Rotax 912 iS
Fuel injected aircraft engine

Thomas Goigitzer
BRP-Powertrain
BRP – Bombardier Recreational Products

BRP is no. 1 in following markets:
- Jetboat
- Boat
- Snowmobile
- Roadster
- Light Sport Aircraft
BRP-Powertrain GmbH & Co KG, Gunskirchen, Austria

- 1,100 employees
Rotax Aircraft Engine Milestones

- **1975**: Certification of the first ROTAX Aircraft Engine
- **1978**: Ultralight engines 501, 505 developed based on snowmobile engine 503
- **1984**: Start of development of ROTAX 912
- **1989**: SOP RotAX 912A (80hp)
- **1998**: SOP RotAX 912S (100 hp)
- **2006**: Gunskirchen EASA certified for design and production of aircraft engines (DOA, POA)
- **2010**: 912/914 TBO up to 2000 hours

**Rotax 447 UL**
- SOP: Late 70s
- Discontinued: 2008

**Rotax 503 UL**
- SOP: Early 80s
- Discontinued: 2008

**Rotax 582 UL**
- SOP: 1989
- In production

**Rotax 912 UL**
- SOP: 1989
- In production

**Rotax 912 ULS**
- SOP: 1999
- In production

**Rotax 914 UL**
- SOP: 1996
- In production

**Rotax 912 iS**
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- Electric & Electronics
- Control Strategy
- Mechanical Impact
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Overview

912 iS Fuel Injected Aircraft Engine

Base technical data:
- Max. Power: 100 hp
- Max. RPM: 5800 RPM
- Bore: 84mm
- Stroke: 61 mm
- Displacement: 1352 cm³
- Compression ratio: 10.8:1
Overview

912 iS Fuel Injected Aircraft Engine

1989

Human

Eyes/Ears
Hands/Feet

Mechanics

Electrics

912ULS

2012

Human

Eyes/Ears
Hands/Feet

Mechanics

Electrics

Control

Calibration

Electrics/Electronics

912iS

Rotax 912 iS - FH Joanneum,
Thomas Goigitzer
Fuel Efficiency

- Break Specific Fuel consumption comparison at sea level

- Break Specific Fuel consumption at 5500 engine rpm over altitude
Fuel Efficiency

Test flight comparison

Measured average fuel consumption on the test aircraft:

- Benchmark engine: 17.6 l/h
- EFI equipped engine: 12.3 l/h.

⇒ 30% fuel consumption reduction
Electric & Electronics

Requirements

- Requirement: Electronic fuel injection
- Requirement: Aviation safety

The 912iS Engine Management System

- ECU consists of two separate control units, so called “Lanes”
- Redundant engine control system is capable of managing the redundant components
- Redundant implementation of all safety-critical sensors and actuators

Lane A  Lane B

Highly redundant Engine Management System with intelligent redundancy management
Electric & Electronics

Implementation of safety-critical sensors

Redundant actuators

Redundant sensors
Electric & Electronics

Redundant Power Supplies

- The 912 engine management system is supplied by redundant regulated power supplies.
  - Two permanent magnet generators
  - Two independent regulators
  - Power distribution unit (Fuse Box)

- System A permanent magnet generator and regulator is assigned for supplying the EMS system only.

- System B permanent magnet generator and regulator is assigned for supplying the aircraft system.
Ignition System

- **Sp1, SP3:** Double ignition coils assigned to Lane A
- **Sp2, SP4:** Double ignition coils assigned to Lane B
- **1B...4B:** Spark plugs assigned to Lane A
- **1T...4T:** Spark plugs assigned to Lane B
Electric & Electronics

Injection system

Auto AB mode

Auto A mode

Auto B mode

<table>
<thead>
<tr>
<th>Pair</th>
<th>Phase 1</th>
<th>Phase 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cylinder 1</td>
<td>Injector 1</td>
<td>Injector 5</td>
</tr>
<tr>
<td>Cylinder 2</td>
<td>Injector 2</td>
<td>Injector 6</td>
</tr>
<tr>
<td>Cylinder 3</td>
<td>Injector 3</td>
<td>Injector 7</td>
</tr>
<tr>
<td>Cylinder 4</td>
<td>Injector 4</td>
<td>Injector 8</td>
</tr>
</tbody>
</table>

A single revolution of the engine is defined as one PHASE of the injection process. 50% of fuel required for cylinder 1 is injected per engine revolution.
Electric & Electronics

Galvanic Separation of Engine and Aircraft

Complete separation of the EMS electrical ground from any vehicle ground

- Increased robustness against direct and indirect effects of a lightning strike
- Robustness against any type of short to vehicle failure
Control Strategy

Redundancy Management - Software algorithms

Lane declares **Fault**
- Possible loss of functionality, not significant enough
- to force a change in system mode.

Lane declares **Failure**
- Critical functionality has been lost and a change to
- a different system mode is required.
## Control Strategy

### Redundancy Management

#### System Modes

<table>
<thead>
<tr>
<th>System Mode</th>
<th>Description</th>
</tr>
</thead>
</table>
| AUTO_A      | Both Lanes Powered  
A Commands Fuel and Ignition |
| AUTO_B      | Both Lanes Powered  
B Commands Fuel and Ignition |
| AUTO_AB     | Both Lanes Powered  
A and B Command Fuel and Ignition  
A Drives B |
| ONLY_A      | A Powered  
A Commands Fuel and Ignition |
| ONLY_B      | B Powered  
B Commands Fuel and Ignition |
| INIT        | A and/or B Initializing |
## Electric & Electronics

### Redundancy Management

#### Warning lamp matrix:

<table>
<thead>
<tr>
<th>Index</th>
<th>ECU operation mode Lane A</th>
<th>ECU operation mode Lane B</th>
<th>Warning Lamp Lane A Status</th>
<th>Warning Lamp Lane B Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Off</td>
<td>Off</td>
<td>not illuminated</td>
<td>not illuminated</td>
</tr>
<tr>
<td>2</td>
<td>Boot up</td>
<td>Boot up</td>
<td>Lamp Test</td>
<td>Lamp Test</td>
</tr>
<tr>
<td>3</td>
<td>Normal</td>
<td>Normal</td>
<td>not illuminated</td>
<td>not illuminated</td>
</tr>
<tr>
<td>4</td>
<td>Normal</td>
<td>Off</td>
<td>not illuminated</td>
<td>continuous illuminated</td>
</tr>
<tr>
<td>5</td>
<td>Off</td>
<td>Normal</td>
<td>continuous illuminated</td>
<td>not illuminated</td>
</tr>
<tr>
<td>6</td>
<td>Fault</td>
<td>Off</td>
<td>continuous illuminated</td>
<td>continuous illuminated</td>
</tr>
<tr>
<td>7</td>
<td>Failure</td>
<td>Off</td>
<td>continuous illuminated</td>
<td>continuous illuminated</td>
</tr>
<tr>
<td>8</td>
<td>Off</td>
<td>Fault</td>
<td>continuous illuminated</td>
<td>flashing</td>
</tr>
<tr>
<td>9</td>
<td>Off</td>
<td>Failure</td>
<td>continuous illuminated</td>
<td>continuous illuminated</td>
</tr>
<tr>
<td>10</td>
<td>Fault</td>
<td>Normal</td>
<td>flashing</td>
<td>not illuminated</td>
</tr>
<tr>
<td>11</td>
<td>Normal</td>
<td>Fault</td>
<td>not illuminated</td>
<td>flashing</td>
</tr>
<tr>
<td>12</td>
<td>Failure</td>
<td>Normal</td>
<td>continuous illuminated</td>
<td>not illuminated</td>
</tr>
<tr>
<td>13</td>
<td>Normal</td>
<td>Failure</td>
<td>not illuminated</td>
<td>continuous illuminated</td>
</tr>
<tr>
<td>14</td>
<td>Fault</td>
<td>Fault</td>
<td>flashing</td>
<td>flashing</td>
</tr>
<tr>
<td>15</td>
<td>Fault</td>
<td>Failure</td>
<td>flashing</td>
<td>continuous illuminated</td>
</tr>
<tr>
<td>16</td>
<td>Failure</td>
<td>Fault</td>
<td>continuous illuminated</td>
<td>flashing</td>
</tr>
<tr>
<td>17</td>
<td>Failure</td>
<td>Failure</td>
<td>continuous illuminated</td>
<td>continuous illuminated</td>
</tr>
</tbody>
</table>
# Mechanical Impact

**Overview**

The Implementation of this unique EMS System forced nearly all mechanical systems on the engine to be changed:

<table>
<thead>
<tr>
<th>System</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crankcase</td>
<td>changed</td>
</tr>
<tr>
<td>Cranktrain</td>
<td>changed</td>
</tr>
<tr>
<td>Cylinderhead</td>
<td>changed</td>
</tr>
<tr>
<td>Gearbox/ transmission</td>
<td>changed</td>
</tr>
<tr>
<td>Induction system</td>
<td>changed</td>
</tr>
<tr>
<td>Fuel system</td>
<td>changed</td>
</tr>
<tr>
<td>Lubrication system</td>
<td>changed</td>
</tr>
<tr>
<td>Exhaust system</td>
<td>changed</td>
</tr>
<tr>
<td>Engine management system</td>
<td>changed</td>
</tr>
<tr>
<td>Cooling system</td>
<td>unchanged</td>
</tr>
<tr>
<td>Electric components</td>
<td>changed</td>
</tr>
</tbody>
</table>
Mechanical Impact

**Generator Performance**

- Yellow line: Generator Lane A
- Blue line: Generator Lane B
- Pink line: Engine / EMS System need

**Resulting Generator Temperatures**

- Yellow line: Temp. Lane A, Oil 135°C
- Green line: Temp. Lane A, Oil 100°C
- Blue line: Temp. Lane B, Oil 135°C
- Pink line: Temp. Lane B, Oil 100°C
Mechanical Impact

Generator Design Changes

Base engine air cooled generator
Oil cooled generator
Questions?