ELECTRIC DEMONSTRATION SYSTEMS OF THE GAS-TURBINE ENGINE FOR THE MORE ELECTRIC AIRCRAFT

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Main features of electric engine

CIAM activities on electric engine

Demonstration system of electrically driven automatic control

Demonstration system of oil supply system with electrically driven pumps
important areas of engine electrification

- Engine working process
- Automatic control and fuel supply systems
- Oil system
- Starting system
- Electric power generation system
- Thrust generation system
ELECTRIC ENGINE FOR THE MORE ELECTRIC AIRCRAFT

Current Technology Engine

- Gearbox
- Power drives by fuel
- Mechanical bearings with oil system
- Air bleed for aircraft systems

Electric Engine

- Without gearbox
- Electric drives
- Magnetic bearings (without oil system)
- Without air bleed
- Embedded starter/generator

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Optimization of air-gas channel for starter/generator arrangement

Engine performance optimization at reduced air bleed

Distributed control system with electric drives:
- low weight electric-driven actuators
- smart sensors and actuators
- multistage centrifugal pumps with high efficiency

Oil system with electrically driven pumps

Magnetic bearings for rotors
CIAM ACTIVITIES ON ELECTRIC ENGINE

- Conception of electric engine
- Demonstration system of electrically driven automatic control
- Fuel system with electrically driven pumps
- Oil demonstration system with electrically driven pumps
- Engine test bed for testing of demonstration systems

Engine-demonstrator
\( n_2 = 17500 \text{rpm}, \ T = 17\text{kN} \)

Tests of automatic control system and oil system with electrically driven pumps

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Demonstration of electric technologies abilities

Selection of actuators

Development of a digital control system for electric drives

Selection of control laws for electric drives management
DEMOSNTRATION SYSTEM SCHEMATIC

- Sensors: rpm ($n_2, n_1$), air pressure at the compressor exit ($P_2$), fuel flow ($G_{fuel}$), etc.
- Control units of actuators (electric drives of the pump and compressor IGV)
- Electromagnetic valves for control of air bleed

**System affects fuel flow, IGV position and air bleed valves**

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**ACCESSORIES**

**Electric drive of fuel pump**
- $N = 3\ kW$
- $N_{\text{max}} = 12000\ \text{rpm}$
- $G_{\text{Fmax}} = 1000\ \text{kg/h}$
- $P_{\text{in}} = 3 - 5\ \text{bars}$
- $P_{\text{max}} = 70\ \text{bars}$

**IGV electric drive**
- $N = 0.14\ kW$
- $N_{\text{max}} = 12000\ \text{rpm}$
- Force = 100 kg
- $V_{\text{max}} = 25\ \text{mm/s}$

**Digital controller**
- CPU speed = 2.2 GHz
- RAM = 226 MB
- CPU clock rate = 33 ms
- Number of input channels = 10
- Number of output channels = 12

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Bypass valve drive

IGV drive

Fuel pump drive
2 operating modes

- Control by rotational speed of electric motor rotor
- Control by torque on electric motor rotor

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Experimental fuel flow characteristic of fuel system

- Control by rpm - blue
- Control by current (torque of electric motor shaft) – red

Installed electric drive system
- At starting, acceleration, advanced acceleration, deceleration and stopping

Dynamic performance at control by rpm and by current are rather different

Transition time from MIN to MAX at control be rpm - 0.2s (2 times less than at control by current)

Control by rpm is more preferable
ENGINE STARTING
n₂ - HPC rotational speed
Qₐ - fuel flow
U₁ - control signal to the pump electric drive
T₄ – turbine exit temperature
Engine control is operable at steady and transient conditions (start, acceleration, advanced acceleration, deceleration, stopping)

IGV electric drive:
transition time - 0.5 sec

Electro - pneumatic bypass valve:
opening / closing time - 0.2...0.3 sec
Oil pumps drive by HP rotor
Breather drive by HP rotor
System for oil heating at the engine start

Independent electric drive feed and scavenge pumps
Electric drive for breather
Electric drive for evacuation of oil from cavities
Efficiency:

- Improvement of oiling quality (increase of life time)
- Decrease of fuel heating
- Weight reduction
- Engine starting improvement at low ambient temperature (t < -30°C)
Laws of oil supply

- **n\text{pump} = const** - constant rotation speed of the feed pump
- **P\text{oil} = const** – constant pressure behind the feed pump (with pressure controller)
- **n\text{pump} = var** - drive of pumps by gear box (conventional system)

1 and 2 laws - best performance relating to oil heating

- **Preferable law n\text{pump} = const (without pressure controller)**
Demonstration systems with electric drive units on the engine-demonstrator have shown an ability for development of More Electric Engine in the near future.