

# Brushless Motor Revolution

## WRAM Seminar 2005

### Introduction

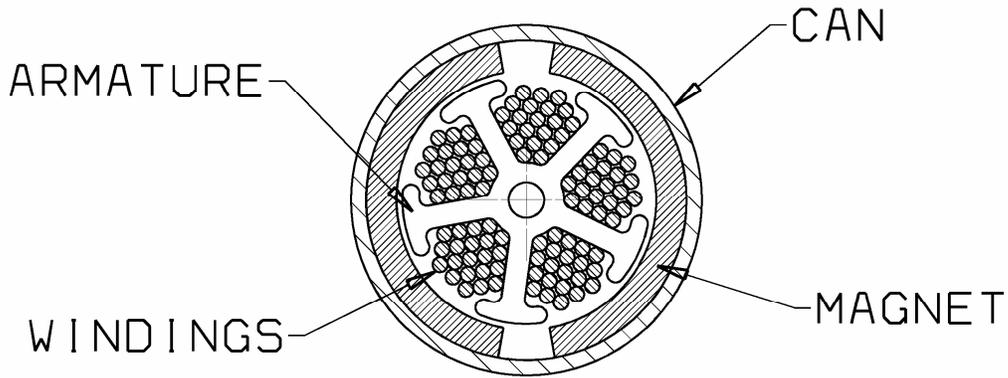
Brushless motors have taken the electric model aircraft movement by storm. Higher demand and larger quantities have made prices fall substantially since their introduction in the early 1990's. Many of the brushless motors found in today's hobby market are specifically made for this market. They are not industrial motors that just happen to work in model aircraft as we have been doing for many years with the inexpensive Mabuchi "sealed can" brush motors. Though they need "special" electronic speed controllers (ESC) the model industry is finally settling in on some standards that allow just about anyone's brushless ESC drive anyone's brushless motor.

- Brushless motor advantages
  - Higher output efficiency than most brush motors of similar power range.
  - Little to wear out (bearings should last 30,000hrs!)
  - About the same cost, if not cheaper than high quality brush motor.
- Brushless motor disadvantages
  - Require special and usually higher cost controller.
  - Motors are much more expensive than the "throw away" Mabuchi "can" motors.
- How much more power?
  - Typical inexpensive brush can motors are about 60-65% efficient when used at their best efficiency point (usually very low current). This level is usually not enough to fly a model aircraft.
  - Typical inexpensive brush can motors are about 50-55% efficient where we actually use them!
  - Brushless motors varying in quality and size can range from 68-90% efficient. That is a BIG range!
  - Brushless motors can be run to fly model aircraft in this range.
- What to do with this extra power?
  - Comparing two "equal" size brush and brushless motors, one can get the following improvements in the model
    - Much longer flights.
  - or
  - A much faster model (or faster climbing model!)
  - or
  - A little of both.
- How to get much longer flights

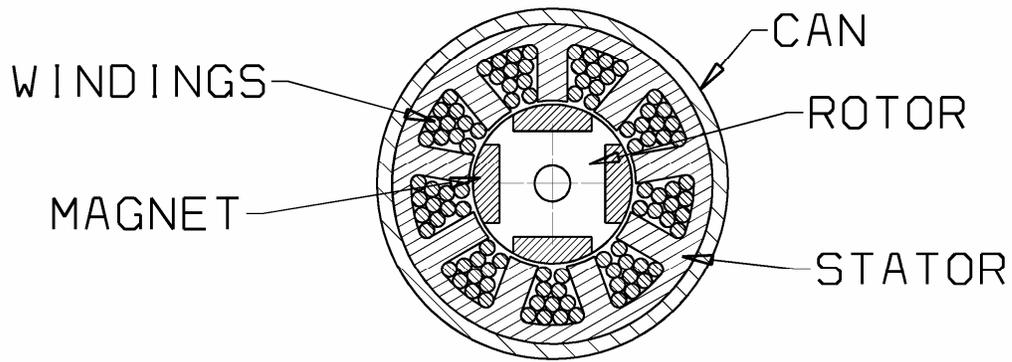
- Choose a brushless motor that swings the same prop for a lower current at the same RPM as the older brush motor.
- How to get much faster flights
  - Choose a brushless motor that swings the same prop for a same current at the higher RPM than the older brush motor.
- How to get a little of both
  - Choose a brushless motor that swings the same prop for a little more current at a slightly higher RPM than the older brush motor.
- Types of brushless motors
  - Sensor type
    - Not many found much anymore, old Aveox and Maxcim.
    - Controller requires information from “sensors” in the motor to know where the rotor is.
  - Sensorless type
    - All new brushless motors seem to be made this way now.
    - Lower part count, cheaper.
    - Controller “reads” the back EMF in the three phases to know where the rotor is to energize the next leg in the stator.
      - Inner rotor
        - High RPM motors.
        - Smaller diameter.
        - Need gearboxes to swing large props.
      - Outrunner type
        - Low RPM motors.
        - Larger diameter.
        - Made for swinging bigger props without the aid of a gearbox.
        - Gearboxes can be used to swing even larger props.
- Motor designations
  - Diameter/length/turns
    - Some manufacturers have been using a three number system to identify the motor. The first number is usually a diameter of the motor (or rotor), the second number the length of the motor (or rotor) and the final number represents the number of turns on the windings (directly related to the Kv)
    - Some manufacturers are imbedding the Kv of the motor in the designation (actually more useful than the number of turns).
    - An Axi 2212/26 has a inside magnet diameter of 22 mm, a magnet length of 12mm and 26 turns on the stator.

- A Mega 22/30/3 has a 22 mm outside diameter magnet, 30mm long magnet, and 3 turns on the stator.
  - A Himax 2812-0850 has a 28mm outside diameter of the motor, a 12mm magnet length and a Kv of 850 RPM/volt
- What is Kv and what does it mean in selecting a motor?
  - Kv or the RPM/Volt constant is a number that relates how fast the motor will turn with an applied voltage WITH NO LOAD!
    - Low Kv inner rotor motors generally have a high number of “turns” on the windings, and high internal resistance, limiting their power by from current. They can swing big props at low voltages or run them at high voltages and smaller props or VERY high voltages on a gearbox and even larger props (though this is rare). Power is best extracted from high voltage and lower currents in these motors.
    - Low Kv outrunner motors can run big props on low voltages, or smaller props on higher voltages. Their “useful” voltage range is smaller than an inner rotor motor with and without a gearbox.
    - High Kv inner rotor motors are just about useless on direct drive, with the exception of some ducted fans. They generally have very few “turns”, a low winding resistance and can tolerate much higher currents than low Kv motors. These motors, outfitted with rather high ratio gearboxes are generally used in larger “3d” models that require relatively low voltages (low weight) and high currents to perform
    - High Kv outrunner motors is kind of like a television set on a honeymoon; useless. The whole point to an outrunner motor is to swing a large prop without the aid of a gearbox. If the Kv is too high, the prop is too small or the current gets excessive.

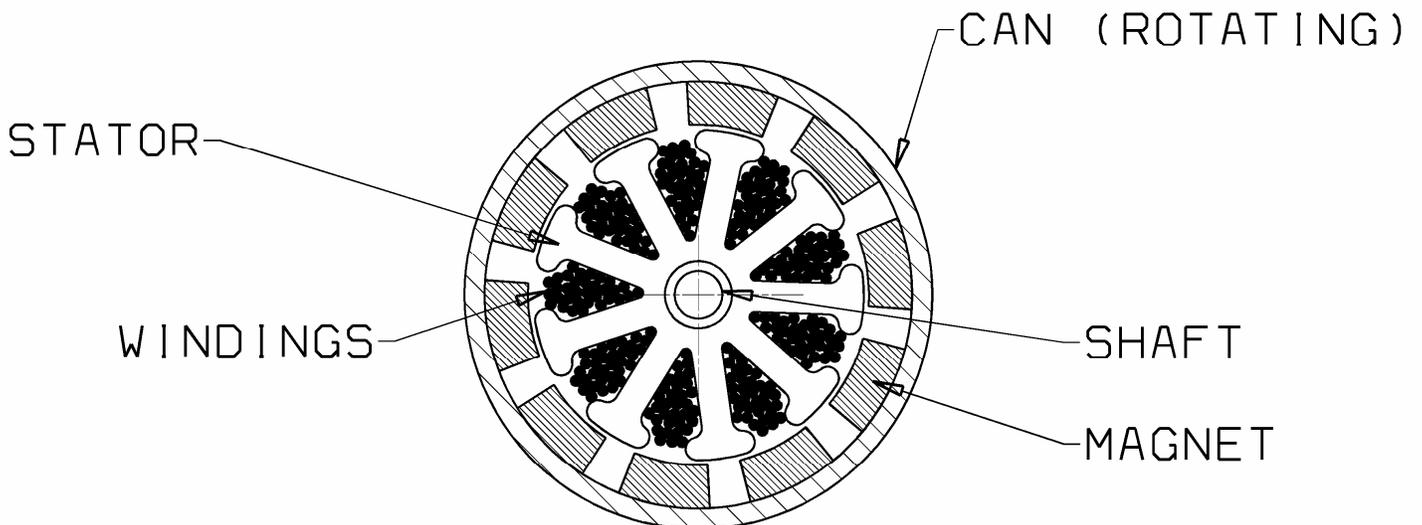
# BRUSH VS BRUSHLESS CONSTRUCTION



TYPICAL BRUSH MOTOR

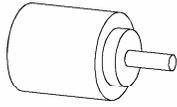


TYPICAL "INNER ROTOR" BRUSHLESS MOTOR

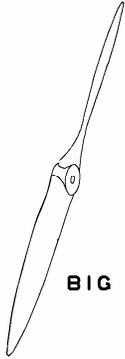


TYPICAL "OUTRUNNER" BRUSHLESS MOTOR

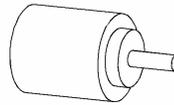
# EFFECT OF Kv (MOTOR SPEED CONSTANT)



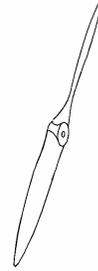
LOW Kv INNER ROTOR MOTOR



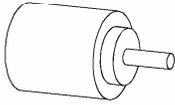
BIG PROP-SLOW TURNING



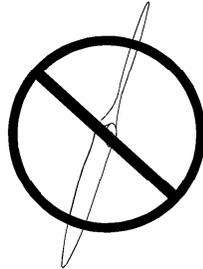
MED Kv INNER ROTOR MOTOR



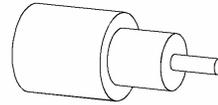
SMALL PROP-FAST TURNING



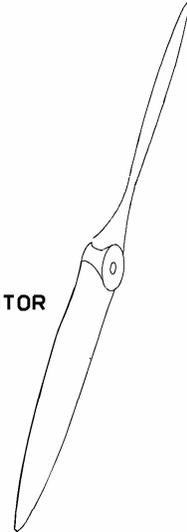
HIGH Kv INNER ROTOR MOTOR



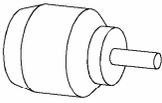
NO SUITABLE PROP



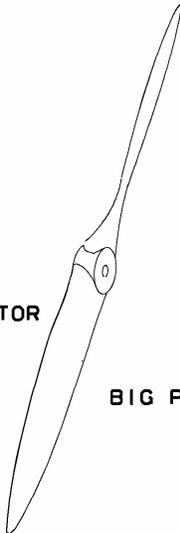
HIGH Kv INNER ROTOR MOTOR WITH GEARBOX



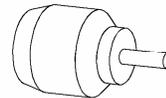
BIG PROP-SLOW TURNING



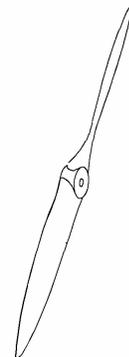
LOW Kv OUTRUNNER MOTOR



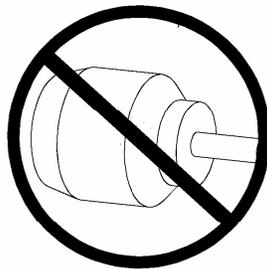
BIG PROP-SLOW TURNING



MED Kv OUTRUNNER MOTOR

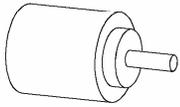


SMALL PROP-FAST TURNING

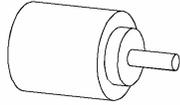


HIGH Kv OUTRUNNER MOTOR NOT A SENSIBLE THING!

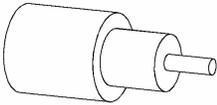
# POWER ABSORPTION (FIXED VOLTAGE)



LOW Kv INNER ROTOR MOTOR  
DIRECT DRIVE



MED Kv INNER ROTOR MOTOR  
DIRECT DRIVE



HIGH Kv INNER ROTOR MOTOR  
WITH GEARBOX

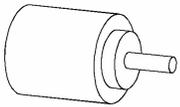
HIGH WINDING RESISTANCE  
LIMITS CURRENT

LOWER WINDING RESISTANCE  
ALLOWS HIGHER CURRENTS

LOWEST WINDING RESISTANCE  
GEARBOX ALLOWS MORE "SUITABLE"  
PROP TO BE USED AND  
EVEN HIGHER CURRENTS

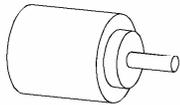
INCREASING POWER  
CAPABILITY

# SIMILAR POWER ABSORPTION (VARYING VOLTAGE)



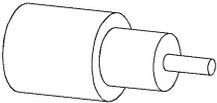
LOW Kv INNER ROTOR MOTOR  
DIRECT DRIVE

USE HIGHER VOLTAGE, LOWER CURRENT



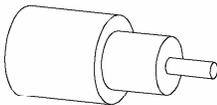
MED Kv INNER ROTOR MOTOR  
DIRECT DRIVE

USE LOW VOLTAGE HIGHER CURRENT



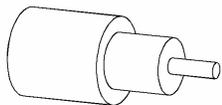
LOW Kv INNER ROTOR MOTOR  
WITH LOW RATIO GEARBOX

USE HIGHER VOLTAGE, LOWER CURRENT



MED Kv INNER ROTOR MOTOR  
WITH INTERMEDIATE RATIO GEARBOX

USE MEDIUM VOLTAGE, MEDIUM CURRENT



HIGH Kv INNER ROTOR MOTOR  
WITH HIGH RATIO GEARBOX

USE LOWER VOLTAGE, HIGHER CURRENT