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The Environment Effect to Improve the Performance of Air Conditioning System by using Statistical Method

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Abstract: The environment effect to improve the performance of air conditioning system has been proposed. The optimum designed heat load, matching current changeable climatic conditions and providing efficient performance of air conditioning system with maximum annual refrigeration effect, has been defined as a result of statistical treatment of data sets of hourly refrigeration outputs year round. The air conditioning system and corresponding refrigeration capacity of refrigeration machine providing the maximum annual refrigeration capacity output and a value of stable heat load as designed basic heat load covered with high efficiency performance of refrigeration machine in nominal mode are calculated. The values of unstable heat loads as boost loads for ambient air pre cooling covered with low efficiency performance of refrigeration machine in partial modes that cause energetic losses are calculated by remainder principle as difference between optimum designed total refrigeration capacity, providing the maximum annual refrigeration output, and a value of stable heat load as designed basic heat load. The operation of refrigeration machine in partial modes needs application of energy conserving methods of air conditioning.

Index term: Statistical data, air conditioning system, air cooler, heat load, annual refrigeration capacity output, changeable climatic conditions.

I. INTRODUCTION

The improving performance of air conditioning systems and waste heat recovery refrigeration techniques explain on the reference [1-3]. The principal of technical innovation sand methodological approaches in waste heat recovery refrigeration might be successfully applied for traditional vapor compression refrigeration technologies of air conditioning systems, in particular, two-stage air cooling, booster ambient air pre cooling by using an excessive refrigeration capacity accumulated at decreased heat loads to cover peak heat loads [4–6].The enlarging duration of efficient performance of vapor- compression refrigeration machines of air conditioning systems at nominal or closed to nominal heat loads are the most attractive reserves of enhancing their energetic efficiency. The optimal design heat loads on air conditioning systems, i.e. optimal installed compressor refrigeration capacities, and the irrational distribution matching current changeable environment conditions and providing maximum annual refrigeration effect.

The proposed analysis is to improve the efficiency of air conditioning system performance in changeable environmental conditions by defining the optimal design heat load matching current climatic conditions through statistical treatment of data sets of hourly refrigeration outputs year round to find a maximum annual refrigeration output.

II. STATISTICAL RESULTS

The performance efficiency of air conditioning systems and their vapor-compression refrigeration machines depends on duration of their operation year round and can be estimated by annual refrigeration output. The longer duration of air conditioning system refrigeration machine operation year round, the larger annual refrigeration output generated, and both of them are the results of designed heat loads selected closer to the current heat loads corresponding to changeable climatic conditions.

The values of annual refrigeration output in ratio value as total annual refrigeration output $\Sigma(Q_0 \cdot \imath)$, kW·h, related to unite of air mass flow: $\Sigma(Q_0 \cdot \imath)/G_a$, or $\Sigma(q_0 \cdot \imath)$, kW·h/(kg/s), where Q_0 – refrigeration capacity, kW;$\cdot \imath$ – time

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duration, h; G_a – air mass flow in air cooler, kg/s, in dependence on designed specific refrigeration capacity $q_0 = Q_0 / G_a$, kW/(kg/s), related to unit air mass flow G_a = 1 kg/s, of installed refrigeration machine for temperatures ofcooled air t_{a2} = 10, 15 and 20 °C and climatic conditions of Nikolaev region, Ukraine, 2015 year ,are presented in Fig. 1

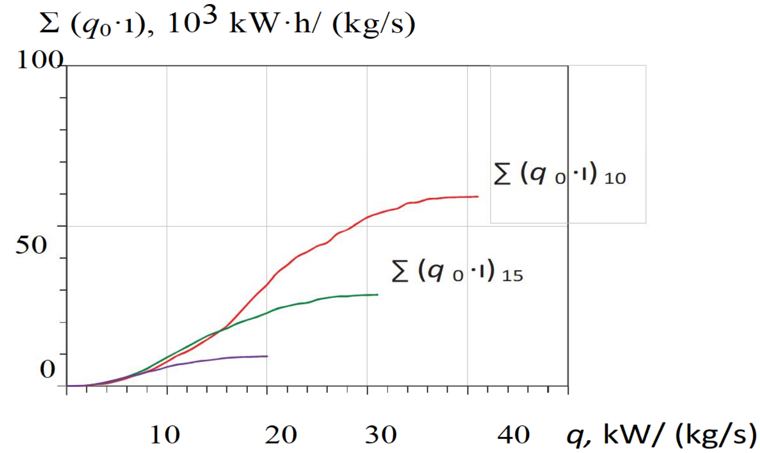
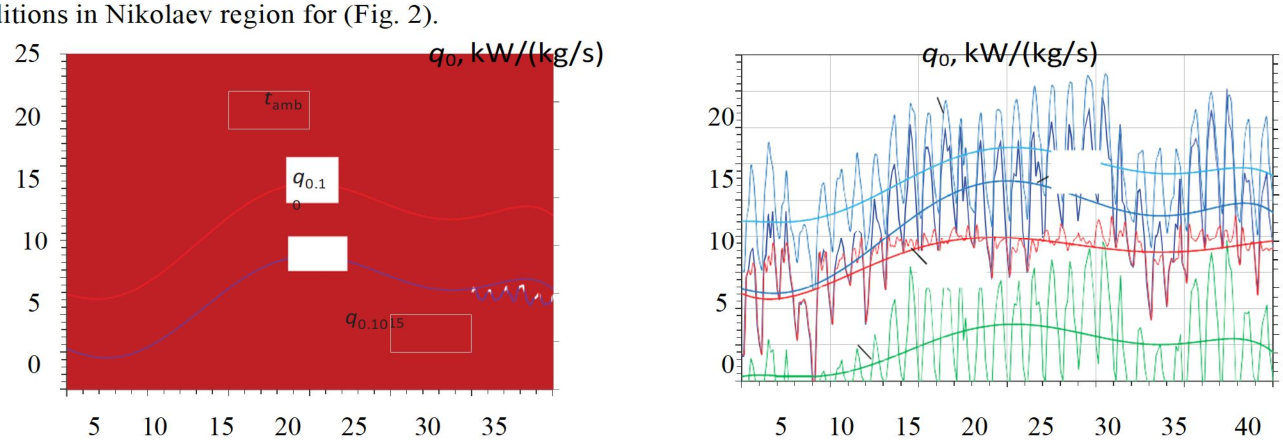


Figure 1 the results of statistical treatment of annual refrigeration output

In ratio values Σ (q_0 ·1) (at air mass flow G_a = 1 kg/s) against designed specific refrigeration capacity $q_0 = Q_0 / G_a$ of installed refrigeration machine for temperatures of cooled air t_{a2} = 10, 15 and 20 °C: Σ (q_0 ·1)$_{10}$ – at t_{a2} =10 ºC; Σ(q_0 ·1)$_{15}$ – at t_{a2} = 15 ºC; Σ(q_0 ·1)$_{20}$ – at t_{a2} = 20 ºC

Because of sharply falling rate of annual refrigeration output increments Σ (q_0 ·1) 10 the further increase in specific refrigerating capacity q_0 from 34 to 40 kW/ (kg/s) does not result in appreciable increment in the annual refrigeration output Σ (q_0 ·1) 10. At the same time the further increase in refrigeration capacity q_0 of installed refrigeration machine causes considerable increase in its capital expenses by 20…30 %. Thus, the specific refrigeration capacity q_0 = 34 kW/(kg/s) is considered as rational one to calculate a total refrigeration capacity Q_0 of installed refrigeration machine according to the total air mass flow G_a,kg/s:$Q_0 = G_a \cdot q_0$, kW.To prove a methodological approach to define the optimum designed heat load, matching current changeable climatic conditions, the values of specific refrigerationCapacity $q_{0.10}$ – for cooling ambient air from $t_{amb}$to t_{a2} = 10 °C, specific refrigeration capacities $q_{0.15}$ – for pre cooling ambient air from $t_{amb}$to intermediate temperature t_{a2} = 15 °C and $q_{0.20}$ – for pre cooling ambient air from $t_{amb}$to intermediate temperature t_{a2} = 20 °C, corresponding specific Refrigeration capacities $q_{0.10-15} = q_{0.10} - q_{0.15}$ for sub cooling air from t_{a2} = 15 °C to t_{a2} = 10 °C and $q_{0.10-20} = q_{0.10} - q_{0.20}$for sub cooling air from t_{a2} = 20 °C to t_{a2} = 10 °C have been calculated for climatic conditions in Nikolaev region for (Fig. 2).



(a) (b)

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Figure 2.Current values of ambient air temperature t_{amb}, specific refrigeration capacity $q_{0.10}$ for cooling ambient air from $t_{amb}$to t_{a2} = 10 °C, specific refrigeration capacity $q_{0.15}$ for pre cooling ambient air from $t_{amb}$to the intermediate temperature t_{a2} = 15 °C and specific refrigeration capacity $q_{0.10-15} = q_{0.10} - q_{0.15}$ for deep sub cooling air from t_{a2} = 15 °C to t_{a2} = 10 °C (**a**) and specific refrigeration capacity $q_{0.20}$ for pre cooling ambient air from $t_{amb}$to the intermediate temperature t_{a2} = 20 °C and corresponding specific refrigeration capacity $q_{0.10-20} = q_{0.10} - q_{0.20}$for sub cooling air from t_{a2} = 20 °C to t_{a2} = 10 °C (**b**) for July 2015

As Fig. 2(a) shows, with pre cooling of the ambient air from t_{amb} to the intermediate temperature t_{a2}=15°C the fluctuations in the current heat load $q_{0.15}$ on the air cooler of the air conditioning system, i. e. in the current refrigeration capacity of the compressor for refrigeration machine, are very significant. This is caused by daily changes in the temperature t_{amb} and relative humidity $_{amb}$ of ambient air with decreasing the temperature t_{amb} at night to 15 °C and lower with corresponding drops of the heat load $q_{0.15}$ on the air cooler to zero. Such significant changes in the current heat loads $q_{0.15}$onthe air cooler of air conditioning system, i. e. in the current refrigeration capacity of the compressor for refrigeration machine $q_{0.15}$, point out a large amount of an excessive refrigeration output in the temperate temperature hours of day round. Significant changes in the refrigeration capacity of the refrigeration machine compressor according to a wide range of changeable heat loads is followed by a decrease in its effective and electrical efficiency, and by an increase in the specific work of compression and electric energy consumption per at the same time, when air is being sub cooled in a stable temperature range from t_{a2} = 15 °C to the temperature t_{a2} = 10 °C, the fluctuations in the heat load on air cooler of air conditioning system $q_{0.10-15} = q_{0.10} - q_{0.15}$ are relatively small: $q_{0.10-15}$ = 11...13kW/(kg/s).Thus, the behavior of the heat load on the air cooler of air conditioning system is different: significant changes in the heat load $q_{0.15}$ for pre cooling of the ambient air from temperature t_{amb} to the intermediate temperature t_{a2} = 15 °C and a relatively stable heat load $q_{0.10-15}$ for sub cooling of air from t_{a2} = 15 °C to temperature t_{a2} = 10 ºC (Fig. 2a).The less fluctuations of the current heat load on the air cooler ,i.e. the closer the selected designed heat load on the air cooler to the relatively stable part of the current heat load, the lower energy losses caused by the operation of the compressor refrigeration machine in partial modes. Obviously, the range of refrigeration capacity controlling according to heat load can be narrowed by sharing the current heat load range on the air cooler in two parts: the relatively stable basic part of it, $q_{0.10-15} = q_{0.10} - q_{0.15}$ = 11...13 kW/(kg/s) while sub cooling air from t_{a2} = 15 °C to the temperature t_{a2} = 10 °C, and it's extremely unstable part $q_{0.15}$ of pre cooling of the ambient air from its current temperature t_{amb} to an intermediate temperature t_{a2} = 15°C.

So, with regards to relatively stable heat load $q_{0.10-15}$for sub cooling air from t_{a2} = 15 °C to the temperature t_{a2} = 10 ºC as compared with extremely unstable heat load $q_{0.15}$ for pre cooling air from the ambient temperature t_{amb} to intermediate temperature t_{a2}=15ºC, the stable heat load value $q_{0.10-15}$ is chosen as designed basic stable part $q_{0.10-15} = q_{0.10} - q_{0.15}$ of the total heat load q_0 = 34 kW/(kg/s) on the whole air cooler of air conditioning system defined according to the maximum annual refrigeration capacity generation(Fig .1).The total unstable current heat load $q_{0.10}$ for cooling ambient air from the changeable current ambient temperature t_{amb} to the temperature t_{a2} = 10 °C can be covered by two stage ambient air cooling: air pre cooling by using boost specific refrigeration capacity (to cover changeable current heat load) $q_{0.A10}$ and air deep sub cooling by using basic refrigeration capacity to cover a relatively stable heat load $q_{0.10-15}$ (Fig.3a). But with this the correspondingly widened basic range of refrigeration capacity for deep sub cooling air is to remain still stable for the same climatic conditions.

If the ambient air is pre cooled from the changeable current ambient temperature t_{amb} to the higher intermediate temperature t_{a2} = 20 °C (instead of t_{a2} = 15 °C), the refrigeration capacity $q_{0.10-20} = q_{0.10} - q_{0.20}$ for deep sub cooling air from t_{a2} = 20 °C to t_{a2} = 10 °C is not already stable. This is due to transference of heat load fluctuations from the boost air pre cooling range to the air sub cooling range that is caused by daily ambient air temperate t_{amb} decreasing lower 20 °C with corresponding drops in the boost heat load $q_{0.20}$ for air pre cooling to zero leading to lowering the air sub cooling heat load range to $q_{0.10-20}$ = 5...10 kW/(kg/s)during 1-8 days against $q_{0.10-20}$ = 15...20 kW/(kg/s) in the rest of July (Fig.3b).

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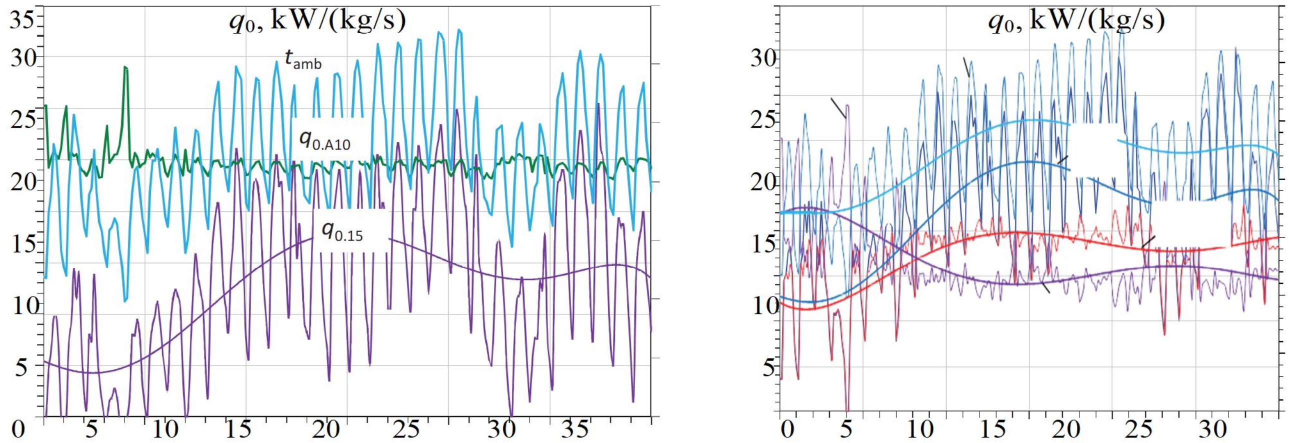
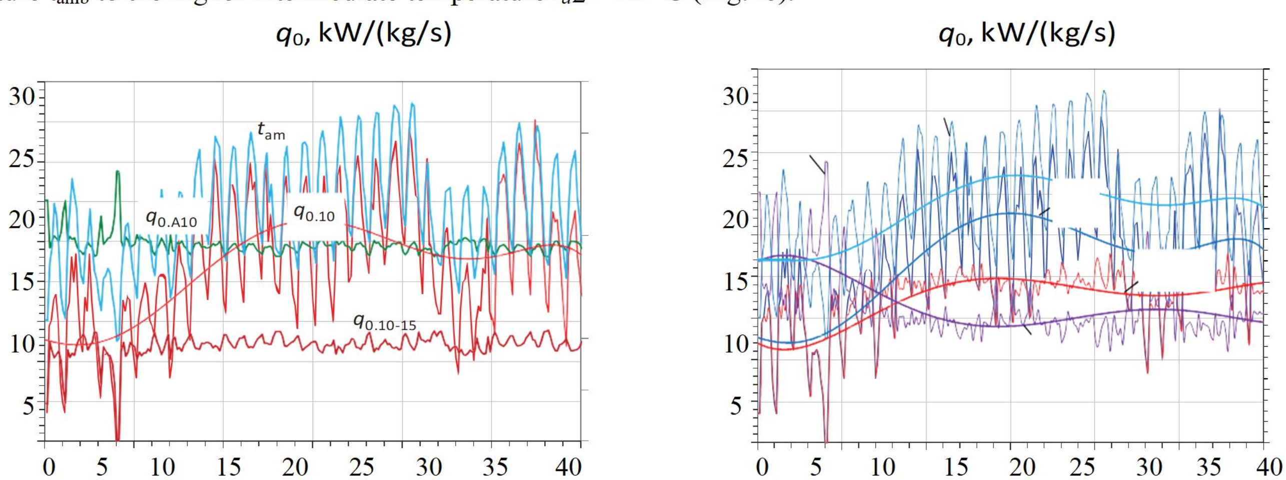


(a) (b)

Figure: 3. Current values of ambient air temperature t_{amb}, changeable current heat loads $q_{0.10}$ caused by cooling ambient air from current temperature t_{amb} to t_{a2} = 10 °C and covered by boost specific refrigeration capacity $q_{0.A10} = 34 - q_{0.10\text{-}15}$ for pre cooling ambient air from t_{amb} to the intermediate temperature t_{a2} = 15 °C and by basic specific refrigeration capacity $q_{0.10\text{-}15} = q_{0.10} - q_{0.15}$ for sub cooling air from t_{a2} = 15 °C to t_{a2} = 10 °C (**a**) and corresponding values of boost specific refrigeration capacity $q_{0.A10\text{-}20} = 34 - q_{0.10\text{-}20}$ for pre cooling ambient air from t_{amb} to the intermediate temperature t_{a2} = 20 °C and basic specific refrigeration capacity $q_{0.10\text{-}20} = q_{0.10} - q_{0.20}$ for sub cooling air from t_{a2} = 20 °C to t_{a2} = 10 °C (**b**) in July 2015.

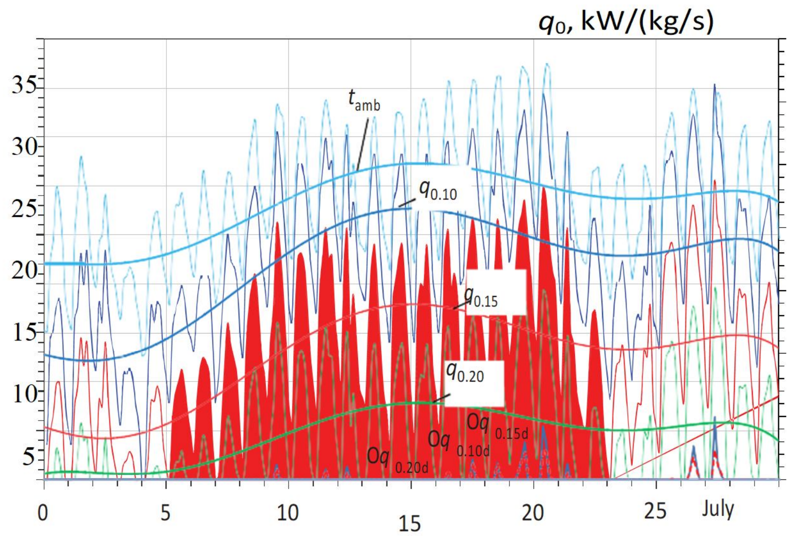
A designed rest boost specific refrigeration capacity $q_{0.A10} = 34 - q_{0.10\text{-}15}$ generally covers current heat loads $q_{0.15}$ for pre cooling the air from the ambient temperature t_{amb} to the intermediate temperature t_{a2} = 15 °C , except some the warmest quite short periods of daytime(Fig.4a).But if the ambient air is pre cooled from the temperature t_{amb} to the higher intermediate temperature t_{a2} = 20 °C (instead of t_{a2} = 15 °C), there is a large excess of boost refrigeration output $q_{0.A10\text{-}20} = 34 - q_{0.10\text{-}20}$ as compared with current boost values $q_{0.20}$ required for pre cooling ambient air from the temperature t_{amb} to the higher intermediate temperature t_{a2} = 20 °C (Fig.4b).



(a) (b)

Figure: 4. Current values of ambient air temperature t_{amb}, changeable current heat load $q_{0.15}$ for pre cooling ambient air from the current temperature t_{amb} to the intermediate temperature t_{a2} = 15 °C covered by boost specific refrigeration capacity $q_{0.A10} = 34 - q_{0.10\text{-}15}$ (**a**) and corresponding values of $q_{0.20}$ and $q_{0.A10\text{-}20} = 34 - q_{0.10\text{-}20}$ for pre cooling ambient air from the current temperature t_{amb} to intermediate temperature t_{a2} = 20 °C (**b**) in July 2015

Because of designed specific refrigeration capacity $q0.10$ = 34 kW/(kg/s) is chosen a bit less than maximum annual refrigeration output $\Sigma(q0 \cdot 1)_{10}$ to provide a high rate of arising the annual refrigeration capacity output $\Sigma(q0 \cdot 1)_{10}$ (Fig.1) it is necessary to check refrigeration capacity deficits for covering current heat loads: O$q0.10d = q0.10 - 34$ kW/(kg/s) and O$q0.15d = q0.15 - 24$ kW/(kg/s) and O$q0.\ 20d = q0.20 - 10$ kW/(kg/s) (Fig.5).



As one can see, there is no practically any deficit of design boost refrigeration capacity O$q0.20d$ for pre cooling ambient air to the intermediate temperature ta2 =20 ºC, but a large excess of design boost refrigeration capacity $q_{0.A10-20}$ = 34 – $q_{0.10-20}$ascompared with current boost heat load values $q0.20$ required for pre cooling ambient air from t_{amb} to the temperature ta2=20 ºC (Fig. 5). And the deficit of design boost refrigeration capacity O$q0.15d$ for pre cooling ambient air to the temperature ta2 =15 ºC is also insignificant and it takes place only 3–4 days within 2–3 hours in July for climatic conditions in Nikolaev region (Fig.5).The results of analyses show that the heat load range for sub cooling the air from its intermediate temperature ta2 = 15 °C to the final temperature ta2 = 10 °C can be chosen as a stable basic design refrigeration capacity $q_{0.10-15}$ = $q_{0.10}$–$q_{0.15}$ (Fig. 2a) and a design boost refrigeration capacity for pre cooling ambient air from changeable current temperatures t_{amb} to the intermediate temperature ta2 = 15 °C is to be calculated by a remained principle as $q_{0.A10}$ = 34 – $q_{0.10-15}$ (Fig. 3a) with total refrigeration capacity $q_{0.10}$=34 kW/(kg/s), providing the maximum annual refrigeration capacity output (Fig. 1).

III. CONCLUSIONS

The optimum heat load on air conditioning system and corresponding designed refrigeration capacity providing the maximum annual refrigeration output, that is a maximum duration of refrigeration machine performance during a year, through a statistical treatment of data sets of hourly refrigeration outputs year round has been developed. A proposed approach is based on the hypothesis of sharing the total range of changeable current heat loads into a basic relatively stable part of heat load for air sub cooling from some intermediate temperature of pre cooled ambient air about ta2 =15 ºC down the any final temperature of cooled air, for example ta2 =10 ºC, which is covered with high energy efficiency due to the operation of refrigeration machine in the nominal mode, and the boost part of heat load for pre cooling ambient air to the intermediate temperature of about ta2=15ºC with less efficient operation of refrigeration machine at partial loads.

A proposed statistical approach provides improving the performance of air conditioning system due to matching the current site changeable climatic conditions.

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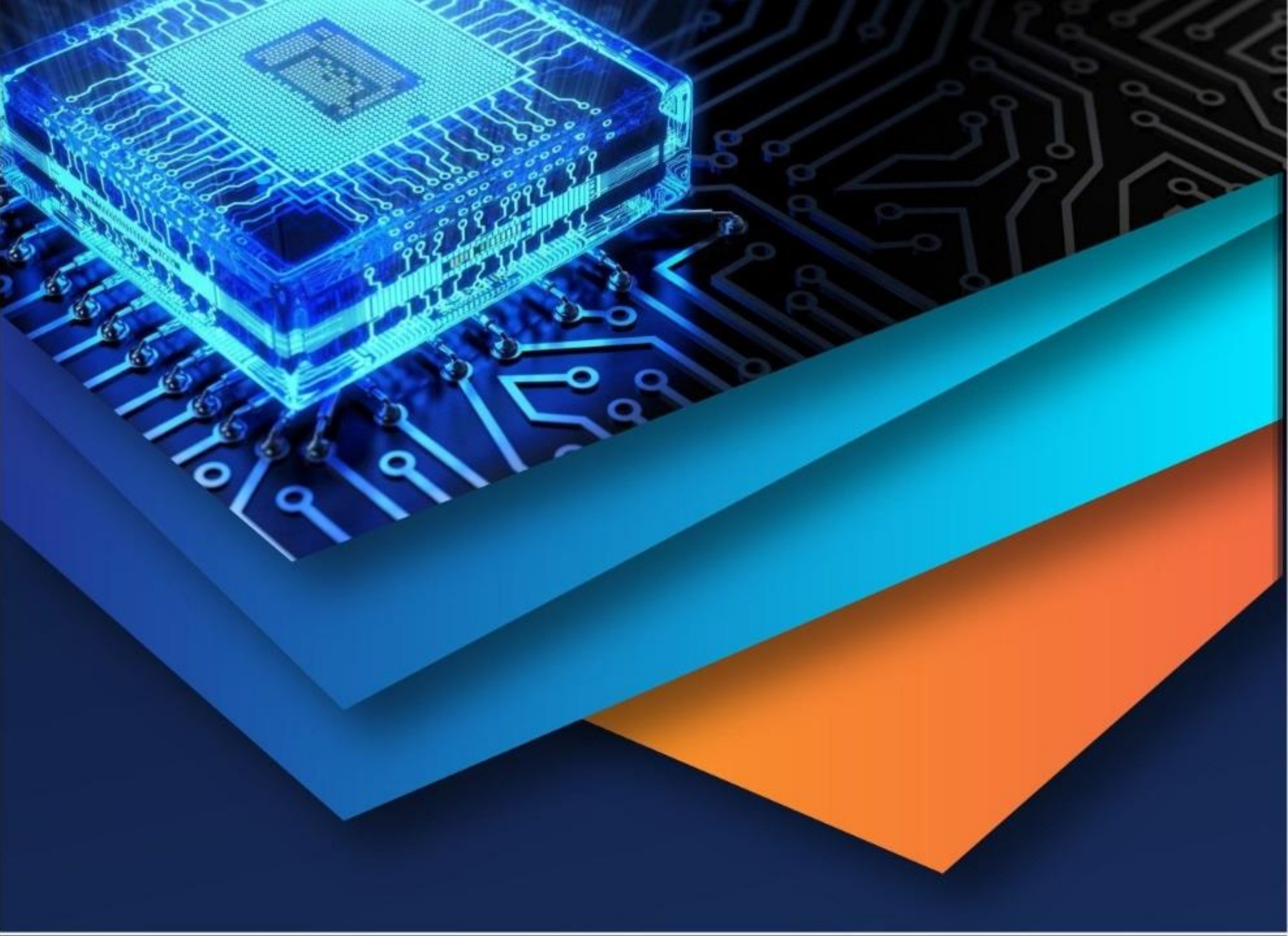

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