특별강연 II

"T-50 초음속 고동훈련기 복합제 적용사례 및 향후 발전방향"

장성섭 상무 (한국항공우주산업(주))
T-50 Supersonic Advanced Trainer
Composite Application and Future Plan

November 2005
Korea Aerospace Industries, Ltd

1. Introduction of KAI Engineering
R&D Manpower

Total: 2,750 Employees

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<tr>
<th>Admin</th>
<th>186 (10%)</th>
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<tr>
<td>Plan/Biz Dev</td>
<td>125 (4%)</td>
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<td>Manufacturing</td>
<td>760 (26%)</td>
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<td>Engineering</td>
<td>1,679 (60%)</td>
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<td>MS/PHD</td>
<td>335 (20%)</td>
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<td>BS</td>
<td>798 (48%)</td>
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<td>Other</td>
<td>546 (33%)</td>
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<td>10+ Years</td>
<td>977 (56%)</td>
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<td>5-10 Years</td>
<td>438 (26%)</td>
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<td>Less than 5 Years</td>
<td>297 (18%)</td>
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By Function

- Aero/Mech/Elec/SW Area Technology Oriented
- Engineering (R&D, Mfg Tech): 58% of Total

Certifications of Engineering

Boeing Assigned Design Delegation Level 4

Acquired: 12 Mar 02
- International Certification For Aircraft Design, Analysis, Manufacture and Test

CMMI Maturity Level 3

Acquired: 28 May 04
- Certification For Avionics And Flight Controller Design (DoD Bid Approved)

Korea Best Top 10 Technology (T-50 Development)

Acquired: 27 Dec 02
- National Approval For T-50 Development
KAI's Engineering INFRA

Research & Development INFRA
- Research S/W & Technical Data
- COMOK, MPDB
- About 1,000 Engineers

Manufacture INFRA
- Part Assembly Facility
- Part Processing Facility
  - Sheet Metal, Composite,
    Heat & Surface Treatment

Test INFRA
- Ground Test Facility & Ability
  - Structure, System Integration
  - Avionics, Flight Control
  - Flight Test Facility & Ability

✓ Design/Manufacture/Test INFRA For Supersonic Fighter
⇒ High Quality, High Precision, High Reliability Foundation
To Assure Successful Research & Development

2. Composite Features of KAI

- KAI's Composite Development Experiences
- Composite Development
  For T-50 Supersonic Advanced Trainer
- On-Going Programs
- Future Plan
Composite Trend

Year of First Flight

Commercial Aircraft

Military Aircraft

KAI's Composite Experiences

SB427/All Composite A/C
KT-1/UAV

429M/B787/A350/
A320/KHP

Biz Jet/Fighter/Helicopter

Small Sized Aircraft

- Wet Lay-up Method
- Conventional Autoclave Method
- Experimental All Composite Aircraft

T-50

T-50 "Golden Engle"

- Indigenous Composite Development for Production Aircraft
- T-50A-59 Composite Empennage

On-Going Project

- Big Part Fabrication
- New Material Application
- RTM Method Development

Future Project

- Data Base of New Material
- Upgraded RTM Method
- One Piece Wing Box
- One Piece Fuselage

Current Phase:
Accumulations of Composite Experience

Next Phase:
New Technology Application

-9-
Twin Engine All Composite Aircraft

- Proof-of-Design Concept Aircraft – 8 Passenger Twin Engine All Composite Aircraft
- Co-development Program with KARI (Korea Aerospace Research Institute)
- Major Development Schedule
  - '93.10 ~ '95.5 Co-Development
  - '95.5 ~ '96.5 Production (2 Shipsets)
  - '96.6 ~ '97.6 Static, Flight Test
- Characteristics
  - Dimension: 35.0 ft(L) × 43.3 ft(W) × 13.9 ft(H)
  - MTOW: 7,000 lb
- All Composite A/C: One-Piece Wing, Two-Pieces Fuselage

Twin Engine All Composite Aircraft
(Composite Details)

Major Parts Assembly

- All Composite A/C: One-Piece Wing, Two-Pieces Fuselage
- Material: Gr/Ep, GI/Ep Tape & Fabric
- Skin: Honeycomb Core Sandwich Structure
- Mfg. Method: Autoclave Curing
- Bonding Method: Co-curing & Secondary bonding

-11-
SB 427 Helicopter

- 8 Seat Twin Engine Helicopter Co-Development with Bell Helicopter
  - Co-Development & Certification
  - Detail Fabrication & Assembly
  - Tool Manufacturing
  - Final Assembly and Sales in Asia

- Major Development Schedule
  - '96 ~ '99 Co-Development
  - '97 ~ '98 Flight Test
  - '00. 1 FAA Certificate
  - '00. 12 Initial Production

- Total $86 M KAI’s Investment and 73 Engineers’ Participation

SB 427 (Composite Parts)

- All Composite Design of Fuselage Structure
- 8 Passenger Commercial Helicopter
- Major Composite Parts: Rotor Blade, Hub, Stabilizer, Side Body Panel, Floor, Cowling

One Piece Side Body Composite Panel
KT-1 Basic Trainer

- Basic Trainer Aircraft Indigenous Development
  - Program to Replace ROKAF’s Aged T-37 and T-41 Fleets

- Characteristics
  - Dimension: 10.3M(L) × 10.6M(W)
  - Speed: 350 KIAS
  - MTOW: 2,500kg
  - Load Limit (G): ±7.0~3.5
  - Engine: P&W PT6A-62 (950 SHP)

- Schedule
  - Development: 1988~1999
  - Production: 1999~2004
  - Derivative Development: 2003~

- Korea’s First Aircraft Exported

KT-1 Basic Trainer (Composite Parts)

- COWLINGLOWER
- COWLING_UPPER
- EXTERNAL FUEL TANK
- WING BODY FAIRING
- SPEED BRAKE
- DORSAL FIN
- TRIM TAB RUDDER
- TRIM TAB_ELEVATOR
- CANOPY
- CFRP ROD
- MLG BAY DOOR OUTBOARDS
- Fuselage Access Doors
- MLG BAY DOOR INBOARDS
- Fuselage Tip Fairing
UAV

Night Intruder 300 (UAV)
- Tactical Unmanned Aerial Vehicle for ROKAF & International Markets
- KAI Development Program (Technical Support by ADD)
- Characteristics
  - Max Speed: 111mph (185kph)
  - MTOW: 640lbs (290kg)
  - Engine: 1X50hp rotary engine
  - Endurance: 6.0hrs
- Major Milestone
  - 1991 Conceptual Design Begined
  - 1996 First Flight Performed
  - 2000 FSD Completed
  - 2001 Initial Production Auth. Signed

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UAV (Composite Parts)

- Fuselage
- Wing
Composite Development For T-50 Supersonic Advanced Trainer

T-50 Supersonic Trainer

T-50 / A-50 Golden Eagle

- Advanced Trainer and Light Attack Aircraft for ROKAF and International Markets
- Full Scale Development (1997. 10 ~ 2005. 9)
  - 2 Structural Test A/C
  - 4 Flight Test A/C

T-50
Advanced Trainer
(-Radar, Gun)
- High Training Effectiveness
- High Energy Management
- Superior Aero Performance
- Economic & Highly Efficient Supersonic Advanced Trainer

A-50
Lead-in Fighter Trainer
(Baseline)
- APG-67 Radar
- Weapon System
  - Gun & AIM-9
  - Bombs & AGM-65
- LIFT with Light Combat Aircraft Capability

F-50
Light Combat Aircraft
(+ Survivability, Night Navigation)
- Survivability
  - RWR, CMD
- Night Attack
- FLIR
- Tactical Data Link
- Day/Night Attacker

- Light Combat Aircraft Capability
- Growth Potential to be a Fighter Class Aircraft
T-50 Supersonic Trainer (Composite Parts)

Vertical Tail
- Skin(LH/RH): Carbon/Epoxy
- LE, TE: Al skin, Al Honeycomb Bonded

Rudder
- Skin(LH/RH): Carbon/Epoxy
- Al Honeycomb Bonded

Horizontal Tail
- Upr/Lwr Skin: Carbon/Epoxy

Wing
- LE Flap, Flaperon, Fixed TE: Al Honeycomb+ Al Skin Bonded

Radome
- E-Glass/Epoxy

Transparency
- Monolithic Stretched Acrylic

Major Composite Part of Empennage

Empennage ISO View

Vertical Tail Assy (Carbon/Epoxy Skin)

Tip Trailing Edge (Al Honeycomb Sandwich)

Rudder Assy (Carbon/Epoxy Skin + Al Honeycomb Sandwich)

Leading Edge (Al Honeycomb Sandwich Structure)

Horizontal Tail Assy (Carbon/Epoxy Skin)
**Vertical Tail Assy**

**Vertical Tail Skin**

- Material: Carbon/Epoxy Prepreg
- OML : Glassfiber/Epoxy Prepreg
- IML : Glassfiber/Epoxy Prepreg
- Number of Ply (18-92 Ply)
  - Tip : 0° 20% / ±45° 80%
  - Root: 0° 45% / ±45° 55%
  - Actuator Attach: 90° 8 Ply
- Max Ply : 92 Ply (Attach Fitting Area)
- Min Ply : 18 Ply (Tip Area)

**Horizontal Tail Assy**

**Horizontal Tail Skin**

- Material : Carbon/Epoxy Prepreg
- OML : Glassfiber/Epoxy Prepreg
- IML : Glassfiber/Epoxy Prepreg
- Number of Ply (12-56 Ply)
  - Root : 0° 33% / ±45°
    52% / 90° 15%
  - Tip : 0° 20% / ±45°
    40% / 90° 40%
- Max Ply : 56 (Pivot Area)
- Min Ply : 12 (Trailing Edge Area)
**Rudder Assy**

**Rudder Skin**

**ISO View**

- Material: Carbon/Epoxy Prepreg
- OML: Glassfiber/Epoxy Prepreg
- IML: Glassfiber/Epoxy Prepreg
- Bonding Ply: Glassfiber/Epoxy Prepreg
- Number of Ply (6 - 21 PLY)
  - Root: 0° 34% / ±45° 66%
  - Tip: ±45° 100%
- Max Ply: 21 (Low Spar Area)
- Min Ply: 6 (Wedge Area)

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**Stress Analysis (1)**

- **Strength Analysis**
  - Ply Pattern Analysis of Structures
    - Ply by Ply of FEM
    - First Ply Failure
    - Maximum Strain Failure Criteria
  - Joint Analysis
    - Mechanical Fastener: Bearing/Bypass Interaction Diagram
    - Bonding: Shear Allowable of Adhesive
Stress Analysis (2)

- Buckling Analysis
  - FEM Approach Using NASTRAN
  - Hand Calculations Using Composite Buckling Formula

- DaDT Analysis
  - Open Hole Allowables Used
    - Open Hole Tension
    - Open Hole Compression
    - Open Hole Shear

- Dynamic Analysis
  - Flutter Analysis (Fullscale)
  - Panel Flutter Check
  - Acoustic Fatigue Check

Test & Evaluation (1)

- Verification Test of Material Allowables

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<tr>
<th>Items</th>
<th>Tensile Test</th>
<th>Flexural Test</th>
<th>Open Hole Tension Test</th>
<th>Filled Hole Tension Test</th>
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<tr>
<td>Items</td>
<td>Bearing Tension</td>
<td>Al Double Lap Shear Test</td>
<td>Al/C/Ep Double Lap Shear Test</td>
<td>Flatwise Tension Test</td>
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Test & Evaluation (2)

- Fullscale Static Test
  ✓ Detrimental Deformations Including Delaminations Shall Not Occur at or Below Limit Loads
  ✓ Catastrophic Failures Shall Not Occur at or Below Ultimate Loads
  ✓ Include Vertical Tail and Rudder

- Fullscale Durability Test
  ✓ The Durability of the Airframe Shall Be Adequate to Resist Fatigue Cracking, Corrosion, Thermal Degradation, Delamination and Wear During
  ✓ Airframe Shall Be Sufficient to Withstand the 2 Service Life
  ✓ Include Vertical Tail and Rudder

Test & Evaluation (3)

Durability & Damage Tolerance Test

- Durability & Damage Tolerance Test (H/T)
  ✓ A Separate Component Test Specimen
  ✓ Demonstrate Compliance with Durability Specification Requirements and Damage Tolerance Requirements for the Composite Skins
  ✓ Show Two-lifetime Service with Service-generated Nuisance Damage
On-Going Programs

- Bell 429M
- B787
- A350
- A320
- KHP
- KFX

Bell 429M Program

- Bell 429M
  - Design/Build Package

![Diagram of Bell 429M Helicopter]

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2005

- About 40 Engineers Dispatched
  (2005. 6. 20 ~ )
Boeing 787 Program

- Boeing 787
  - Design/Build Package
    - Wing Sec. 11
  - Fixed Trailing Edge

- CATIA V.5 Composite Design (CPD / FiberSim)
- New Manufacturing Equipments to be Purchased

- AUTO TAPE LAYUP M/C
- HOT DRAPE FORMING
- IMMERSION C-SCAN

Boeing 787 Program (Wing Sect. 11)

- Front Spar
  - (2.5 x 5.7 m, 80 plies)
  - CFRP Web / Stiffener

- Rear Spar
  - (1.2 x 5.7 m, 110 plies)
  - CFRP Web / Stiffener

- Spanwise Beam
  - (1.5 x 5.6 m, 80 plies)
  - CFRP Web / Stiffener

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- About 10 Engineers at Fuji, Japan (2005. 8 ~ 2006.2)
Boeing 787 Program (Wing FTE)

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- About 33 Engineers at Seattle (2005. 4 ~ 11)
- About 70 Engineers at Sachon, Korea (2005. 12 ~ 2006.10)

A350 Program

- Potential A350 Wing Package
- Skin Panel (Top, Bottom)
- Size: Length 30 M, Width 6 M
- Big Size One-Piece Composite Structure (Skin + Stringer Co-Bonded)
- Winglet/Tip
- Size: Height 7 M, Width 5 M
- Composite /Metal Assembly (Composite Skin + Metal Rib)
- LE Assy
- 30 M Long One-Piece Composite Spar (Composite Spar + Metal Rib & Skin)
A350 Program

- New Forming Method Application for Spar
  - Current Method
    - Constant sectional Stringers
    - Shorter than 12m
  - Requirement
    - Thickness Variant Stringers
    - 30m Long

Development of New Flexible Hot Forming Method

- Roller Assembly
- PREPREG Laminate
- Lay-up Mandrel
- Parting Film
- Roller Assembly Direction

A350 Program

- Major Equipment for A350
  - Automated Tape Layer
  - Autoclave
  - 5x Milling M/C
  - U.T C-Scanner
Joint Study of A320 Wing

- New RTM Technology Development for Composite Wing
  - Honeycomb core Sandwich Structure
  - Foam core box beam
  - Structural I-beam
  - Structural box beam
  - Leg Shell
  - Corrugated I-beam
  - Thick Composite
  - Large Plate

KHP (Korea Helicopter Program)

Background
- Replacement for ROK Army’s Obsolete Helicopters:
  - UH-1H (Over 30 Years in Service)
  - 500MD (Over 25 Years in Service)
  - AH-1S (Replacement after Y2012)

Overview
  Serial Production (2010 ~ 2020, 000 A/C)
- Prototypes: Flight Test 5 A/C, Ground Test 4 A/C
- Accommodations: Pilots 2, Crews 2, Troops 7~9 (Total 11~13)
- Weight: 15,000 lbs

In Major Structures including Rotor Blades,
Composite Materials to be Used
**KFX Program**

- One Piece Composite Wing
- One Piece Composite Vertical Tail
- One Piece Composite Horizontal Tail
- One Piece Composite Fuselage Section

**New Technology Development**
- RTM Method Application
  - Wing
  - Horizontal Tail
  - Vertical Tail
- Autoclave Application
  - Fuselage
  - Radome
  - Bonded Structure

**Future Plan**

- Stealth Technology Application
- Large Scale Composite Structure
- Automatic Manufacturing System

Composite Technology Level

Advanced Trainer
Military/Fighter
Commercial/Helicopter


Commercial Aircraft / Biz Jet
KFX