Advances in Aerospace
Structural Titanium Forging Technology

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Wyman-Gordon Forgings

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San Diego, CA
Forging Presses and Other Grafton Capabilities

- Raw material conversion
- Heat treatment
- Forging machining
  - Rough and target machining
- Die machining
  - New die sinking
  - Existing die modification and refurbishment
- NDT
  - Sonic inspection
  - Penetrant inspection
  - Magnetic inspection
- Chemical etching and milling
- 3D forging surface scanning
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Grafton Product Lines

**Industrial Gas Turbine**

- WG 18088
  - 7FA Stage 1/2 Spacer
  - 10,000+ Lbs. Inconel 706

**Landing Gear**

- WG 18305/06
  - A320 Main Fitting
  - 3,700+ Lbs. Alloy Steel

**Airframe**

- WG 11238
  - F-35 Bulkhead
  - 6,000+ Lbs. Ti 6Al-4V ELI
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F-35 Program
59 New Forgings
Across 3 Aircraft Variants
Titanium and Steel

Mid-Fuselage 496 CV Bulkhead
(6,000+ lbs Ti)

Aft, Mid-Fuselage & Landing Gear Forgings
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787 Program – 24 New Forgings

MLG Main Fitting (10,000 Lbs. Steel)
9 ft.

Door Frame (400+ Lbs. Ti 6-4)
12 ft.
3D Design & Simulation

3D CATIA Forging Design

Tooling Design & Simulation

Tooling Die Stress Analysis

Forging Process Simulation

3D Forging Surface Scanning
Forging Process Simulation – FEA Modeling

Culture and Technology

- 3D modeling now routine
- Every metalworking operation is modeled
  - Open-die and closed-die
  - New part development
  - Re-engineering of older jobs
  - Cost reduction
  - Die stress analysis
  - Problem solving and process improvement

Software

- Transvalor Forge 3D
- Deform

Modeling Reports Database

- CY2009 – 314 reports
- CY2010 – 371 reports
- CY2011 256 reports to-date
- Database of simulation vs. execution
Process Modeling Example – Open Die Operation

Simulation shows how the work piece deforms under the applied boundary conditions and is used to properly design the work piece and tools.

- Bend/Edge Operations
- Cogging Operations
- Upset Operations
Open Die Forging Example – Simulation and Execution
Ti-6Al-6V-2Sn Retract Bracket Example – Simulation and Forging Blocker Forge Step

- Evaluate die fill – verify volume allocation of the input to the output
- Eliminate material flow defects
- Evaluate/determine forging loads
- Evaluate tool loads

18,000 Ton Press
Ti-662 Retract Bracket Example – Simulation and Forging Blocker Forge Step

Engineered Result

Production Photo
Ti-662 Retract Bracket Example – Simulation and Forging
Finish Forge Step

18,000 Ton Press
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Ti-662 Retract Bracket Example – Simulation and Forging
Finish Forge Step

Press Data Monitoring System
Landing Gear Closed Die Forging Process Modeling

- Large or Small
- Complex or Simple
- 1 forge operation or 8 forge operations
Process Simulation Tooling Design

- Determine potential die impression failures and redesign the process before the tools are manufactured
- Determine adequate tool size to reduce the cost of over designed tools
- Evaluate side loads that could result in leader pin/tool failure
Process Simulation: Material Flow Design

- Predict material flow defects
- Modify the work piece geometry or dies or both to remove the risk
F-22 Center Frame Product Family
F-22 Center Frame Forging Process

Billet → Finish Forged Product
Center Frame Burn

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Oxy–Acetylene Torch (NC)
Center Frame Burn
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Center Frame Bend

- 35,000 Ton Press
- Horizontal Bend
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Center Frame Bend
Center Frame Blocker Forge

- 35,000 Ton Press
- Closed Die
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Center Frame Blocker Forge
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Center Frame Finish Forge
Simulation Reports

- Summary of results by the Process Modeling Manager
- Summary of the environment conditions
- Link to the “movie” of the simulation
- Location of the work piece in the tools
- Result of the simulation
- Forging loads
Simulation Database

- List of all simulations performed
- History of design changes made to reach the final design
- Use previous simulations to design new forgings with similar properties
- Simulations are run on every step of the entire forging process

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Simulation vs. Production Photos

• Shows accuracy of forging simulations
• Gives production a tool to view what forging processes should yield
• Tracks results of process improvements / cost reductions
Simulation Accuracy

Simulation Result

Production Photo
787 Door Frames

- Multiple lengths, cross sections and bend geometries
- Optimization requires multiple dies, starting stock sizes, etc.
- How to minimize tooling and production costs?
4” plate @ 3,000 lbs

Input weight per frame (Plate) 1,000 lbs

Input weight per frame (Forging) 425 lbs

Solids per Frame (Plate) 400 lbs

Solids per Frame (Forge) 80 lbs

Chips per frame (Plate) 550 lbs

Chips per frame (Forge) 295 lbs

Ti total Plate “losses” 950 lbs

Ti total Forge “losses” 375 lbs

575 lbs/frame ‘Ti-savings’ using Forging
22 frames per plane
575 lbs X 22 frames = 12,650 lbs
96 planes/year X 12,650 lbs
~ 1,000,000 lbs per year

~ 50 lb Machined Part

575 lbs X 22 frames = 12,650 lbs
96 planes/year X 12,650 lbs
~ 1,000,000 lbs per year
Customer Design – Non-Optimized
More than 200 pounds material savings

Neat: 418#
PVA: 965

Input: 5.75 Dia @ 614#
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Finalized Material Requirements

- Engineered stock sizes for highest material efficiency
- Finalized and approved all stock sizes for procurement
- Negotiated dimensional requirements with TMX/mills
- Developed material ordering specification
- Instrumental in material handling equipment design

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Range of Sizes and Bend Depths

WG 11072/73

WG 11080/81

WG 11077
35kT Press Multiple Ram Capability

- 2-step forging cycle (bend/finish) in one heat
- Mechanically controlled process
- Reduced Cycle Time
- Reduced Variable Cost
- Repeatability
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Initial FEA Forge Process Simulation
Initial CATIA Design

- Quick Change Tooling
- Bender Slide
- Common Bolster
- Stock Locators
Tooling Design

Design Objectives:

- Design a common bolster (that would run at room temperature)
- Design part specific tooling
- Design tooling with safety in mind
- Design for minimal tooling setup time
- Achieve a minimal forge process cycle time (semi-automated process < 3 minutes)
- Design part quality into the tooling (reduce human error)
- Develop tooling standards to reduce design and manufacture lead-time
- Engineer for broadest component diversity

- Modular Component Tools
- P/N Specific

Common Tooling Assembly
Door Frame Forging Process
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Manufacturing Implementation - Forge

- Handling technique
- Lubrication practices
- Cycle reductions
- Operator/crew training
Consistency of Forging Results
Validation of Forging Results

Simulation Results

Production Results
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Grafton Bulkhead Experience

**F22 Bulkhead**
- Dimensions: 160 x 65 x 7
- Buy-to-fly: 11:1
- Finish: 5500 sq in
- Preform: 5
- Finish: 5

**F35 Bulkhead**
- Dimensions: 205 x 79 x 18.5
- Buy-to-fly: 9:1
- Finish: 6300 sq in
- Preform: 3
- Blocker: 5
- Finish: 3

Forge Operations