Kobe Steel’s Activities in Aerospace

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Shinya Ishigai
Titanium Technology Department
KOBE STEEL, LTD.
Contents

- Titanium Market of Aerospace in Japan
- Development Programs for Airplanes and Jet Engines
- State of Manufacturing Technologies
  - Die Forging
  - Near Net Ring Rolling
- Developed Alloys with Excellent Formability
Mill Product Shipments by Applications in Japan

Total amount of shipment in 2006 was 17,317 tons

- Consumer & Medical 7.3%
- Sports 3.1%
- Desalination 1.2%
- Ships 1.2%
- Aerospace 6.8%
- Automotive 9.3%
- PHE 20.5%
- Chemical 9.4%
- Electric Power 14.9%
- Electrolysis 8.5%
- Others 6.2%

- Forgings for Engine (Disk, Blade, Shaft, Case etc.)
- Forgings for Airframe (Fittings, Bulkhead)
- Titanium Alloy Plate & Sheet
- CP Titanium Sheet
## Recent Development Programs for Civil Airplanes and Jet Engines in Japan

<table>
<thead>
<tr>
<th>Airplane</th>
<th>1980’s</th>
<th>1990’s</th>
<th>2000’s</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domestic Defense</td>
<td></td>
<td>C-X</td>
<td>P-X</td>
</tr>
<tr>
<td>Boeing</td>
<td></td>
<td>B777</td>
<td>B787</td>
</tr>
<tr>
<td>Regional Jet</td>
<td></td>
<td></td>
<td>MRJ</td>
</tr>
<tr>
<td>Business Jet</td>
<td></td>
<td>Honda JET</td>
<td></td>
</tr>
<tr>
<td>Jet Engine</td>
<td>1980’s</td>
<td>1990’s</td>
<td>2000’s</td>
</tr>
<tr>
<td>IAE</td>
<td>V2500</td>
<td>GE90</td>
<td>GEnx</td>
</tr>
<tr>
<td>GE</td>
<td></td>
<td>Trent900</td>
<td>Trent1000</td>
</tr>
<tr>
<td>RR</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Regional Jet</td>
<td>CF34</td>
<td>Eco Engine</td>
<td></td>
</tr>
<tr>
<td>Honda</td>
<td></td>
<td>HF120</td>
<td></td>
</tr>
</tbody>
</table>
Japanese Developed Airplanes

Transport Cargo Plane C-X

Both planes were launched in September 2007

Patrol Plane P-X

Designed and Assembled by KHI

Photos: Courtesy of Asagumo Shimbunsha Inc.
Regional Jet

- Full Composite Wing and Body
- 70 – 90 Passengers
- Large Cabin Space
- Comfortable Seats
- Expected Launch in 2012

Mockup model of MRJ exhibited in 2007 Paris Air-show
HONDA Business Jet

- Over-the-wing Engine Mount
  Lower Drag, Larger Cabin Space
- All Composite Fuselage
- Original Developed Turbo Fan Engine “HF120”
- Lightweight, Fuel-efficient, Low-Emission

Photos:Courtesy of Honda R&D Co.,Ltd
Turbo Fan Engines

Japanese manufactures of aero-engines have joined new engine development programs for B787

GEnx Engine

Trent 1000 Engine

-Photo: copyright Rolls-Royce plc
V2500 Turbo Fan Engine

Photos: Courtesy of Kawasaki Heavy Industries
Trent 900 Engine

Ti-6Al-4V IPC CASE
Manufactured by Near Net Ring Rolling

Photos: Courtesy of Rolls Royce plc
Key Points to Grow-up the Amount of Titanium Alloy for Civil Airplane

➢ Reliability, High Quality

Stable manufacturing procedure based on sophisticated forging technologies contribute to achieve reliability of material.

➢ Cost Reduction

Reduce material input weight by achieving “Near Net Shape” forging.
Reduce forging cost through using material with excellent formability.
Titanium Forgings for Civil Aero-engine

Titanium alloys used for jet engines:
- Ti-64, Ti-811, Ti-6242S, Ti-17, Ti-6246, IMI834 etc.
Forging Technology of High Strength Ti-6Al-2Sn-4Zr-6Mo HPC Disk

- High strength
- Higher fracture toughness

Full acicular microstructure through β processed final forging

A) Microstructure of conventional α + β forging
- High fatigue strength
- High elongation
- Low fracture toughness
- High speed crack propagation

B) Microstructure of β-processed forging
- High fatigue strength
- Low elongation
  - High fracture toughness
  - Slow crack propagation

Ti-6246 Forged Disk (700 mm dia.)
Simulation Analysis for Die Forging

- It is important to control material temperature and forging strain during die forging in order to achieve superior material properties.
- Forging simulation analyses are very useful and necessary to establish proper forging conditions (Deformation, Temperature, Cooling rate analysis on forging and solution heat treatment)
- β-processed Ti-6-2-4-6 disk forged by computer controlled hammer
Example of Simulation Analysis for Die Forging

Change of material temperature distributions during die forging
Near Net Ring Rolling

Fan Case of V2500 Engine (Ti-6Al-4V, 1700mm dia.)

IPC Case of Trent 900 Engine (Ti-6Al-4V, 1200mm dia.)
Example of Simulation Analysis for Near net ring rolling
High Cost-performance Alloys

We propose two kinds of developed titanium alloys with superior formability to apply for airframe material, “KSTI-9” and “KS EL-F”

✓ Expensive?
Are titanium alloys difficult to be rolled or forged?

🌟 Change the image of Titanium alloy by using of our advanced alloys !!

➢ These alloys have excellent formabilities with equal and higher mechanical properties than Ti-6Al-4V !

1) Coilable alloy;
   KS TI-9 (Ti-4.5Al-2Mo-1.6V-0.5Fe-0.3Si-0.03C)

2) Easy to forge alloy;
   KS EL-F (Ti-4.5Al-4Cr-0.5Fe-0.2C)
Coilable Alloy “KS TI-9”

- Cold Rolled in coil to coil as same as CP titanium
- Capable of SPF/DB

KS TI-9 (ASTM G35)

2.0 t mm

SPF/DB
Honeycomb structure

Smooth axial fatigue properties of KS TI-9 1.2 mm thick sheet
Advantage of KS Ti-9 Compared with Ti-6Al-4V

Process for Sheets of Ti-6Al-4V
- Should be cut and hot rolled with steel pack
- Low Productivity
- Higher Cost

Process for Coil Strip of KS Ti-9
- Cold rolled in coil to coil by the steel mills with high productivity

Temperature
- β transus 965°C
- Breakdown Forging
- Rolling
- Hot Rolling
- Ann. & Pickling
- Cold Rolling
- Cold Strip

KOBE STEEL, LTD. Proprietary Information
Advantage of KS EL-F

- Extra Low flow stress and excellent hot forge-ability
- Easy to make precision net forgings as same as steel
- Reduce material input weight, reheating times in forging, and defects

Temperature dependence on tensile strength compared with KS EL-F and Ti-6Al-4V
Summary

The amount ratio of titanium product shipment for aerospace market is about 7% in Japan.

There are many development programs of civil airplanes and jet engines in Japan.

Reliability and high quality required to aerospace material can be achieved by sophisticated forging technologies, such as computer controlled forging and near net ring rolling supported by simulation analysis.

Our developed titanium alloys with excellent formability have great advantage on cost reduction.