LIGHTWEIGHT ALLOYS FORGING 101

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Presenters

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Scientific Technology (Contributor)

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Roger Rees – SMS Meer

Scientific Forming Technologies Corporation

WEBER METALS
an OTTO FUCHS Company

TRANSVALOR AMERICAS

SMS group

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

What is Forging?

A MANUFACTURING PROCESS WHERE METAL IS PRESSED, POUNDED, OR SQUEEZED UNDER GREAT PRESSURE INTO HIGH STRENGTH PARTS KNOWN AS "FORGINGS."

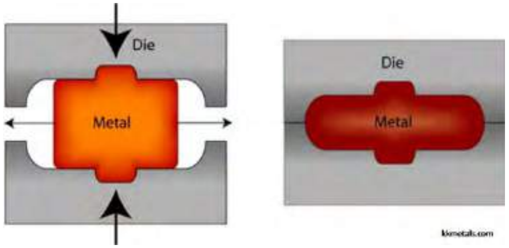
What is Forging? (Continued…)

- 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

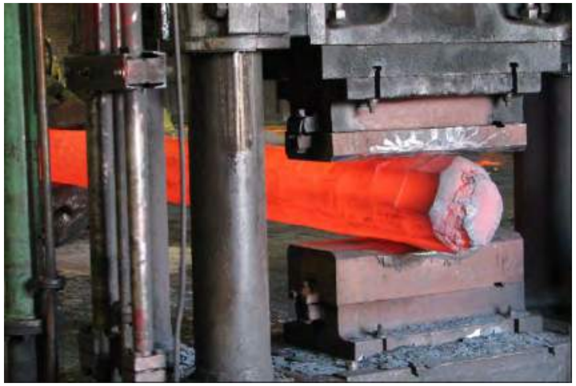
Forging Processes

- Open Die
- Closed Die
- Ring Rolling



Open Die Forging

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.



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Open Die Forging

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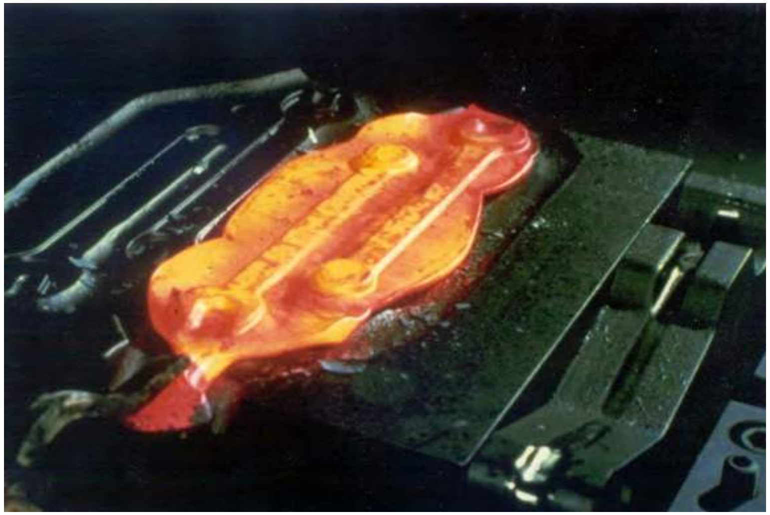
Closed Die / Impression Forging

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.



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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.

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Lightweight Alloy Forgings are used in many different industries…

- Aerospace
- Automotive
- Defense
- Medical Equipment

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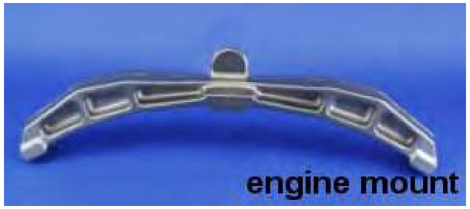
Aerospace

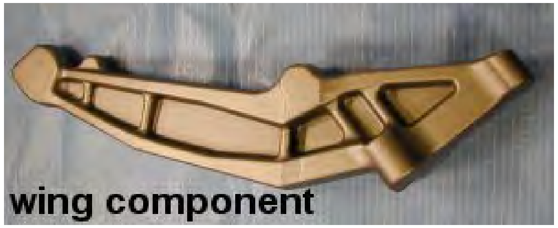
Open Die Forging

Fan Blades



engine mount

Turbine Disks



wing component

Commercial Aerospace Outlook

Boeing Commercial Market Outlook 2021-2040

Airplanes Forecast on a Page

		Asia-Pacific Detail											
	Asia-Pacific	**China**	**Southeast Asia**	**South Asia**	**Northeast Asia**	**Oceania**	**North America**	**Europe**	**Middle East**	**Latin America**	**Russia & Central Asia**	**Africa**	**World**
Economic Growth (GDP) (2019-2040)	3.7%	4.4%	3.9%	4.9%	1.0%	2.3%	2.1%	1.4%	2.8%	2.4%	2.1%	3.0%	2.7%
Airline Traffic Growth (RPK) (2019-2040)	5.0%	5.4%	5.5%	6.9%	1.7%	3.0%	2.7%	3.1%	4.1%	4.8%	2.9%	5.4%	4.0%
Airline Fleet Growth (2019-2040)	4.2%	4.4%	5.0%	6.6%	1.2%	1.9%	1.7%	2.7%	4.1%	3.4%	2.5%	3.6%	3.1%
DELIVERIES (2021-2040)													
Regional Jet	400	360	20	<10	10	10	1,610	60	40	10	230	40	2,390
Single Aisle	13,460	6,490	3,600	2,110	720	540	6,350	7,100	1,570	2,290	1,150	740	32,660
Widebody	3,500	1,650	770	290	580	210	790	1,460	1,320	220	140	240	7,670
Freighter	285	200	25	10	50	<5	410	85	70	10	20	10	890
Total	**17,645**	**8,700**	**4,415**	**2,410**	**1,360**	**760**	**9,160**	**8,705**	**3,000**	**2,530**	**1,540**	**1,030**	**43,610**
2019 FLEET													
Regional Jet	150	60	<5	10	50	30	1,890	240	30	80	190	130	2,710
Single Aisle	5,720	3,050	1,140	590	560	380	4,080	3,690	660	1,200	770	400	16,520
Widebody	1,800	620	430	90	540	120	700	980	740	150	140	150	4,660
Freighter	350	200	30	10	80	30	940	310	80	110	160	60	2,010
Total	**8,020**	**3,930**	**1,600**	**700**	**1,230**	**560**	**7,610**	**5,220**	**1,510**	**1,540**	**1,260**	**740**	**25,900**
2040 FLEET													
Regional Jet	480	390	30	<10	40	20	1,610	60	60	30	340	130	2,710
Single Aisle	13,740	6,700	3,440	2,260	800	540	7,030	6,890	1,750	2,580	1,390	980	34,360
Widebody	3,770	1,730	870	330	610	230	1,000	1,690	1,570	340	210	320	8,900
Freighter	1,160	810	100	70	140	40	1,195	500	150	145	155	130	3,435
Total	**19,150**	**9,630**	**4,440**	**2,660**	**1,590**	**830**	**10,835**	**9,140**	**3,530**	**3,095**	**2,095**	**1,560**	**49,405**

** 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

Pax Units

Category	Africa	Asia-Pacific	CIS	Europe	Latin America	Middle East	North America	Total
Small	960	12,765	1,298	5,760	2,400	1,630	4,911	**29,724**
Medium	188	2,168	125	1,035	189	473	696	**4,874**
Large	101	1,391	75	639	95	1,097	362	**3,760**
Total	**1,249**	**16,324**	**1,498**	**7,434**	**2,684**	**3,200**	**5,969**	**38,358**

Freight Units

Category	Africa	Asia-Pacific	CIS	Europe	Latin America	Middle East	North America	Total
Small	-	-	-	-	-	-	-	**-**
Medium	14	102	16	56	12	14	285	**499**
Large	6	117	29	49	-	31	124	**356**
Total	**20**	**219**	**45**	**105**	**12**	**45**	**409**	**855**

Total Units

Category	Africa	Asia-Pacific	CIS	Europe	Latin America	Middle East	North America	Total
Small	960	12,765	1,298	5,760	2,400	1,630	4,911	**29,724**
Medium	202	2,270	141	1,091	201	487	981	**5,373**
Large	107	1,508	104	688	95	1,128	486	**4,116**
Total	**1,269**	**16,543**	**1,543**	**7,539**	**2,696**	**3,245**	**6,378**	**39,213**

** Above Data is from Airbus 9/2019

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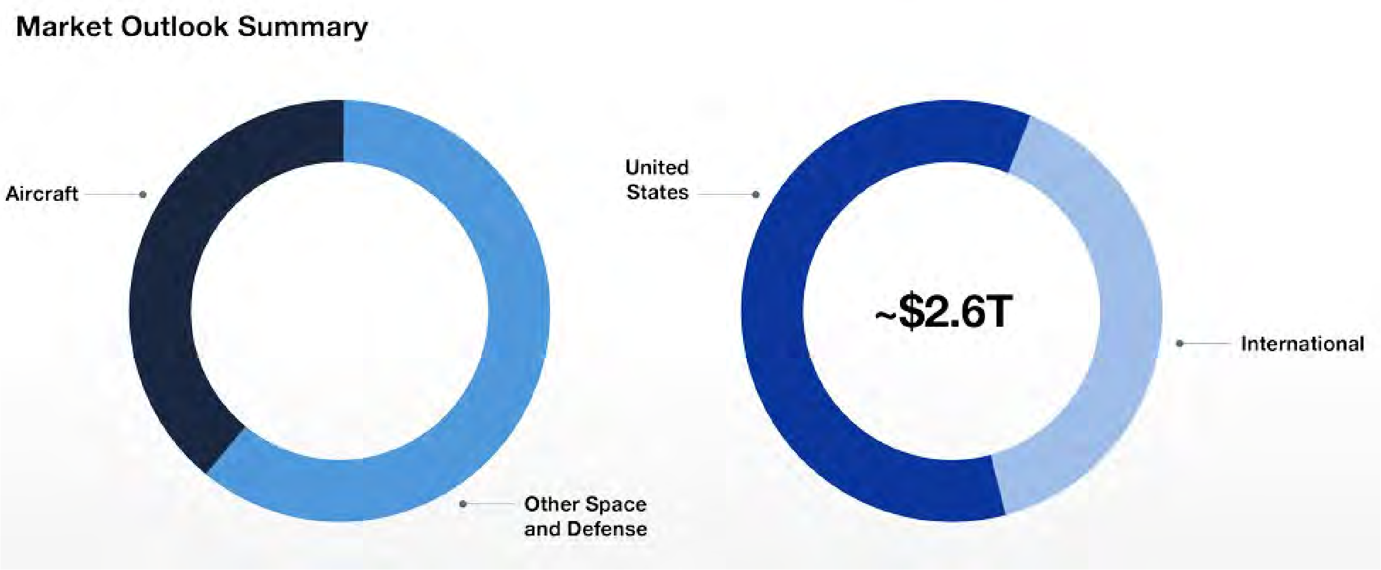
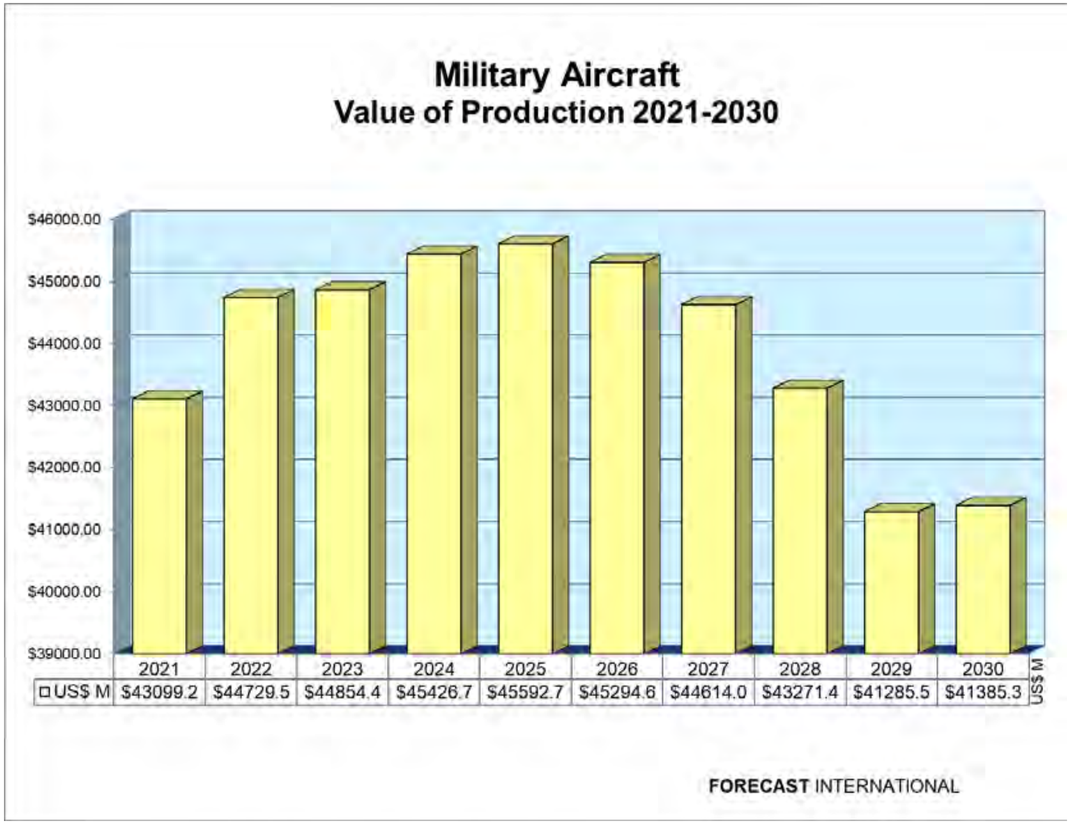
Defense Aerospace Outlook

10-year outlook from Boeing



Defense Aerospace Outlook

10-year outlook from Forecast International



Automotive

Wheels

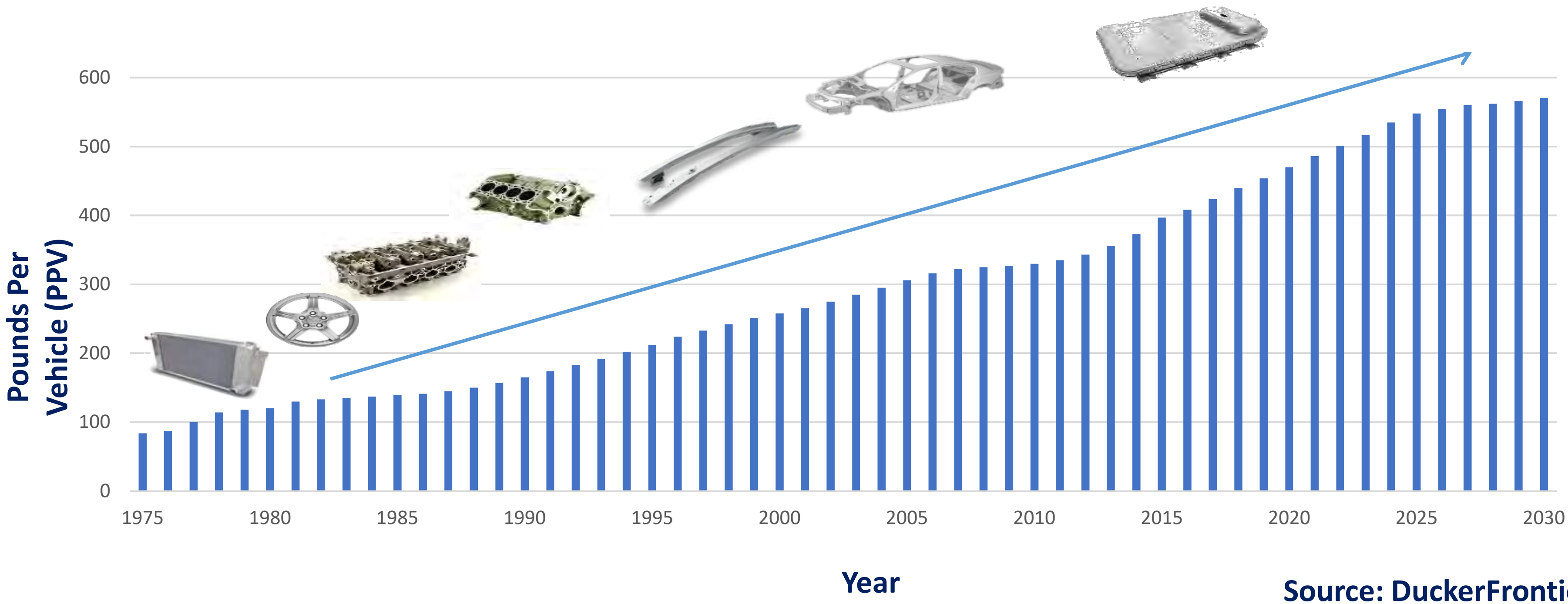
Axle Shaft

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

Fasteners, etc.

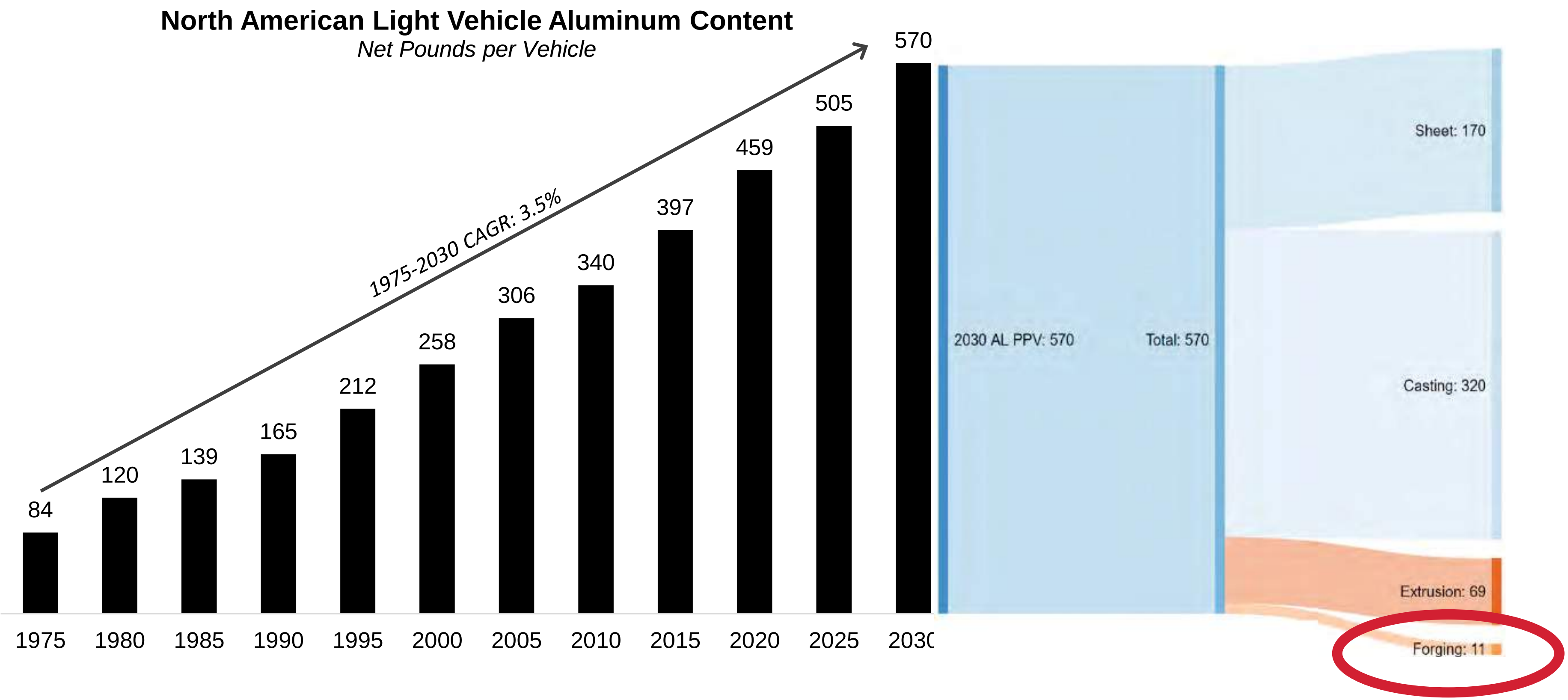
Automotive

55 YEARS OF AUTO DEMAND GROWTH



Source: DuckerFrontier

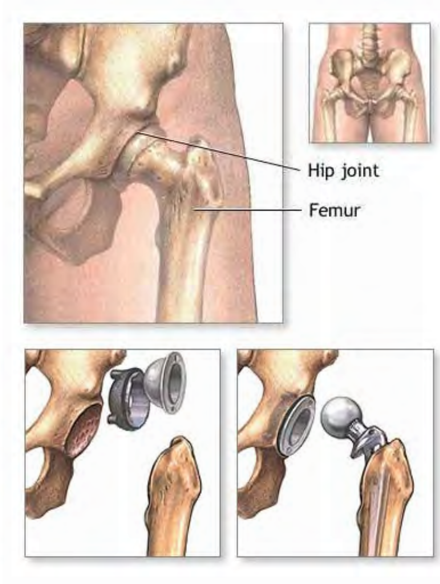
Automotive – Long Term Growth



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.

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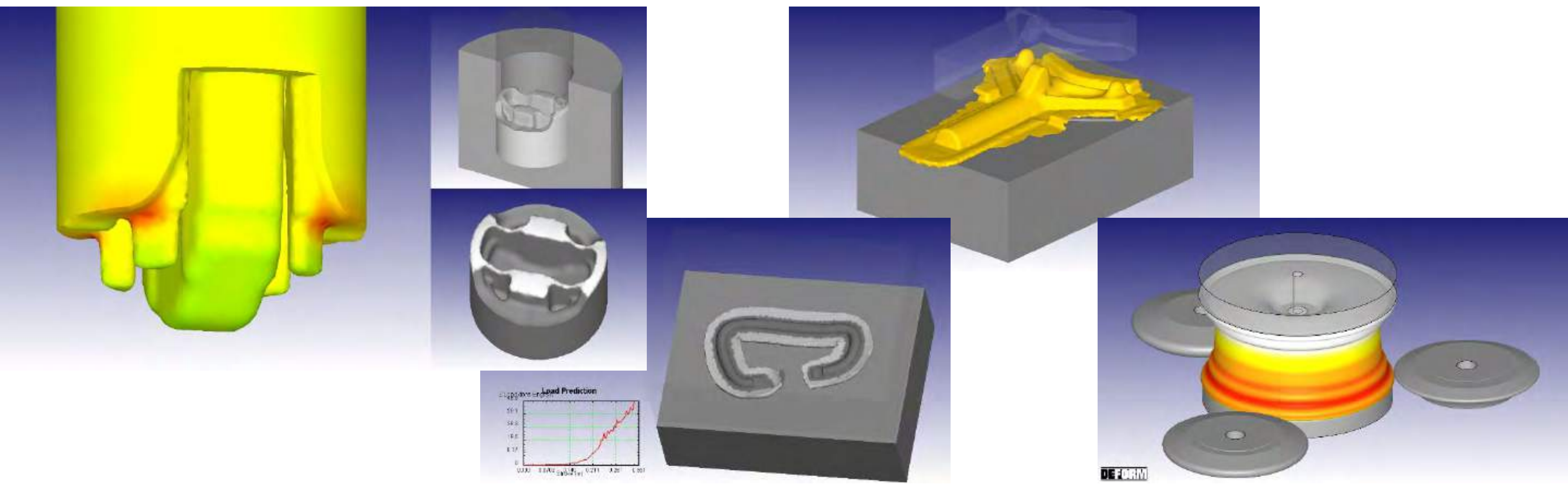
Lightweight Alloy Process Simulations

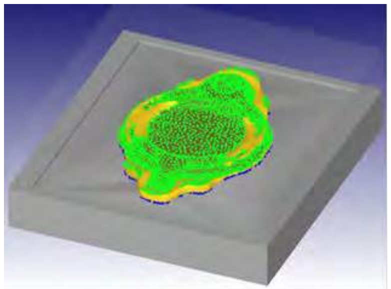
Forgers specializing in steel might not have experience with lightweight alloys.

Predictive computer simulation are key to quickly understanding new processes.

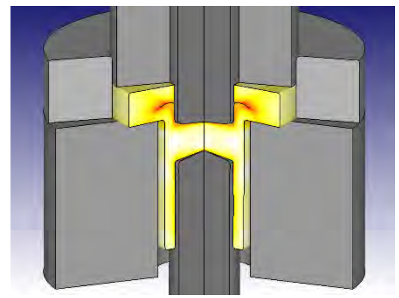
Simulations aid tooling design, preform development, process optimization, equipment sizing and raw material selection efforts.

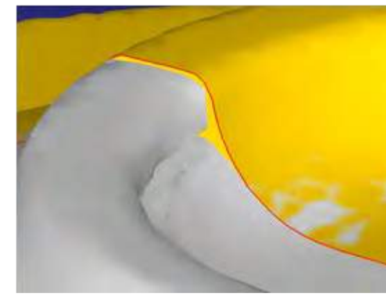


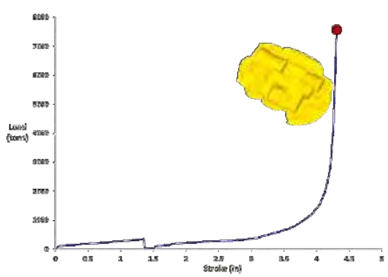
Common Process Design Considerations

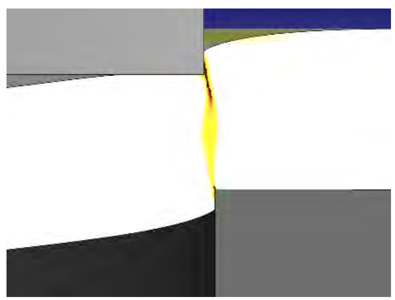

Nonfill/Underfill

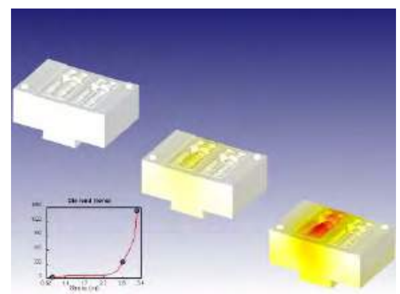

Gas/Lube Trap

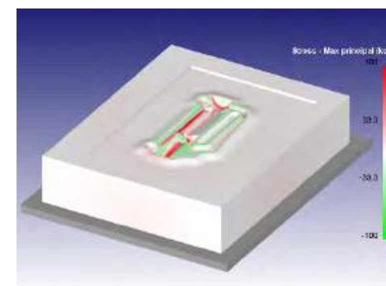

Folds/Laps


Flow Defects


Forming Load


Part Fracture

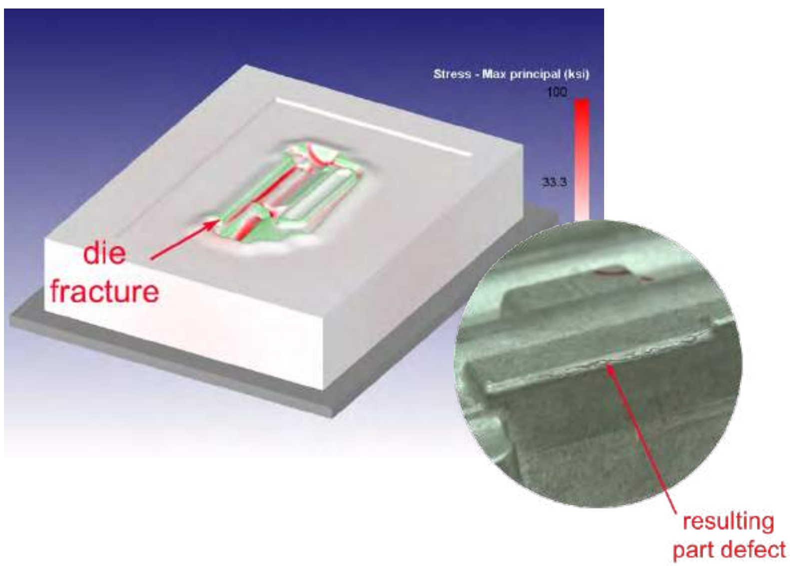

Die Deflection


Die Failure

Process Simulation Case Study

A manufacturer hot forged an aluminum receiver for the M16 rifle.

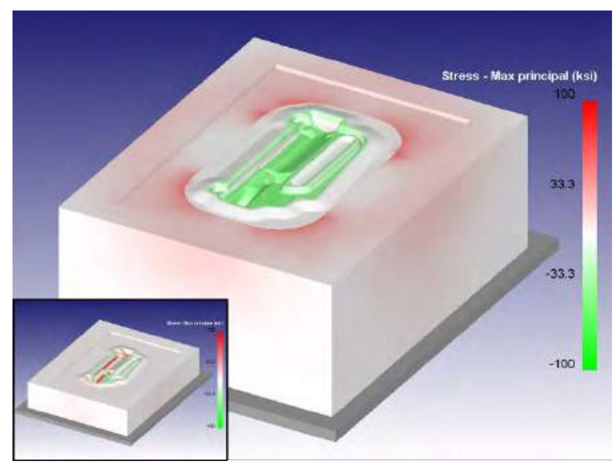
Premature die cracking occurred at a particular die corner.



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.



Courtesy: Anchor-Harvey

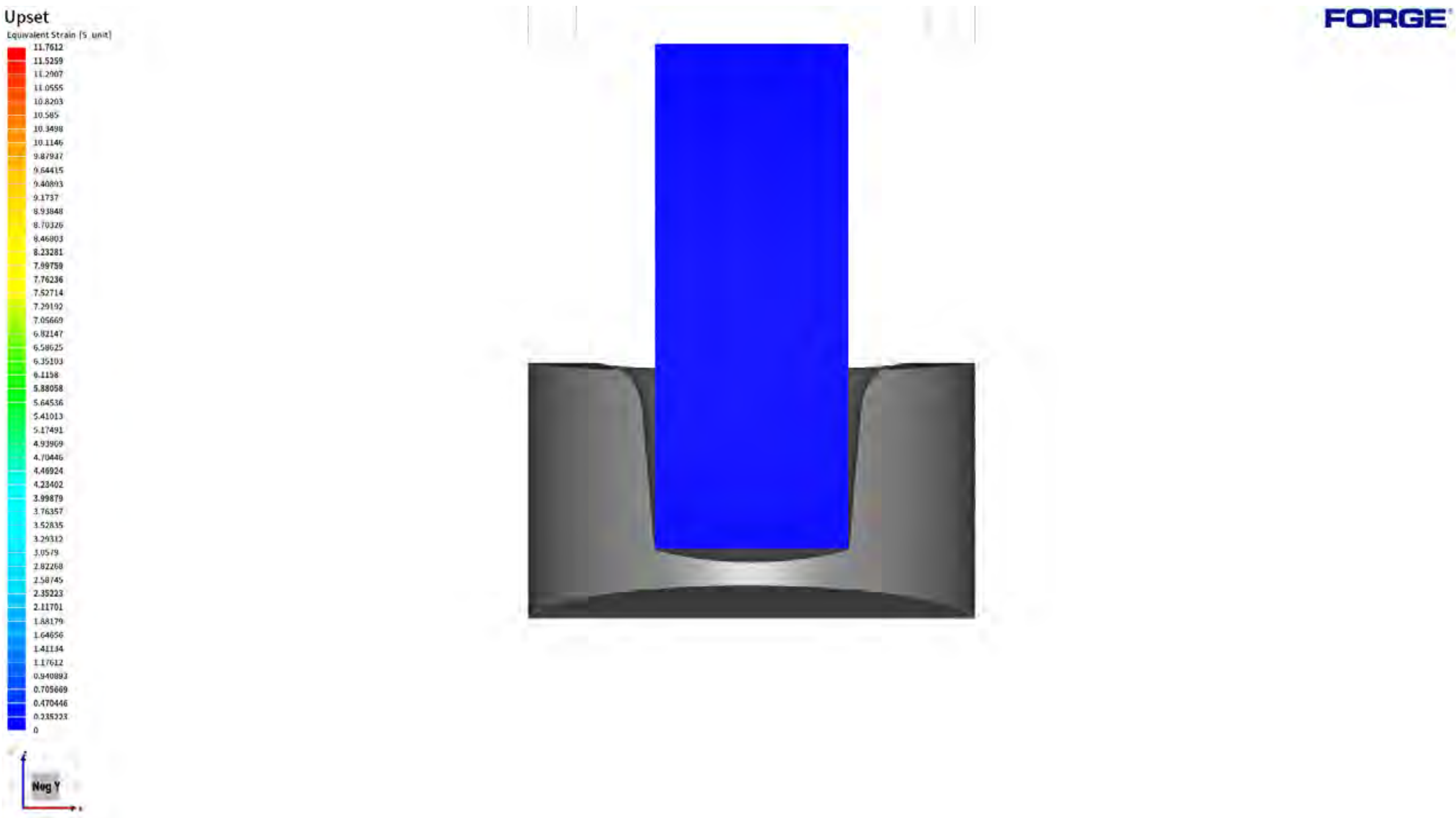
Process Simulation

Nicolas Poulain

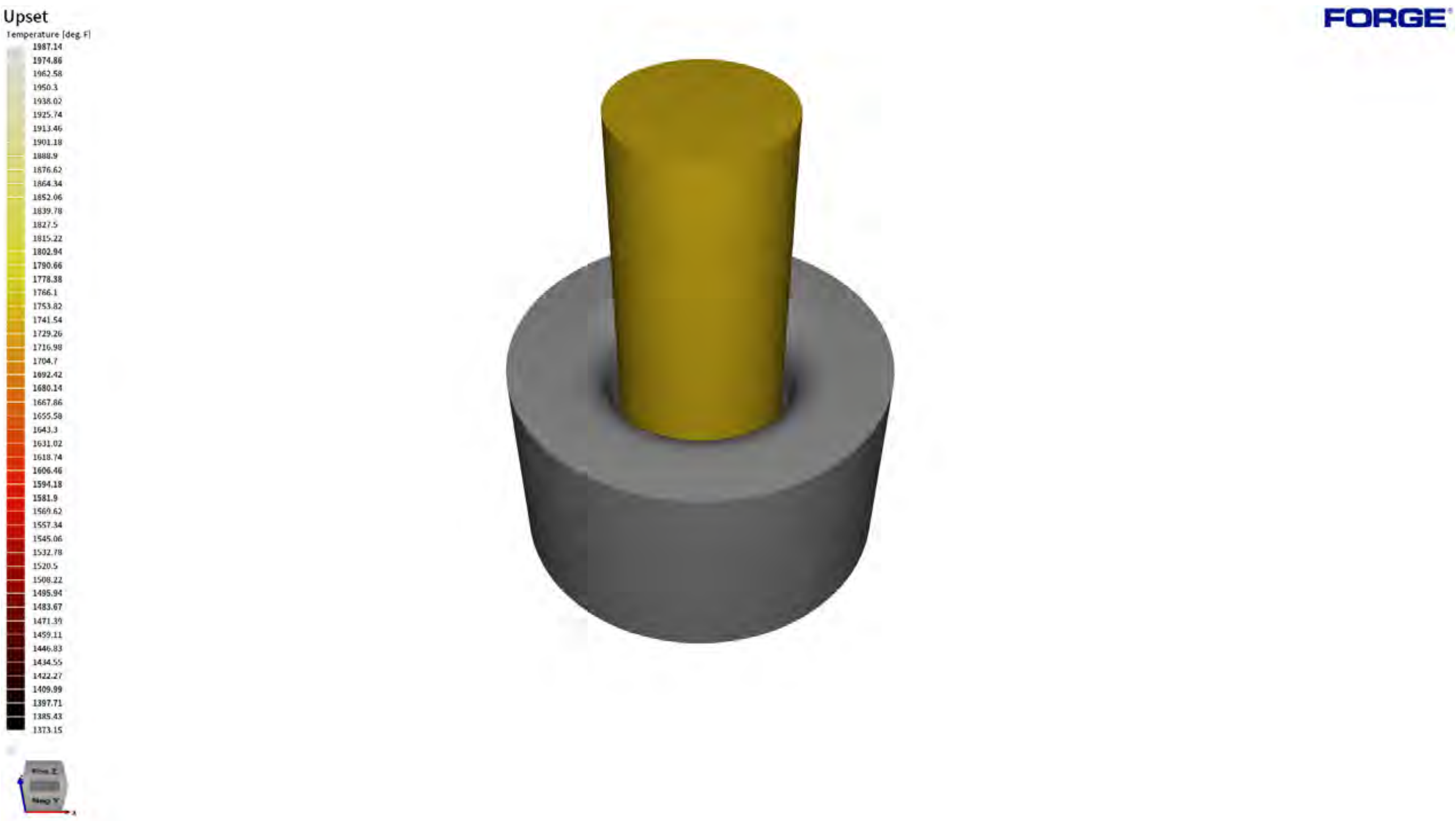
Director of Sales and Technology

TRANSVALOR AMERICAS

Process Simulation Ti6-4



Process Simulation Ti6-4



Process Simulation Ti6-4

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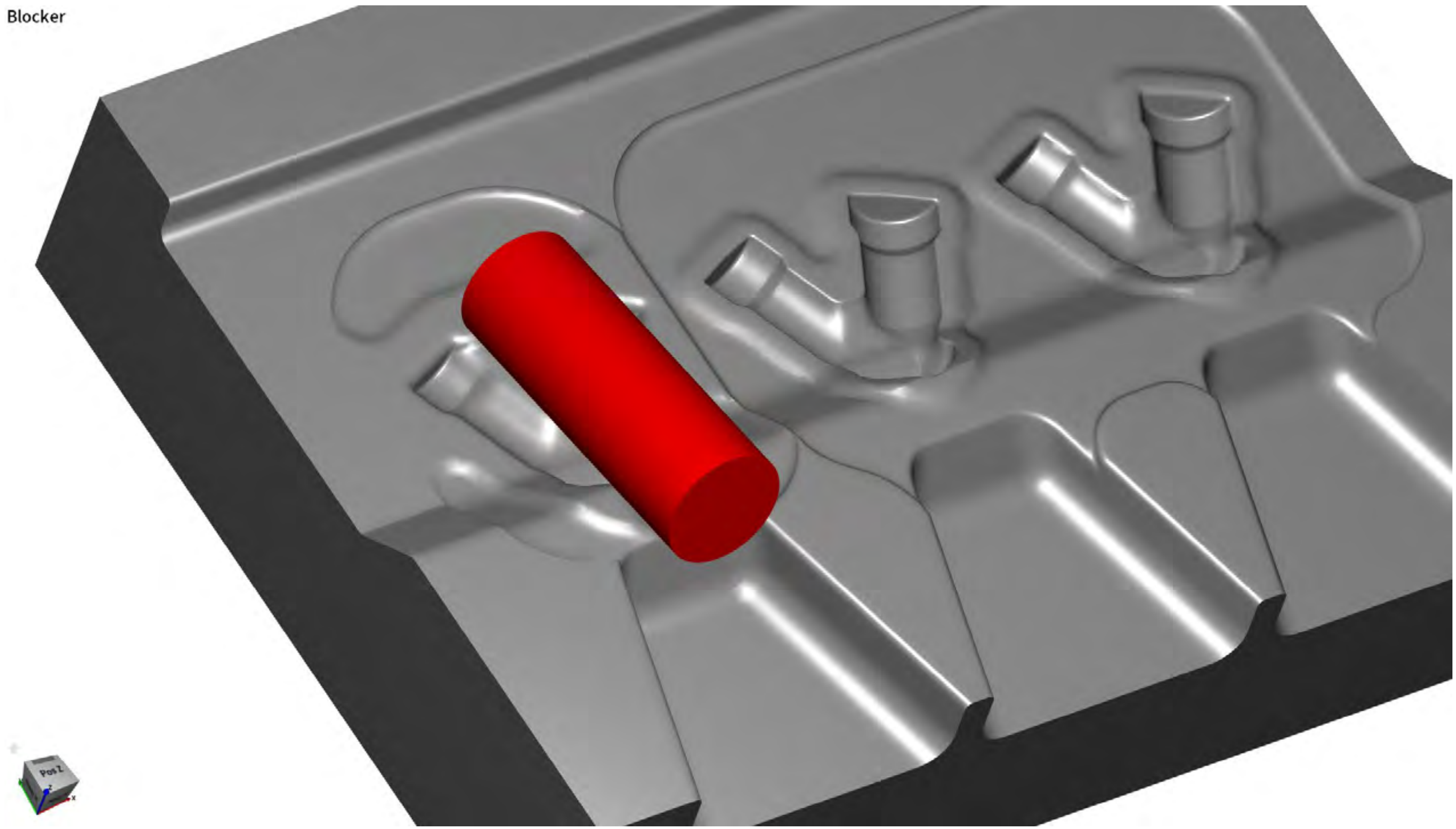
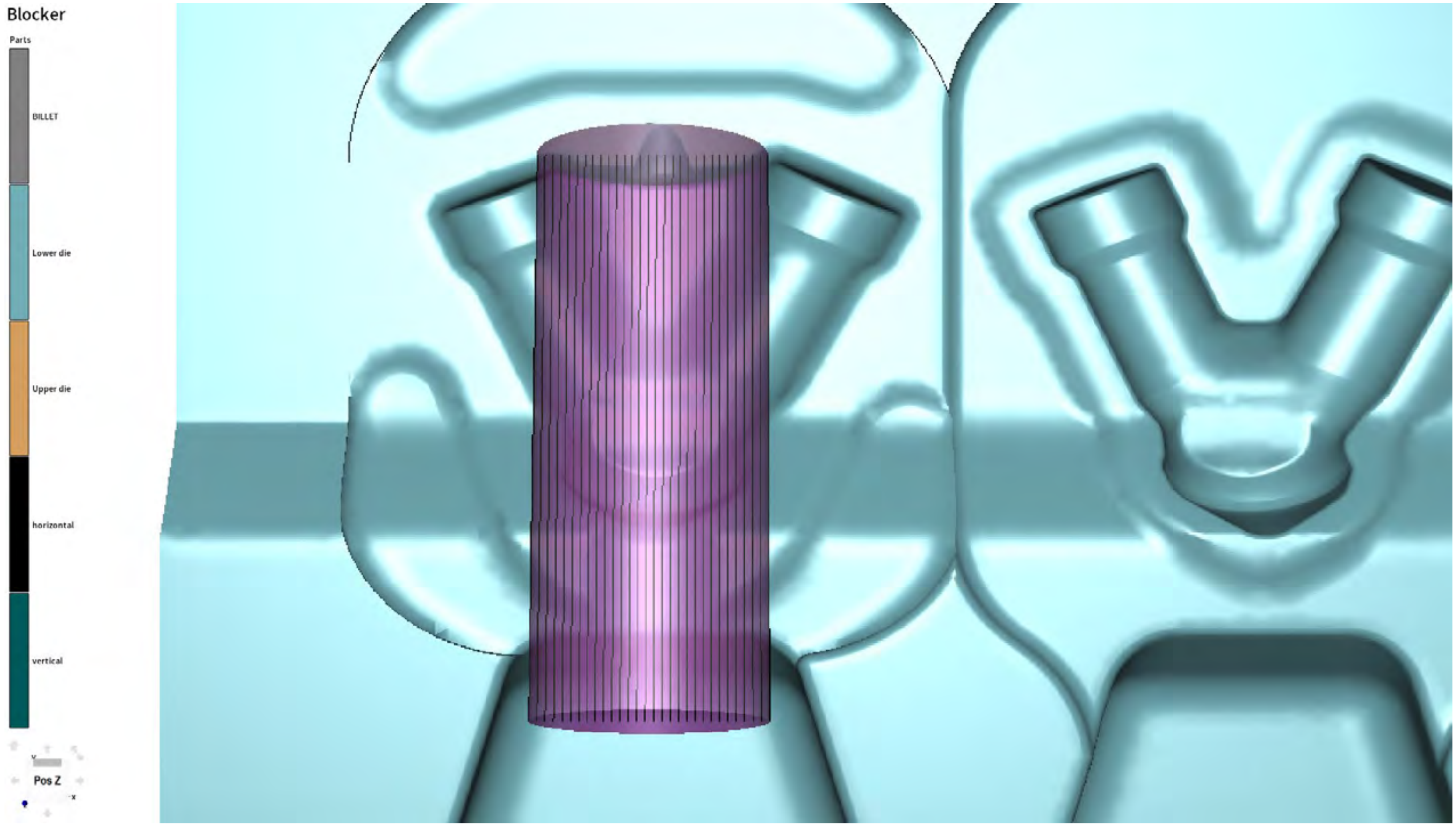
Process Simulation Inco 625



Process Simulation Inco 625



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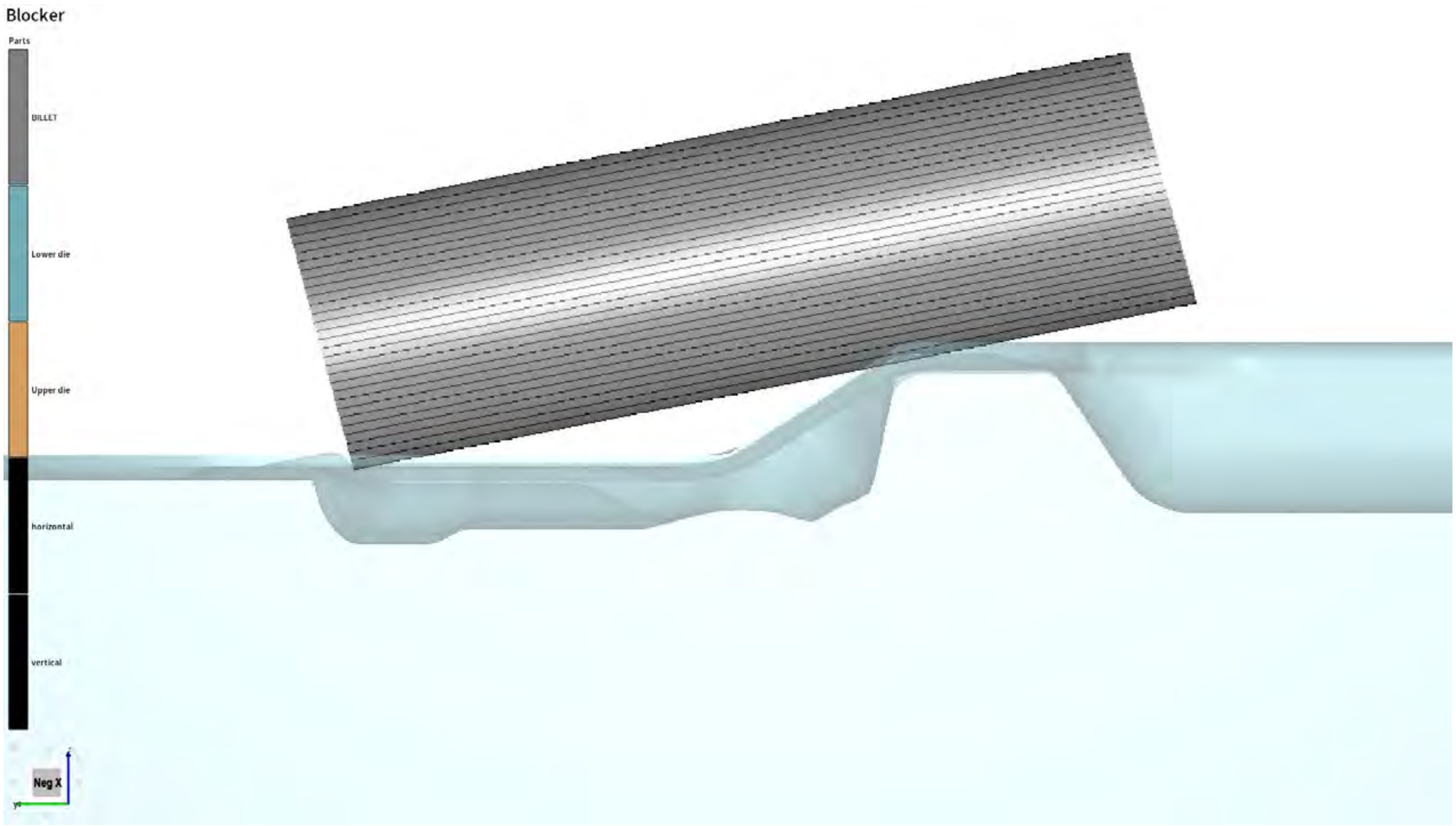
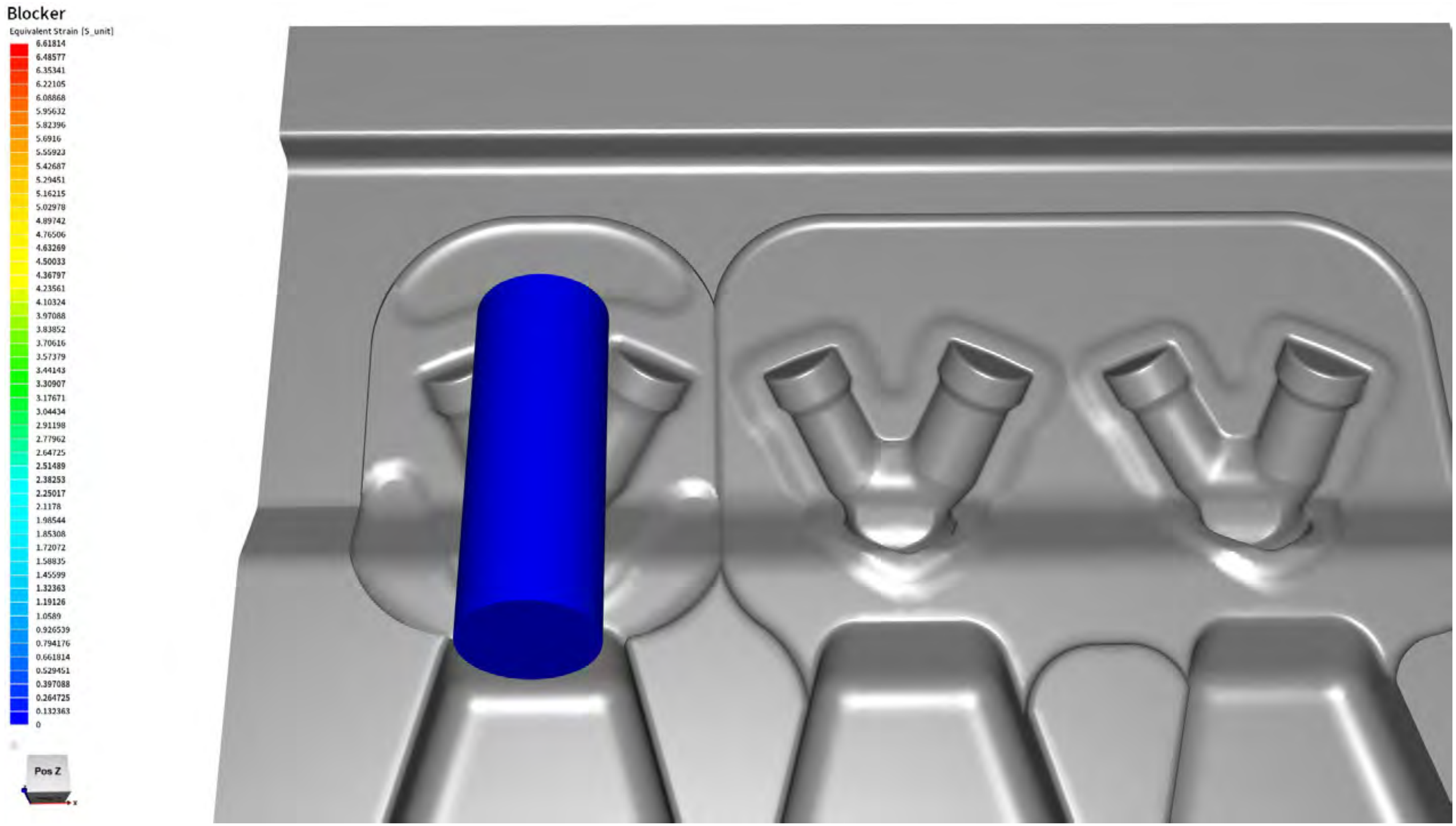
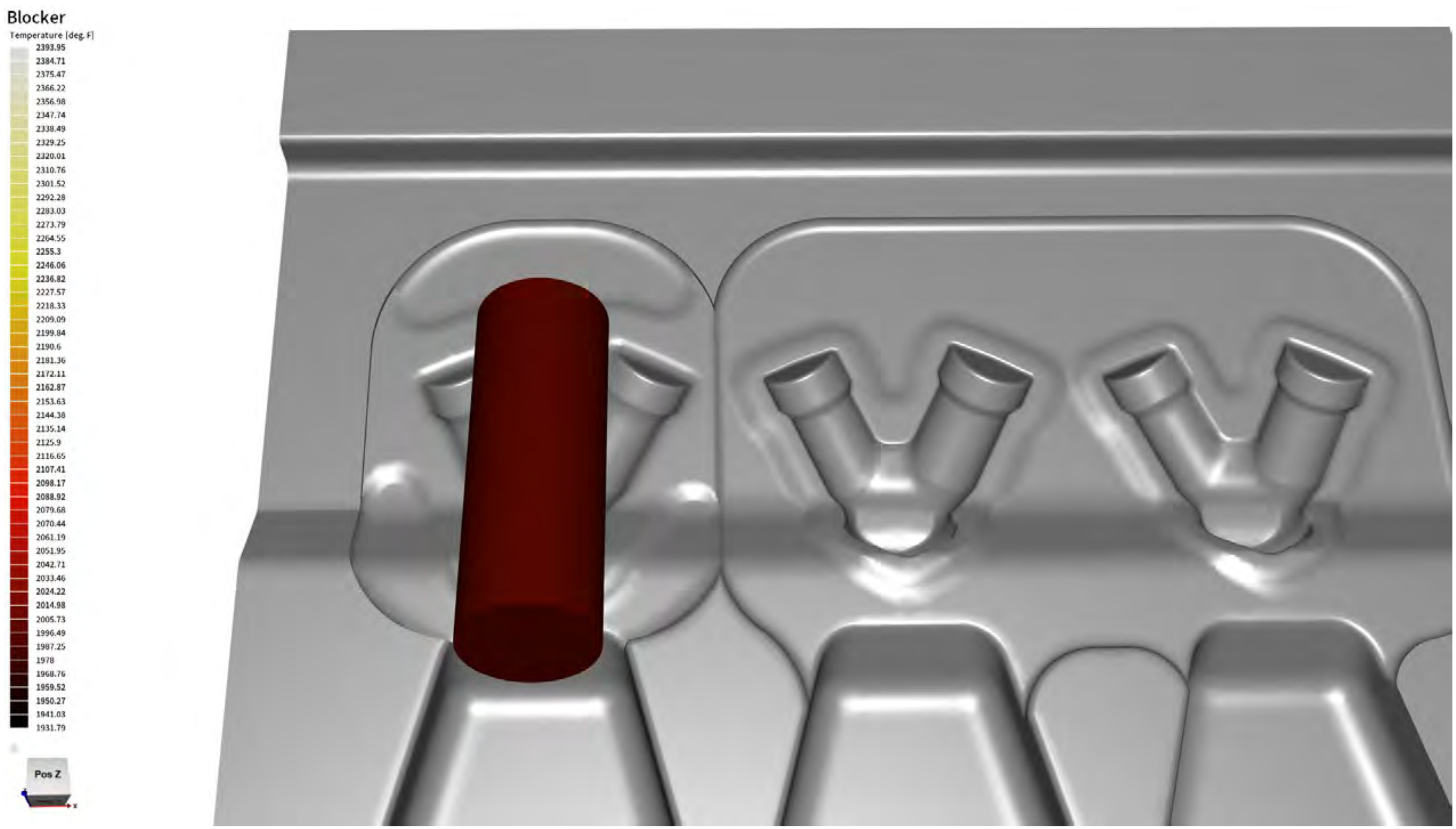
Process Simulation Inco 625



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 aluminuim

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

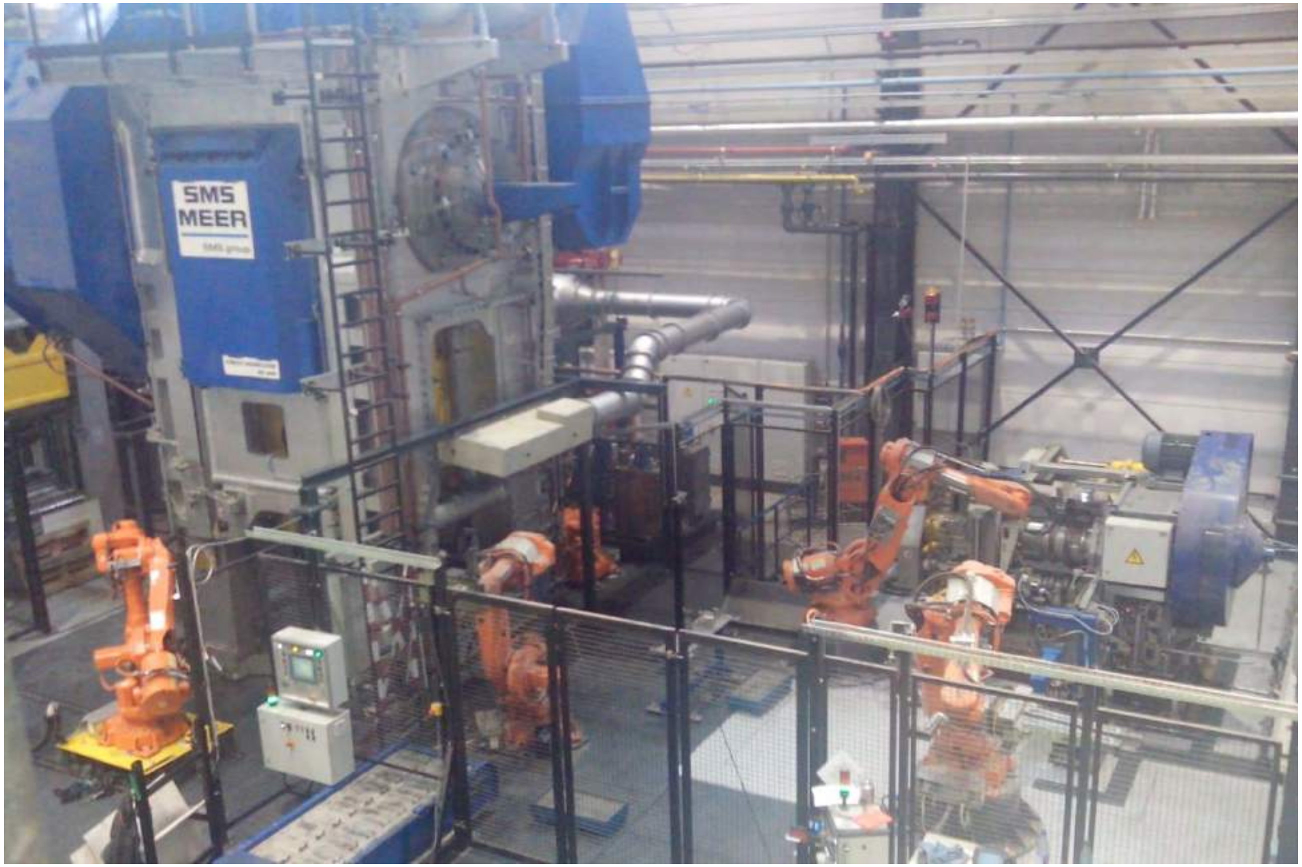
3150 ton Eccentric Press MP 3150 for Forging of Suspension Parts

Integrated forging line to establish a T5-Process, mainly consisting of:

- Preheating Furnace
- Main Forging Press AMP 3150
- Trimming-/Piercing Press

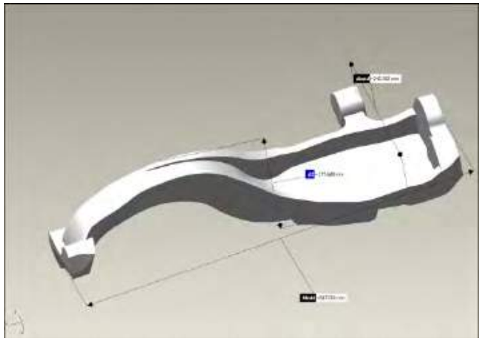
Example Forging Lines

4000 ton Forging Line for Steering Knuckles



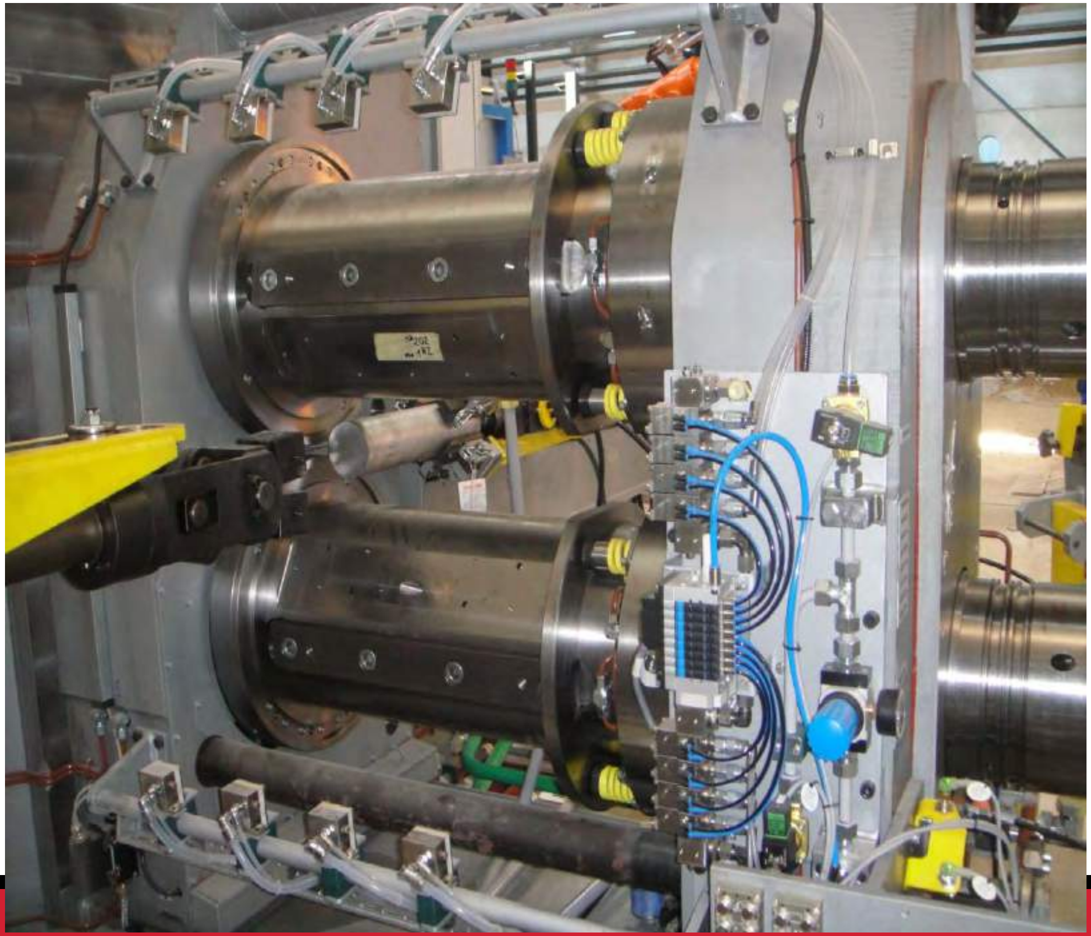
Integrated forging line to establish a T6-Process, mainly consisting of:

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



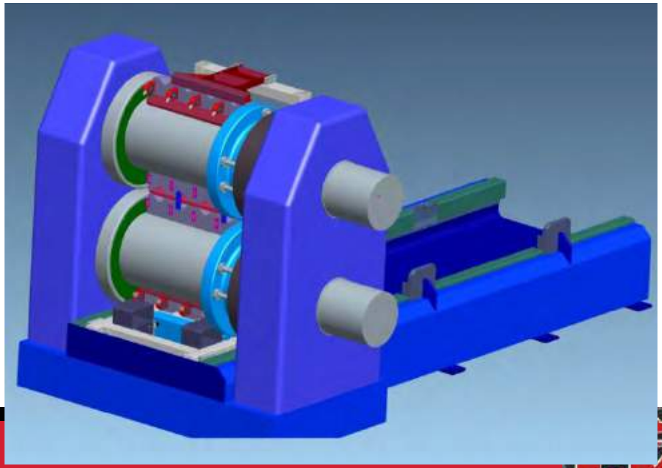
Example Forging Lines

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

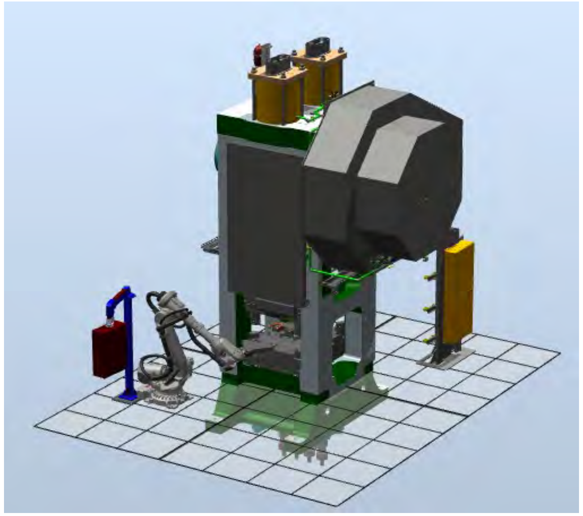
finish forging

trimming / piercing

annealing

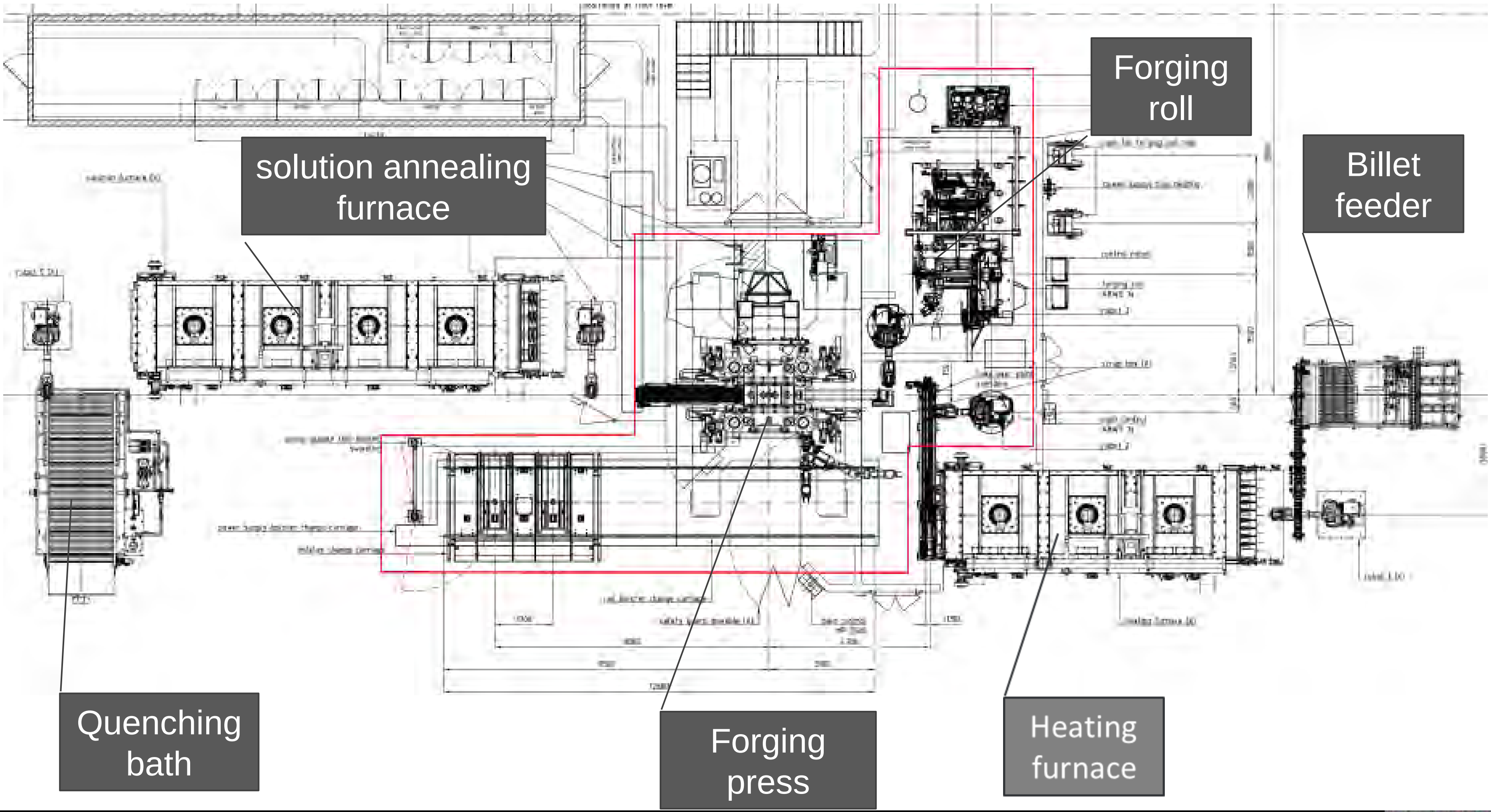
quenching

artificial aging



Example Forging Lines

Floorplan and line layout



Example Forging Lines

Preforming device: Forging roll ARWS

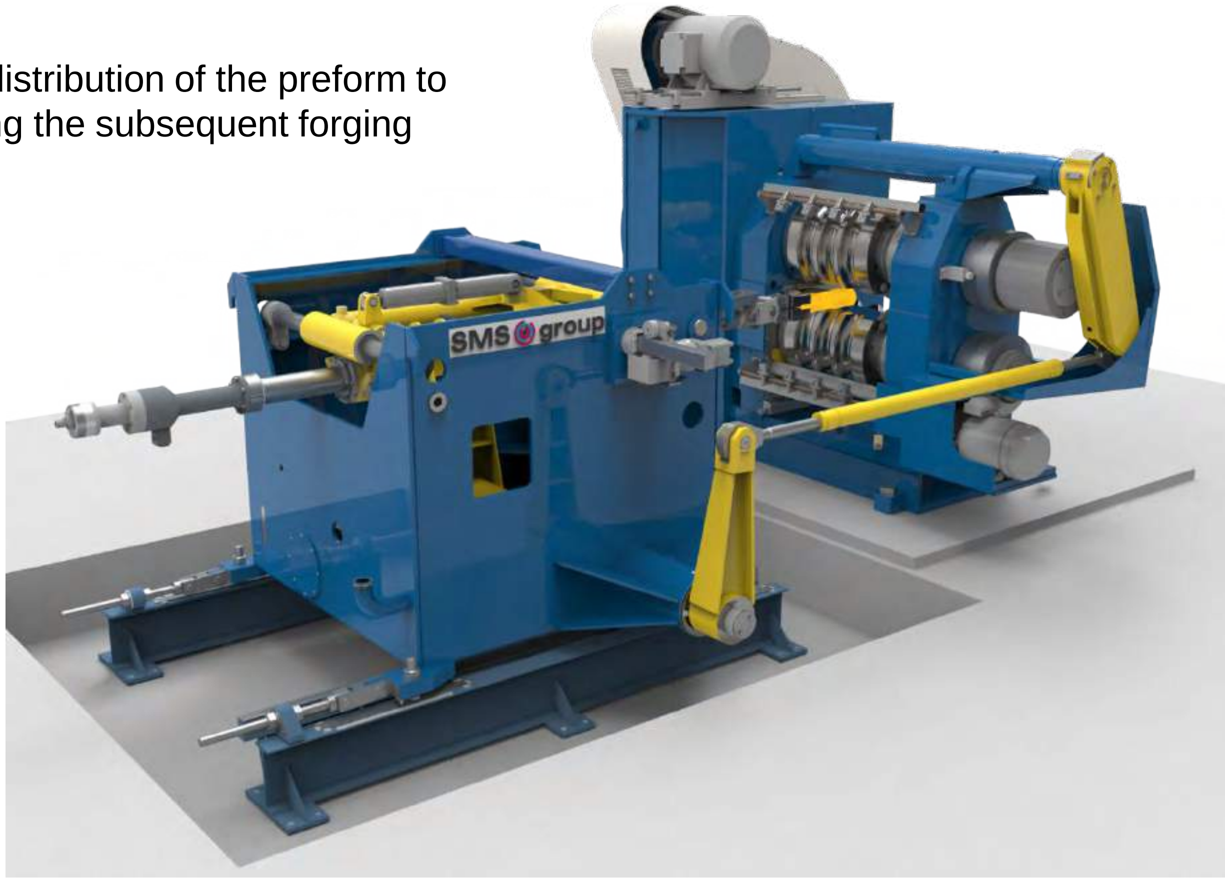
Individually designed material distribution of the preform to improve the material yield during the subsequent forging operations

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.

FIERF Magnesium Project

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

The Aluminum Association

ELLWOOD City Forge