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Rethinking Biomass Cook stove Innovations and Issues

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Abstract- India's residential sector is a major consumer of energy whose energy demand will grow with prosperity and population growth. About 67% of households in India, which is equivalent to 166 million households, remain wedded to solid fuels like coal, wood, branches, twigs, dungcakes, agricultural residues or even leaves and grass as their primary source of cooking fuel. While conversion to modern fuels has accelerated in urban areas, population in rural areas have been slow to move away from solid fuels. Solid biomass fuels will continue to play an important role in energy mix of households and use of traditional cookstoves for utilizing these fuels in them will remain an area of concern for years to come. "Traditional Biomass cookstove" is a physical structure that contains air-fuel combustion for heat release, and subsequently, directs the heat of combustion towards a cooking target. The smoke emitted from such biomass cookstove is made up of total suspended particulates and gaseous chemicals. The people in inaccessible and rural areas cook their food on such poor thermal efficiency cookstoves that creates serious health problems for women and children. It is estimated that about 3% of the diseases are caused due to incomplete combustion of biomass, which results in around 1.6 million premature deaths every year including around 0.9 million children death. This paper review the issues related with the biomass cookstoves and give suggestion to improve it utilization techniques. The scientific community around the globe is working on improving the cooking environment and has developed various models of improved biomass cookstoves. Improved cookstoves technology is technically feasible, socially reliable and economically viable and it reduces the pressure on the biomass resources, minimise the household expenditure on biomass, reduces the time required for collection of fuel wood and reduces indoor air pollution.

Keywords: biomass, cookstoves, energy, indoor air pollution, policy, programme

I. INTRODUCTION

Developing countries are using biomass fuels in the traditional cookstoves to meet their cooking demand, heating water and keeping the house warm in winter season. Cooking is an everyday vital activity and when the biomass fuels like agricultural residues, wood and branches of trees, dungcakes, twigs or coal are used in the traditional cookstove or open fires, large amount of smoke is emitted. These harmful smokes consist of gaseous particulates and oxides of carbon and nitrogen along with various gases and formaldehydes.

In developing nations, it is anticipated that, almost 70% of the household use bio-fuels for cooking [1], [2]. People in remote and rural areas cook their food on unvented open fire leading to poor thermal efficiency, which also releases high level of pollutants and create serious health problems for women and children [3]. It was found that, the biomass fuels are extensively used in area where the low-income group reside in large number and the availability of clean fuel are neither affordable nor sufficient. However, 3% of the diseases are instigated due to incomplete combustion of biomass fuels, resulting in approximately 1.6 million premature death every year which includes 0.9 million children death under five year of age [4], [5]. There are many health related issues such as, asthma, respiratory diseases and abridged lung functions, breathing problems, stinging eyes, low-birth weight and sinus problem associated with the biomass cookstoves [6], [7].

The scientific community around the globe along with the support of the lawmakers, local organizations, and world banks has made vast struggle to improve the cooking environment and ultimately reduce environmental pollution, health hazardous, deforestation and global warming. The improved biomass cookstove technology came into existence, which is technically feasible, socially reliable and economically viable [8] – [11]. The improved biomass cookstove not only reduces the pressure on the biomass resources but also lessen the household expenditure on biomass, reduce the time required for collection of fuel and it also reduce indoor air pollution [12], [13], [3]. Sharma et al., in 1990 emphasized the strategy on adoption and large-scale dissemination of improved cookstoves to improve the health of rural women and to reduce the consumption of firewood [14]. Approximately 400 million people's health gets affected due to indoor air pollution caused by inefficient cookstoves. In addition to the health impacts, inefficient cookstoves practices requires long cooking hours, which can extent up to 5-8 hours of cooking per day. Almost 20% of this time is devoted in the collection of fuel.

The performance of an improved biomass cookstove is estimated based on energy efficiency. The energy efficiency means how efficiently fuel can be utilized; it depends upon various performance parameters that can be evaluated by various tests. During the past few decades, few tests that have been commonly practiced are Water Boiling Test (WBT), Control Cooking Test (CCT) and Kitchen Performance Test (KPT). Few authors have mentioned results that are more realistic about the performance of a system, where not only the quantity but also the quality of energy is concerned [15], [16]. Tyagi et al., (2013) experimentally studied the various improved biomass cookstoves models based on energy and exergy analysis. Exergy is that part of the energy that can be converted without restrictions to all other types of high-grade energy or work. It was established that the exergy efficiency is lower than that of the energy efficiency for all type of cookstoves model. There is ample scope of work on systematic studies on cookstoves options with possible modifications and improved design models in terms of fuel characteristics, emission predictions and their energy utilization efficiency based on energy and exergy concepts.

II. ENERGY SCENARIO AND BIOMASS COOKSTOVE

The energy demand is increasing with increasing population and prosperity. The residential sector is the major energy-demanding sector in India, where highest percentage of thermal energy is used up in cooking. Therefore, both the commercial (electricity, kerosene, and liquefied petroleum gas) and non-commercial (direct use of biomass) energy are required and used accordingly.

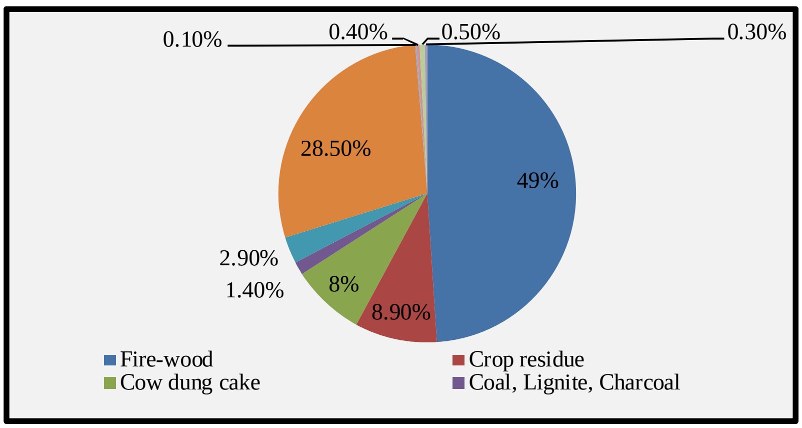

Fig.1 Cooking fuel used in India [17]

According to the Census of India (2011), many households still rely on firewood fuel for cooking and approximately 20% rely on other forms of biomass fuels. In rural areas, approximately 80-90% of households are dependent on biomass for cooking. In contrast to cleaner fuels, kerosene and LPG were accounted for 19% and 48%, respectively.

In 2003–2004, household consumed only 8% of the commercial energy and 85% of non-commercial energy; it is alarming for the Indian economy (GOI 2005). The various cooking fuels used in India with their fraction of share are shown in Fig.1. Approximately 67% of households in the country (equivalent to 166 million households) remain wedded to solid fuels as their primary source of cooking fuel. The consumption of commercial fuels has been accelerated in urban areas, but population in rural areas still consumes solid fuels [17], [18]. Wide ranges of fuels have been used for cooking in India. The factor that decides the cooking fuel choices are:

Biomass availability: easy and almost free of cost availability of biomass fuels in rural areas is the main factor behind its high usage;

Economic condition: income does influence fuel choice but not to the extent predicted by linear energy ladder;

Education and awareness: education of the cook may affect fuel choice, but many a times she is not the decision maker for fuel purchasing for domestic usages;

Cultural practice and food preferences: most of the household uses multiple fuels with clear preferences for a particular type of fuel for some food items.

III. HISTORY OF BIOMASS COOKSTOVE INNOVATIONS

History of cookstoves is too old and it started long back with the invention of fire. During the first ice age period, that is about 400,000 years ago in China at Chou Kutienin city the use of fire was first reported. With the use of refined stones, cultivation of plants and domestication of animals along with the mastery of fire the race of human civilization started. In the earlier age, open fire was used for cooking and roasting of meat where the fuels were arranged in a pyramid configuration for cooking. Initially, a major step was taken with the development of cooking pots that led to the development of other types of cookstoves. Later on, shielded fire was used in place of open-fire to balance the cooking pot over the fire and to maximize the heat energy gain by the cooking pot. Initially the simplest form of the shielded fire was a three stone arrangement where the stones was arranged at suitable angles on the plain ground to support the pots of various sizes. This improved the cooking efficiency and reduced the scattering of fire from different atmospheric conditions. The three stone fire gradually changed into a U-shaped mud enclosure. All the cookstoves developed before 17th century has low thermal efficiencies, poor material of construction, emitted a very high level of smoke and was called as "traditional cookstoves". With the further progress of human civilization, change in cookstoves took place and gradually with time old open fire cookstoves were replaced with improved cookstoves. There are various types of biomass cookstoves and their classification is shown in Fig. 2.

"Biomass cookstove" is a device that has air and fuel combustion for heat release, and subsequently, directs the heat of combustion towards a cooking target in the form of pot, griddle and pan. These stoves also provide useful energy for lighting, space heating, water heating, smoking and roasting of meat and other food items. Improved cookstoves have high thermal efficiency, low emissions, and safety for the user. There is large number of designs of cookstoves available across the globe as there is a wide range of fuel availability and people have different food habits, socio and cultural practices. Improved cookstoves have a very good potential to save fuel wood as they have higher thermal efficiency, energy efficiency and exergy efficiency. Due to fuel saving obtained by the improved cookstoves it has tremendous scope for the mitigation of greenhouse gases. It is found that by using improved cookstoves large quantity of fuels can be saved and hence the expenditure on fuel purchase can be reduced. Hence, economically these cookstoves are very much viable. Besides all the advantages mentioned above, time is also saved during the cooking activities with improved cookstoves and women can utilize this time for other activities.

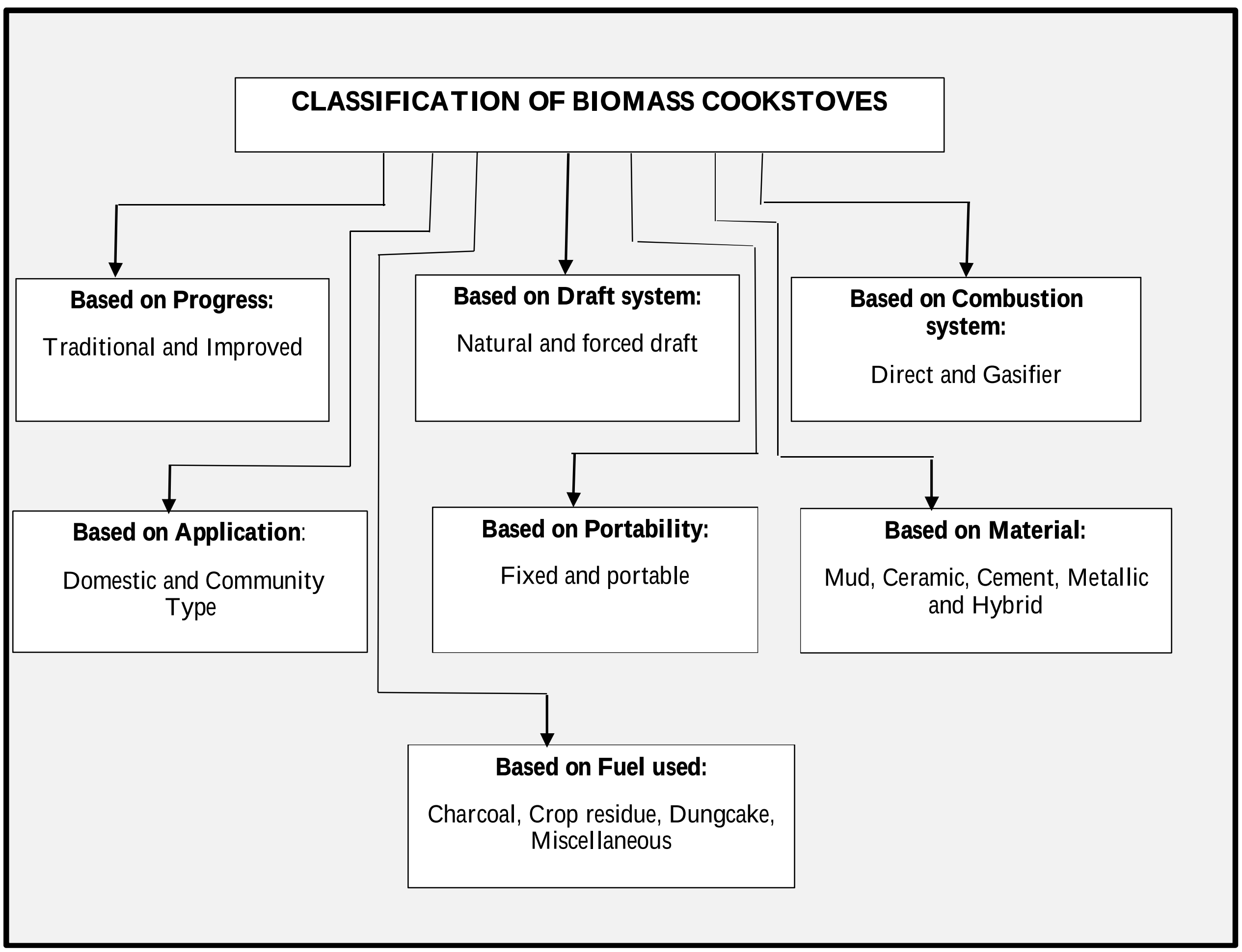

Fig. 2 Classification of Biomass cookstoves

Both the traditional and improved cookstoves are used in India. These stoves are fired up with the biomass fuels such as wood, agro residues, branches, twigs, dungcakes, or coal. These stoves release smokes, which is made up of particulates and gaseous chemicals. The improvement in the design of cookstoves will provide the major solution that could provide a conduits between biomass energy and the commercial energy but unfortunately, it is ignored. It is less expensive for households that are dependent on the biomass cookstoves. Improved biomass stoves lessen the smoke emission in the household but this reduction is not as substantial as that for household with complete switch to LPG.

Global programmes for improved cookstoves can offer some understanding on the feats and problems that are tangled in the promotion of effective biomass cookstoves [19], [20]. The energy efficiency and improved health are known to be the most important trading facts about the improved cookstoves. Although few researchers have rigorously evaluated the Indian National Programme of Improved Cookstoves (NPIC). Numerous ingenuity have been reported: e.g. the ceramic and metal stoves in East Africa, which have proved to be popular and provide employment to the local and improved cookstove interventions in Guatemala [21]- [23].

The progress in the biomass based cookstoves started in India in early 1940s. These cookstoves were known as improved mud cookstoves or first-generation flued (FGF) cookstoves. In 1947, the first improved mud cookstove called 'Magan Chulha', was developed in India. Mr. Raju introduced an improved multi-pot mud cookstoves for rural household in India. In 1954, Theodorovic conducted laboratory test on biomass based improved cookstoves in Egypt. In 1961, Singer measured the efficiency of improved multi-pot cookstove in Indonesia that was inspired by the cookstoves developed by Raju. In these improved cookstoves, a chimney was provided to remove smoke from kitchen and they are made-up of high mass and had adjustable metal dampers to regulate the air fuel ratio.

In the 1970s decade, a new wave for improved cookstoves was witnessed and globally focus was shifted on the improvement of environmental conditions and conservation of energy resources. A number of models of improved cookstoves using wood have been developed which is known as second-generation flued cookstoves. These cookstoves were designed and invented on the basis of engineering principles and hence, were more proficient and robust as compared to the first generation cookstoves. The aim of improved design was to increase efficiency of the cookstoves and reduce the consumption of fuel. This way it prevent deforestation, reduce drudgery and expenditure of procuring cooking fuel with the focus on reduction in smoke. Finally, the second-generation unflued cookstoves were developed to increase the fuel utilization and heat transfer efficiency by complete combustion. It was estimated that due to improved combustion, the emission per food/meal cooked would be less and the level of emission will come down [24]. The greater thermal efficiency was attained with the help of baffles, dampers and smoke reduction in kitchen premises with the help of a chimney. However, in maximum cases, women did not use the damper and that resulted in consumption of additional fuel owing to unrestricted access of air into the firebox. Due to metallic dampers, the chances of getting burnt increased and women were unable to use it during their cooking period. Later on cookstoves minus damper was developed for the women.

IV. NATIONAL PROGRAMME ON IMPROVED COOKSTOVES

The Indian National Programme on Improved Cookstoves that was established in 1983. It has following main goals:

Preserving fuel

Decreasing smoke releases in the cooking area and improving the health conditions

Decreasing deforestation

Controlling the drudgery of womenfolk and offspring and tumbling the cooking time,

Improving the employment prospects for the rural residents.

The Ministry of Non-Conventional Energy Sources was accountable for designing, setting goals and approving cookstove designs and plans. However, state-level agencies divulge this information to the local government organizations or non-government organizations. In each state a technical backup division was set which expertise the rural women or unemployed youths to become a self-employed skilled person to construct and install the cookstoves. The programme disseminated more than 33 million improved cookstoves between the year 1983 to 2000 but in spite of government persuasive efforts the improved cookstoves now account for less than 7% of all the cookstoves. Due to poor quality of cookstoves and lack of its maintenance, the life span of cookstoves was of 2 years only.

The Programme failed due to the following four main problems:

The state did not placed adequate emphasis on commercialization, which is crucial for operative and sustainable commitment.

There was not enough interaction with the consumers, self-employed workforces and non-governmental organizations and the schemes did not meet the requirement of the households. In addition, there was pitiable uptake for the user-training programme.

Quality control for installation and preservation of the cookstove with its suitable use was missing.

High rank of subsidy (about 50% of the stove cost) was established to reduce the household enthusiasm for its usage and maintenance.

The most successful and accomplished area of the programme engrossed on the resources on technical assistance, research and development, promotion and dissemination of information. Later on, Indian government decentralized the programme and reassigned all the responsibility for its implementation to the state level. Since the year 2000, the programme endorses only the durable cement cookstoves with chimneys, which have a minimum lifespan of five years. The introduction of these cookstoves has mark the adhesion of technical stipulations and quality control at much ease.

V. LATEST INNOVATIVE DESIGNS AND IDEAS

Electrification has a vital role in expansion and development [1], [25], [26] [27]. There is some evidence from South Africa that population with grid access experience lesser pollutant exposure [28]. Electricity is not expected to fetch large reduction in exposure to indoor air pollution in low-income nations. The poor householders of developing countries can only pay for lighting and entertainment appliances but not for the far more energy intensive and infesting requirement of cooking and space heating. The International Energy Agency (2012) has of late carried out a comprehensive review of electrification, together with the issues involved in supply and cost regaining amongst the poor population (and especially rural). Involvement in the promotion of LPG has also been quantified, for example, Indian Deepam Scheme and LPG rural energy challenge [29]. This latter ingenuity, established by UNDP and the World LPG Association in 2002, endorses the development of original, commendable markets for LPG in developing countries. Key element consist of development of organizations in countries, empowering regulatory environment which enables LPG business expansion and product distribution, taking steps towards the reduction of barriers to implementation, like introduction of small gas bottle and better government and consumer awareness about cost and benefit. Rai and McDonald in 2009 have identified several key lessons that arose from involvement with the promotion of several cookstoves markets [30].

Moreover, intervention expertise has been developed without a passable reference to user’s wish and consequently it is poorly used, retained, or unrestrained. Thus, it is vital to involve users, particularly women, in evaluating their needs and developing suitable interpolations. Sustainable acceptance has to be promoted through greater ease of access choice of suitably priced intercessions in local markets. Wide varieties of interventions are already offered, and new expertise and tactics are emerging. However, the greatest test is in obtaining widespread recognition of effective intervention among those who are at bigger risk in the path of sustainability. Enabling policy across various regions, and at different levels in societies, is required.

However, the rank of indoor air pollution allied with biomass and particularly stoves with flues can reduce other solid fuel usage substantively. The experiences illustrate that the exposure intensities are not much reduced because emission remains high and people are exposed in the vicinity of their homes. Biomass cookstoves using secondary combustion may offer benefit due to much reduced emissions. Clean fuels like LPG and natural gas, offer the maximum reduction in indoor air pollution, but cost cutting and practical concern in particulates reduction has to be optimized.

Cookstoves can become a beneficial opportunity for the private organization to reduce the harmful impact of the cookstove and improve the health outcomes and livelihood opportunities for millions of households [31], [32], [33]. However, in order to scale up both the supply and demand for cookstoves, support is obligatory in four areas, that is, facilitating greater partnership between stakeholders and sharing of knowledge within the segment; developing and endorsing acceptable and minimum standards for stove performance; promoting awareness of cookstoves and positive benefits they hold; and promoting a wider base and multiplicity of financing options for both consumers and dealers.

VI. FUTURE EFFECT AND SCOPE OF RESEARCH

The study carried out in this paper is helpful for the future study, development and implementation of the cookstoves. Some of the future scopes are discussed below.

The monitoring of the air pollutants from the cookstoves can be study in variety and design improvement. It seems that complete switch to cleaner fuels like LPG, biogas and electricity is difficult to achieve in near future keeping in view the economic, technical, social and traditional constraints. We can utilize biomass energy to efficaciously supplement the conventional energy in meeting cooking energy needs of the country and ensuring access to clean fuels to all. So design improvement in the cookstoves are needed to increase the efficiency and exergy. This includes different type and size of grates in the cookstove, material used for building cookstove, added chimney with its perfect size and location for optimum efficiency, and heat recovery system added for improving overall thermal performance.

Different type of gasifier and pyrolysis techniques can be study and tested in the future for utilization of the solid biomass fuels. Briquettes can be made and utilize in the place of fuel wood stalks. Nozzle design can be improved in LPG and Kerosene cookstove for the next generation.

VII. CONCLUSION

The biomass fuels will continue to remain in use for years to come. Attempts to convert the households using solid biomass fuels to modern clean fuels or from traditional cookstoves to more efficient and cleaner burning cookstoves through alteration of the energy sector or ethnic innovative technology is a complex process which has to be implemented taking the local and traditional factors into consideration.

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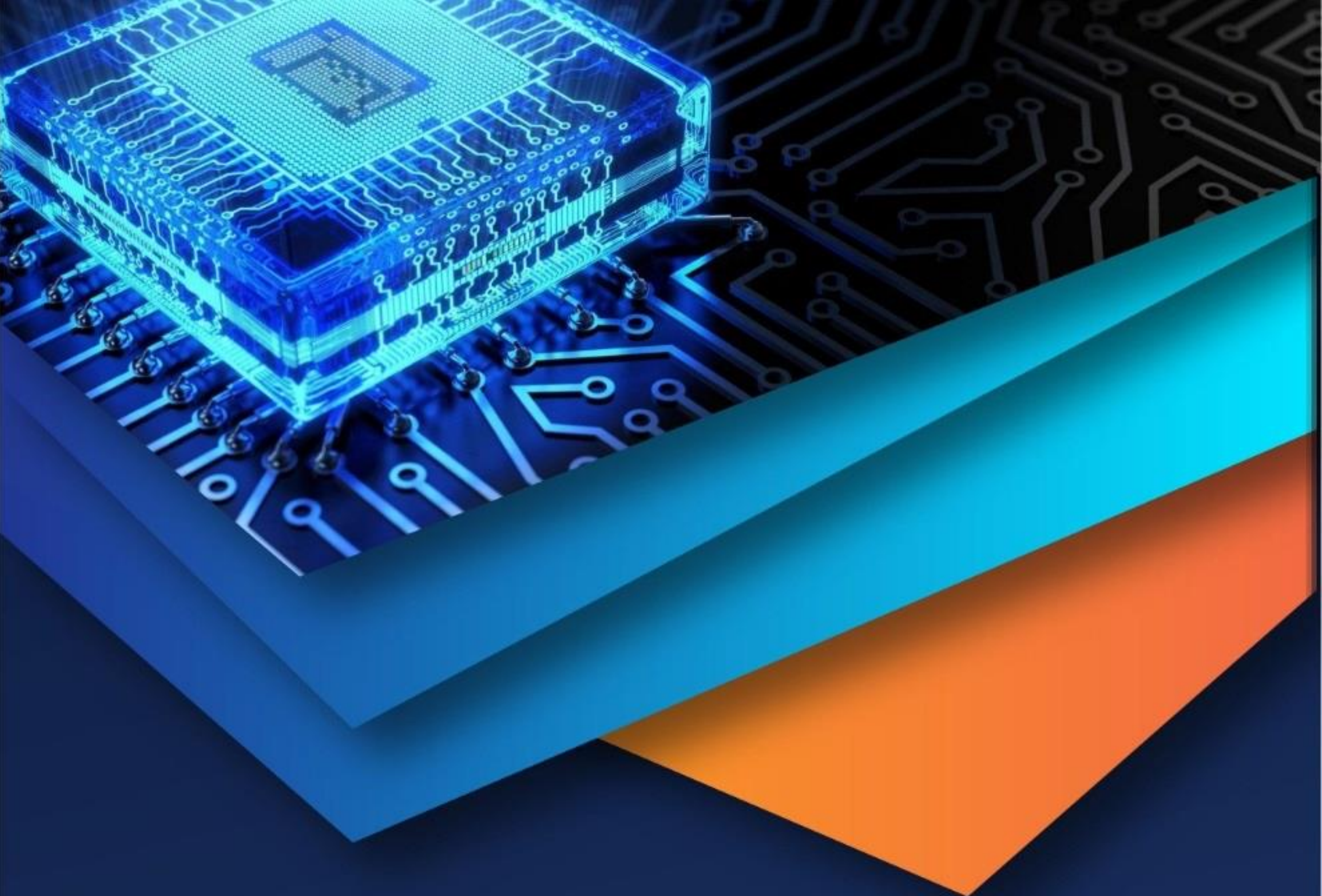

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