

Many objective optimization of advanced power systems for aircraft

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Test cases
A quadcopter (11.2 kg)
A hexacopter (16.8 kg)
A generic Medium Altitude Low Endurance UAV (500 kg)
General Atomics Predator RQ(1020 kg)

Models for engines & motors
- A library of fuels and engines (piston, turbine, rotary)
- A library of electric machines
- PEM and advanced fuel cells
- Reference stationary maps
- Scaling techniques

Design procedure
STEP 1: Aircraft & powertrain
STEP 2: Components
STEP 3: Performances
STEP 4: Mission based analysis

Modeling the battery
A modified version of the Shepherd model, extensively validated against experimental data of Lithium-polymer and Zebra batteries in charge and discharge.

Optimization
INPUTS:
→ Mission specification;
→ Engine size;
→ Battery capacity and voltage;
→ Hybridization ratio;
→ Energy management strategy
GOALS:
↑ Endurance in electric flight
↑ Fuel economy in hybrid mode
↓ Takeoff mass
↓ Additional volume

Results & conclusions
QUADCOPTER: best results with the thermal power system.
HEXACOPTER: best endurance (72.7min) with the hybrid electric system.
GENERIC MALE: electric endurance 0.5h, Fuel economy + 12%
Overall mass: +20%
PREDATOR RQ1:

↑ Electric endurance = 30 minutes
↑ Hybrid fuel economy = -11% than non hybrid case
↓ Additional volume = 48 liters

Which is the best algorithm?

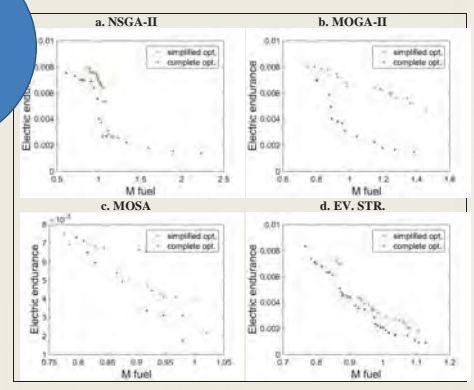
Performance metrics

- Hypervolume (hv)
- Generational Distance (GD)
- Inverted Generational Distance (IGD)
- Average distance between solutions (Davg)
- Distance variance between solutions (Var)
- Number of non-dominated solutions (NNS)
- Number of feasible solutions (NFS)
- Maximum or Minimum sum of the objective values (MaxSum/MinSum)
- Sum of the maximum objective values (SumMax)
- Sum of the ranges of the objective values (Range)
- Computational time (time)
- Percentage of a Pareto front dominated by the other one (C_AB)

HYBRID ELECTRIC UAV (Test case 1) SYNERGY BETWEEN POWER SYSTEM AND MISSION

Objective functions: electric endurance & fuel consumption

BI-OBJECTIVE problem

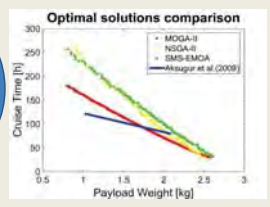


ELECTRIC VTOL (Test case 2)

SYNERGY BETWEEN AIRCRAFT ARCHITECTURE AND ELECTRIC POWER SYSTEM

Objective functions: cruise time and payload

BI-OBJECTIVE problem



	MOGA-II	NSGA-II	SMS-EMOA
NNS	318	90	149
NFS	6.916	10.810	11.959
Var	0.0729	0.0010	3.0484e-04
Davg	0.2374	0.0279	0.0203
HV	0.4228	0.6426	0.6859

C(A,B)		B	
A	MOGA-II	NSGA-II	SMS-EMOA
MOGA-II	-	~93%	100%
NSGA-II	~6%	-	~87%
SMS-EMOA	0%	~9%	-

Four goals: cruise time, payload, range, takeoff area

	MOGA-II	NSGA-II	SMS-EMOA
NNS	477	352	150
NFS	4.304	10.997	14.324
Var	0.2461	0.1929	0.3355
Davg	0.2672	0.4531	0.8178
HV	0.6419	0.9681	0.9574

C(A,B)		B	
A	MOGA-II	NSGA-II	SMS-EMOA
MOGA-II	-	100%	100%
NSGA-II	0%	-	0%
SMS-EMOA	0%	100%	-

Many-Objective problem

Four goals: electric endurance, fuel consumption, additional volume & take-off field length

C(A,B)	B			
	MOGAII	NSGAI	MOSA	Ev. Str.
A				
MOGAII	-	38%	7%	6%
NSGAI	4%	-	5%	15%
MOSA	27%	32%	-	35.6%
Ev. Str.	24.8%	35.4%	8.1%	-

Many-Objective problem

Conclusions for test case 1

- MOGAII is the best method in the bi-objective optimization problem
- NSGAI that turns out to be the best method in the many-objective optimization problem
- Evolution Strategy gets the best definition and distribution
- MOSA is the worst method for this application

Performance degradation in many-objective optimization is always observed

NOTE: This test case considers a higher number of design variables and constraints than test case 1