LIGHTWEIGHT ALLOYS FORGING 101
FORGING INDUSTRY ASSOCIATION
Presenters

Weston Gillfillan/Jim Kravec – Weber Metals
Scientific Technology (Contributor)
Nicolas Poulain - Transvalor
Roger Rees – SMS Meer
Agenda

- What is a lightweight alloy
- What is forging
- Applications for lightweight forgings and projections
- Challenges of Ti and AL forgings
- Forging Simulations (Deform/Transvalor)
- Forging Equipment (SMS Meer)
- FIERF Magnesium Project Update
What is a Lightweight Alloy

Non-Ferrous Metals
- Aluminum
- Titanium
- Magnesium
A MANUFACTURING PROCESS WHERE METAL IS PRESSED, POUNDED, OR SQUEEZED UNDER GREAT PRESSURE INTO HIGH STRENGTH PARTS KNOWN AS “FORGINGS.”
What is Forging? (Continued…)

- Forging is a bulk forming process where metal is deformed into shaped components.
- It can be performed cold, warm, or hot.
  - With warm and hot forging, there is a required preheating operation.
- Input material can be an ingot, billet, bar, wire, or a preformed shape.
- Forging is a solid-state process. This is unlike casting, where the metal is melted and poured into a mold.
- It is also a constant volume process (unlike welding or machining).
Forging Basics
Forging Processes

- Open Die
- Closed Die
- Ring Rolling
Open Die forging is the process of deforming a piece of metal between multiple dies on a press that does not completely enclose the material. The metal is altered as the die's “presses” the material through a series of movements until the desired shape is achieved. Open Die forging is often used for short runs of parts that are simple in design; such as discs, rings, sleeves, cylinders, blocks, and shafts.
Open Die Forging
Closed Die forging (also referred to as an impression die forging) is a metal deformation process that uses pressure to compress a piece of metal to fill an enclosed die impression. In some closed die forging processes, a succession of impression dies are used to modify the shape of the material into the final desired shape and form. Examples of equipment used to create these shapes are hammers, presses, up-setters, and impactors.
Ring Rolling

Ring rolling is a particular category of metal rolling, in which a ring of smaller diameter is rolled into a precise ring of larger diameter and a reduced cross section. This is accomplished by the use of two rollers, one driven and one idle, acting on either side of the ring's cross section. Edging rollers are typically used during industrial metal rolling manufacture, to ensure that the part will maintain a constant width throughout the forming operation. The work will essentially retain the same volume, therefore the geometric reduction in thickness will be compensated for entirely by an increase in the ring's diameter. Rings manufactured by ring rolling are seamless. This forming process can be used to manufacture not only flat rings, but rings of differently shaped cross sections as well, producing very precise parts with little waste of material.
Lightweight Alloy Forgings are used in many different industries...
Aerospace Open Die Forging

Fan Blades

Turbine Disks

engine mount

wing component
## Boeing Commercial Market Outlook 2021-2040

### Airplanes Forecast on a Page

**Asia-Pacific Detail**

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<th>China</th>
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<td>4.9%</td>
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### DELIVERIES (2021-2040)

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<th>Widebody</th>
<th>Freighter</th>
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### 2019 FLEET

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**Above Data is from Boeing 9/13/2021**
Commercial Aerospace Outlook

New deliveries 2019-2038

Source: Ascend, Airbus
Note: 100+ seaters (passenger aircraft) and 10t+ (freighters)
Categories: Demand forecast is based on generic neutral seating categories grouped into the following segments for simplification purpose

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** Above Data is from Airbus 9/2019
Defense Aerospace Outlook

10-year outlook from Boeing

Market Outlook Summary

- Aircraft
- United States
- Other Space and Defense
- International

~$2.6T
Defense Aerospace Outlook

10-year outlook from Forecast International

![Military Aircraft Value of Production 2021-2030](image-url)

Source: Forecast International
Automotive

Wheels

Axle Shaft

Suspension Components, Transmission Gears, Steering Arms, Pinion Gears, and Crankshafts

Fasteners, etc.
Automotive

55 YEARS OF AUTO DEMAND GROWTH

Source: DuckerFrontier
Automotive – Long Term Growth

North American Light Vehicle Aluminum Content
*Net Pounds per Vehicle*

1975-2030 CAGR: 3.5%

Source: DuckerFrontier April 2020
Defense
Medical

Implants

Pins & Screws
Miscellaneous
Challenges AL Forgings

- Low flow stress – can lead to laps/other defects easily if design is not optimized
- Soft material (especially prior to heat treatment/aging) – can lead to handling defects (scratches/gouges/nicks/dings/etc..) – more dangerous on near net/net surface forgings with no allowance for grinding/polishing
- Grain size – temperature control of forging stock/forging dies can be critical depending on alloy
- Weight control – can be critical depending on part due to flow defects, mismatch, die closure, etc.
- Penetrant jobs can be a difficult especially when facing corrosion, blisters, or general handling marks
- Process Parameters such as Die Temp, Stock Temp, Lubrication are key to avoiding said defects
- Stress Relieve Dimensional Control critical
Challenges Ti Forgings

- High flow stress – can lead to excessive die wear (require more expensive die materials/ rework/ etc. to combat this)
  - This also means that the flow related defects seen in aluminum are uncommon in titanium forgings
- High temperature differential between forging stock/ forging dies can lead to fill problems and other defects if transfer times from furnace to press and die temperatures aren’t controlled properly
- Distortion due to creep during heating of forging stock (also seen in later heat treatment stages) – could require special racking/ fixturing, etc.
- Managing die wear is important
- Weight control a major factor in wear and fill
- Material recovery vs die design.
- High temp distortion
- Conversion, maximizing yield is a big topic for us right now.
Lightweight Alloy Process Simulations

Forgers specializing in steel might not have experience with lightweight alloys.

Predictive computer simulation are key to quickly understanding new processes.

Simulations aid tooling design, preform development, process optimization, equipment sizing and raw material selection efforts.
Common Process Design Considerations

- Nonfill/Underfill
- Gas/Lube Trap
- Folds/Laps
- Flow Defects
- Forming Load
- Part Fracture
- Die Deflection
- Die Failure
A manufacturer hot forged an aluminum receiver for the M16 rifle.

Premature die cracking occurred at a particular die corner.

The crack resulted in a defect on the forging.

Simulations identified the root cause, a high tensile stress concentration.

The assembly was redesigned to eliminate the tensile stress, cracking and defect.
Process Simulation

Nicolas Poulain

Director of Sales and Technology

TRANSVALOR AMERICAS
Process Simulation Ti6-4
Process Simulation Ti6-4
Process Simulation Inco 625
Process Simulation Inco 625
Process Simulation Inco 625
Process Simulation Inco 625
Process Simulation Inco 625
Example Forging Lines

Roger Rees

Business & Product Development – Forging & Powder Presses

SMS Meer
Example Forging Lines

Over 40 years of experience in closed-die forging of aluminium

First project realized in 1978 (Raufoss AS, Norway: Automated forging line with 1600ton hydraulic closed-die forging press HPVE 1600)

In 1990 Installation of integrated aluminium forging line at Thécla, Switzerland (HPVE 1600)

Numerous closed-die forging presses (e.g. HVP 2000) for Otto Fuchs Metallwerke
Example Forging Lines
3150 ton Eccentric Press MP 3150 for Forging of Suspension Parts

Integrated forging line to establish a T5-Process, mainly consisting of:
- Preheating Furnace
- Main Forging Press  AMP 3150
- Trimming-/Piercing Press
Example Forging Lines

4000 ton Forging Line for Steering Knuckles

Integrated forging line to establish a T6-Process, mainly consisting of:

- Preheating Furnace
- Forging Roll ARWS 2
- Main Forging Press AMP 4000
- Trimming-/Piercing Press
- Robot automation
Example Forging Lines

Revamping of Forging Roll ARWS2 including options for aluminium processing

Considerable options for aluminium processing, mainly consisting of:

- Internal water cooling for rolling axis
- Internal electrical heating of forging rolls
- Spray cooling for rolling axis
- Bearing temperature monitor
- Robot automation
Example Forging Lines
large-scale production forging for bar-shaped parts T6 process

- billet heat-up
- temperature monitoring
- preforming 1
- preforming 2
- pre-forging
- finish forging
- trimming / piercing
- artificial aging
- quenching
- annealing
Example Forging Lines

Floorplan and line layout

- Quenching bath
- solution annealing furnace
- Forging roll
- Billet feeder
- Forging press
- Heating furnace
Example Forging Lines

Preforming device: Forging roll ARWS

Individually designed material distribution of the preform to improve the material yield during the subsequent forging operations

Cycle time reduction – Increase of production throughput

Optimization of material distribution helps to reduce the pressing forces and to improve the die lifetime

Improves the grain flow of the forgings

Helps to fully utilize the capacity of the main forging press
FIERF Magnesium Project

University of Waterloo has been actively engaged with FIERF on the study of magnesium for forging. Particularly Paresh Parakash did his PhD Thesis in this study.
Magnesium alloys offer tremendous weight saving potential in automotive applications, owing to their significantly lower densities, and superior specific strength and stiffness values, compared to traditional structural materials. However, the current use of Mg alloys in the automotive industry, particularly in wrought form, such as forged Mg alloy components, is rather low, owing to difficulties associated with forging them under ambient conditions.
Special Thanks/Questions

drivealuminum.org
aluminum.org