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Review: Electro Rheology for Smart Automotive Suspension by Using Zeolite Base ERR Fluid

Deepak Mahale[1], Sujit Deshmukh[2], Sameer Chincholkar[3], Dhirajkumar Saindane[4]
[1,2,3,4]*Mechanical Engineering, Sandip Polytechnic, Nashik*

Abstract: the purpose of the paper reported was to substantiate the capability of electro rheological (er) technology for adaptive control of suspension forces on wheeled vehicles. The shear strength properties of er fluid are proportional to an electric field applied. This change is quick and reversible.

Electro-rheological fluids consist of slurries of fine hydrophilic solids in hydrophobic liquids. In the absence of an electric field, these fluids behave like newtonian fashion, but when an electric field is applied, the fluids become more viscous as the electric field increases. The process reverses when the electric potential is removed, and the er fluid returns to its fluid state. If we applied strong electrical field er fluid becomes solid.

We can use this property in automobile suspension in the damper where resistive forces controlled by an external electrical signal. The device was applied in a semi active suspension system. The paper contains range of development tasks including er fluid formulation, design of an er damper.

The design of shock absorber consists of a fluid filled cylinder and piston member travelling in cylinder and electro-rheological valve controlling the passage of fluid through the cylinder. The electro-rheological valve placed in piston to control the flow of fluid. And this design can be easily adapted in present size of shock absorbers

Keywords: electrorheology, er dampers, electro rheological fluid, and zeolite.

I. INTRODUCTION

ER fluids offer an inherent electrical-to-mechanical interface, the technology is of interest wherever the need exists for the active electronic control of a mechanical function. In the case of motor vehicles, active suspensions offer a means of managing a broad range of variables that otherwise aggravate ride vibrations when only a fixed damping device is installed. Without an active damping function, for example, a fixed shock absorber must be designed for the mean operating condition, offering too much damping when the vehicle is unladen and, say, running on roads, but too little damping when the vehicle is fully loaded and is traversing rough terrain. It is also not possible, using a passive device. Although the traditional tools of electrohydraulic have been examined for creating active dampers for motor vehicles, the control devices have typically been rather complex and the broad set of system requirements have generally militated against their frequent application.

ER technology is based upon certain fluids which offer a change in their mechanical properties in response to a strong electrical field. The changes essentially involve resistance to flow and are entirely reversible and very broad in temporal bandwidth. An ER device, then, is a mechanical actuator, damper, valve, or other element which contains an ER fluid and is configured to apply an electric field across it for the sake of realizing a net mechanical outcome.

Since ER fluids offer an inherent medium for mechanical control, there has been an interest in exploring the suitability of this technology for the active control of automotive damping. The basic concept that was explored in this paper involved using the fluid in a device that directly substituted for the conventional shock absorber.

The monitoring of vehicle motions using accelerometers and stroke transducers provided the basis for deriving an electrical signal, which was applied as a command signal to the ER-controlled device. The instantaneous thickening of the fluid with increasing signal level produces a resistance to motion which is calculated to manage the gross ride vibrations which accrue.

A. Er Mechanism

Electrorheological phenomena, some- times referred to as the "Winslow effect," were first reported in detail by Willis Wins- low in 1949 [1]. He reported the following features of suspensions of silica gel particles in low-viscosity oils.

an electric field of magnitude on the order of 3 kV/mm, the suspensions show a tendency to fibrillate, and highly elongated condensed structures of particles form parallel to the field.

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A force proportional to the square of the electric field is necessary in order to shear the fluid between the electrical plates. Thus, at low shear stresses, the system behaves like a solid.

At stresses greater than this yield stress, the fluid flows like a viscous fluid, but with a large viscosity, again proportional to the square of the electric field.

In order to take advantage of fast information processing in mechanical engineering, it is necessary to have a fast interface between an electric circuit and the mechanical response of a system. The ER response is extremely rapid; although full structure formation after the application of an electric field can take several seconds, the viscosity increases significantly over a time scale of 10^{-3} S.[2]

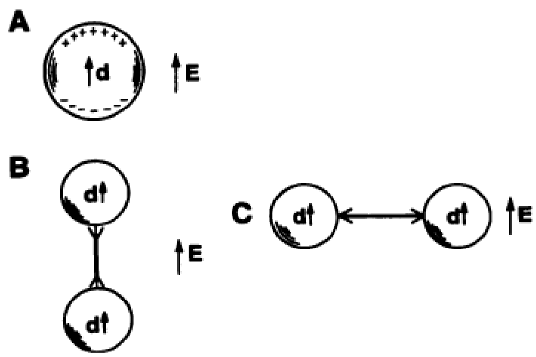

Fig 1. (A) A particle whose dielectric constant is mismatched with the surrounding medium develops a dipole moment as a result of its polarization in an electric field. (B) Two such particles attract if they are arranged along the electric field direction or (C) repel if they are in the plane normal to the electric field direction.

A crude model of the origin of the ER effect is shown in Fig. 1A. Suppose that the dielectric constant of the suspended particles is larger than that of the solvent. An electric field then polarizes the particles, leading to the appearance of induced charge at the particle surfaces. This charge creates a dipolar field around the particle, which can be modeled as a simple dipole moment d = βr3E, Where β is an effective polarize ability of the particle,

The interaction energy u between two such polarizable particles is given by

$U(r, \phi) = d^2/r^3 (3 \cos^2 \phi - 1)$

Where **r** is the distance between the particles and **ϕ** is the angle between the vector connecting the two particles and the electric field direction.

Particles aligned along the field (Fig. 1B) attract one another, whereas particles in a plane perpendicular to the field (Fig. 1C) repel one another. There is a critical angle ϕ_c such that, if the angle ϕ satisfies $\phi < \phi_c = 55^0$, then the interaction will be attractive; if $\phi > \phi_c$ the interaction will be repulsive. The force is proportional to the square of the dipole moment d^2; thus, it is proportional to E^2.

Also the attractive force between the particles consisted of a dipole–dipole interaction between the oriented polar molecules and the dipole–charge interaction between the polar molecules and nanoparticles (Fig. 2 a & b)[4]

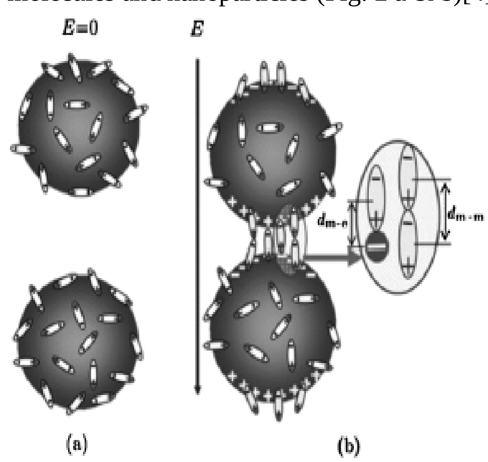

Fig 2: Schematic diagram of the polar molecules aligned in the gap of the particles under an applied electric field.

II. AN INTRODUCTION TO VEHICLE SUSPENSION CONTROL TECHNIQUES

A. Passive Suspension

A conventional passive suspension usually consists of a spring and a shock absorber (a damper). The spring can only store and return energy for some portion of a suspension cycle, and the shock absorber can only dissipate energy. The damping properties of the passive suspension are constant. There is no means of supplying external energy or signal to the system for controlling of the suspension properties. In order to cover a broad set of conditions, a passive system can be designed to have parameters varying with stroke or velocity of the suspension system. The range of the operating conditions often exceeds the coverage obtained by varying parameters passively.[3]

B. Active Suspension

An active suspension is a system in which an actuator either totally replaces the conventional spring and damper elements or acts in parallel with a spring. Active suspensions require external power to drive the actuators, which are normally hydraulic cylinders, to generate the desired forces in the suspensions.[3]

C. Semi Active Suspension

The most common semi active suspensions are those whose damping characteristic is adaptively controlled, -although some have also entailed direct control of the spring characteristic in the spring case, however, varying the stiffness without, at the same time, effectively varying the free length of the spring produces the undesirable results of having unpredictable distribution of load on the four wheels of a cornering vehicle. Solving this problem may be more difficult than solving those of a fully active system. Recognizing this issue, the following discussion is limited to semi active suspensions having controllable damping.

The use of ferromagnetic fluids is generally eliminated from automotive consideration by their demand for high levels of electric power, although recent research has indicated a promising new approach .ER fluids offer a solution which avoids both thermal and power-based adjustments in viscous response and which may be practicably scaled for automotive application. With its much simpler design, better efficiency and lower cost, a semi active suspension may compete well against active suspensions in practical terms while delivering performance that is much superior to that of passive suspensions. As far as controlling body motion due to roadway unevenness is concerned, semi active systems can be virtually as effective as fully active systems using state variable feedback. application. With its much simpler design, better efficiency and lower cost, a semi active suspension may compete well against active suspensions in practical terms while delivering performance that is much superior to that of passive suspensions. As far as controlling body motion due to roadway unevenness is concerned, semi active systems can be virtually as effective as fully active systems using state variable feedback.

D. An Electrorheological Test Fluid

Within this paper, alternative formulations of electro rheological fluid were studied in an attempt to improve upon fluid shear strength capability and to reduce settling of the particulate component in ER suspensions. Three alternative fluid categories were examined, namely, 1) homogenous solutions, 2) colloidal dispersions or gels, 3) a zeolite-based suspension. The consideration of each will be discussed below-

E. Homogeneous Solution

ER active solutions present the ideal conceptual approach for solving the problem of settling that is otherwise seen in the multiphase (suspension) materials most commonly used as ER fluids. That is, a solution is, by definition, a single phase system that is inherently stable in terms of the physical distribution of its constituents. Recent discoveries have shown that solutions of poly gamma benzyl-L-glutamate (PBLG) and poly n-hexyl isocyanides (PHIC) exhibit an ER-active behavior. The PBLGs, although ER active in many solvents, are known to be soluble only in polar solvents, resulting in relatively high levels of conductivity and thus requiring rather high levels of electrical power for sustaining the electric field condition.

F. Colloidal Dispersion/Gel

By a second approach, steps were taken to prepare ER fluids which, under quiescent or static conditions, would constitute a gel which inherently resists settling of a particulate phase of the materials. The desired gel formulation, of course, would exhibit an ER response to an electric field but would otherwise have a very low viscosity when deformed over a range of shear rate values. Various colloidal, as opposed to soluble, gelling agents were used primarily because the colloidal systems produce gels that are highly shear-thinning. By this approach, the gel effect would hold the fluid in a semisolid state, at rest, presenting an essentially zero static shear strength in the absence of an electric field. Upon even very slight initial loading, the gel would yield and thereafter exhibit a very low viscosity (i.e., thinning) response to increasing shear rate.

G. Amorphous Substituted Alumins-Silicates

The term, zeolite, applies to a crystalline form of alumina-silicates (AVSi) that were observed by University of Michigan researchers to be an effective ER active particulate.[3] Amorphous forms of Al/Si as the dispersed phase in ER fluids have also been shown to produce ER active suspensions. The amorphous materials are intrinsically more attractive because the chemistry can be much more radically varied without concern for constraints on the crystalline structure and because the materials are much less hydrophilic than the crystalline. The effort was successful in varying the Al/Si ratio over large ranges and in combining the silicon atoms with a wide variety of elements other than Al. Research continues in this area, given indications that further increases in static stress capability are possible.[3]

III. DESIGN OF ER FLUID DAMPER

Conventional shock absorbers are either of a single or double cylinder type. Single cylinder type absorbers have a cylindrical casing filled with fluid (e.g. pressurized gas or oil), and a reciprocating piston that travels within the casing in response to the movement of the struts used to suspend a chassis of an automobile. Fluid pressure within the cylinder exerts a force opposing the piston travel, thus damping the movement and oscillation of the struts. In a single piston shock absorber, a rod supports the piston within the shock absorber casing and is attached to one of the ends of the strut. As the strut is compressed, the rod is thrust inside the casing, causing the piston and a section of the rod to travel longitudinally. The section of the rod that is thrust within the casing displaces a volume of compression fluid which must be compensated for in order for the shock absorber to function properly. As is known, the displacement of volume in the cylinder often results in mixing of liquid and gas, which can cause fluid foaming that impairs the damping action of the absorber. It has been recognized for several decades that certain fluids respond to the influence of an electric potential by evidencing a rapid and pronounced increase in viscosity and an increased resistance to shear.[5] Such electro-rheological or electro-viscous fluids comprise slurries of finely divided hydrophilic solids in hydro phobic liquids. In the absence of an electric field, these fluids behave in a Newtonian fashion, but when an electric field is applied, the fluids become proportionately more viscous as the potential of the electric field increases. In strong electric fields, the fluids can thicken into a solid. The electro-rheological phenomenon reverses when the electric potential is removed, and the material returns to its fluid state. Electro-rheological fluids change their state very rapidly when electric fields are applied or released, with typical response times being on the order of one millisecond. The ability of electro-rheological fluids to respond rapidly to electrical signals makes them well suited as elements in mechanical devices. Fluids behave in a Newtonian fashion, but when an electric field is applied, the fluids become proportionately more viscous as the potential of the electric field increases. The present invention discloses an electro-rheological shock absorber of a single cylinder type capable of producing damping effects of different magnitudes in response to a control signal generated by an on-board vehicle computer or by other means. In the preferred embodiment, the present invention comprises a cylindrical casing filled with an ordinary compression fluid, an arm member extending into the casing, a damping member that is attached to the arm and that divides the casing into upper and lower sections and a bypass passage that connects the sections of the casing and that is controlled by an electro-rheological valve. The clamping member is attached to the vehicle chassis and reciprocates within the casing in response to movements and oscillations of the vehicle. As the damping member travels longitudinally, it compresses the fluid within the casing and forces it into the bypass passage. The electro-rheological valve within the passage contains an interior chamber filled with electro-rheological fluid. Viscosity of electro-rheological fluids increases in an electric field and depends for its magnitude upon the field’s duration and intensity. The electro-rheological valve is constructed so that when an electrical field is applied to the electro-rheological fluid within it, the change in the fluid’s viscosity is translated into resistance to movement by the valve body from a position that completely or partially blocks the bypass passage. The damping member within the shock absorber casing encounters increased resistance to its longitudinal travel and a damping effect is created. Another embodiment of this invention comprises a cylindrical casing filled with conventional compression fluid, a perforated damping member reciprocating within the casing and a hollow arm member that supports the damping member and also contains an electro rheological valve. The valve is configured in such a way that when an electric field is applied to it, the perforations within

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the clamping member itself are blocked. In this manner the damping member becomes essentially solid and a damping effect is created. The magnitude of the damping effect depends on the intensity and duration of the electric field within the Electrorheological valve. The valve is capable of reducing the flow of oil through the bypass passage from 100% to 0%.[5]

IV. ER VALVE PISTON ARRANGEMENT

A final embodiment of the electro-rheological valve piston is illustrated in FIGS. 3A and 3B. As with the previous embodiments, the piston head comprises a cylindrical casing having perforated top and bottom members 162, 1620. The casing contains a molded temperature resistant plastic disk 160. Disk 160 contains numerous radially extending apertures 161 through which electro-rheological fluid can flow and which are mated with the top and bottom members 162, 162a. The opposite sides of each radial aperture are coated or plated with copper or other conductive material and function as respective positive and negative electrodes. The electrodes are parallel and separated at a uniform distance. The width of each aperture 161 should be between 0.5 and 1.5 millimeters. As shown, insulated electric wires 28 are extended through hollow arm 34 and electrify the opposite sides of each aperture 161. Electro-rheological fluid 35 flows through the apertures

161 until electrified. When the electrodes are activated, the electro-rheological fluid 35 contained within each aperture 161 solidifies, and the flow through piston 36 forms a solid or semi-solid barrier within the valve chamber 33.

V. ER DAMPER CONSTRUCTION

Fig. 4, illustrates another embodiment of the present invention. ‘In this embodiment the electro-rheological shock absorber 10 comprises a single cylindrical casing 17 and a perforated damping member 83 supported by a hollow arm member 18 and an electro-rheological valve 26 for controlling the degree of damping. The shock absorber is attached to a vehicle’s chassis and hub through connection members 12 and 14. An interior chamber 16 of the absorber is filled with oil, gas, or any other compression fluid 22._Inside the arm member 18, a valve piston 98 filled with electro-rheological fluid 35 is provided. An internal perforated piston member 36 is provided within the fluid 35. In its preferred embodiment, the piston is an electrode, having one of the configurations of FIGS 3A, 3B , held stationary within the valve piston 98 by a rod 34. The clamping member 83 contains perforations 830 which are opened and closed by electro rheological controlled needle valves 89 inserted into and retracted from the perforations 83a. The needle valves 89 are inserted into and retracted from valve seats 91. The interior of the arm member 18 between the valve piston 98 and the needle valves.89 is also filled with oil or another compression fluid 92. When no damping action is required, oil flows freely through the damping member perforations 83a, exerting an inward pressure on the needle valves 89. The needle valves 89 are thrust inward and the valve piston 98 is thrust upward against a biasing spring 30. The biasing spring 30 must be calibrated to permit the needle valves 89 to be thrust inward when the damping member 83 travels longitudinally in either direction.

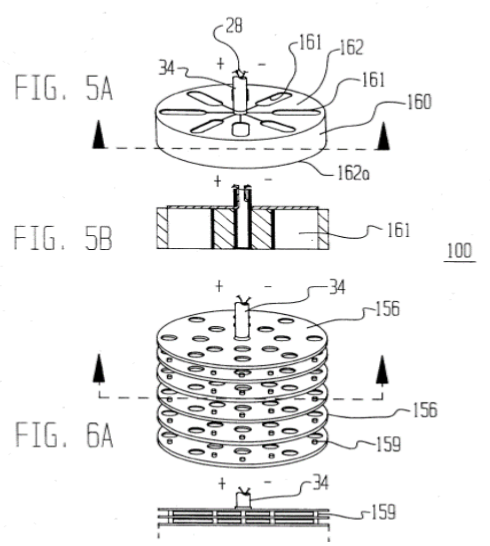

Fig 3. ER Valve Piston Arrangement

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The piston member 36 may comprise any suitable Electrorheological activating construction, such as one of the four electrode configurations disclosed herein and depicted in FIG.A B C through 6. Electrodes may be activated through wires 28 that extend up the shaft of the arm member 18. When an electric field is applied to the electrodes contained within the perforated piston36, electro-rheological liquid within the perforations becomes solid or semi-solid. The piston member 36 is thus transformed into a solid barrier halting the flow of electro-rheological fluid 35 through the perforated piston member 36 and providing resistance to any pressure exerted against the valve piston 98, effectively locking the valve piston 98 in place. During a period of reduced fluid flow tension and in the absence of an electric field, the biasing spring 30 exerts a biasing force on the valve piston 98, causing the valve piston 98 to travel downwards in the fluid 92 and to thrust the needle valves 89 into the damping member perforations 830. Once the needle valves 89 are in their desired position with respect to the perforations 830, the application of the electric field will solidify the piston member 36 and lock the valves 89 in place for the duration of the electric field activation As the flow of oil 22through the perforations 83a becomes obstructed, a damping effect is created. That effect is a function of the needle valves 89 within the perforations 83a, and the intensity and duration of the signal activating the electrodes within the electro-rheological valve internal plunger 36.

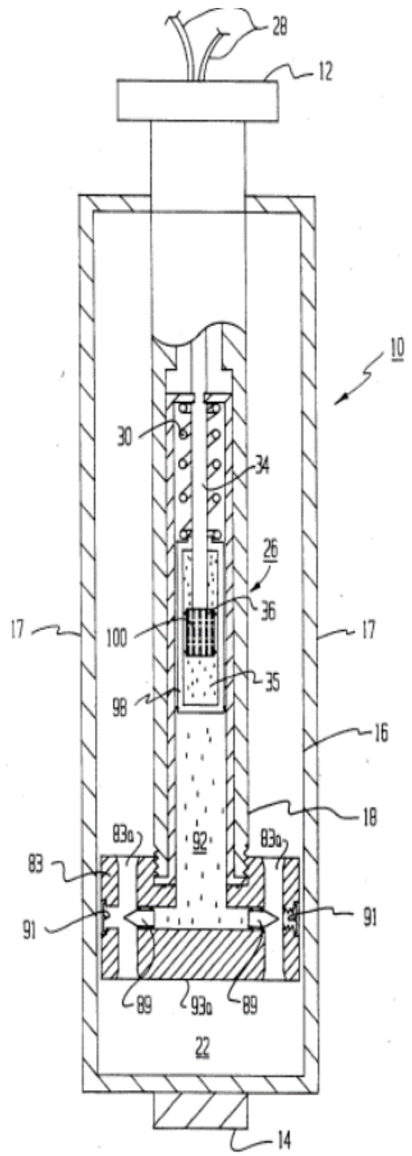

Fig 4: Construction of ER Damper

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VI. CONCLUSION

Conclusion of this paper, a relatively conventional form of dampers and ER damper are studied and ER dampers are very good to sustain the high shocks and forces. Also this paper contain ER fluid which is (nominally dry) commercial zeolite particulate dispersed into a medium of transformer oil. And different arrangement of ER piston valve and actuating devices. Nevertheless, as the document will show, a workable ER Damper was demonstrated in this paper.

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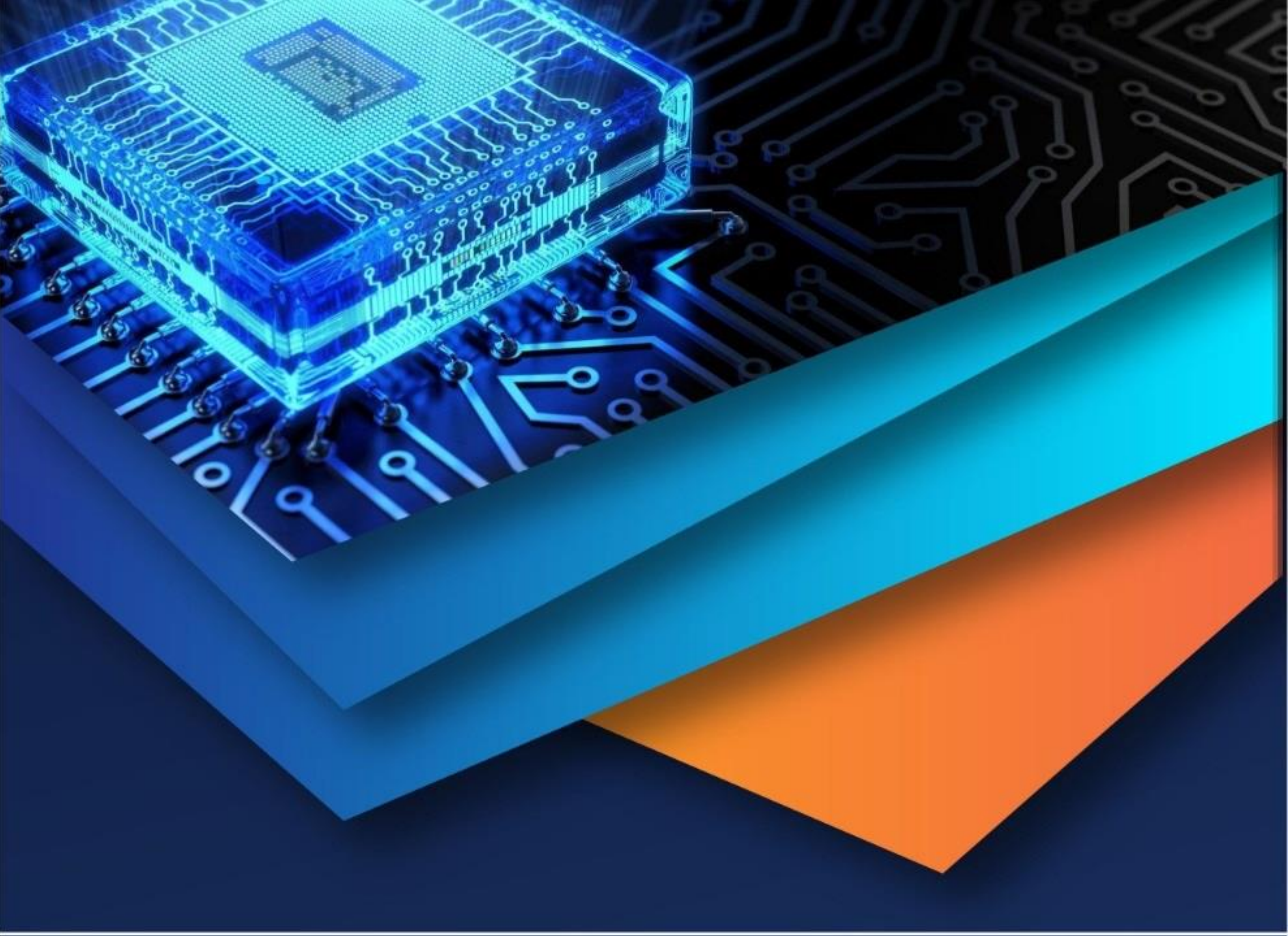

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