2003 [4].

The year of 2004 witnessed its beginning of commercial operation. The train runs at the highest speed of 430km/h in the day and 300km/h in the morning and evening. Up to June 2011, the maglev train has covered a mileage of about 9 million kilometer and carried passengers of about 29 million person times. In the past years, the maglev system has undergone bad weather such as hurricane, heavy snow, and typhoon. No accidents that injured people have happened, nor has the operation been interrupted by bad weather. Statistical results of the past years since 2004 show that average operation punctuality rate reaches 99.72% and 99.88% of the operation schedule is fulfilled [4].

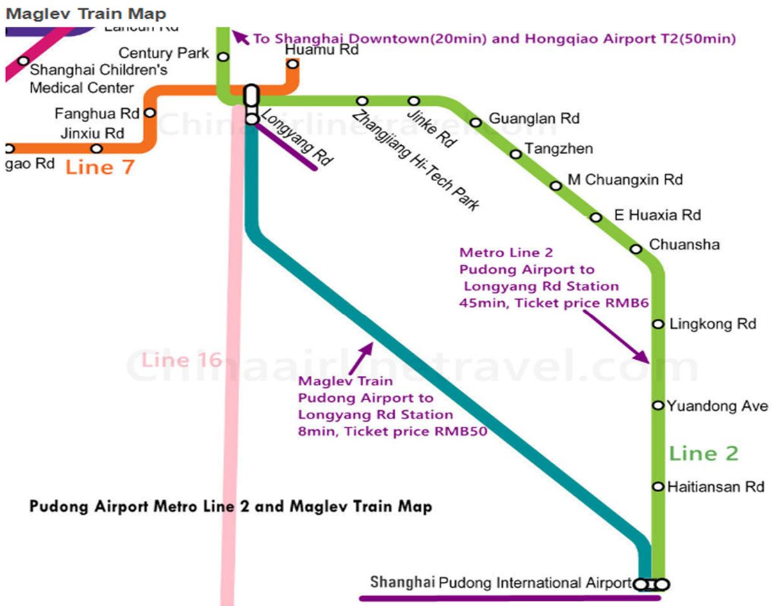

Fig.5 Map depicting the shanghai maglev route

D. India

In the recent advancements India has shown a keen interest in bringing Maglev technology to the country ,the agreement has been signed in the backdrop of the Prime Minister's 'Make in India' and 'Aatmanirbhar Bharat' initiatives, and will enable the country to bring the latest, world-class technology to it and manufacture state-of-the-art Maglev trains indigenously.

On 15.09.2020 in ordrer to expand its footprint in the urban transportation sector as a part of its diversification initiatives, India's largest engineering firm, Bharat Heavy Electricals Limited (BHEL), signed an agreement for cooperation with SwissRapide AG for Maglev Train projects in India.

The MoU was signed by SV Srinivasan, GM and Head (Transportation Business Group), BHEL and Niklaus H Koenig, President and CEO, SwissRapide AG, with the intent to expand BHEL's footprint in the urban transportation sector as a part of its diversification initiatives. The MoU sets out the foundation to cooperate and explore mutually beneficial business opportunities, and utilise both companies' inherent capabilities, skills, knowledge and assets.

Leading to the proposal Maglev is planned to run between the following routes:

1) Bengaluru-Chennai
2) Hyderabad-Chennai
3) Delhi –Chandigarh
4) Mumbai- Nagpur

The SwissRapide AG is a Swiss company specialised in the promotion, project management, planning, specification, design, implementation and commissioning of international Maglev Rail projects and related technologies. It holds the unique position of offering Transrapid Maglev technology, the only established and commercially proven ultra-high-speed Maglev Rail system in the world, in addition SwissRapide Maglev rail system has the following advantages over conventional high-speed railway systems:

a) *Ultra-speed*: 2 – 3 times faster point-to-point connections.
b) *Energy efficient*: 25% less energy consumption per seat & km at 300 km/h.
c) *Environmentally friendly*: 50 % fewer noise emissions at 300 km/h.
d) *Cost-efficient*: 5 times lower maintenance and operating costs.
e) *Smart urban planning*: Elevated guideway requires 6 times less land.
f) *Punctual*: Fully automated, highly reliable system

Furthermore another initiative was taken recently (13.02. 2020) regarding the maglev advancements by the The Mumbai Rail Vikas Corporation (MRVC) which proposed an ambitious project to operate the proposed Chhatrapati Shivaji Maharaj Terminus (CSMT)-Panvel elevated fast corridor using Maglev technology on a public-private partnership (PPP) model, MVRC wrote to the Maharashtra government and Railway Board seeking an in-principle approval for the project that envisages a 55-km-long elevated line connecting CSMT-Panvel with a spur to the under construction Navi Mumbai International Airport (NMIA). Under the proposal, the train's speed will be capped at 200 km per hour and will be able to complete the entire distance in 35 minutes.

IV. FUTURE RECOMMENDATIONS IN INDIA

Although it looks difficult to implement this technology in India but we have few suggestions that would help in implementing this technology in India.

A. We can initially connect the cities comprising the golden quadrilateral and the SEZ's (Special economic zones) in order to make it feasible for the industrial and business class of the country to avail an alternative to the airways thus reducing the burden on the domestic airlines and also add value to the time of the business class making travel feasible and fast for the economic and industrial activities of the country.

B. Maglev trains being environment friendly would allow lesser environmental pollution as it do not run on fuel since being eco-friendly is need of the hour in today's overpopulated world where increased number of flights will only deteriorate the condition.

C. Maglev along with being a passenger train can also be employed for transportation of sensitive raw materials. For example the raw materials that used in electronics and telecommunication like silicon whose shortage led to the prices hike in auto industry.

D. Fast transportation and reduced time frame of travel will allow the production and supply chain be strengthened and eventually will lead to a strong manufacturing and service sector and thus the speed of the capital flowing in the economy will be enhanced and will which eventually lead to more number of industries being set up and thus increasing the job opportunities in India, this will lead to the formation an ecosystem of enhanced foreign investment and capital.

E. Making this technology available in India will eventually lead to more private players in the Maglev technology market thus increasing the efficiency and future prospects of being an important player in the advancements of railways in the world.

V. CONCLUSIONS

The Maglev train is considered for both metropolitan transportation and intercity transportation operations. They Move a lot faster than normal trains because they are not affected by ground friction; they would only have air resistance or drug resistance. Furthermore the more the technology is adapted the more will be the scope of technological advancements especially in developing countries. Now that we have known how the technology works, we believe that maglev systems can be researched further to be used in advanced applications and maglev technologies are high in demand due to it being environmentally friendly. Even though maglevs have drawbacks in terms of the cost to build it, the major advantages overshadow the drawbacks in a long term. Adapting Maglev in India is initially going to be expensive and filled with hurdles but eventually in the long run it is going to bring a huge impact on the functioning of the nation , we can take the example of the Metro technology of Delhi which become a great success and it is being replicated now in almost every capital of a state and important cities, it started as an alternative to public bus service and eventually became a primary and most desired public transport transforming the canvas of the city and creating mass acceptance creating a positive image of the nation, similarly Maglev may also be a revolutionary idea due to be implemented.

VI. ACKNOWLEDGEMENT

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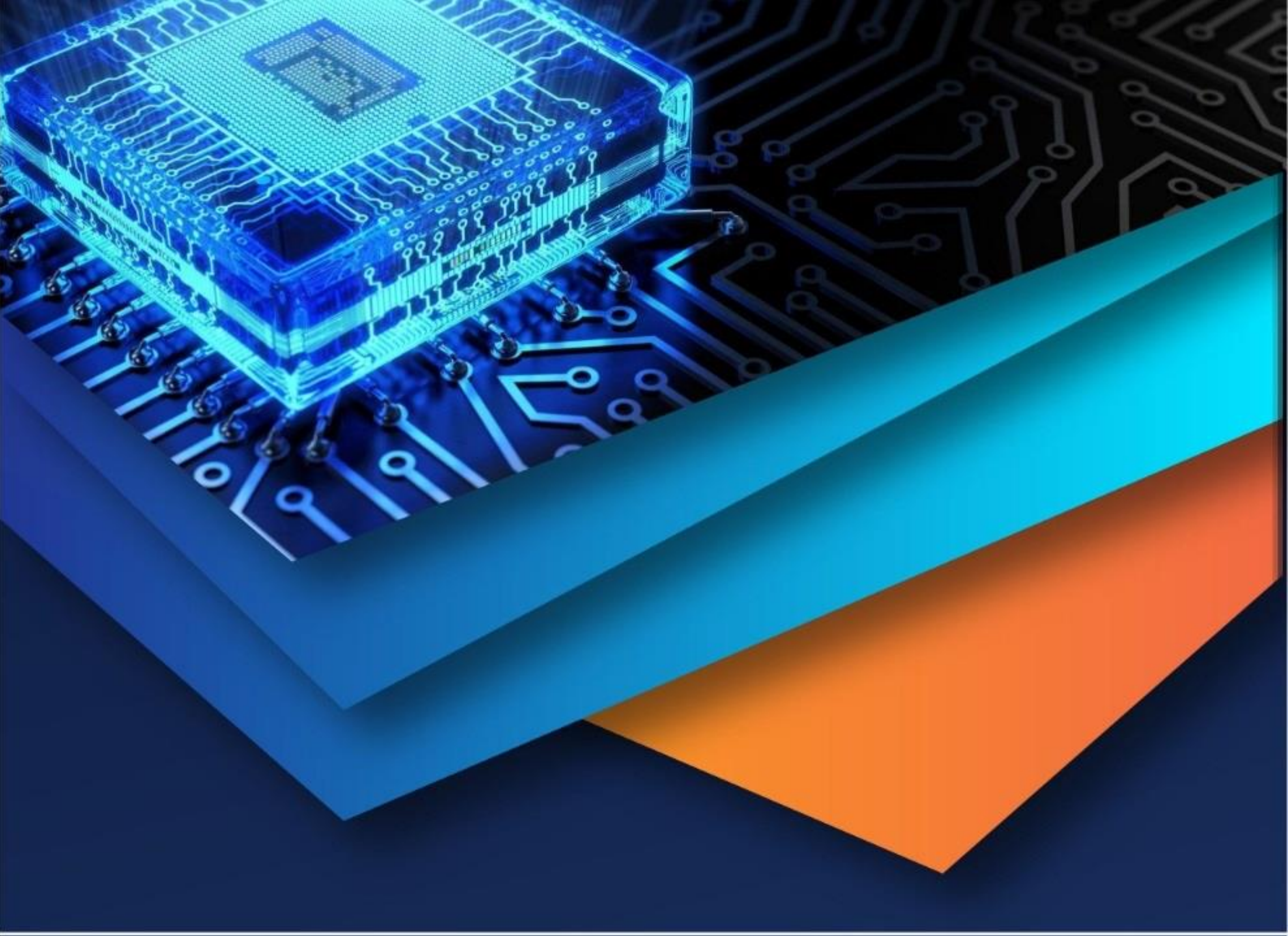

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