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Orbital Performance Simulation of Ring Type Electro Motor Compared with Radial Motor Using Magnet Software

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ABSTRACT

The use of fossil fuels is currently very high, resulting in an increase of CO_2 in the atmosphere. The transport sector is currently the largest contributor to the greenhouse effect worldwide. Electric vehicles are the main solution for researchers to develop. This study compares force, torque, and orbital flux of electro-orbital ring-type motors and radial electro-motors. This research uses a simulation method to determine the value of force, torque, and linkage flux in each type of motor using MagNet Software. This research is development research using a simulation approach. The simulation test subjects consisted of computers, MagNet 7.5 software, Solidworks, Calipers, Protractors, and Rulers. There are 3 data collected in this research, and the data are as follows: (1) force, (2) torque, and (3) linkage flux. Data analysis was done by simulating with magnet software and then comparing the test results on the linkage force, torque and flux. The simulation results are then compared to determine the performance of each motor. The result of this research is that the performance of the ring-type orbital electro motor compared to the radial electro motor is better in attractive conditions, but lower in repulsive conditions. In the magnetic attraction condition, the average value ratio of the ring type orbital electro motor compared to the radial electro motor is 1.08:1 force, 1.68:1 torque, and 1:1.03 linkage flux. In the reject condition, the average ratio of ring-type electro motor orbitals compared to radial electro motor is 1:1.3 force, 1:1.06 torque, and 1:1.6 linkage flux.

Keywords: Flux, Radial, Orbital, Motor

INTRODUCTION

The automobility literature has spent the last decade or so attempting to observe and influence the dynamic tenacity of passenger vehicles [1]. Future development ideas for the three components of energy consumption are proposed: total control, energy structure layout optimization, and energy comprehensive transportation system construction [2]. Current technological advances encourage the development of various kinds of increasingly sophisticated equipment. One of the many efforts made by various countries in the world in the current era of technological development is in the field of transportation.

One of them is the development of electric cars. The existence of an electric car is one of the breakthroughs from batteries to electric motors. The history of electric car breakthroughs has been running from ancient times and is very long, starting in the 1700s to 1800s [3]. An electric car is one that is powered by an electric motor that is powered by electrical energy stored in a battery [4]. Around the 18th century, electric cars began to be developed, several scientists from the United States (US), the Netherlands, Hungary began to focus on electric vehicles. Adoption of electric vehicles (EVs) has the potential to reduce greenhouse gas emissions, energy dependency, and resource scarcity [5]. A time series analysis summarizes the possible relationships between new energy vehicles and crude oil imports, i.e., new energy vehicles will reduce demand for oil in the transportation sector as alternatives to fuel vehicles [6].

The use of fossil fuels is currently very high, resulting in an increase in CO_2 in the atmosphere. The growing public demand for automobiles as a mode of transportation for daily activities is also driving the increase in the number of motorized vehicles [7][8]. The transport sector is currently the largest contributor to the greenhouse gas effect worldwide [9]. Various types of vehicles that exist today mostly use motors / engines with gasoline fuel, so that the exhaust gases that come out contribute to environmental pollution, especially air [10][11]. Vehicle efficiency is currently a problem that engineers are researching. Vehicles that can produce maximum power and torque, as well as fuel-efficient and environmentally friendly are the main points in the process of designing a vehicle.

Electric motors or electric motors consist of rotors, stators, windings [12], commutators which have their respective functions. Electric motors are divided into 2 types, namely AC (alternating current) electric motors and DC (direct current) electric motors. B DC engines are used in many manufacturing and household applications. BLDC motors have lower maintenance costs and have better efficiency levels than previous DC motors [13]. BLDC motor is a motor that is sourced in direct current to support its work [14]. Bouloukza researched and analyzed the electromagnetic design of a permanent magnet radial flux electromotor [15]. The design and analysis of the magnet are in 2 dimensions using the Finite Element method. In a 2-dimensional view, the motor magnet is drawn in a master-slave representation on the 600 surfaces. The magnet material used is NdFe30. The finite element analysis (FEA) results show that the maximum flux density is around 1.8 T, which is considered sufficient for the machine. Transient case and harmonic analysis reveal that the magnetic flux, voltage, current, and mechanical torque signals are rich in high-order harmonics. In the EMF analysis at 300 rpm, the peak-to-peak voltage was 126 V as the maximum voltage. The maximum simulated current amplitude is 8.5 A at 300 rpm. The engine can produce an average torque of 65 Nm based on the results obtained. However, the torque curve has negative and positive values because the simulation has been realized under no-load conditions. In this study, it was concluded that 3-phase motors promise torque and current for lower electrical loads.

Waghmare et al. designed and simulated a permanent magnet brushless DC motor using Ansys [16]. The analysis design uses a 2-dimensional model and the Finite Element Analysis (FEA) method. The author includes several stator and rotor parameters for analysis in this design. The main parameter chosen in comparing the analysis results is the width of the magnet because the width of the magnet is the main factor that affects the size of the flux output. The magnet type used is NdFe30, with a maximum thickness of 35 mm. In the first analysis, with a magnet width of 20 mm, a power output of 500 watts is produced, a torque value of 1.5813 Nm, an air gap flux density of 1.1 T, an average inrush current of 2.5322 A, a speed value of 3020 rpm. In the second analysis using a 28 mm wide magnet with the same parameters, a power output of 1000.21 Watt was produced, a torque value of 4.36285 Nm, an air gap flux density of 0.578028 T, an average inrush current of 5.72171 A, a speed value of 2189, 24rpm. Based on the research that has been done, it is concluded that the size of the magnet affects the resulting output power—the smaller the width of the magnet, the smaller the output power, and vice versa.

Aslan et al. conducted a study entitled Design and Modeling of Internal Permanent Magnet Motor [17]. The design of a radial brushless motor with an internal permanent magnet (IPM) with the specified yield parameters is about 35 Nm of torque, 1500 Watts of power, 72 Volts of DC source voltage, 600 rpm of motor speed, and 40 Amperes of current. The design uses a mathematical model based on predetermined parameters. IPM motor sizing and magnetic and thermal analysis were carried out using the Finite Element Methode (FEM). The flux density chosen for the material is 1.21 T with the type of magnet N35UH, and the maximum operating temperature of the magnet is 180^0 C.

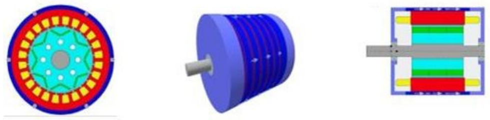

Figure 1. IPM motor in visualization

Kholis designed a permanent magnet synchronous generator using MagNet Infolytica 7.5 Software [18]. The method applied is Finite Element. The generator designed in his research is a radial flux type with a combination of 12 slots, 8 poles, 5 cm thick, using 12 rotary windings rotated at 100 rpm, 13 cm in diameter, and a frequency of 66.667 Hz. This research aims to know the results of variations in the generator model, geometry, number of turns, type of material, rotational speed, efficiency, and desired output power. The simulation is carried out without and using load, with variations in load and rpm. Generator design is a full 2-dimensional model in MagNet 7.5 Software. Variations in rpm applied to obtain output and efficiency data are 500, 1000, 1500, and 2000 rpm. The simulation results with a speed variation of 2000 rpm get the highest voltage value of 361.8 Volts which is a no-load simulation. Simulation tests using a load get the lowest efficiency of 83% and the highest efficiency of 89%.

Mathematical modeling used in this study includes force equations, magnetic modeling, coil resistance and coil inductance, torque and EMF calculations, energy calculations, and the power generated. Internal permanent magnet motor design using CAD for electric motor design. Permanent magnet motors are designed in 2 dimensions and 3 dimensions. The calculation results are used to determine the dimensions of the designed IPM motor.

Torque, power, and IPM motor speed are continuously observed at a predetermined number. The thermal analysis results show that the designed IPM motor has an efficiency of around 92%.

The considerable potential of electrical energy can replace fossil fuels in various types of motors / engines[19], due to the decreasing supply of fossil fuels, and the government is increasingly strict in determining emission regulations. With these problems, the need to develop energy-efficient and environmentally friendly transport is being targeted in all circles. Electric vehicles are the main solution for researchers to develop. Some of the efforts of researchers in the efficiency of electric vehicles such as motor selection, battery systems, drive topology, and control algorithms. Electric motors currently on the market have several types. In general, electric motors can be divided into two based on their voltage source, namely AC (Alternating Current) and DC (Direct Current) motors[20]. Designed and simulated a permanent magnet brushless DC motor using Ansys [16]. The analysis design uses a 2-dimensional model and the Finite Element Analysis (FEA) method. In this design, the author includes several stator and rotor parameters for analysis. The main parameter chosen in comparing the analysis results is the width of the magnet, because the width of the magnet is the main factor affecting the size of the flux output.

There are two main components in an electric motor, namely the stator which is the stationary part and the rotor which is the rotating part. AC motors are divided into synchronous motors and induction motors, while DC motors are divided into separately excited DC motors and self-excited DC motors. Various types of electric motors have their own advantages and disadvantages that still have to be developed. BLDC motor is one of the types of DC motors that use permanent magnets. One type of BLDC motor is a radial flux BLDC motor. This motor converts electrical energy into mechanical energy with an operating voltage of 10 W to 20 W. This type of motor has the advantage of brush removal which makes it easier to maintain and can eliminate friction loss between the rotor and brush, but the torque produced by the brushless motor is not too large. brushless motor is not too large, this is a consideration in the design of the electric motor development that the author is working on.

Based on the weaknesses that exist in electric motors in general above, the author together with the supervisor has a new idea, namely the design of a ring-type orbital electro motor. The design that the author designed is expected to be able to produce maximum torque output and be able to be mass produced. Analyses have also been carried out but there are still shortcomings. Therefore, re-analysis is needed by comparing the developed ring-type orbital electro motor with another type of electric motor, namely radial electro motor. The analysis was done in more detail using MagNet software.

RESEARCH METHOD

This research is development research [4][7][21–31]. Development on orbital electro motor ring type and compared with radial electro motor to determine the comparison of electromagnetic output that converts electrical energy into mechanical energy. Electric motors currently on the market have several types. In general, electric motors are divided into two based on the voltage source, namely, 1) AC (Alternating Current) and 2) DC (Direct Current) motors. Development was carried out because the previous design had shortcomings and errors in determining the magnetic poles.

The simulation test subjects consisted of computers, MagNet 7.5 software, Solidworks, Calipers, Protractors, and Rulers. There are 3 data collected in this research, and the data are as follows: (1) force, (2) torque, and (3) linkage flux. Data analysis was done by simulating with magnet software and then comparing the test results on the linkage force, torque and flux.

The development stage starts from analyzing the design and simulation results of previous ring-type orbital electro motors, then designing and performing the development design and performing simulations, which are then compared with radial electro motor simulations. The simulation results compared include force, torque, and linkage flux. Before conducting the analysis, the parameters were determined first.

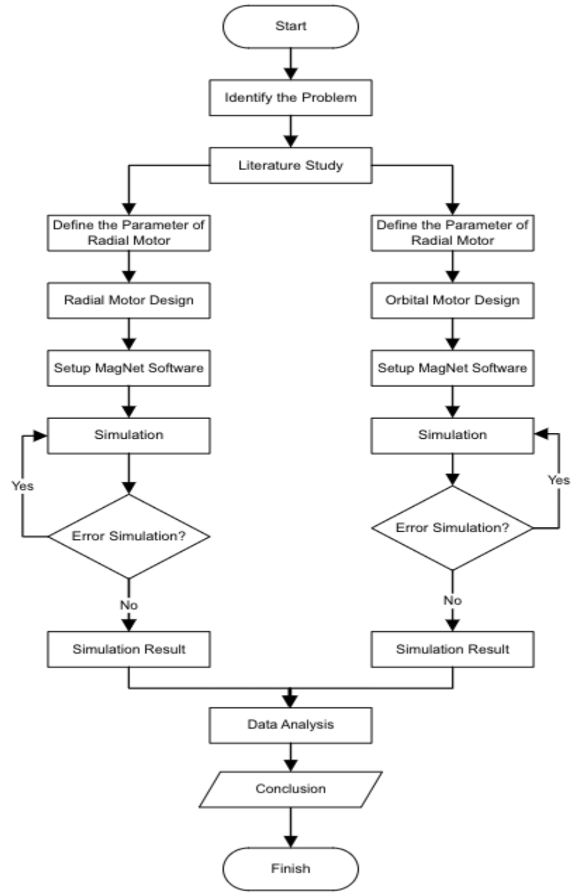

Figure 2. Flowchart of the research

The geometry creation stage is the initial stage before carrying out the simulation. The design is made based on a predetermined size.

1. Setting Units

Setting units is the first step that needs to be done before the design process in the MagNet Software. This process is carried out to determine the units used in the design or analysis. The unit setting step is by clicking the Tools menu, selecting Set Units, and selecting the units to use.

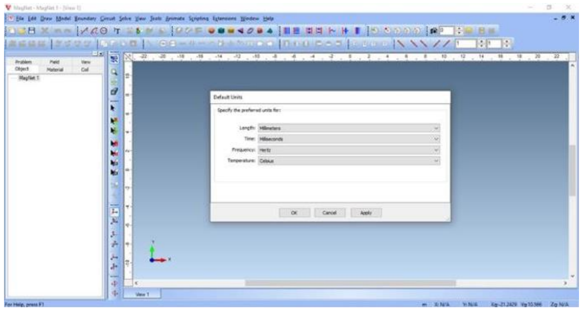

Figure 3. Magnet software unit's settings

2. Construction Grid Settings

The Construction Grid is a guideline which, in this case, is in the form of dots that line up with each other to make it easier to make 2D designs. The Construction Grid setting aims to bring out these lines. Set Construction Grid by clicking the View menu, selecting Set Construction Grid, then clicking the Construction Grid. The following image is a display of the construction grid settings.

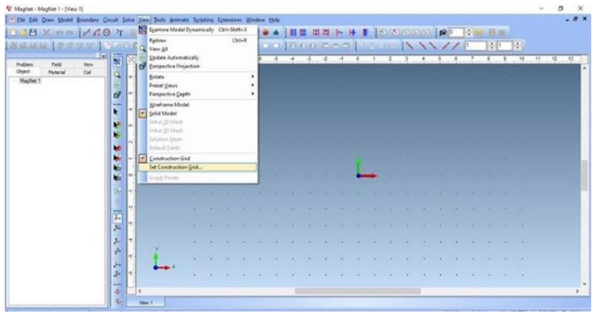

Figure 4. Magnet software magnet construction grid settings

3. Design Process

After setting the units and the construction grid is complete, the next step is to design the ring-type electro-motor orbital magnet and electro-motor radial in the software.

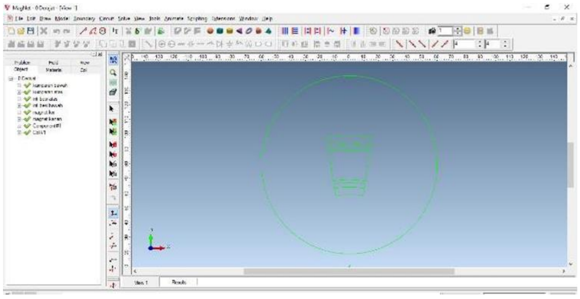

Figure 5. Geometry design

4. Determination of Simulation Parameters

In this case, our research objects are the center of attention in a study. This study uses three variables, namely as follows:

5. Independent Variable (Defined Variable)

The independent variables in this study are the dimensions of the electric motor and the degree of magnetic shift. The variation in the degree of magnetic shift used is

-200, -180, -160, -140, -120, -100, -80, -60, -40, -20, 0, 20,40, 60, 80, 100, 120, 140, 160,180, 200.

a. Bound Variable (Variable sought)

The dependent variable used in this study is sought and influenced by the independent variables. The variables are thrust, linkage flux, and torque generated by the electro-orbital ring-type motor and the electro-radial motor.

b. Control Variable (Input Variable)

The control variables in this study are the number of coil turns, the current value, the voltage value, and the material used in the motor components.

c. Simulation Stage

This stage is the simulation stage in the software after making the model. This process has several stages that need to be carried out, including the following:

6. Material Settings

Material settings aim to select the material for each part so that the testing process can be carried out. Material settings can be done by selecting the part to be set, then selecting the make component in a line menu on the toolbar or pressing CTRL+Shift+L, then selecting the material to be used.

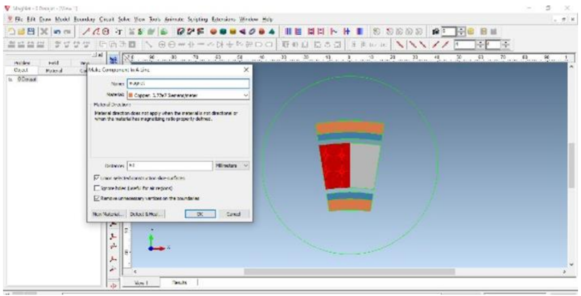

Figure 6. Material settings

7. Simple Coil Properties Settings

Before setting the simple coil properties, you must make a simple coil first by selecting the coil section in the design (Ctrl+Click the top coil+Click the bottom coil), then select the Model menu on the toolbar, then select Make Simple Coil.

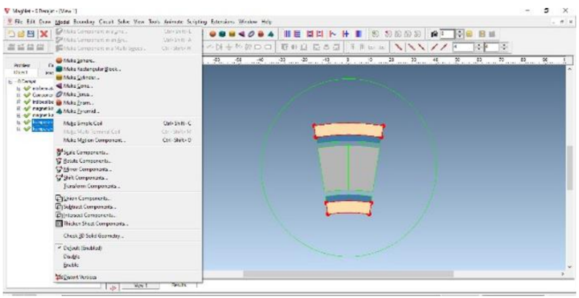

Figure 7. Make simple coil

The next step is setting properties by specifying The of Turns. Simple coil rightclicks, select properties, select coil attributes, and fill in No of Turns.

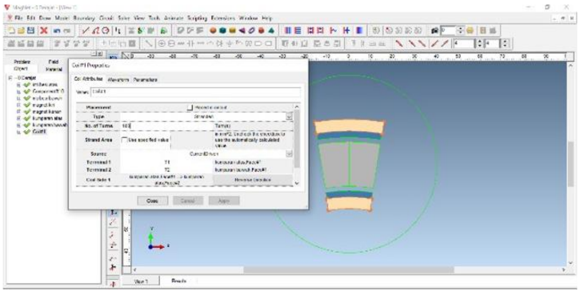

Figure 8. Coil properties settings

The waveform setting is to change the current to DC. Setting current and voltage is done by selecting the parameters menu, then filling in the current used in analysis or testing.

8. Object Properties Settings

This process is the step of setting Mesh and Adaptation before analysis or testing. Setting Mesh is done by right-clicking the main object, selecting properties, selecting Mesh, then checking the maximum element size—the more detailed the Mesh settings, the more accurate the results.

After setting the Mesh, then setting the adaptation, the way to set the adaptation is the same as setting the Mesh because it is still in the properties menu.

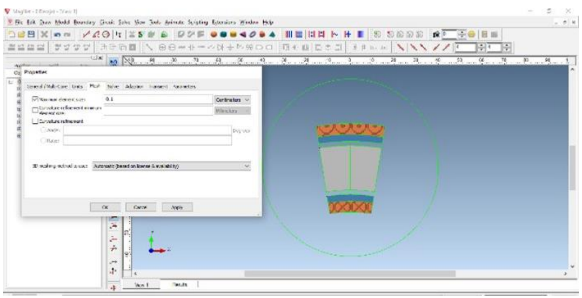

Figure 9. Object properties settings

9. Process Simulation

After the mesh and adaptation settings are complete, the simulation process is ready to run. Click on the sub-object name, then right click select solve static 2D. Wait until the simulation process is complete.

RESULT AND DISCUSSION

The development of ring-type orbital electro-motors is in the design of magnets and coils as well as input parameters during the simulation process using MagNet 7.5 software.

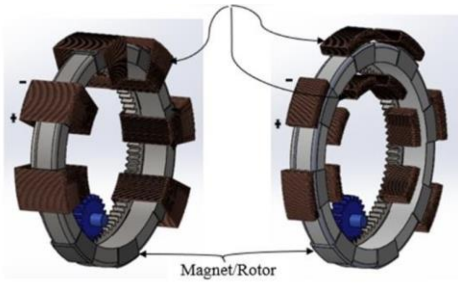

Figure 10. Magnet/Rotor

The design is done with the provisions in the design parameters. The design parameters that have been determined by researchers will be applied in this design, the design parameters include size, material, and boundary conditions.

Table 1. Size of materials

Component	Size (mm)	
	Orbital	Radial
Armature outside diameter	210	200
Inner diameter of armature	120	120
Top and bottom roll diameter	25	
Output gear diameter	60	
Thickness of magnet	20	20
Magnet width	20	20
Magnet length	60	60
Air gap	7	7

Table 2. Materials

Materials	Type
Magnet	Neodymium Iron Boron: 28/32
Rotor	Copper: 5. 77e7 Siemens/meter
Housing	CR10: Cold rolled 1010 steel

Table 3. Boundary condition

Parameter Types	Number	Units
Current	46.5	Ampere (A)
Voltage	48	Volt (V)
Number of turns	100	

The simulation uses variations in the degree of magnetic shift. The variation of the degree of magnetic shift used is -200, -180, -160, -140, -120, -100, -80, -60, -40, -20,0, 20,40, 60, 80, 100, 120, 140, 160, 180, 200. Tests were carried out under attractive and repulsive magnetic conditions. There are 3 data collected in this study, these data include [1] Force, [2] Torque, and [3] Linkage Flux.

Development was carried out on the orbital design of the ring-type electro motor. This development design aims to get more accurate and better results. The results of the development design can be seen in Figures 10 and 11.

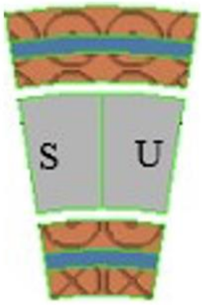

Figure 11. Ring type electro motor orbital design

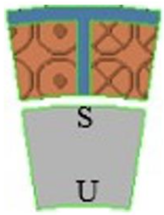

Figure 12. Radial Design Electro Motor

Simulations were conducted using MagNet Software with a 2D static testing model. The simulation uses a variation of magnetic shift. The data obtained in the 2D static simulation are flux contour, force, torque, and linkage flux [32]. Examples of flux contour simulation results can be seen in Figures 12 and 13.

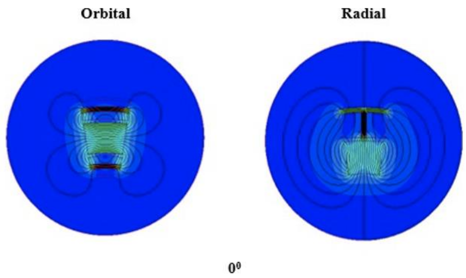

Figure 13. Tensile flux contour

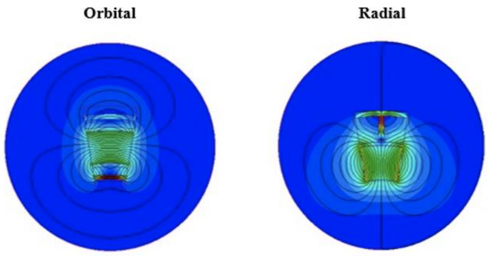

Figure 14. Flux contour reject

From the data of each force, torque, and linkage flux, the average calculation is then carried out for both attractive and repulsive conditions. The following table shows the results of the calculation of the average force, torque, and linkage flux. Simulation results prove the feasibility and effectiveness of the designed spectral decomposition flux observer [33].

Table 4. Average calculation result of attraction magnetism

Types	Average Force (N)	Torque (Nm)	Flux *Linkage* (Wb)
Orbital	109,4	8,7	0,029
Radial	100,8	5,15	0,03
Comparation	1,08:1	1,68:1	1:1,03

Table 5. Average calculation result of rejecting magnet

Types	Average Force (N)	Torque (Nm)	Flux *Linkage* (Wb)
Orbital	109,4	8,7	0,029
Radial	100,8	5,15	0,03
Comparation	1,08:1	1,68:1	1:1,03

CONCLUSION

The simulation results show that the performance of the ring-type orbital electro motor compared to the radial electro motor is better under attraction conditions, but lower under repulsion conditions. In the magnetic attraction condition, the average value ratio of the ring-type orbital electro motor compared to the radial electro motor is 1.08:1 force, 1.68:1 torque, and 1:1.03 linkage flux. In the rejecting condition, the average ratio of ring-type electromotor orbitals compared to radial electromotor is 1:1.3 force, 1:1.06 torque, and 1:1.6 linkage flux.

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