SOCIETY OF AUTOMOTIVE ENGINEERS

AERO DESIGN CHALLENGE 2021

FABRICATION OF COMPONENT REPORT

Submittedby

OSPREY

ADC20210128

TKM COLLEGE OF ENGINEERING KOLLAM

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ANNEXURE B

2021 SAEISS AERO DESIGN CHALLENGE

STATEMENT OF COMPILANCE

CERTIFICATION OF QUALIFICATION

Team Name	OSPREY
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Faculty Advisor	AHAMMAD VAZIM
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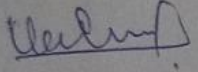
As Faculty Advisor, I certify that the registered team members are enrolled in collegiate courses. This team has designed, constructed and/or modified the radio controlled airplane they will use for the SAE Aero Design Challenge 2020 competition, without direct assistance from professional engineers, R/C model experts or pilots, or related professionals.



Signature of Faculty Advisor

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Note: A signed scanned copy of the statement should be included in your Design Report Page 2

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CHAPTER 1: LITERATURE REVIEW

The present demand for superior performance and exceptional energy efficient motors is due to strict electricity consumption standards and electricity prices. The demand for energy-saving motors is in raise globally on the account of growing demand for motors for cars, household appliances and other motor drive systems. Moreover, to improve the efficiency of the motor, globally the manufacturers are encouraged to follow exacting design and manufacturing standards resulting in energy-saving motors.

The development of high-performance motor drives is very important in industrial as well as other purpose applications. Brushed DC motors have been in commercially use since 1886 on the other hand Brushless DC motor did not become commercially viable until 1962. The high performance of BLDC motor drive system must have good dynamic speed command tracking and load regulating response. BLDC drives are less complex with a single power conversion from AC to DC. BLDC drives are normally less expensive for most horsepower ratings. DC motors has its long history. It has been used in the industries for many years now. They provide simple means and precise way of control. In addition, they have high efficiency and have a high starting torque versus falling speed characteristics which helps high starting torque and help to preventsudden load rise. The dc motors have some deficiencies that needed to be attended towhich gave rise to design of some other alternative types of dc motors for example, the lack of periodic maintenance mechanical wear outs, acoustic noise, sparking, brusheseffects are some of the problems that were needed to overcome the defects in dcmotors. BLDC motors have a long tradition of use as adjustable speed machines and awide range of options have evolved for this purpose. In these applications, the BLDCmotor should be precisely controlled to give the desired performance. Various methodsof control schemes such as proportional integral (PI), PID, adaptive, and FLCs, have been developed for speed control of dc motors. These are introduced controllersystems consist of PID controller and DC drive for the speed control.

The BLDC motors are used in many applications such as defense, industries, Robotics and medical applications, owing to their superior speed-torque characteristics, high efficiency, less maintenance, and wide operating speed range. Particularly for small-scaled UAVs (Unmanned Aerial Vehicles), the BLDC motor are receiving an increasing number of attentions with the advantages of small size, high power density, and easy control and operation.

CHAPTER 2: BRUSHLESS DC MOTOR

2.1 INTRODUCTION

A brushless DC motor (BLDC) is a permanent magnet synchronous electric motor which is powered by direct current electricity (DC) and are also referred as trapezoidal permanent magnet motors. Unlike conventional brushed type DC motor, where in the brushes make the mechanical contact with commutator on the rotor so as to form an electric path between a DC electric source and rotor armature windings and it accomplishes electronically controlled commutation system (commutation is the process of producing rotational torque in the motor by changing phase currents through it at appropriate times) instead of a mechanically commutation system, BLDC motor also employs electrical commutation with permanent magnet rotor and a stator with a sequence of coils. Here permanent magnet (or field poles) rotates and current carrying conductors are fixed. The armature coils are switched electronically by transistors or silicon-controlled rectifiers at the correct rotor position in such a way that armature field is in space quadrature with the rotor field poles and hence the force acting on the rotor causes it to rotate. Hall sensors also called rotary encoders are most widely used to sense the position of the rotor and are positioned around the stator.

The rotor position feedback from the sensor helps to determine when to switch the armature current and this electronic commutation arrangement eliminates the commutator arrangement and brushes in a DC motor and hence more reliable and less noisy operation is achieved. Due to the absence of brushes, BLDC motors are able to run at high speeds and also the efficiency of BLDC motors is typically from 85 to 90 percent, whereas as brushed type DC motors are 75 to 80 percent efficient. Brushes eventually wear out, sometimes causing dangerous sparking, limiting the lifespan of a brushed motor. BLDC motor have much longer lifespans and are quiet, lighter. As the computers control the electrical current, brushless DC motors can attain much more precise motion control. Due to of all these advantages, brushless DC motors are often used in modern devices where low noise and low heat are required, especially in devices that run continuously. BLDC motors are available in wide variety ranging from small power range to fractional horsepower, integral horsepower and large power ranges.

2.2 WORKING

BLDC motor works on the principle which resembles to conventional DC motor, as a consequence of reaction force, the magnet will experience an equal and opposite force. i.e., the Lorentz force law which states that whenever a current carrying conductor placed in a magnetic field it experiences a force. In case BLDC motor, the current carrying conductor is stationary while the permanent magnet moves. It becomes electromagnet and starts producing the uniform field in the air gap when the stator coils are electrically switched by a supply source. Though the source of supply is DC, switching makes to generate an AC voltage wave form with trapezoidal shape. Rotor continues to rotate due to the force of interaction between electromagnet stator andpermanentmagnet rotor.

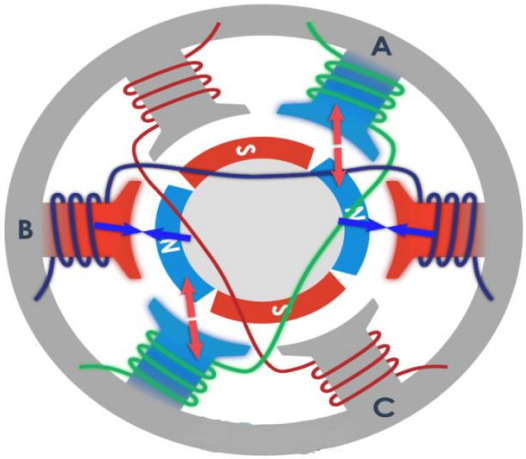


Fig 2.1 Winding connection

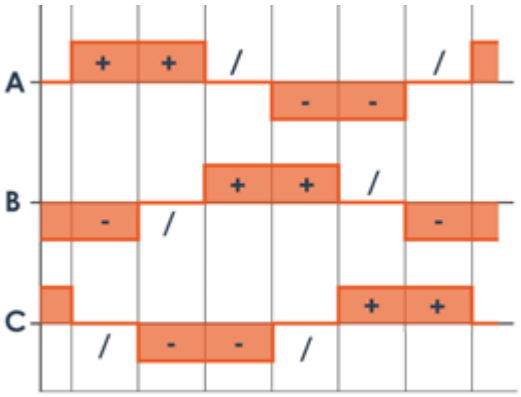


Fig 2.2 Current waveform

In order to increase the efficiency of the motor we can wind two opposite coils as a single coil in way that will generate opposite poles to the rotor's poles, thus we will get double attraction force. With this configuration we can generate the six poles on the stator with just three coils or phase. We can further increase the efficiency by energizing two coils at the same time. In that way one coil will attract and the other coil will repel the rotor. In order the rotor to make a full 360 degrees cycle, it need six steps or intervals. If we take a look at the current waveform, in each interval there is one phase with positive current, one phase with negative current and the third phase is turned off. This gives the idea that we can connect the free end points of each of the three phases together and so we can share the current between them or use a single current to energize the two phases at the same time.

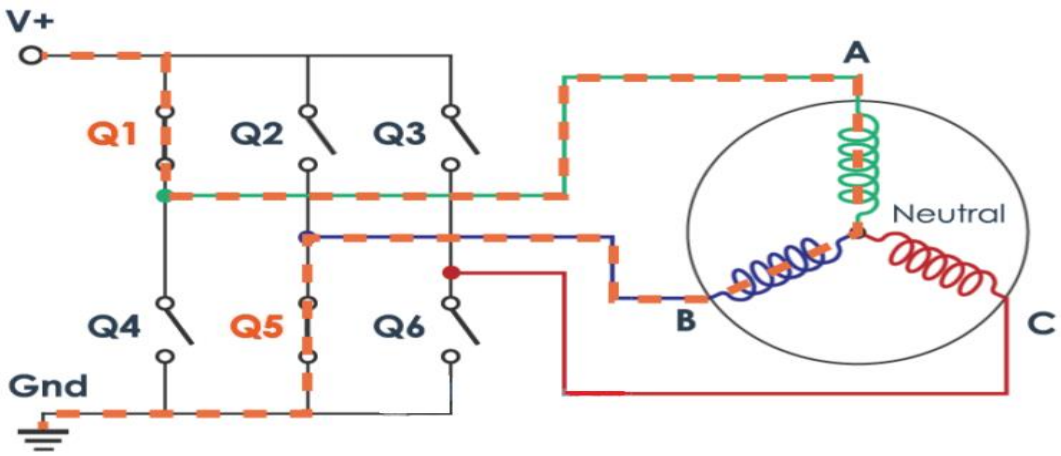


Fig 2.3 BLDC Motor connected with MOSFETS

If we pull up phase A High, or connect it to the positive DC voltage, with some kind of switch, for example a MOSFET, and on the other side, connect the phase B to ground, then the current will flow from VCC, through phase A, the neutral point and phase B, to ground. So, with just a single current flow we generated the four different poles which cause the rotor to move. With this configuration we actually have a star connection of the motor phases, where the neutral point is internally connected and the other three ends of the phases come out of the motor and that's why brushless motor have three wires coming out of it. So, in order the rotor to make full cycle we just need to activate the correct two MOSFETS in each of the 6 interval and for that ESC are used.

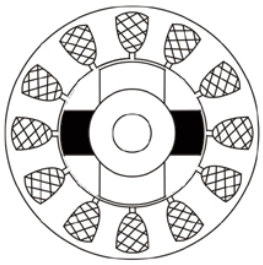
An ESC or an Electronic Speed Controller controls the brushless motor movement or speed by activating the appropriate MOSFETs to create the rotating magnetic field so that the motor rotates. method used for determining the rotor position is through sensing the back electromotive force or back EMF. The back EMF occurs as a result of the exact opposite process of generating a magnetic field or when a moving or changing magnetic field pass through a coil it induces a current in the coil. So, when the moving magnetic field of the rotor pass through the free coil, or the one that's not active, it will induce a current flow in coil and as result a voltage drop will occur in that coil. The ESC captures these voltage drops as they occur and based on them it predicts or calculates when the next interval should take place.

2.3 TYPES OF BLDC MOTORS

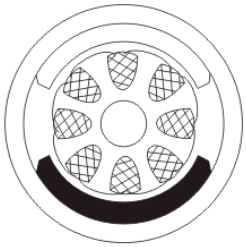
BLDC are of two types; one is **outer rotor motor** and other is **inner rotor motor**.

The basic difference between the two is only in designing, their working principles are same.

INNER ROTOR DESIGN	OUTER ROTOR DESIGN
In an inner rotor design, the rotor is located in the center of the motor and the stator winding surround the rotor. As the rotor is located in the core, rotor magnets do not insulate heat inside and heat get dissipated easily. Due to this reason, inner rotor designed motor produces a large amount of torque and validly used.	In outer rotor design, the rotor surrounds the winding which is located in the core of the motor. The magnets in the rotor trap the heat of the motor inside and do not allow to dissipate from the motor. Such type of designed motor operates at lower rated current and has low cogging torque.



Inner Motor



Outer Motor

CHAPTER 3: MANUFACTURING PROCEDURE

- **Housing and End Bell**

The end bell is the part where propellers are attached. The housings are steel shells or extrusions suitable for good heat transfer. In most modern small motors, the end bells and stator base are made from aerospace grade aluminum because of its properties like high strength and light weight or from Zinc.CNC machines are used for manufacturing these parts. If the tolerance of these part is not within to 0.001mm it is scrapped or recycled. After manufacturing these parts will send to factory for assembly where it's tolerance, mass distribution will be checked.If the mass distribution is not correct it leads to vibration.Micrometer is used to check the depth of the shaft in motors with hollow shafts. If any component does not pass the quality control test it will scrapped or recycled.

- **Stator**

The stator of BLDC motor consists of stacked steel lamination with windings placed in the slots that are axially cut along the inner periphery. BLDC motors have three stator winding connected in delta configuration. Each of these windings are constructed with numerous interconnected coils. Each of these windings are distributed over the stator periphery to even number of poles.

- **Winding of Stator**

Based on rpm and torque required the diameter of the wire is selected. Insulated copper wires are used for insulating purposes. Winding is a crucial step. y pattern gives high torque and the delta pattern gives low torque at low at low rpm. This is because in the delta configuration half of the voltage is applied across the winding that is not driven thus increasing losses and in turn efficiency and torque.For RC aircrafts delta configuration is used.Stator part is placed on the winding machine and at a time two wire is wound over the stator in delta or y configuration.The ends will cutoff manually and its end is soldered separately by a soldering machine. The start and end of each phase wires will be soldered together with high gauge wires manually.To avoid shorting; heat shrink tube is attached to the end wires with the help of heat air gun.

- **Base and Stator Assembly**

The base is manually glued to the stator. Bell cap and ring assembly is done next by a pneumatic press because uniform pressure has to applied and the magnets are glued to it.

- **Permanent Magnet Mounting**

Stator is attached along with the ring and placed in the center of the machine where the magnet is inserted. based on the requirement north pole and south pole arranged. Magnet get inserted in the bell and ring housing, ring is made of metal structure the magnet is glued to avoid the disturbance with the rotation and excess glue is cleaned off. A manual check is done to ensure that it is inserted properly if not it is corrected. Visual inspection is done prior to the curing the glue in the oven for one hour.

- **Rotor**

The rotor is made of permanent magnet and can vary from two to eight poles with alternate north and south poles. Based on the required magnetic field density in the rotor, the proper magnetic material is chosen to make the rotor. Permanent magnets arrangement depends upon the number of magnet equal to that of a stator. Neodymium magnets are used as permanent magnets in BLDC motor.

- **Shaft and Motor Bearing**

The selection of bearing is done based on the shaft diameter and it is inserted on base of the rotor.

- **Current Leakage Test**

High voltage test checks the stator for current leakage, if there are any burs or worn coil insulation is found in Stators that leads to current leakages. Current leakage more than 1maH of current then the stator gets scrapped.

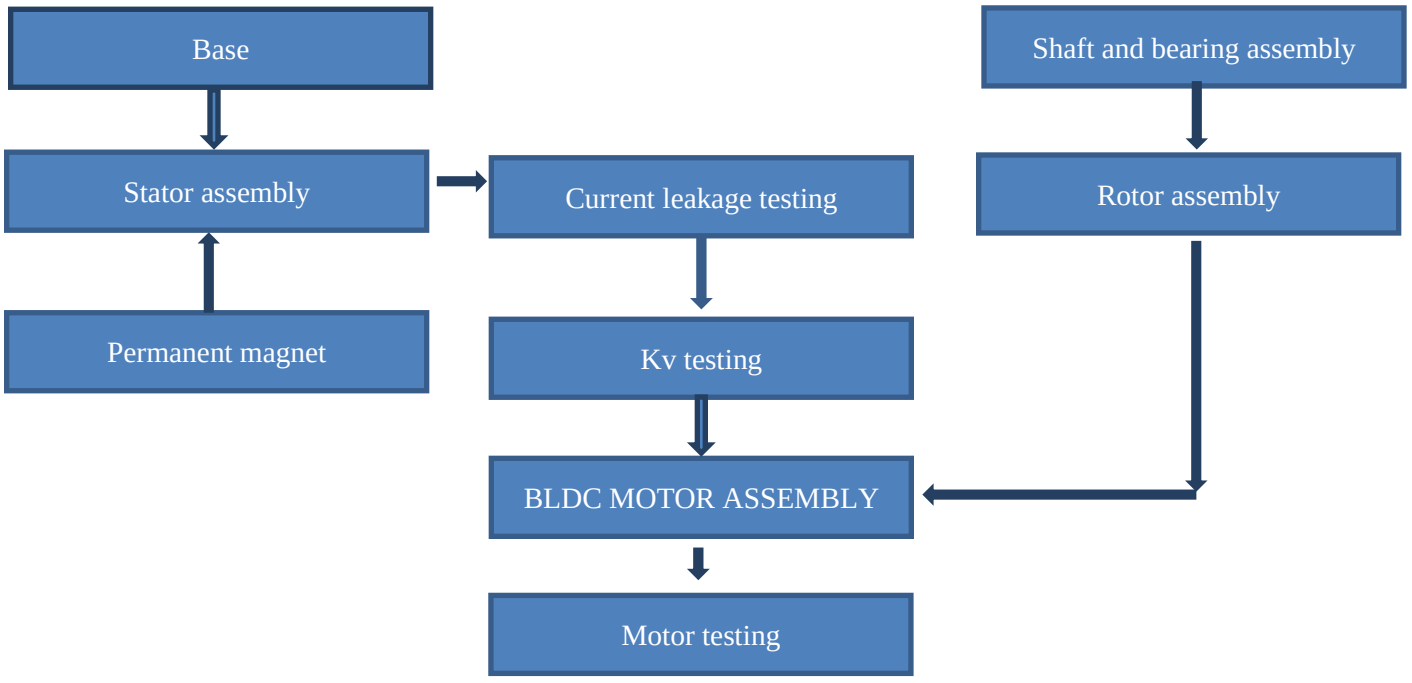
- **Motor Kv Testing**

For every motor there will a Kv rating which is the rpm that a motor turns when 1 volt is applied with no load attached to the motor. Based on the resistance of the coil Kv is identified for the motor. For every coil the Kv is checked on the multimeter.

- **Motor Assembly and Motor Testing**

Stator and rotor are assembled and then Rpm of the motor is checked. Any vibration found on the motor in working condition a small mass will be attached to counter the vibration and if it large the motor will be scrapped or recycled.

FLOWCHART



CHAPTER 4: THEORETICAL ESTIMATION OF PERFORMANCE

Torque and Efficiency

For the study of electric motors, torque is a very important term. By definition, torque is the tendency of force to rotate an object about its axis.

$$Torque\ (Newton - meters) = Force\ (Newton)\ X\ Distance\ (meters)$$

Thus, to increase the torque, either force has to be increased – which requires stronger magnets or more current – or distance must be increased – for which bigger magnets will be required. Efficiency is critical for motor design because it determines the amount of power consumed. A higher efficiency motor will also require less material to generate the required torque.

$$Efficiency = \frac{Output\ Power}{Input\ Power}\%$$

$Output\ Power = Torque\ X\ Angular\ Velocity$, and

$Input\ Power = Voltage\ X\ Current$

Speed vs. Torque curve.

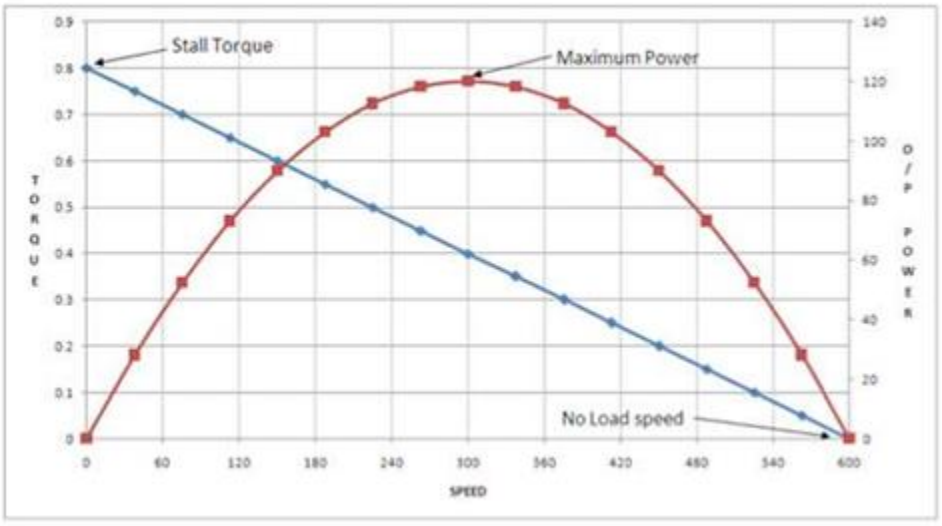


Fig 4.1: Speed-Torque Curve

Following are the takeaways from the graph shown above

- With an increase in speed, the torque reduces (considering the input power is constant).
- Maximum power can be delivered when the speed is half of the “no load” speed and torque is half of the stall torque.

CHAPTER 5: ADVANTAGES, DISADVANTAGES & APPLICATIONS

Advantages

- High Speed Operation – A BLDC motor can operate at speeds above 10,000 rpm under loaded and unloaded conditions.
- Responsiveness & Quick Acceleration – Brushless DC motors have low rotor inertia, allowing them to accelerate, decelerate, and reverse direction quickly.
- High Power Density – BLDC motors have the highest running torque per cubic inch of any DC motor.
- High Reliability – BLDC motors do not have brushes, meaning they are more reliable and have life expectancies. This results in fewer instances of replacement or repair and less overall down time for your project.They also have longer lifetime (no brush and commutator erosion).
- Efficiency – the brushless DC motor is the most efficient motor available in the present industry.
- Size – the brushless DC motor is the smallest of the motors available with a given power rating and light weight making handling it easier.
- Brushless motors offer several advantages over brushed DC motors, including more torque per weight, more torque per watt (increased efficiency), increased reliability, reduce noise,

Disadvantages

- Higher cost of construction
- Control is complex and expensive
- Electric Controller is required to keep the motor running. It offers double the price of the motor.

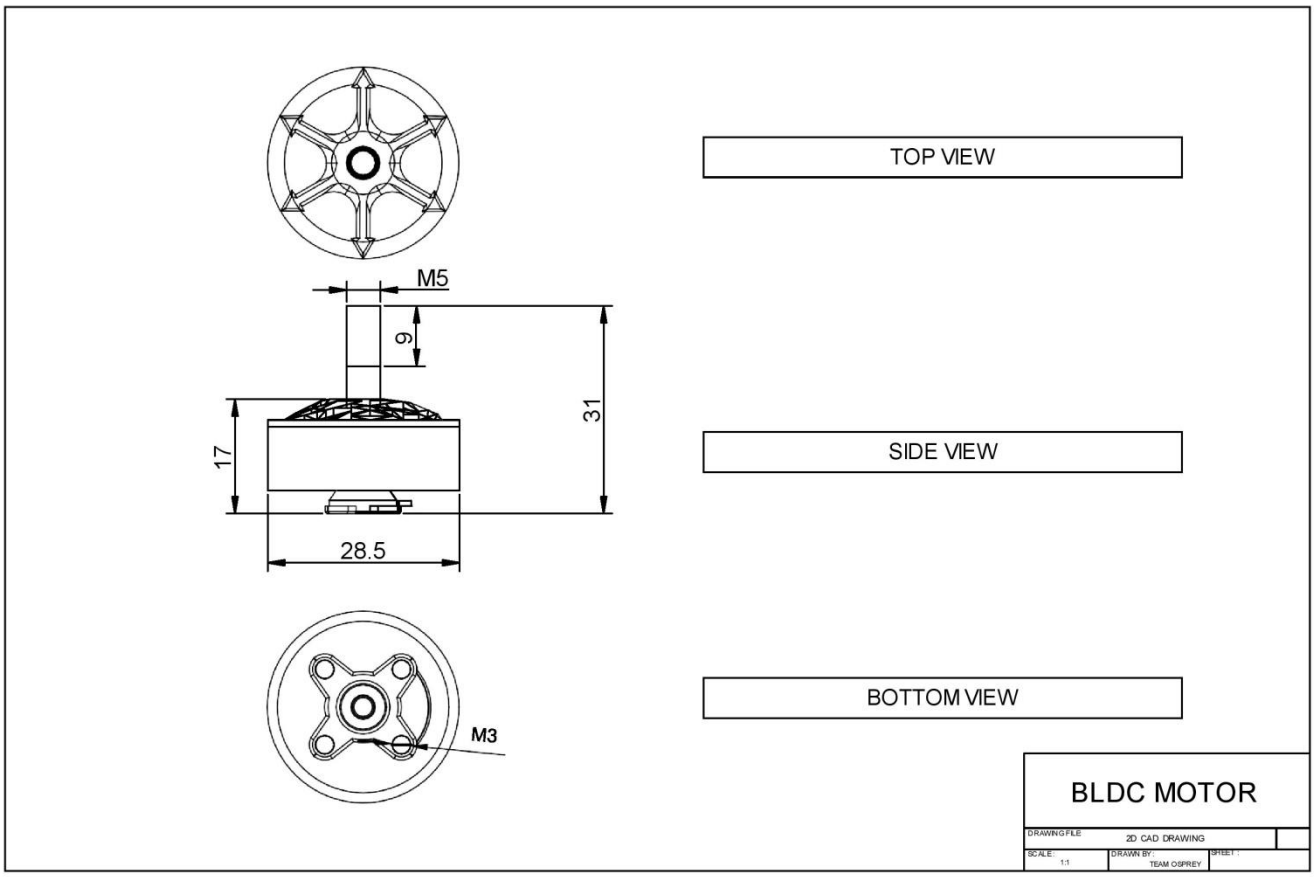
Applications

- Medical: Artificial heart, microscopes, centrifuges, arthroscopic surgical tool, organ transport pump systems.
- Vehicles: electronic power steering, electric vehicles.
- Airplanes: an electric self-launching sailplane, flies with a 42kw dc brushless motor and Li-Ion batteries and can climb up to 3000m with fully charged cells.
- Consumer electronics: hard drives, pc cooling fans, RC airplanes, air conditioners.

CHAPTER 6: COST AND SPECIFICATION

Item Name: EMAX ECO II 2306 Motor	**Cost: Rs 980/-**
Brand	**Emax**
KV rating	**1700KV**
Framework	**12N14P**
Length	**31.6mm**
Diameter	**28mm**
No.of cells	**3-6S 1700KV**
Propeller	**5"-5.5"**
Weight	**30.4g(W/O Silicone Wire) 1700KV**
Prop adapter shaft thread	**M5**
Bearing Shaft	**4mm**
Shaft Thread	**CW**
Idle current (10v)	**1.1A**
Internal resistance	**74mΩ**
Peak current (6S)	**36A**
Max. power (6S)	**910W**

CHAPTER 7: CAD DRAWING



CONCLUSION

On the whole BLDC motors offer excellent efficiency, controllability, and longevity. But careful and proper control is essential to taking full advantage of these motors' potential. Because of their efficiency and longevity, they are widely used in devices that run continuously. Electrical noise, in particular, is the result of the strong sparks that tend to occur at the areas where the brushes pass over the gaps in the commutator. BLDC motors can control continuously at maximum rotational force (torque)and in contrast, reach maximum torque at only certain points in the rotation. For a brushed motor to deliver the same torque as a brushless model, it would need to use larger magnets.

Even small BLDC motors can deliver considerable power and are often considered preferable in applications where it is important to avoid electrical noise.BLDC motors are ideal for UAV Their ability to deliver precision control makes them especially suited for multirotor drones, where the UAV attitude is controlled by precisely controlling the rotational speed of each rotor.

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