Evaluation of consumption and performances for aircrafts

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SMA (SAFRAN)
Frankfurt am Main, 26. October 2015
AGENDA

SMA & the SR305-230E engine

Aircrafts modeling

Evaluation of consumption & performances

Conclusions & Perspectives
SMA & THE SR305-230E ENGINE

⇒ SMA (SAFRAN group)
  - Subsidiary of SNECMA, one of the world leader in aircraft & rocket engines
  - ~70 peoples on 3 locations (2 in France, 1 in the USA)
  - Designs, produces and supports gas oil engines for light aviation
  - History
    - 1997 → Joint venture between Socata and Renault Sport F1
    - 2002 → FAA certification for the SR305-230
    - 2005 → SAFRAN becomes 100% shareholder of SMA

⇒ SR305-230E engine
  - Certified in 2011 by EASA and FAA
  - Designed for the general aviation market
  - Main advantages
    - Use of Jet fuels available around the world
    - Fuel costs savings by over 30% compared to gasoline engines
    - No lead emissions at exhaust
  - Selected by Cessna for the Turbo Skylane JT-A
SMA & THE SR305-230E ENGINE

→ SR305-230E main characteristics

- Flat 4 configuration
- Compression ignition (Diesel cycle)
- Swept volume of 5L
- CR of about 15:1
- Direct injection (inline pump, up to 1200bar)
- Air and Oil Cooled
- Turbocharged

- Direct drive
- Single Control Lever (power adjusted by fuel flow)

- Max power of 230hp up to 10 000 ft (ISA conditions)

ISA → standard model of atmosphere (15°C on ground)
ISA+30 → hot conditions
Current tool → excel files
- Evaluation of required power on specific operating points
- Steady-state tool (no dynamic taken into account)
- No consumption evaluation and weight evolution on a full mission

Discussion with GT to build aircraft models in the GT environment
AIRCRAFTS MODELING – ENGINE

➡️ Engine model
- Mapped ICE model
- Addition of two 3D maps for power & consumption
  - Function of altitude, engine speed & « engine load »

➡️ Principe
- Evaluation of maximal available power (with atmo. conditions)
- Comparison with required power coming from aircraft model
- Choice of the minimum of both power
- Evaluation of consumption according to the chosen power

➡️ Mapping of the engine
- GT model of the SR305
- Calibration with tests on ground & in flight
- Extraction of maps for main engine results
AIRCRAFTS MODELING – AIRCRAFT (A/C)

➔ Aircraft model
- Quasi steady-state model
- Atmosphere model (based on ISA)
  - Outside conditions (pressure, temperature…)
- Body → frame and “ghost” road laws (no friction)
- Propeller → fixed engine speed
  - Efficiency map for the propeller

➔ Flight equations
- Same equations for all phases

Aircraft forces
- Lift
- Drag
- Thrust
- Weight

Lift forces
- Cz

Drag forces
- Cx

Powers calculation

Required power
Rotorcraft model

- Same architecture as for the aircraft
- Rotor → fixed engine speed
- Descent phase not modeled
  - Physics too complex for our modeling level
  - Add of stationary phase to compensate

Flight equations

- Different equations according to the considered phase
- Logical flow chart to select the phase
- For each phase, calculation of 3 power components
Pilot model
- 1st step → missions imposed to the aircraft (validated)
  - Aircraft speed and altitude as function of time
  - No adaptation of flight profile due if too low A/C performances
- Simulation still needs a posteriori validation by the user
  - To check if performances results don’t exceed aircraft capabilities
  - Will be useless when step 2 will be implemented

- 2nd step → missions with objectives (in study)
  - Dynamic behavior with adaptation

<table>
<thead>
<tr>
<th>Phase</th>
<th>Objectives</th>
<th>Initial point</th>
<th>Option</th>
<th>Application</th>
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<tr>
<td>Taxi</td>
<td>Duration</td>
<td>Altitude</td>
<td>-</td>
<td>A/C</td>
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<tr>
<td>Hovering</td>
<td>Duration</td>
<td>Altitude</td>
<td>IGE/OGE</td>
<td>R/C</td>
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<tr>
<td>Climb</td>
<td>Final altitude</td>
<td>Altitude</td>
<td>Horizontal speed</td>
<td>A/C &amp; R/C</td>
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<td>Cruise</td>
<td>Duration</td>
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<td>Descent</td>
<td>Final altitude</td>
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<td>A/C</td>
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<tr>
<td>Winching up</td>
<td>Duration</td>
<td>Altitude</td>
<td>Additional mass</td>
<td>R/C</td>
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</table>

~ 110s simulation for 1h mission

Mission phases
Selected aircraft → Socata TB-20

- Fuel
  - Jet-A1 (265 kg) or Avgas (242 kg)

- Payload
  - 4 seats in the aircraft (included pilot) → 100 kg each

- Weight hypothesis
  - 1 pilot + % of payload + max fuel (up to MTOW)

### MTOW with payload variation

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<table>
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<tbody>
<tr>
<td>MTOW</td>
<td>1400 kg</td>
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<tr>
<td>Empty W</td>
<td>900 kg</td>
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<tr>
<td>Fuel tanks</td>
<td>336 L</td>
</tr>
<tr>
<td>Payload max</td>
<td>300 kg</td>
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</tbody>
</table>

- Cruise (260 km/h, 10 000 ft)
- Descent (5 m/s)
- Climb (5 m/s)
- Taxi (5 min)
- Rotorcraft mission

- Taxi (5 min)
Simulation results

- Zone A → range available for both engines and all payload conditions
- Zone B → range available for SMA engine with a higher payload than for the competitor engine
- Zone C → range only available for SMA engine

With maximal payload
SMA engine can fly ~600km more than its main competitor (+175%)

With maximal TOW & fuel capacity
SMA engine can fly ~1800km more than its main competitor (+175%)

Maximal range with SMA engine is above 3000km, when its competitor can only reach ~1300km
Selected aircraft → Robinson R44

- **Fuel**
  - Main tank → Jet-A1 (87 kg) or Avgas (80 kg)
  - Add. Tank → Jet-A1 (50 kg) or Avgas (46 kg)

- **Payload**
  - 4 seats in the aircraft (included pilot) → 100 kg each

- **Weight hypothesis**
  - 1 pilot + % of payload + max fuel (up to MTOW)

MTOW: 1135 kg
Empty W: 660 kg
Fuel tanks: 111 L + 64 L
Payload max: 300 kg

Rotorcraft mission:
- Hovering (5 min)
- Cruise (160 km/h, 10 000 ft)
- No descent
- Climb (5 m/s)
Simulation results

- Cruise speed for competitor engine → 210km/h (Robinson data)
- Cruise speed for SMA engine chosen for optimal consumption → 160km/h

Next step → simulate performances with SMA engine and a cruise speed of 210km/h to get a full comparison
CONCLUSIONS & PERSPECTIVES

Development of simulation tools for consumption/performances evaluations on aircrafts

- Excel sheets for operational points (steady-state) → GT models for evaluation on a whole mission (quasi steady-state)
- First validation of the models with comparisons made between SMA engine and the gasoline engine mounted on the aircrafts
  - Aircraft model with a Socata TB-20
  - Rotorcraft model with a Robinson R44
- Tool now available in SMA to help early design and discussions with customers

Perspectives

- Take into account inertia effects
- Refine the weight estimation (taking into account engine weight differences for example)
- Complete the tool to include other items
  - Thermal management
  - Accessories consumption…
- Develop a pilot model which will drive the aircraft through mission objectives (and not only time)
THANKS FOR YOUR ATTENTION

Any question?
ANNEXES
SMA & ITS ENGINE SR305-230E

- Diesel most efficient engine for low and medium power
MODELING ARCHITECTURE

AIRCRAFTS MODELING – PRINCIPLE

- Modeling architecture

Pilot

Atmosphere

Pression, Temperature...

Mission (speed, altitude)

Aircraft

Efficiency

Propeller, Rotor

Required power

Available power

Engine

Performances, Consumption

Available power

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