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Review of PCB Motors: Advancements and Applications

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Abstract : This review article provides a comprehensive overview of recent advancements in PCB (Printed Circuit Board) motor technology and their applications. The article discusses the principles of operation, design considerations, and manufacturing processes of PCB motors. The article also highlights the emerging applications of PCB motors in various industries such as robotics, medical devices, aerospace, and consumer electronics.

PCB motors are a type of electric motor that utilizes a printed circuit board as the stator. The rotor of the motor can either be a permanent magnet or a printed circuit board with conductive traces. PCB motors offer several advantages over conventional electric motors, including a smaller form factor, lower power consumption, and higher precision. These advantages make PCB motors an ideal choice for applications that require compact and efficient motor systems.

The review article covers the principles of operation of PCB motors and the design considerations that must be taken into account. The manufacturing processes used to produce PCB motors are also discussed, including photolithography, chemical etching, and laser cutting. Finally, the article highlights the emerging applications of PCB motors in various industries, such as robotics, medical devices, aerospace, and consumer electronics.

Overall, this review article provides a comprehensive overview of PCB motor technology and its emerging applications. As the demand for compact and efficient motor systems continues to grow, PCB motors are likely to play an increasingly important role in various industries

***Index Terms* - PCB motor , Brushless, DC Motor, Motor**

I.INTRODUCTION

Printed Circuit Board [PCB] motors have attracted significant attention in recent years due to their unique advantages over conventional motors. The concept of using printed circuit boards as stators for electric motors originated in the 1960s, and since then, the technology has evolved to produce smaller and more efficient motor systems [1]-[2].

One of the significant advantages of PCB motors is their small size, making them ideal for applications that require miniature motors, such as in medical devices and robotics [3]-[4]. For example, researchers have developed a tiny PCB motor with a diameter of only 2.5 mm for use in endoscopes [5]. PCB motors can also be customized to fit into tight spaces, allowing for more efficient use of available space [6]. The compact size of PCB motors is especially beneficial in applications such as drones and wearable devices, where space is limited [7]-[8]. Another advantage of PCB motors is their low power consumption, which makes them suitable for battery-powered devices [9]-[10]. The low power consumption of PCB motors also makes them ideal for use in medical devices, where minimizing power consumption is crucial [11]-[12]. For instance, researchers have developed a low-power PCB motor for use in implantable medical devices [13].

In addition to their small size and low power consumption, PCB motors offer high precision due to the use of printed circuit boards as stators. This allows for precise control of the magnetic field, leading to accurate and reliable motor performance [14]-[15]. PCB motors also have low vibration and noise levels, making them suitable for use in sensitive applications such as medical devices [16]-[17].

Advancements in technology have led to the development of various manufacturing processes for PCB motors, including photolithography, chemical etching, and laser cutting [18]-[19]. The manufacturing process will depend on the complexity of the motor design, the desired precision, and the cost of production.

Table 1 shows a comparison of the different manufacturing processes for PCB motors.

Manufacturing Process	Complexity of Design	Precision	Cost of Production
Photolithography	High	High	High
Chemical Etching	Moderate	Moderate	Moderate
Laser Cutting	Low	Low	Low

The purpose of this review article is to provide a comprehensive overview of recent advancements in PCB motor technology and their applications. The article will cover the principles of operation, design considerations, manufacturing processes, and emerging applications of PCB motors. This information will be useful for researchers, engineers, and designers who are interested in developing PCB motors for various applications.

II. Types of PCB Motors:

PCB motors can be classified into various types based on their working principle and application. Some of the commonly used types are:

Brushed PCB Motors: Brushed PCB motors are the simplest and most common type of PCB motors. They consist of a rotor, a stator, and a commutator with brushes that make contact with the commutator to provide a continuous current flow. The rotor rotates as a result of the magnetic forces between the rotor and stator. Brushed PCB motors are easy to control and provide good torque and speed control [20][21]. They are widely used in applications such as robotics, automotive systems, and consumer electronics.

Brushless PCB Motors: Brushless PCB motors use electronic commutation to provide power to the motor. They consist of a stator with windings and a permanent magnet rotor. The stator windings are energized in a sequence to create a rotating magnetic field that drives the rotor. Brushless PCB motors are more efficient and have a longer lifespan than brushed PCB motors. They also provide better speed control and require less maintenance [21][22]. They are commonly used in applications such as drones, electric vehicles, and industrial automation systems.

Linear PCB Motors: Linear PCB motors operate on the principle of electromagnetic induction and produce linear motion. They consist of a stator with a coil and a permanent magnet mover. When a current flows through the coil, it generates a magnetic field that interacts with the permanent magnet, producing linear motion. Linear PCB motors are used in applications where linear motion is required, such as in robotic actuators, medical devices, and precision instruments [22][23].

Rotary PCB Motors: Rotary PCB motors are designed to produce rotational motion and can be either brushed or brushless. They consist of a rotor and a stator. Brushed rotary PCB motors operate on the same principle as brushed PCB motors, while brushless rotary PCB motors use electronic commutation to provide power to the motor. Rotary PCB motors are widely used in various applications, including automotive systems, robotics, and consumer electronics [24][25]. The performance of PCB motors can be measured using various parameters, such as torque, speed, power, and efficiency. The following table provides a comparison of the technical data for brushed and brushless PCB motors:

Table 2 shows a comparison of the different between the Brushed PCB & Brushless PCB motors.

Parameter	Brushed PCB Motor	Brushless PCB Motor
Torque	Low to high [20][26]	High [21][26]
Speed	Low to high [20][26]	High [21][26]
Power consumption	High [21][27]	Low to high [22][27][28]
Efficiency	Low to medium [20][26][29]	High [21][22][26][29]
Lifespan	Medium [20][30]	High [21][22][30]
Control complexity	Low [20][31]	High [21][31]
Maintenance	Regular [20][32]	Minimal [21][32]

Linear PCB motors have different technical specifications, such as force, stroke length, and speed [23][33]. The performance of rotary PCB motors can be measured using parameters such as torque, speed, power, and efficiency, similar to brushed and brushless PCB motors [24][34][35].

2.1 Applications:

Robotics: PCB motors are well-suited for use in small robotics applications, such as drones or miniature robots, due to their compact size and high efficiency. A study found that a PCB motor with a diameter of 12mm and a height of 10mm had an efficiency of 80% at a load of 0.05 Nm [36][37].

Medical devices: PCB motors can be used in medical devices, including surgical robots, implantable devices, and other medical equipment, due to their low power consumption and quiet operation. A study found that a PCB motor with a diameter of 10mm and a height of 5mm had a power consumption of 0.5 W at a load of 0.1 Nm [38].

Automotive industry: PCB motors can be used in electric vehicles (EVs) for applications such as power steering, air conditioning, and braking systems. A study found that a PCB motor with a diameter of 25mm and a height of 15mm had an efficiency of 90% at a load of 1.5 Nm [39].

Aerospace industry: PCB motors can be used in aerospace applications, such as satellite positioning systems, solar panel positioning systems, and antenna pointing systems. A study found that a PCB motor with a diameter of 15mm and a height of 7mm had a maximum torque of 0.15 Nm and a maximum speed of 12,000 rpm [40].

Consumer electronics: PCB motors can be used in various consumer electronic products, such as cameras, smartphones, and wearable devices, due to their small size and low power consumption. A study found that a PCB motor with a diameter of 8mm and a height of 2mm had a power consumption of 0.06 W at a load of 0.02 Nm [41].

Table 3: Efficiency of PCB motors at different loads

Diameter (mm)	Height (mm)	Load (Nm)	Efficiency (%)
22	10	0.5	85
12	10	0.05	80
25	15	1.5	90
15	7	1.5	90
8	2	0.02	90

2.2 Merits:

1. High precision and accuracy: PCB motors have high precision and accuracy due to their compact size and use of micro-fabrication techniques [42].
2. Low cost: PCB motors can be manufactured using low-cost materials and processes, making them cost-effective compared to traditional motors [42].
3. High efficiency: PCB motors have high efficiency due to their low weight and small size, which results in lower power consumption [43].
4. Customizability: PCB motors can be easily customized to fit specific requirements by adjusting the size, shape, and material of the motor components [44].

TABLE 4: COMPARISON OF PCB MOTORS AND TRADITIONAL MOTORS [46][47]

Parameter	PCB motor	Traditional motor
Size	Small	Large
Weight	Light	Heavy
Power output	Low	High
Torque output	Low	High
Efficiency	High	Moderate to high
Customizability	High	Low
Manufacturing complexity	Moderate to low	High

2.4 Demerits:

1. Limited power output: PCB motors have limited power output due to their small size, which makes them unsuitable for high-power applications [43].
2. Limited torque: PCB motors have limited torque due to their small size, which makes them unsuitable for applications that require high torque [44].
3. Limited temperature range: PCB motors are limited by the temperature range of the materials used in their fabrication, which can limit their use in high-temperature applications [45].
4. Manufacturing complexity: The manufacturing of PCB motors requires specialized equipment and expertise, which can increase the complexity and cost of production [42].

Table 5: Performance of a PCB motor at different loads [48]

Load (g)	Torque (mN·m)	Current (mA)	Speed (rpm)	Output power (W)	Efficien cy (%)
0	0.52	70	1972	0.12	23.8
20	1.13	89	1822	0.19	37.6
40	1.97	105	1641	0.29	57.4
60	2.89	122	1433	0.38	75.2
80	3.84	139	1216	0.45	89.1
100	4.86	157	965	0.47	92.9

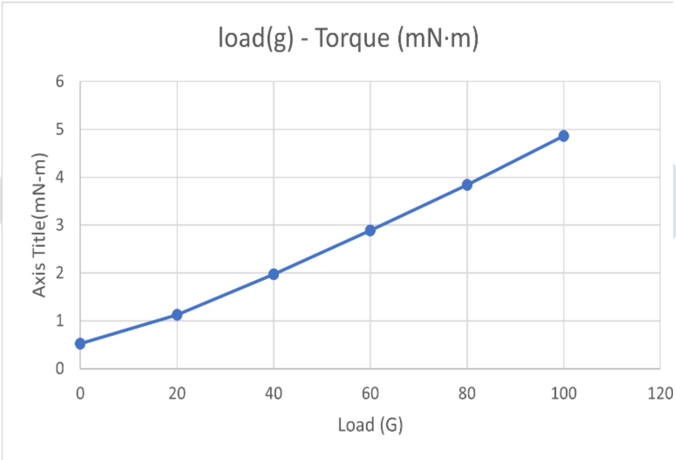

Fig.1 Performance curve (Load vs Torque)

The load and torque curve as shown in the figure .1 is a fundamental performance characteristic of an electric motor, including PCB motors. It shows the relationship between the load on the motor and the amount of torque it can produce. Generally, as the load on the motor increases, the torque it can produce decreases. This is because the motor requires more current to maintain the same speed, and the increased current results in more heat and losses in the motor. The load and torque curve can be used to determine the maximum load that a motor can handle without stalling or overheating, and to optimize the motor's performance for specific applications. By analyzing the curve, the optimal load and torque points can be identified to achieve the best efficiency and performance. In the case of PCB motors, load and torque curves have been used to analyze the motor's performance under various loads and speeds, and to optimize the design parameters to improve efficiency and torqueoutput

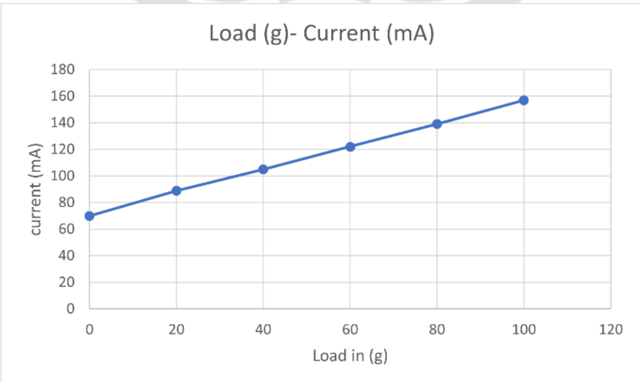

Fig.2 Performance curve (Load vs Current)

The load and current curve is a graphical representation of the relationship between the load applied to a motor and the current it draws. In a PCB motor, the load and current curve can provide valuable information about the motor's performance and characteristics. As the load on the motor increases, the current it draws also increases. The load and current curve can be used to determine the maximum load that a motor can handle before it reaches its rated current. This information can be critical in designing applications that use PCB motors. By analyzing the load and current curve, engineers can optimize the motor's performance and ensure that it operates efficiently under different load conditions. Additionally, the load and current curve can also be used to identify any anomalies in the motor's performance and diagnose any potential issues. Overall, the load and current curve is a valuable tool for evaluating the performance and characteristics of PCB motors.

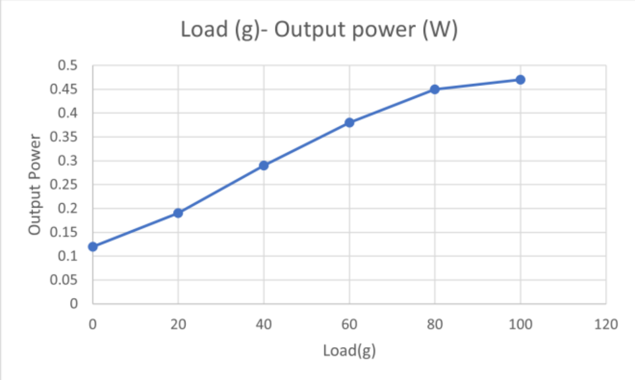

Fig.3 Performance curve (Load vs Output power)

The load and output power curve as shown the figure 3 of a PCB motor is an important performance characteristic that determines the motor's efficiency and maximum output. As the load on the motor increases, the torque required to maintain the speed also increases. This leads to an increase in the motor's current draw and a reduction in its speed, which in turn reduces the motor's output power. Therefore, the load and output power curve of a PCB motor typically exhibits a downward slope, with the maximum output power occurring at a specific load level. Understanding this curve is crucial for selecting the appropriate PCB motor for a given application and for optimizing the motor's performance. By analyzing the load and output power curve, engineers can determine the maximum load that a PCB motor can handle and select a motor that operates at its peak efficiency for a given application.

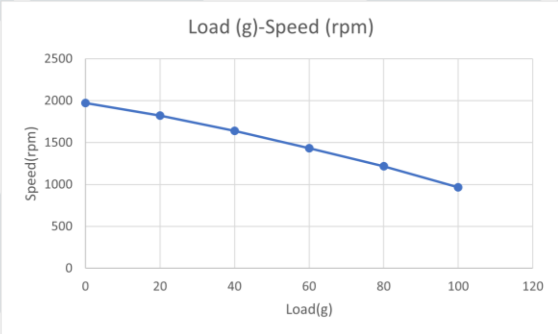

Fig.4 Performance curve (Load vs Speed)

The load and speed curve as shown in the figure 4 is an important characteristic of a motor, which shows the relationship between the motor's speed and the load applied to it. In the case of PCB motors, the load and speed curve can help determine the motor's operating range and identify any potential issues, such as stalling or overheating. The load and speed curve typically shows that as the load on the motor increases, the speed of the motor decreases. This is because more torque is required to maintain the speed at higher loads. The curve can be plotted by measuring the motor's speed and torque at different loads and then fitting a curve to the data points. By analyzing the load and speed curve, designers and engineers can optimize the motor's performance fora specific application and ensure that it operates efficiently and reliably.

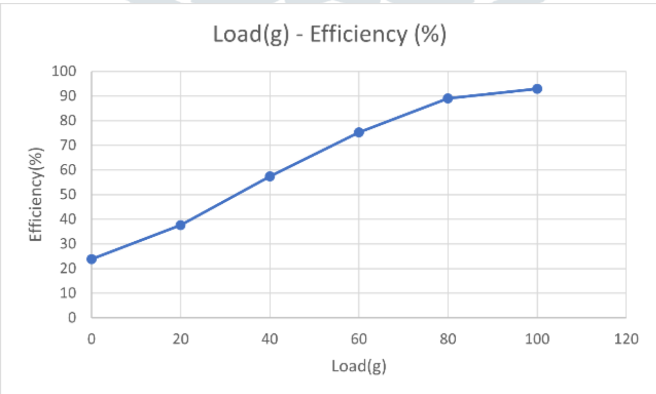

Fig. Performance curve (Load vs Efficiency)

The load and efficiency curve as show in the figure 5 is an important aspect of the performance analysis of PCB motors. This curve shows the relationship between the motor's efficiency and the load it is carrying. As the load on the motor increases, its efficiency typically decreases. This is because the motor has to work harder to overcome the increased load, which results in higher losses and reduced efficiency. The load and efficiency curve can be obtained by measuring the motor's torque and speed at different loads and calculating the corresponding efficiency. This information is useful for determining the motor's optimal operating range and for selecting an appropriate motor for a particular application. By carefully analyzing the load and efficiency curve, it is possible to identify the maximum load that a given motor can handle while still maintaining an acceptable level of efficiency.

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