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A Critical Review on Modelling of Industrial Chimney

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Abstract – Chimneys are characterising landmarks of power plants and industrial setups. Chimneys are required to carry vertically and discharge, gaseous products of combustion, chemical waste gases, and exhaust air from and industry to the atmosphere. Rapid growth of industrialisation and increasing need for air pollution control as made RC chimneys a common structure in the modern scenario. With large scale industrialization, number of chimneys and stacks being constructed is increasing year by year. In many industries chimneys are required to leave hot waste gasses at greater height. The chimneys of 50-100m are very commonly used RC chimneys becoming more and more popular because of economy in construction and maintenance. Maintenance cost of steel chimneys is high and brick chimneys become to bulky and costly when height of chimney is more than 30m. The outer diameter of chimneys may be kept constant throughout or may be linearly varied. The thickness of concrete shell may be varied in steps or linearly. Reinforced concrete chimneys are subjected to various loads such as self-weight, wind load, earthquake load and temperature variation. The design of RC chimney is carried out by selecting the section first and then checking for stress development.

The present paper comprises of literature review of latest papers published in the field of chimneys. This study offers a comprehensive review of the research papers published in the field of industrial chimneys and gives latest information and developments taken place in chimneys design and construction. The paper focuses on modelling aspects of industrial chimneys, which includes case studies, analysis and design using software's, experimental studies etc. The Current review paper represents a complete collection of the studies done on chimneys and would give an updated material for the researchers. The references included in this paper are mostly concentrated on the review article published after 2005.

Keywords- Chimney, Design, Modelling, Review, Stacks

I. INTRODUCTION

A Structure which provides ventilation for hot flue gases or smoke from a boiler, stove, furnace or fireplace to the outside atmosphere is known as CHIMNEY. Chimneys may be found in buildings, steam locomotives and ships. During the last few decades the use of reinforced concrete chimneys in place of brick masonry and steel chimneys have become very popular due to their low cost and durability. Composite material like reinforced concrete is eminently suited for chimney stacks. The height of a chimney influences its ability to transfer flue gases to the external environmental via stack effect. The maintenance of steel chimneys are minimum in the case of concrete stacks. The thickness of the concrete shell generally varying from 120 to 300 mm is considerably smaller than that required in the case of brick chimneys. Concrete stacks with lesser maintenance costs are architecturally superior to masonry and steel chimneys.

Fig1- Industrial Chimney

A. Design Of Chimney

The design of a chimney has the following stages:

1) Physical dimension
2) Load calculation
3) Analysis for wind
4) Analysis for earthquake
5) Shell design
6) Linear design
7) Accessories design

B. Various Loads Considered For Design Of Chimney

The following loads are considered for the analysis and design of the chimney:

1) Dead loads
2) Live loads
3) Wind loads
4) Seismic loads
5) Temperature effects

II. REVIEW ON CASE STUDIES OF INDUSTRIAL CHIMNEY

Many researchers have carried out analysis and design on industrial chimney. Case studies have been chosen and the analysis is carried out with various parameters. Below mentioned literature papers gives a survey of case studies.

Dr. MANOJ K. R. GUPTA, Dr. V. K BAJPAI, Dr. T.K GARG (2014) [1] "LATEST MEASURES TO KEEP CHIMNEYS IN STEP WITH PLANT CHANGES" The present paper is designed to provide a useful guidance tool and set of reference for practicing engineers and will results in cost savings. Chimneys and stacks are expected to operate through out a plant life of 30 to 50 years. Pollution regulations have forced a rapid increase in chimney heights and have reached a staggering magnitude of 400m plus today these fulfil a critical function at any industrial facility and are affected by operational changes in the process cycle. It is hoped that the present paper will lead to a better pragmatic approach for practicing engineers and will lead to significant cost savings.

ALEKSANDAR.M.SIMONOVIC, SLOBODAN.N.STUPAR, OGNJEN.M.PEKOVIC [2] "STRESS DISTRUBUTION AS A CAUSE OF INDUSTRIAL STEEL CHIMNEY ROOT SECTION FAILURE", this paper has studied failure initiation of the root section of 60m tall industrial steel chimney. Cracks that occurred in steel wall of the wind shield have significantly influenced integrity of the structure. Analytical numerical analysis of failure occurrence was performed. Industrial steel chimneys are exposed to various harmful mechanical-chemical-thermal actions. Complex loads can cause various types of damage influencing the structure integrity as a section with maximum loads, geometrical discontinuities duct flue openings and manufacturing flaws, root sections of the industrial steel chimney are subject to failures occurrence.

PROF.WAKCHAURE.M.R, SAPATE.S.V, KUWAR.B.B, KULKARNI.P.S (2013) [3], "COST OPTIMIZATION OF REINFORCED CONCRETE CHIMNEY", The design reinforced concrete chimney structure almost always involves decision making with a choice of set of choices along with their associated uncertainties and outcomes. While designing such a structures, a designer may propose large number of feasible designs, however, only the most optimum one, with the least cost be chosen for construction the comparison between conventional and optimal design is made and further results are presented. In final results, percentages saving in overall cost of construction are presented in this paper .in optimtool,interior point method is more interactive method so the results are more elaborated by using interior point method.

ALOK DAVID JOHN, AJAY GAIROLA, ESHAN GANJU AND ANANTH GUPTHA,(2011) [4], "DESIGN WIND LOADS ON REINFORCED CONCRETE CHIMNEY-AN EXPERIMENTAL CASE STUDY", The present paper is aimed at providing a better understanding of effect of interference and influence of streaks for wind load on TPS chimneys. In the present study, particular attention has been given to bending moment due to across-wind vibration, because it has been found that across-wind vibration is

more predominant for the case of interference at an angle of wind incidence. Bending moment due to across wind vibration for interference is found to be approximately double compared to that of stand-alone condition. In this paper the amplification of wind loads on 100m tall chimney due to interference of surrounding structures and influence of strakes has been studied.

III. REVIEW ON ANALYSIS OF INDUSTRIAL CHIMNEY USING SOFTWARES

The Review article comprises of literature papers on analysis of industrial chimney using various software's. The analysis carried out using software with different loading has given different outcomes.

K.ANIL PRADEEP, C.V.SIVARAMA PRASAD, (2014) [5] "GOVERNING LOADS FOR DESIGN OF A 60m INDUSTRIAL RCC CHIMNEY "in his experiment he described that industrial chimneys are generally intended to support critical loads produced by seismic activity wind. So it is essential to evaluate the dynamic response of chimney to seismic activity and wind loads. As per draft code the deflection at the free end of the chimney should be well within the permissible limit. The effect of wind force for 55m/s wind speed is quite significant as compared with the earthquake forces in zone 2 and 3. Moment due to earthquake in zone 3 is almost equal to the combined moment due to wind speed of 55m/s.

H.W.KLEIN, W.KALDENBACH [6], "A NEW VIBRATION DAMPING FACILITY FOR STEEL CHIMNEYS", The article outlines various means of damping and their technical implementation. A concept for passive vibration damping by means of fluid dampers is proposed using a 125m high chimney as an example. Using standard pipe-engineering components, a damper unit has been constructed which has none of the drawbacks of the classical chimney-head damper. The unit functions during the construction of chimneys, is effective over the entire frequency range, is easily maintained and can be extended at any time.

Mr.VIJAY.B.SARODE, PROF.PRASHANT.N.ULHE, (2014) [7] "DESIGN AND OPTIMIZATION OF STEEL STRUCTURE FOR SOLAR ELECTRICAL PANNEL", the project is considered is an activity that has interfaces with basic structural sections to make it a complete mechanical structure. We intent to work for an industry that develops support structures to various electrical units. On initial study we could see that such industries are into manufacturing and provide the structure for various control panel .this is done based on their experience. We could see the structures are over designed because of conventional manufacturing and past experience. By this analysis we expect that the best structural design for electrical control panel with, to get optimum design, cheaper and less material, overall cost reduction, better structural stiffness and lighter structure.

NIKHIL ASOK N AND M UNNIKRISHNAN, [8] "DESIGN AND OPTIMIZATION OF A STEEL CHIMNEY", In this project a steel chimney will be designed considering dead load, wind load at thermal load, the Bureau of Indian standards (BIS) design codes procedures will be used for the design of the chimney. After designing the chimney is modelled using ANSYS .than booth wind load and structural load analysis will be carried out using ANSYS. Finally the thickness of the steel shell is optimized which will result in material saving and reduction weight of structure.

VICTOR BOCHICCHIO, [9] "DESIGN OF CHIMNEY WITH GRP LINER FOR LOW AND HIGH TEMPERATURE OPERATION", The design of this chimney presented several interesting and challenging aspects related to the high temperature By-Pass operation. The use a highly ventilated annulus added in addressing concerns regarding access into the annular space and in the thermal design of the GRP liner. A large construction opening, reinforced by pilasters, provided structural performance equivalent to that of a similar chimney with a normal sized openings, at a significant cost savings.

M.G.SHEIKH, MIE, H.A.M.I.KHAN, [10], "GOVERNING LOADS FOR DESIGN OF A TALL RCC CHIMNEY", the present paper discuses reinforced concrete tall chimney. The main focus is to compare the wind analysis result with that due to seismic one. Wind analysis is done for along wind by peak factor method as well as by gust factor method and for across wind by simplified method as well as by random response method. The results obtain in above cases are compared. The seismic analysis is performed using response spectrum method. Finally, the maximum value obtained in wind analysis and seismic analyses are then compared for deciding the design value. The effect of wind forces is quite significant as compare to earthquake forces over 220m height RCC chimney. The geometry of chimney has to be so chosen that deflection of chimney at the top is within permissible limits.

J.L.WILSON, (2000) [11], "CODE RECOMMENDATIONS FOR THE ASEISMIC DESIGN OF TALL REINFORCED CONCRETE CHIMNEYS", This paper presents results of recent experimental tests which indicate that reinforced concrete chimneys possess some ductility when subject to cyclic loads. Based on these tests an inelastic procedure has been established for assessing the performance of reinforced concrete chimneys subject to severe earthquake ground shaking. This procedure has been used to analyses a number of chimneys, develop design recommendations and establish appropriate ductility factors. Tall reinforced concrete chimneys being highly tuned, profiled cantilevers respond in a complex manner to earthquake excitation, with the response dominated by higher mode effects, in both the elastic and inelastic range.

SAGAR S,BASAWARAJ GUDADAPPANAVAR,(2015) [12], "PEFORMANCE BASED SEISMIC EVALUATION OF INDUSTRIAL CHIMNEYS BY STATIC AND DYNAMIC ANALYSIS", This paper mainly deals with the linear static and dynamic analysis of RC and steel chimney having height of 65m and chimneys were modelled with the help of SAP2000 version 12.00 software, than main purpose of this chimney studying the effect of base shear, maximum lateral displacement, fundamental time period and frequency of all the zones from zone2 to zone 5 and their comparison of the results of all the zones. Deflection at the free end of chimney should be within the permissible limits of 0.003h for the both the RC and steel chimney, and is more economical in all aspects compared to RC chimney.

YOGANATHAM.C, HELEN SANTHI.M, (2013) [13], "MODEL ANALYSIS OF RCC CHIMNEY", The analysis and design of chimneys are normally governed by wind are earthquake load. In this paper modal analysis of a RCC chimney in a cement factory is carried out using the FEM software package ANSYS. The effects changes in the dimensions of the chimney on the modal parameters such as fundamental frequency, displacement et are evaluated. The displacement of chimney is found to decrease with increase in all geometric parameter ratios.

DR S.S. PATIL, MUNDEWADI A.R.,(2015) [14], " COMPARISON OF P-DELTA EFFECT ON A SLENDER RCC CHIMNEY BY USING BEAM-COLUMN THEORY AND STTADPRO, The analysis carried out manually by using beam column theory and later by STAAD pro it can be concluded that, for the combination wind and dead load, the effect of second order increases with increase in height. This paper presents the analysis of a slender RCC chimney with a combination of dead load and wind load firstly beam column theory is applied on a tall slender chimney and general equations are developed for bending moment with and without the consideration of second order analysis.

RAKSHIT.B.D, RANJEET.A, SANJEET.J, CHETAN.G, (2015) [15], "ANLYSIS OF CANTILIVER STEEL CHIMNEY AS PER INDIAN STANDARDS", this paper summarizes analysis and design concepts of chimneys as per Indian codal provisions incorporation was also made through finite element analysis. Effect of inspection manhole on the behaviour of cantilever steel chimney, two chimney models one with the manhole and other without manhole where taken into consideration. The main objective of the present study was to explain the importance of geometrical limitations in the design of cantilever steel chimney.

K.S RAHANE, M R WAKCHAURE,(2012) [16] "EFFECT OF THE SUPPORTING STRATA ON DESIGN OF WIND MILL TOWER", In this paper they are attempt show the effect of wind and earthquake load on tubular type wind mill and its foundation considering hard, medium and soft soil strata. The modelling of wind mill tower was done in computer software by finite element modelling technique. The effect of wind is significant as compared to earthquake and has to be considered in the analysis of wind mill. The foundation sizes, concrete material, reinforcement material shall be increase with respect to hard, medium and soft strata. So cost of structure also increased.

RAJAVARMA ,(2014) [17], "STUDY THE WORKING STRESS METHOD AND LIMIT STATE METHOD AND IN RCC CHIMNEY DESIGN", Chimneys with various heights from 65m to 280m are analysed and designed by working stress method and limit state method for collapse and comparison of results are discussed in this paper. Generation of interaction curves for hollow circular section is also discussed in this paper.

MEGHA BHATT, RAKESH SHAH, AANAL SHAH,(2015) [18], "COMPARISON BETWEEN LIMIT STATE METHOD AND WORKING STRESS METHOD FOR RCC CHIMNEY DESIGN", Chimneys with various heights i.e. 65m, 70m, 85m and 220m

are analysed and designed by working stress method and limit state method for collapse comparison of results are discussed in this study. Limit state design RC circular hollow sections can be followed for the purpose to achieve a suitable combination load factors availability of interaction envelopes and computer algorithm immensely helps the designer in expeditiously solving the design problem.

CHOPPALI KALYANI RAMRAO, PATIL YOGESH D, [19], "EFFECT OF OPENINGS IN THE ANLYSIS OF SHELL FOR A 275M TALL MULTIFLUE RCC CHIMNEY", Most of existing studies have focused on the load considerations for design of tall chimney. A step further, an attempt has been made through this paper, to analyse the stress developed in the chimney shell due the provision of functional openings. A comparison has been made between the stress levels for a 275m tall multiflue RCC chimney for two conditions I.e. chimney shell without openings and chimney shell with require functional openings.

K.S.BABU NARAYAN, SUBHAS C. YARAGAL, AND YUKIO TAMURA, (2006) [20], "INTERACTION ENVELOPS FOR LIMIT STATE DESIGN CHIMNEYS", Chimneys as an indirect and effective means of air pollution control is popular from time immemorial. Environmental protection agencies have been forced frame, implement and monitor stringent pollution control policies. From the study the following conclusion are availability of interaction envelops and computer algorithm immensely help the designer in expeditiously solving the design problem. The program developed can be used in structural optimization exercise wherein the total cost can be minimized are the ratio of cost to strength or cost to efficiency can be minimized

IV. REVIEW ON EXPERIMENTAL STUDIES

A.L.RANTETAMPANG ,ALIMIN MAIDIN,MUHAMMAD FURQAAN NAIEM AND ANWAR DAUD (2013) [21] "CHIMNEY INSTALLATION IN HONAI TRADITIONAL HOUSE TO REDUCE THE EXPOSURE OF SO2 AND NO2 IN WAMENA, PAPUA PROVINCE, INDONASIA" , In his study biomass has been used to warm the honai indoor air temperature at night in wamena regency. As this mountain area is cold inhabitant burn kahusuari wood from evening to mid night to warm their body. As a result, they continuously inhale the sulfurdioxide (SO2) and nitrogen dioxide (NO2) contaminated air in Honai room. Based on the results of the study, it can be concluded that the indoor air concentration of so2, and NO2 in the Honai hose mostly exceed the standard.

ARTEMIS AGELARIDOU-TWOHIG, FRANCO TAMANINI, HOSAM ALI, AMIN ADJARI, ASHKAN VAZIRI,(2014) [22], "THERMAL ANLYSIS OF REINFORCED CONCRETE CHIMNEYS WITH FIBER GLASS PLASTIC LINERS IN UNCONTROLLED FIRES", This paper presents a simple method to calculate fire duration and flue gas temperatures for reinforced concrete chimneys with fibre glass reinforced plastic(FRP), liners based on experimentally determined burning characteristics of the liner material. Two chimney designs were used to demonstrate a calculation of the transient temperature profiles across the concrete thickness based on the fire duration scenario dependent average temperature of the air inside the chimney.

HRISTO KAPSAROV, [23], "THEORETICAL AND EXPERIMENTAL INVESTIGATION OF HIGH REINFORCED CONCRETE CHIMNEY IS FOR MATHEMATICAL MODEL FORMULATION", In modern design and analysis of high reinforced concrete chimneys the following three basic problems should be resolved: determination of the mathematical model; definition of external forces (wind pressure and earthquake ground motion) ; and definition of safety criteria. The full-scale ambient vibration dynamic tests confirmed the basic assumptions used for the mathematical model formulation for theoretical determination of the dynamic characteristics of the two chimneys, which are the subject of the investigation.

V. SUMMARY & CONCLUSIONS

The Present paper focuses on review articles on modelling aspects of industrials chimney, this review article includes case studies, Software analysis, design aspects, modelling of superstructure, Experimental studies etc. The paper gives collection of research literature papers published after 2005.
The modelling of industrial chimney including all loads, its analysis and design is challenging to structural engineers.
Following conclusions could be drawn from current review article.

A. The Modelling of chimney (superstructure) involves accurate analysis, design and practice, since it is subjected to various

loading. The design involves various parameters which should be carried out with standard code of practices.

B. The Industrial chimney is greatly influenced by dynamic loadings. The earthquake and wind being major dominant loads, the analysis must be made for all possible critical loads and load combinations.

C. The Behaviour of RCC chimney is influenced by soil underneath superstructure. The stresses displacements occurring in shell structure is influenced by soil foundation system. Hence soil structure interaction studies must be carried out

D. The Experimental studies carried out on RCC chimney gives validated results for the design and analysis. Hence RCC chimney must be modelled and analysed in software as well as experimentally.

E. The RCC chimney must be analysed considering soil parameters (Superstructure and substructure) as a whole in order to understand the exact behaviour of structure.

F. RCC chimney being flexible structures is affected by wind loading. The optimality study can be carried out to find optimum height and thickness of structure.

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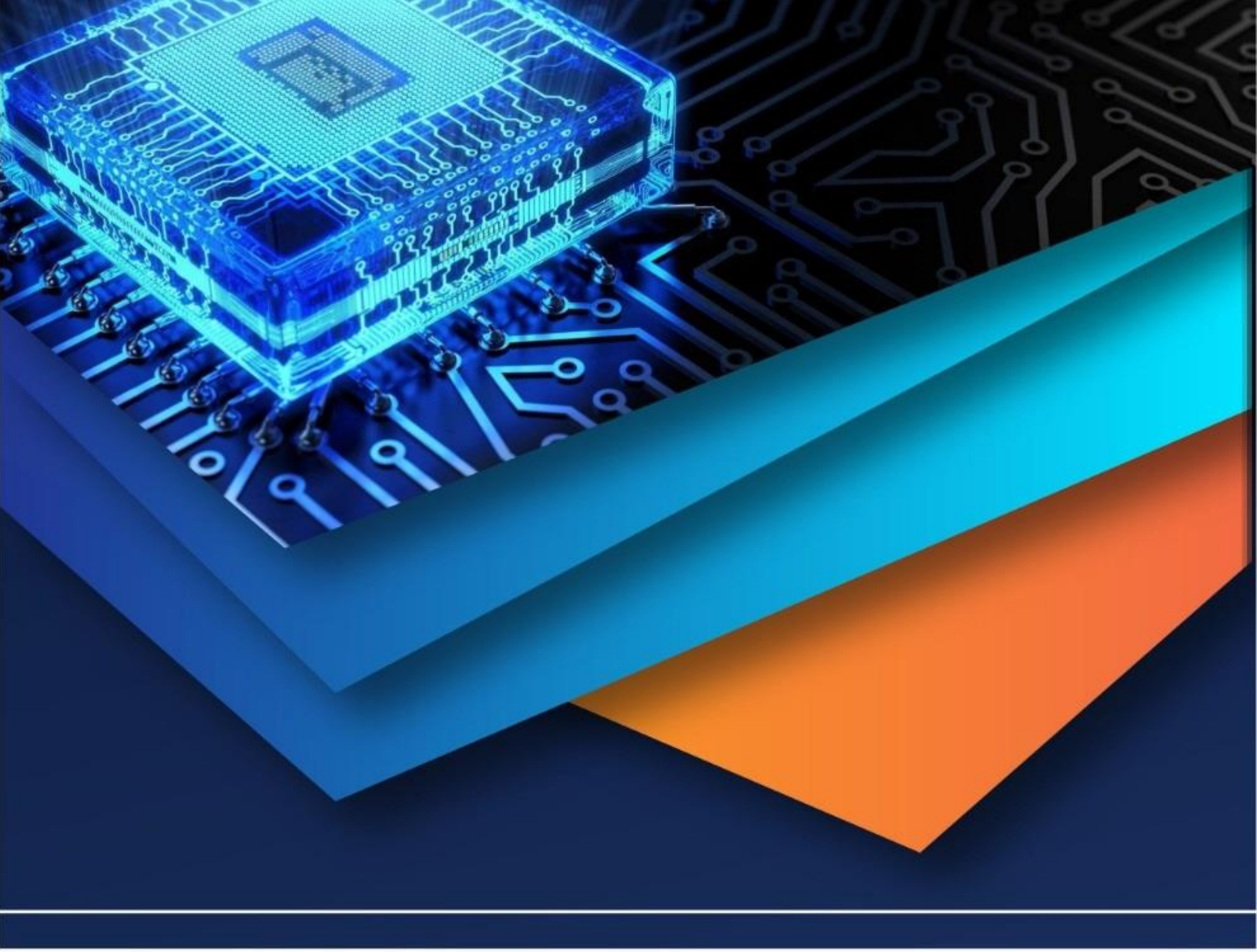

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