Model Aircraft Setup & Trimming
Basic

Roger Hammel - September 9, 2008
Goals of Setup & Trimming

• Basic
  • Hands off – straight & level flight
  • Predictability & repeatability
  • Control – enough stability balanced w/ desired maneuverability. Minimize pilot “corrections”
  • No adverse & unpredictable aircraft actions & behaviors
  • Cost balance with performance & weight

• Advanced
  • Aerobatic – non-level flight – maneuvering
  • Deal with “coupling” issues
  • Special Cases

• Other ??

• Inescapable conclusions –
  • No single “right” answers
  • Someone always knows more than you do
  • There is usually a different way of viewing the problem
Setup & Trimming Scope

• What is included in setup & trimming?
  • Alignment
  • Power vs. Weight & prop
  • CG Location
  • Incidences
  • Control Surfaces
  • Thrustline Settings
  • Computer Radio Capabilities
    • Dual Rates
    • Exponential
    • Mixes
  • Flight testing from Maiden Flight

• When does setup & trimming start?

• When does setup & trimming stop?
Tools of the Trade

• General – calculator, plane stand, soft shims, & O.F.K.
• Alignment - cut corner triangles, string, tape, pins & ruler
• Powerplant & prop – scales, tach, pitchmeter, ruler
• CG position – balancing “machine”
• Wingloading – scales & ruler
• Control Surfaces – throwmeter, pointer sticks
• Servos – servo tester/programmer, pointer
• Incidences – incidence gauges
• Thrustline – reference plane, ruler, incidence meter,
O.F.K. = Other Folks Knowledge

- AMA  http://www.modelaircraft.org/
- AMA Special Interest Groups
  - NSRCA - http://nsrca.us/
  - IMAC - http://www.mini-iac.com/
- AMA R/C Clubs & Club members
- Online Groups & Forums
  - RC Universe  http://www.rcuniverse.com/
  - RC Groups  http://www.rcgroups.com/
  - E-Zone  http://www.ezonemag.com/
  - Wattflyer  http://www.wattflyer.com/forums/
  - Flying Giants  http://www.flyinggiants.com/
- Monthly Publications
  - AMA’s Model Aviation
  - RC Reports
  - Quiet Flyer
- Books
  - Mastering Radio Control Flight – Scott Stoops
  - Several 1st US Flight School Books – David A Scott
  - 3 Books by Don Apostolico: Proficient Flying, Crosswind Flying, Gas Engines & Giant Planes
- Other interesting sites
  - Airfoil simulator -  http://www.grc.nasa.gov/WWW/K-12/airplane/foil2.html
Setup Details

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Alignment

• Follow instructions, plans or manual  !!!!

• Wings
  • Top View – square to fuselage center datum line  (string method)
  • Front View – equal dihedral - left vs. right. Shim or recut fuselage side.
  • Side view (incidence)  - covered later – Shim or recut fuselage side
  • Undesired & uneven warpage – Visually inspect,  measure to reference plane (flat table) to discover Left vs. Right differences from warpage

• Tail Feathers
  • Horizontal Stabilizer –
    Top view – similar to wing
    Front View - Orthogonal to fuselage vertical plumbline. Cut corner triangle
    Side view - Incidence – (Covered later) shim or cut fuselage
  • Vertical Stabilizer -
    Top View – parallel to fuselage centerline. String & pin method
    Rear /Front View - Parallel to fuselage vertical plumbline

• Thrustline – Use manufacturers recommendations  ...  (covered later)
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Power & Powerplant vs. Weight & Prop selection

• Engine selection at heart of setup. May influence:
  • Aircraft weight & balance
  • Servo & equipment placement in airframe
  • Fuel load
  • Wallet load $$$
• Can you have too much power? 2 schools of thought:
  • No – power absolves all sins. 3D influence. Unlimited vertical. Macho.
  • Yes – Price of power $\rightarrow$ weight $\rightarrow$ balance $\rightarrow$ more weight $\rightarrow$ higher wingloading $\rightarrow$ higher flying speed $\rightarrow$ maneuverability penalty
  • More power @ same overall weight – almost always good. Duh!
• Decision?
  • Individual preferences dictate. No “right” answer for all cases.
  • What is your flying style??
  • Caution: Manufacturer’s suggestions may often result in underpowered plane.
  • Suggest consulting O.F.K. But with large dose of caution.
  • Personal examples – UltraStick 40, UCD46; Venus II.
• Propeller considerations
  • Fly style - 3D, Funfly $\rightarrow$ lower pitch larger diameter;
    -Sport & Aerobatics $\rightarrow$ higher pitch smaller diameter.
  • Determine engine manufacturer prop recommendations
  • Match pitch speed of prop with speed expectations for plane
    Pitch Speed (mph) = Krpm x pitch (inches) x .95
  • For equivalent loads on motor from different props - consult Jim/Arlen’s propload calculator formula. Rough rule of thumb $\rightarrow$ Change of 1” D = 2” pitch
  • Consider drag characteristics of airframe
  • Prop changes $\rightarrow$ unanticipated effects & coupling during aerobatics
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Stability - Primer

- **Stability** = ability of an aircraft to return to original position if involuntarily displaced
  - Natural restorative force counteracting involuntary position or movement
    - Gravity action
    - Aerodynamic
  - Stability vs. Maneuverability - inversely proportional

- **Keys**:
  - **Pitch stability** - Horizontal Cp aft of CG (Aerodynamic - dart) – Can be “fatal” if not followed
  - Yaw stability – Vertical Cp aft of CG (Aerodynamic - dart) – Can be “fatal” if not followed
  - Roll stability – Horizontal Cp above Cg (Gravity - pendulum), Dihedral (aerodynamic) – Usually can “live with instability” via aileron corrections.
Optimal CG location:
It’s all just a matter of balance...

• CG location
  • CAVEAT - “Nose heavy planes fly poorly, tail heavy planes fly once…”
  • Acceptable CG must be in front of Cp for unassisted stable flight – dart analogy
    CG – not single “point”, rather “range” of acceptable “points”, all with tradeoffs
    CG further aft, more maneuverable, less stable. Snaps & spins easier.
    CG further forward, less maneuverable, more stable. Axial rolls easier
  • Initial location: Consult plans & O.F.K. for CG location inputs. Helpful website:
    http://www.geistware.com/rcmodeling/cg_super_calc.htm
  • Other Rules of thumb
    Initial CG at “thickest” part of wing, often on spar or slightly forward
    Initial CG range – 25% to 35% M.A.C. 25% is safer
    Cp of wing (only) usually about 25% chord. Cp of horizontal stab @25% stab chord.
    Overall Cp → relative surface areas of stab vs. wing & distance between them
      Large horizontal tail feathers vs. wing → more rearward CG allowable
      Long tail moment arm distance → more rearward CG allowable
    High “normal” throws → more conservative (forward) initial CG
  • Flying style influences choice –
    3D – well toward tail heavy (helps “stalled flight” maneuvers)
    Pattern – neutral to slightly tail heavy
    Sport – neutral to slightly nose heavy
    Trainers – nose heavy (safe)
  • KEY - Plan for CG adjustments. Move components vs. add weight.
• The model should balance OK before flight trimming starts. Lateral balance too.
• Iterative process - If CG changed, other trim parameters must be rechecked.
• Flight testing – Test-in “right” CG (close) first.
Optimal CG location: Testing Methods

• Flying tests for approximate CG location (assumes proper wing incidence, horizontal stab incidence & thrustline setup). ...Iterative process....
  • Roll into inverted flight at cruise speed
    a) Considerable “push” of elevator required for level flight → nose heavy
    b) If any pull is required → tail heavy (assuming no excessive downthrust)
    c) No pull or push → slightly tail heavy, may be OK for some fliers
    d) If slight push is required, balance is close
  • Roll into vertically banked turn at cruise speed, neutral rudder.
    a) If model drops nose first → nose heavy
    b) If model drops tail first → tail heavy
    c) If model drops approximately level, balance is close

• CG location refinement & optimization
  • Advanced flight tests for CG involve advanced aerobatic maneuvers e.g. long downlines, Knife Edge flight, snaps & spins; for 3D - use stalled flight maneuvers (e.g. hovers, harriers, flatspins.)
  • Ultimate CG determination is an iterative process of testing and personal preferences.
  • Some fliers use 2 different CG locations, one for aerobatic flight, and a more rearward CG for 3D flight.
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Wing Incidence Settings

- Lift vs. Angle of Attack (see David Scott of “1st US Flight School” pic source)
  - “Angle of attack” is wing angle relative to airflow using “zero lift” line as reference
  - KEY - All airfoils need a positive angle of attack (measured from ZLL) to produce lift
  - Angle of attack achieved one of two ways:
    - Wing/stab at 0/0. Thus elevator “+” trim necessary – plane is pitched nose up to achieve sufficient pos. angle of attack
    - Positive wing incidence - 1/2 degree to 1 degree, horizontal stab at 0 (neutral)
  - Significant number of ARFs designed with 0 wing incidence & 0 stab incidence.
  - Fly & try. If negatively stable, consider adjusting wing incidence via shims or redoing fuselage wing cutouts.

![Diagram of wing incidence settings]
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Control Surfaces

• Control Surface - Throws vs. Size
  • Throws - Use manufacturer recommendations & OFK inputs
  • Larger control surfaces need smaller throws for precision flight.
  • Start with low throws and increase after initial flights
  • Caution: Large aileron throws especially with large ailerons \(\rightarrow\) crash waiting to happen

• Hinges: Hinge lines - straight and centered on the surface
• Pivot Point of Control Horns: Control horns setup with pivot point of horn exactly on the hinge line to avoid accidentally building in a differential.
• Servo Arms: The arm on the servo should be exactly parallel to the hinge line. Servo arms should be switched around until you get the spline alignment correct.
• Servos: Select quality servos of sufficient torque. Test & match for best setups. Centering is critical.
• Subtrims are for fine tuning only. Do NOT use the radio “sub trims” or fine tuning to center the servos more than a couple of degrees !!!
• Hinge lines should be sealed so no air can pass through.
• Eliminate slop & “play”. Minimize pushrod slop. Do not oversize holes. Use high quality ball link attachments and machined aluminum servo arms for the best setups.
• Aileron & Elevator Setup - Mechanically adjust linkages so that ailerons & elevators are perfectly centered and get only the maximum throw recommended by the manufacturer. Equal up and down.
• Rudder setup – Achieve maximum available throw for rudder. Secure mechanical advantage to ensure good resolution and power
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Engine Thrustline Settings

• Thrustline - typically need slight down-thrust and right-thrust
  • Issues appear most often in high power but low speed flight situations
  • Takeoffs, stall turns, tops of loops & Immelmann’s, Cuban Turnaround Uplines
  • Caused by combination of slipstream & P factor effects
  • Sometimes excess wing incidence (down-thrust correction) at high speeds

• Initial Thrustline settings
  • Use manufacturer’s suggested settings
  • OPK inputs with large degree of caution & discretion.
  • Default – Right-thrust 1 to 2 degrees, down-thrust 1 to 2 degrees then test.

• Flight Testing Thrustline settings – Thrust controls uplines
  • Do after CG is established as “close” & wing incidences are set “close”
  • Initial flights good to do without cowl till settings verified. Access & adjustment issue.
  • Wings level, moderate speed directly into wind, pull up hold power. Observe changes as plane slows toward top half of upline. Repeat with the wind.
    • Plane tucks to belly, \(\rightarrow\) reduce down-thrust
    • Plane pulls to canopy \(\rightarrow\) increase down-thrust
    • Plane pulls to left \(\rightarrow\) increase right-thrust, also possible down-thrust increase
    • Plane pulls to right \(\rightarrow\) reduce right thrust
    • Results may change if props are changed. Retest & verify.
  • Large down & right thrustlines settings different from 1,1 or 2,2 degrees \(\rightarrow\) may indicate other issues. Retest & verify, recheck for other causes - e.g. incidences.
    • High speed straight level flight directly into wind – quickly cut throttle. Observe plane.
    • Significant flightpath changes may indicate “other” issues. Iterate other trimming steps & tests.
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**Computer Radio Capabilities**
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Computer Radio Capabilities

- **Dual Rates**
  - USE dual rates.
  - Primary flying on low rates for precision
  - 3D maneuvers, possibly snaps & flatspins on higher rates.
  - High rate ailerons can quickly get you into trouble
- **Exponential**
  - Use judiciously
  - Low rates – small % EXPO. Must still feel the controls for smoothness
  - High rates – Larger % EXPO stops unwanted jerky movements
  - EXPO is NOT a substitute for precise stick movement & control
  - High rates + large % EXPO does not always make a smooth flier
- **Mixes**
  - Use to coordinate dual surfaces (slave) from one input (split elevators)
  - Use to correct unwanted flight & coupling issues if mechanical or aerodynamic changes not viable .(Mix out problems.)
  - Caution - Can cause unintended & unforeseen effects & consequences
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• Flight Testing from Maiden Flight
Maiden Flight
(...hope the plane don’t crash...)

• Ground check of controls & engine throttle.
• Takeoff & attain altitude
• Adjust Xmitter trims for straight & level flight.
  • Ailerons first. If OK proceed.
  • Elevator next If OK, proceed.
  • Vary throttle, does plane climb & dive? If OK, proceed.
• Low rates – are throws are sufficient, but not too much? If OK, proceed.
  • Rudder trim adjusting –
    • Straight into wind, wings perfectly level, good speed, pull vertical & observe.
    • Fly with tailwind, wings perfectly level, high speed, pull vertical & observe.
    • Repeat to verify. Any heading change or roll at outset? Trim rudder correction.
    • Optional - Loop straight into wind, wings level, see if corkscrewed. Trim rudder correction.
  • CG flight tests 1 & 2 (previously covered). Consistent results?
• Land & adjust
  • Measure deflections set & record.
  • Adjust trims mechanically (or with subtrims if deflections are small) to achieve same deflections recorded but w/ neutral trims
  • Fly and verify trim settings.
  • Adjust CG as necessary from tests. Test fly for results.
  • Readjust & test fly.
  • Test other parameters in flight. One change at a time. Test fly for results.
  • Iterate process