Gearing for efficient electric flight

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- Basic motor parameters
  - Kv rpm/volt constant (Kt = Kv/1346 units = in-oz/amp)
  - Internal resistance
  - No-load current
  - Fixed/adjustable timing
  - Brush motors
    - Replaceable
    - Sealed can
  - Brushless
    - Sensorless
    - Sensored

- Power
  - Watts = volts x amps (HP = Torque x RPM / 5,252)
  - 746watts= 1 hp
  - plain bearing 40 is about 1 hp.

- Why we use direct drive
  - Motor electric properties
    - Too low a Kv
    - Motor specifically designed for DD
  - Physical model constraints
    - Ground clearance
    - Fuselage clearance (mutli-motored)
    - Volume constraints in cowl, fuselage.
  - Racing

- Why we gear
  - Motor electrical properties
    - Too high a Kv
  - Larger propeller
    - More efficient
    - Higher thrust
    - Better climb
    - Scale look
    - But…. will slow the model down
- Gearing types
  - Spur and pinion (outer)
  - Spur and pinion (inner)
  - Planetary

    - Compound
    - Belt drive

- Spur and pinion (outer)
    - Most popular type found
    - FOD prone
    - Significant offset between motor and prop shaft.
    - Reverses direction of motor
        - Can cause problems with fixed timing motors.
        - Might require use of "pusher" props
    - Some have changeable ratios.
- Spur and pinion (inner)
    - Becoming more popular with at least low-power motors
    - Does not reverse motor direction
    - Better at FOD
    - Less offset than outer S+P
    - Fixed ratio, though many are offered.
- Planetary
    - Concentric shafts (motor/output) (compact)
    - High efficiency
    - Absorbs high power levels
    - Fixed ratio, usually no choices
- Compound
    - Two or more "reductions" in one housing
    - In-line shafts of only slight offset
    - Least efficient of all the gearbox types
    - Fixed ratio, usually no choices
- Belt Drives
    - some fixed ratio, others almost infinitely adjustable.
    - Very quiet
    - Very tolerant of FOD even though generally "open construction"
    - Drive efficiency not effected greatly by set-up.
    - Large motor/prop shaft offset.
    - Limited RPM range
        - Belts do not like high motor shaft speeds

Direct drive/gear drive flight profile

- Direct drive
    - Lower climb angle
    - More time (watt-minutes) to "station"
    - Higher power level at cruise.
- Gear drive
    - Steeper climb angle at slower speed

- Less time to station
- Lower power level at cruise

- Choosing a "system"
  - Manufacturer's recommendations
  - Experienced modeler
  - Replicating similar model
  - Ecalc-Motocalc
  - Generalizations
    - The lower the Kv, the lower the ratio (numerically)
    - The higher the Kv, the higher the ratio
    - The higher the ratio the larger the prop or the higher the cell count
    - Noise is losses
    - Vibration is losses
    - Power consumption increases as a cube function of the RPM
    - Thrust output increases as a square function of the RPM
    - Adding cells (voltage) drives up current (prop/ratio fixed)
    - Adding diameter drives up current faster than pitch
    - Reducing the ratio increases current (prop/cell count fixed)
    - Multi bladed props absorb power at an alarming rate.
      - 20% increase in power absorption for one extra blade
      - 10% increase in thrust for one extra blade
      - 5% decrease in top speed for one extra blade
      - 30% increase in power absorption for two extra blades
      - 15% increase in thrust for two extra blades
      - 10% decrease in top speed for two extra blades

Motor AVEOX 1412/3Y AT 2.66/1 ON 16 CELLS

EFFECT OF PITCH

			%Delta	
Prop KRPM	5.77	5.58	3.2%	decrease
Motor Watts	373	426	14.2%	increase
Motor Amps	21.9	25.5	16.4%	increase
Motor Volts	17.1	16.7	2.3%	decrease
Prop Diameter	14.00	14.00	N/A	
Prop Pitch	8.00	10.00	25%	increase
Climb ft/min	912	1006	10%	increase
Climb angle	30	33	10%	increase
Max. MPH	49	55	12%	increase
Thrust oz	62	67	8%	increase

EFFECT OF DIAMETER

			%Delta	
Prop KRPM	5.77	5.54	4%	decrease
Motor Watts	373	437	17.1%	increase
Motor Amps	21.9	26.3	20%	increase
Motor Volts	17.1	16.6	2.3%	decrease
Prop Diameter	14.00	15.00	7%	increase
Prop Pitch	8.00	8.00	N/A	
Climb ft/min	912	1081	18.5%	increase
Climb angle	30	36	20%	increase
Max. MPH	49	48	2%	decrease
Thrust oz	62	72	16.1%	increase