Helicopter Performance
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Carson Helicopters S-61N
Operated by U.S. Forest Service
Weaverville, CA
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Topics

- Hover performance
- Ground effect
- Translational lift
- Hover performance of S-61N with Carson Composite Main Rotor Blades (CMRBs)
  - Carson RFMS #8
  - Sikorsky 2010 prediction
- Simulations of accident takeoff
Hover Performance

Power required to hover

Net rotor thrust, or helicopter weight
Hover Performance

- Net rotor thrust, or helicopter weight
- Total engine power
- Power available
- Max hover weight
Ground Effect

Hover Out of Ground Effect (HOGE)

Ground plane

Hover In Ground Effect (HIGE)

Ground plane
Ground Effect

Net rotor thrust, or helicopter weight

Total engine power

Power required to HOGE

Power required to HIGE

Helicopter weight

HOGE

HIGE
Ground Effect

Total engine power

Net rotor thrust, or helicopter weight

Power available

HOGE weight

HIGE weight
Translational Lift

Power required for level flight

Forward speed

Hover
Translational Lift

Reduction in power required due to “translational lift” → Additional power available for climb
Translational Lift

Power required for level flight vs. Forward speed

High forward speed
Takeoff Profiles

- **Weight < HOGE weight:** vertical takeoff possible
- **Weight = HOGE weight:** Short takeoff run required
- **Weight > HOGE weight:** Longer takeoff run required
Helicopter HOGE Capability

• Carson RFMS #8
  – S-61N; no Fire King tank
  – Based on flight tests in 2006
• Sikorsky 2010 prediction based on NVH-3A tests
  – Configuration differences accounted for by calculation
  – Prediction “spot checked” by joint Sikorsky / Carson flight tests of an S-61A helicopter
  – Scatter in S-61A test data attributed to wind effects
• Fire King tank effects accounted for by calculation
Helicopter HOGE Capability

Power at 6106 ft, 23°C, 103% $N_R$ (HP)
Thrust at 6106 ft, 23°C, 103% $N_R$ (lb)
(Includes 100 lb. decrement due to Fire King tank)
17000 17500 18000 18500 19000
1800 1900 2000 2100 2200 2300 2400

Power at 6106 ft, 23°C, 103% N_R (HP)

Thrust at 6106 ft, 23°C, 103% N_R (lb)
(Includes 100 lb. decrement due to Fire King tank)

Accident weight = 19,008 lb.

Accident power = 2,300 HP

In winds ≤ 3 knots:
2010 prediction – crosswind, tailwind included
RFMS #8 – crosswind, tailwind excluded

~560 lb.
Simulations of Accident Takeoff

- Sikorsky “GenHel” helicopter simulation
- Helicopter weight = 19,008 lb.
- Engine power and torque based on $N_G$ & $N_R$ speeds from CVR & General Electric engine models
- Collective control driven to match available torque
- Cyclic control driven to match time to tree impact
- HOGE performance per RFMS #8 and 2010 prediction for S-61N with CMRBs
- Fire King tank effects included
- Air temperatures of 20° C and 23° C
- 4 scenarios (2 temps x 2 performance bases)
Simulations of Accident Takeoff

GenHel simulation results: RFMS #8 performance, 20° C

- Altitude of rotor hub
- Altitude of wheels
- Terrain
- Tree
- Rotor blade strike location

Distance from liftoff point, ft.

Altitude, ft. MSL

70 ft.
Simulations of Accident Takeoff

GenHel simulation results: RFMS #8 performance, 23° C

- Red line: Altitude of rotor hub
- Black line: Altitude of wheels
- Green line: Terrain
- Yellow diamond: Tree
- Yellow diamond with star: Rotor blade strike location

Distance from liftoff point, ft.

Altitude, ft. MSL

40 ft.
Simulations of Accident Takeoff

GenHel simulation results: 2010 prediction performance, 20° C

- Altitude of rotor hub
- Altitude of wheels
- Terrain
- Tree
- Rotor blade strike location

Distance from liftoff point, ft.

Altitude, ft. MSL

4 ft.
Simulations of Accident Takeoff

GenHel simulation results: 2010 prediction performance, 23° C

- Altitude of rotor hub
- Altitude of wheels
- Terrain
- Tree
- Rotor blade strike location

Distance from liftoff point, ft.
Altitude, ft. MSL

6 ft.
Summary

- Assuming RFMS #8 performance, HOGE capability about equal to helicopter weight.
- Assuming 2010 predicted performance, HOGE capability ~560 lb. less than helicopter weight.
- Assuming RFMS #8 performance, helicopter clears tree by 40 - 70 ft.
- Assuming 2010 predicted performance, rotor strikes tree within 6 ft. of measured strike mark.
- Performance differences due to different ways of accounting for wind during flight testing.