AluMag®

North America 2015 9th - 11th of Nov

AUTOMOTIVE LIGHTWEIGHT

PROCUREMENT SYMPOSIUM

Cobo Center, Detroit, USA

SYMPOSIUM FOCUS

- Aluminum
- Carbon Fibre
- Composites
- High Strength Steel
- Magnesium

The 3rd Automotive Lightweight Procurement Symposium to be focused on automotive lightweighting, supply / process chain and procurement management, will take place in Detroit from the 9th – 11th of Nov 2015. The symposium is held in the days leading up to the "ALUMINUM USA" exhibition taking place at the Cobo Center, Detroit, Michigan (Walking distance to symposium venue)

ATTENDING COMPANIES:

BOCAR GROUP, Ford, DAIMLER, NACFE, Gibbs Die Casting, UACJ, AluMag, NISSAN, Carbon War Room, GM, StrikoWestofen Group, Nano Al, SEISSENSCHMIDT, Remy, Rio Tinto Alcan, GRÄNGES, MARTINREA, ESD The Engineering Society of Detroit, NNi Training and Consulting Inc., Martinrea Honsel, Al Circle, HT Honda Trading, Automotive Insight, RUSAL, atieva, MERITOR, EXEDY Corporation, nemak, Sumitomo Corporation, ITOCHU, BHARAT FORGE GLOBAL HOLDING, MOTORINDIA, ALMAMET, ALMAG Aluminum, Rane Expanding Horizons, Rassini, LINAMAR, VERSEVO, TENNECO, NEUMAN ALUMINIUM RAUFOSS, JOGMEC, HONDA, FCA FIAT CHRYSLER AUTOMOBILES, lift, SUBARU

EXHIBITORS:

EJOT, kurtz ersa, BOCAR GROUP, ACTech, WHITEHALL INDUSTRIES, CPC, BHARAT FORGE ALUMINIUMTECHNIK, ALUMINUM BLANKING COMPANY, INC.

ORGANIZING PARTNERS & SPONSORS

Reed Exhibitions, Aluminum USA, ESD The Engineering Society of Detroit, BOCAR GROUP, kurtz ersa

AluMag®
Europe 2016 27th - 29th of Nov
AUTOMOTIVE LIGHTWEIGHT
PROCUREMENT SYMPOSIUM
Hilton Hotel in Duesseldorf, Germany

AluMag®
Asia 2016 6th - 8th of July
AUTOMOTIVE LIGHTWEIGHT
PROCUREMENT SYMPOSIUM
Jumeirah Himalayas Hotel in Shanghai, China

AluMag®

Europe ■ India ■ Americas ■ Asia

THE MARKET DEVELOPER

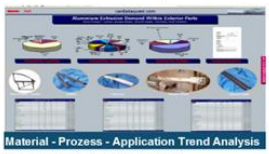
AluMag is "The Market Developer" that successfully penetrates new markets, creates business and localize leading supplier for your company. AluMag access any promising markets and open doors for your business – regardless of region, market, application, material, process or product. AluMag makes you successful – worldwide!

AluMag® offers the four following services - worldwide:

Market Research

- Aluminium Extrusion Customer Database
- Foundry & Tool Maker Database
- Automotive Application, Material & Process Analyses
- Various Industrial Application Research & Analyses

AluMag as your provider of automotive research and forecasting studies, offers you and your business, the market intelligence you need to realize the best strategic decisions



Material - Prozess - Application Trend Analysis

Large variety of market accesss, local & global:

- business database with 6,970+ companies and 18.700+ contacts
- 150+ satisfied customers worldwide
- Arranged 20+ roadshows/events since 2008

Extrusion Application

Your Benefits:

- Learn about your [potential] clients and competitors
- Obtain an inside view of the market
- Identify opportunities and threats
- Minimize risk and optimize profits
- Position your company successfully
- Based on data off the shelf, secondary re-search and interviews, AluMag generates validated researches

Market Development

- Analysis & Development of Market Opportunities
- Accelerate Market Penetration
- Manage New Product Launches
- Establish a Sales Force Sales on Demand

AluMag guides and supports your organization globally through the different market development phases until we have successfully launched, implemented or executed your project.

Map of activity - SAMPLES

Manage and integrate each aspect of your organization by initiating, planning, con-trolling, executing and closing out a new project. AluMag offers liaison mana-gement services as an addition to our customer's staff by bringing in the resources that define us.

JATCO Head Quarters Meeting in Japan

Your Benefits

- Analysis and development of Markets
- Realize opportunities
- Accelerate market penetration
- Establish a sales force
- Provide warehousing and distribution services
- Manage new product launches
- Sales on demand

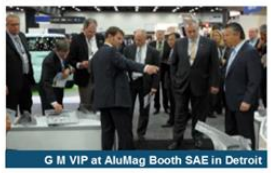
Roadshows / Events

- Organization of Technical & Commercial Roadshows
- Oversea Commercial & Technical Events
- Host In-House Events & Presentation
- Common Technology Booth at Leading Exhibitions

AluMag roadshows, tech-meetings and symposia are the first class events used by exhibitors and guest as a unique benchmark platform.

Daimler Sindelfingen as Roadshow Location

The AluMag think tank events are bringing in decision makers and executives in EUROPE, ASIA and NAFTA.



G M VIP at AluMag Booth SAE in Detroit

Upcoming Events:

- 2015 Nov: Automotive Lightweight Procurement Symposium in Detroit, USA
- 2016 April Common tech- booth at the SAE World Congress in Detroit, USA
- 2016 Jul: Automotive Lightweight Procurement Symposium in Shanghai, China
- 2016 Nov: Automotive Lightweight Procurement Symposium in Duesseldorf, Germany.

Strategic Localization

- Warehousing & Distribution Service
- Supplier & Tie-up Localization
- Identification & Trade-off of new Technology
- Foreign Market Business Cases and whose Realization

AluMag has the global expertise to search, identify, evaluate and validate potential strategic business opportunities for expansions and partnerships that will assist your business growth plans regionally and globally

On-Site Greenfield Planning Meeting

Services for:

- Search, develop and present potential acquisition candidates for regional and global business expansions
- Localization of new manufacturing / service sites for business expansions
- Identification of new technology supplier development related to products, processes and materials
- Search, develop and present potential business partners / suppliers to support regional and/or global supply programs
- Evaluate potential competitor profiles for new or existing business in non-presence geographies
- Evaluate new emerging technologies and processes for business expansions

Are you:

- **looking for specific data, information and outlook about product, material, customer, supplier, technologies, ...**
- **want to discuss your project, increase sales, access new markets, ...**
- **interested to participate in one of our roadshows / events or organize your customized showcase ...**
- **looking to localize, expand into new markets, countries, tie-up targets, ...**

please contact your AluMag Team to receive a quote or proposal

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N. America Automotive Lightweight Procurement Symposium

2015 9th – 11th Nov

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THE MARKET DEVELOPER

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Company Speechs by:

Agenda

Agenda: (Is Continuously Being Updated)

Monday The 9th Of November – Cobo Center, Detroit

05:30pm - 07:30pm

Pre-registration and Welcome

Reception

Tuesday The 10th Of November – Cobo Center, Detroit

08:30am – 09:15am

Registration

Morning Coffee / Tea

09:15am – 09:30am

Welcome:

Mr. Jost GAERTNER - Managing Partner At AluMag Automotive GmbH

09:30am – 10:25am

Opening Keynote: Mr. Craig RENNEKER - Chief Engineer, New A/T Programs & Component – Transmission & Driveline Engineering At Ford Research & Innovation Center

Lightweight Transmission & Driveline Components: Practical Challenges

10:25am – 11:00am

Break for Refreshments/Coffee/Tea, Snacks, Networking, Tech Exhibition

11:00am – 11:45am

Paper 1: Mr Mike ROETH – Executive Director At North American Council for Freight Efficiency (NACFE) & Operations Leader – Carbon War Room

Paper 1: Mr. Karl MAYER – Director Product Line Management At Meritor

Lightweighting Heavy Duty Class 8 Tractors and Trailers

11:45am – 01:45pm

Break for Lunch, Refreshments, Networking, Tech Exhibition

01:45pm – 02:25pm

Paper 2: Mr Ryan BROWN – Director Of Sales At StrikoWestofen America

Analysis Of Cost Drivers When Buying Lightweight Solutions / Materials & The Elimination Of These

02:30pm – 03:10pm

Paper 3: Mr. Lothar HARTMANN – Managing Director Foundry Machines & Trimming Presses At Kurtz GmbH

Chassis & Suspension Weight Reduction By LPDC Aluminum With Hollow Cross Sections

Mr. Kevin CROY - NAFTA Sales Manager Foundry Machines & Trimming Presses At Kurtz GmbH

03:15pm – 03:45pm

Paper 4: Mr. Jörg MANTWILL – Director Sales At Bharat Forge Aluminiumtechnik GmbH & Co. KG

HCM And Aluminum Forging – Partnership To Birth Chassis Parts' Safety

03:45pm – 04:15pm

Break for Refreshments/Coffee/Tea, Snacks, Networking, Tech Exhibition

04:15pm – 04:55pm

Paper 5: Mr. Gary F. RUFF - President and Chief Executive Officer, Ruff and Associates, LLC 8/12 - Present

Advanced Counter Pressure Casting Process for Light-Weighting of Auto and Truck Chassis and Suspension Components

05:00pm – 05:55pm

Closing Keynote: Mr. Gilberto SALDIVAR – New Projects Group Manager At Bocar Group

Key Factors To Achieve Mechanical Properties In Lightweight Structural Parts

05:55pm – 06:00pm

Summary:

Mr. Roberto BOEKER – Managing Partner At AluMag Automotive LLC

Agenda

06:00pm - 08:00pm

Dinner Speech:

Mr. Richard KLEIN - Responsibility Strategic Planning - Business Development & German Business At BOCAR

Wednesday The 11th Of Nov – Cobo Center, Detroit

08:15am – 08:55am

Mr. Ali JAMMOUL – Global Director Body Exterior And Safety Engineering At Ford

Body Lightweighting

09:00am – 09:40am

Paper 1: Dr. Gerald COLE – President At Light Weight Strategies LLC

Light Weighting the Automotive Industry - The Road to 2025 CAFÉ

09:45am – 10:25am

Paper 2: Mr. Laurence CLAUS - President At NMI Training & Consulting Inc. & Technical Consultant To EJOT Fastening Systems LP USA

EJOT Fastening Solutions Enable Lightweight Body-in-white Assembly

10:25am – 11:00am

Break for Refreshments/Coffee/ Tea, Snacks, Networking, Tech Exhibition

11:00am – 11:40am

Paper 3: Dr. Akio NIIKURA - General Manager R&D Division At UACJ Corp.

UACJ's Global Strategy And Approach To The Automotive Aluminum Market

11:45am – 12:05pm

Paper 4:
Mr. Lawrence E. BROWN – Executive Director At Lightweight Innovations For Tomorrow

Lightweight Innovations For Tomorrow!!!!

12:10pm – 12:40pm

Closing Keynote:
Ms. Laura ANDERSON – CEO At Aluminum Blanking Company

The Story Behind Aluminum's Sourcing Evolution: A North America Perspective

12:40pm – 12:45pm

Summary:

Mr. Jost GAERTNER, Managing Partner At AluMag Automotive GmbH

12:45 pm – 01:30pm

Reception Speech With Snacks & Finger Food

Mr. Michael KOEHLER - Industry Vice President At Reed Exhibitions USA

01:30pm – 05:30pm

Individual Or Guided Visit At The 2015 "Aluminum USA" Exhibition

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TITLE

Advanced Counter Pressure Casting Process for Light-Weighting of Auto and Truck Chassis and Suspension Components

ABSTRACT

1. Background of “Light-Weighting” Automotive and Truck Components
2. Advanced Counter Pressure Casting

Advanced Counter Pressure Casting for Light-Weighting of Auto and Truck Chassis and Suspension Components

North American Automotive Lightweight
Procurement Symposium
Detroit, Michigan
November, 2015

Gary F. Ruff
Ruff & Associates, LLC

Why Light-Weighting?

- Variability in Fuel Prices
- Additional Safety Feature Requirements
- Increased Operating Performance
- Need to Support Alternate Propulsion Systems (hybrid, electric, fuel cell, etc.)
- Latent Desire for “Muscle” cars and “Retro” styles
- Ongoing CAFE Regulations for Improved Fuel Economy

Evolution of Light-Weighting

- Vehicle Size and Associated Weight Reduction
- Part Size and Wall Thickness Reduction
- Direct Conversion of Components to Lighter Weight Materials
  - Initial Focus was Powertrain and Drivetrain Components, Along with Wheels
- Use of Existing Processes with Lightweight Materials

…mostly "low-hanging fruit"

Need for Ongoing Light-Weighting

- *Continued Increasing CAFE Targets Required More Dramatic Actions*
  - Increased Use of Computer Aiding Engineering to Optimize Designs for Weight Removal and Improved Performance
  - Initiation of Work on Higher Integrity, Safety-Critical Structural Components Involving the Chassis, Suspension, and Brake Systems, Up to this Point Almost Untouchable
  - Entirely New Materials Such as Metal Matrix Composites, Carbon Fiber Composites and others
  - Introduction of Entirely New Processes to Provide the Ability to Produce the Thinnest Sections, Unique Geometries and Utilize Advanced Materials

Production of High Integrity, Structural Castings for Chassis and Suspension Applications

High Integrity Structural Castings

- High Integrity Structural Castings, "definition":
  - Consistent & reliable, with in-process real time testing and analysis
  - Most often, high tensile and yield strength, plus high ductility
  - Good fatigue life
  - Sometimes, moderate strength, with *very* high ductility (e.g. subframes, crossmembers)
  - Good impact resistance
  - Good surface finish

High Integrity Structural Castings

Example: General Motors rigidly defines the expectations for structural aluminum castings in GMW 16704 and 16705, along with the following print requirements:

- Tensile Strength and Yield Strength obtained from specific in part locations are required to meet Weibull B_1 minimum values of 290 MPa and 220 MPa, respectively
- Elongation must be greater than 8%
- The Manufacturing Process and PPAP must be Validated using out-of-part Overstress Probe and Staircase Fatigue Tests, also to B_1 minimum values.
- Part integrity via 100% x-ray based upon FEA Analysis with areas defined as Highly Critical classified as Grade A of ASTM B 686-95, moderately stressed as Grade B and remainder Grade C. This equates to ASTM E155 exceeding Level 1, Level 1 and Level 2, respectively.
- 100% Fluorescent Liquid Particle Inspection with No Linear Defect Indications Allowed

Metallurgical Parameters That Must Be Addressed to Meet These Specifications

- The Casting MUST be:
  - Sound (No gas, inclusions or similar defects)
  - Grain refined
  - Modified
  - Solidified as Rapidly as Possible (to support grain refinement and silicon modification)

Keys to Achieving Optimum Aluminum Casting Properties

1. Prevent the formation of oxide films or folds
2. Eliminate shrinkage
3. Eliminate inclusions
4. Eliminate gas bubbles
5. Modify or refine the eutectic silicon
   -Finer SDAS
6. Refine the grain size
   -More, small dendrite trees

High Integrity Casting Processes

- Vacuum Die Casting (vs Conventional)
- Permanent Mold & SPM, Tilt, Reverse Tilt
- Low Pressure
- Squeeze
- SSM
- Vacuum Low Pressure
- ***Advanced Counter Pressure Casting***

What is Advanced Counter Pressure Casting?

Advanced Counter Pressure Casting™ (ACPC) is a *unique and advanced* adaptation of low pressure casting using the Counter Pressure process that is capable of producing *high integrity aluminum structural and safety parts*

Typical parts include:

- Steering knuckles/spindles
- Control and swing arms
- Structural brackets
- Yokes-chassis and suspension
- Subframes and crossmembers
- Others Under Investigation

Consequently, Advanced Counter Pressure Casting has evolved as the fastest growing process globally for the production of high strength and ductility, lightweight steering knuckles and control arms.

How Did "Counter Pressure Casting" Evolve?

Evolution-Counter Pressure Casting (CPC)

- Invented at the Institute of Metal Science and Technology of the Bulgarian Academy of Sciences
- Additional research and development was done at the University of Sofia in Bulgaria in the 1980's
- First commercialization was to replace die-casting
- CPC/Ilinden obtained the patents and know-how in the 1990's, improved the process and redesigned the machines
- The CPC Group initially targeted the specialty wheel market because the high integrity allowed aluminum wheels to be chrome-plated and cast in larger sizes
- Because of the high quality and low cost of CPC's process and equipment, high volume production vehicle wheels started being made using this process
- The CPC Group became the global leader in aluminum wheel production equipment

How Did Advanced Counter Pressure Casting Evolve?

Evolution-Advanced Counter Pressure Casting (ACPC)

- Conversion of many aluminum structural and safety parts, such as knuckles, began in earnest in the 1990's
- Starting with conventional low pressure, advancements were made by using squeeze casting (CMI) and vacuum/pressure riser-less casting (A-CMI), particularly for front knuckles and control arms
- Short comings and quality issues with these processes led to further development to provide a better, more risk-free process with lower costs
- The original process used by the CPC Group to make wheels was evaluated but judged to need improvements to make it capable of providing the structures and properties required for parts such as front knuckles and control arms

How Did Advanced Counter Pressure Casting Evolve?

Evolution-ACPC

- In 2000, Intermet, which was the largest supplier of iron knuckles worldwide, decided to develop with a process based on CPC to produce aluminum knuckles, but integrate in the strong points of the other processes
- The ACPC process then was developed by adding significant mold/part cooling capability, more sophisticated pressure controls, and improved metal treatment and chemistry control to counter pressure filling, the sealed chamber, and controlled, uniform fill of the CPC process
- A demonstration cell was constructed and based on the quality, properties and strict controls, many customers became interested
- The first high volume production started in September, 2001 with the GM U/W front knuckle which had annual volumes of approximately 2 million knuckles per year

First ACPC Cell (circa 2000)

PCPC Desirable Process Features

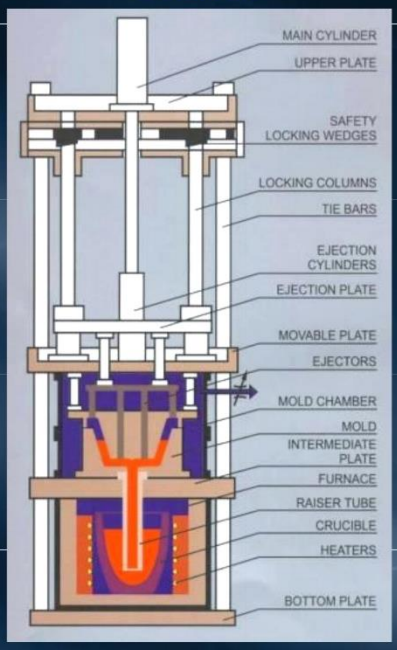
- Metal enters die cavity from bottom
- Metal flow is controlled against pressure head (counter pressure)
- Flow is smooth and non-turbulent (tranquil)
- Metal is filtered two times during the casting process (bottom of inlet tube and at sprue)
- Solidification is controlled via thermally modeled mold design and directional cooling
- Once metal enters the heated crucible furnace, and is degassed and de-drossed, it is never disturbed again throughout the entire casting process

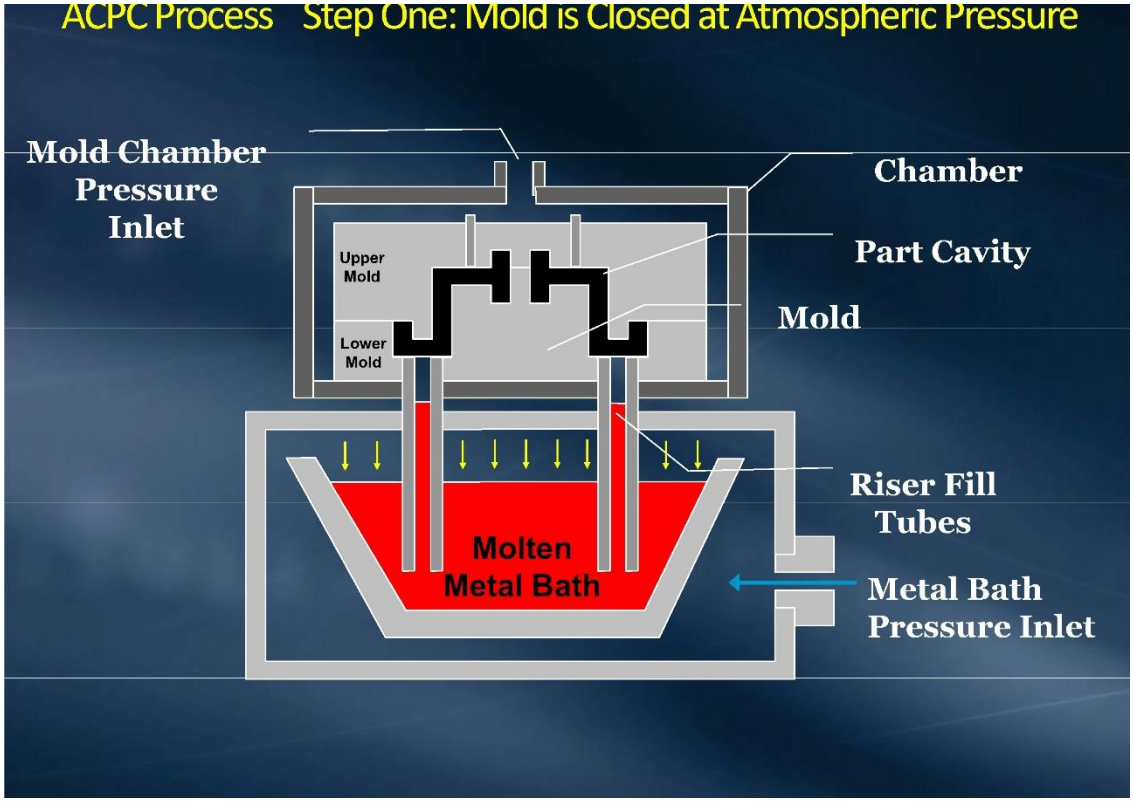
How Does ACPC Work?

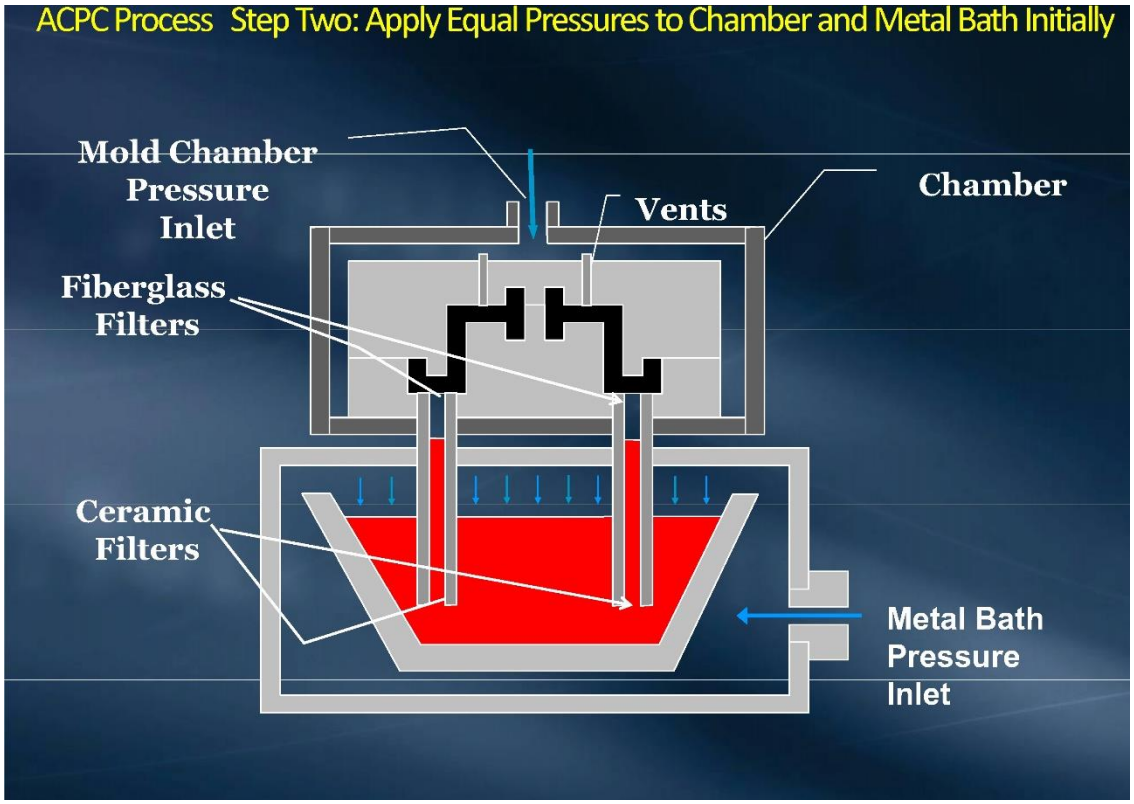
Casting Machine

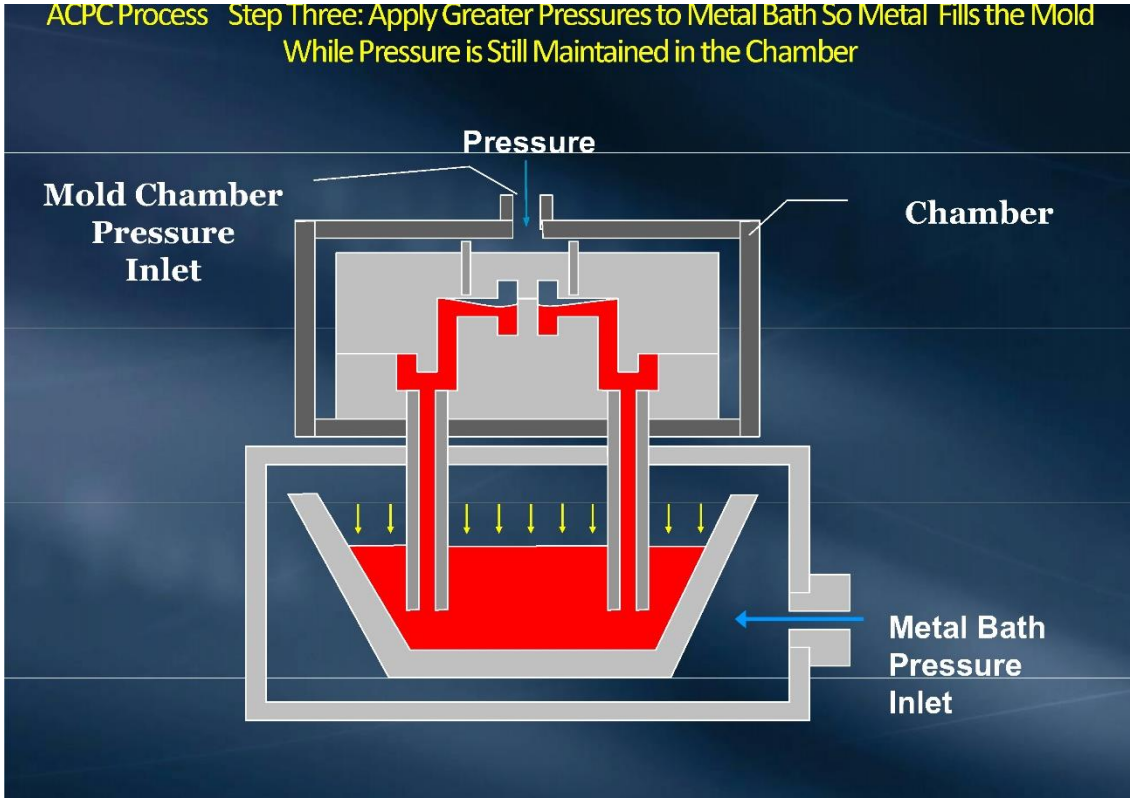
- A process utilizing a ***double sealed*** metal mold and a ***sealed*** crucible of molten aluminum below the mold.
- An initial ***Counter Pressure*** is applied to both the mold cavity and the molten metal in the crucible.
- Both volumes are stabilized to the same pressure and then the two volumes are separated by closing an isolation valve.
- The pressure in the furnace is increased in mbar increments to fill the mold cavity using a computer controlled fill profile.

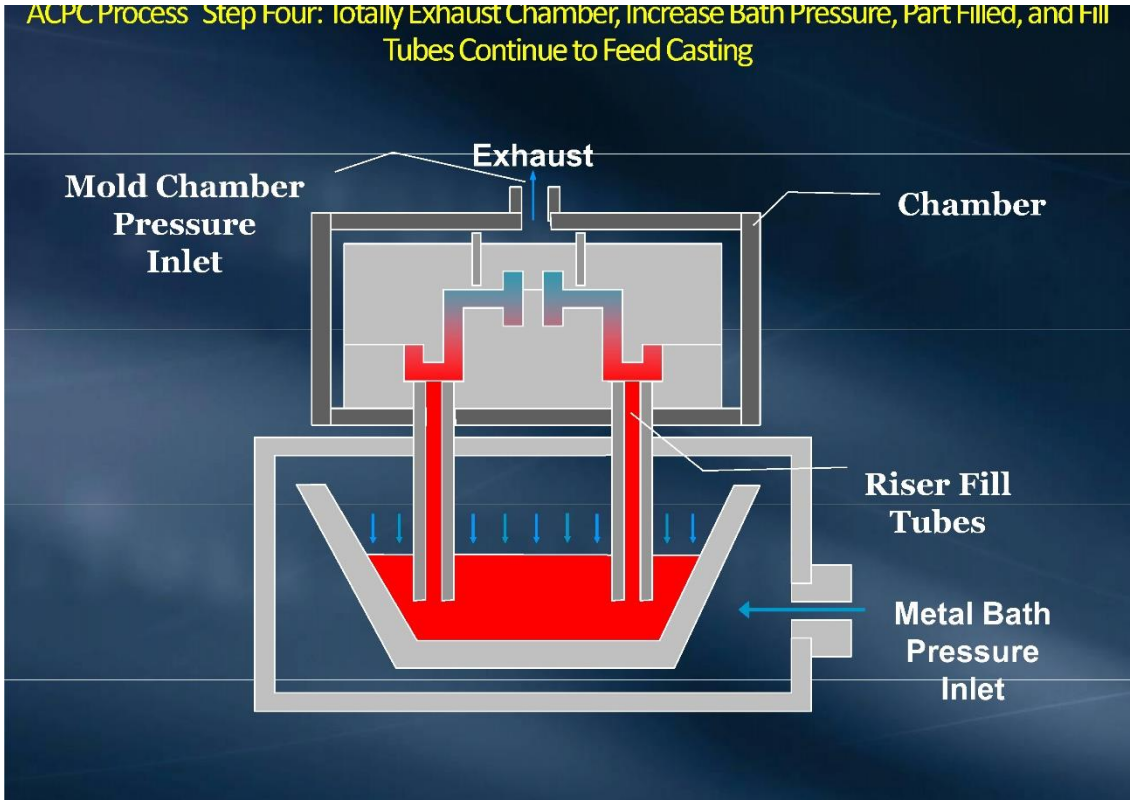
Schematic



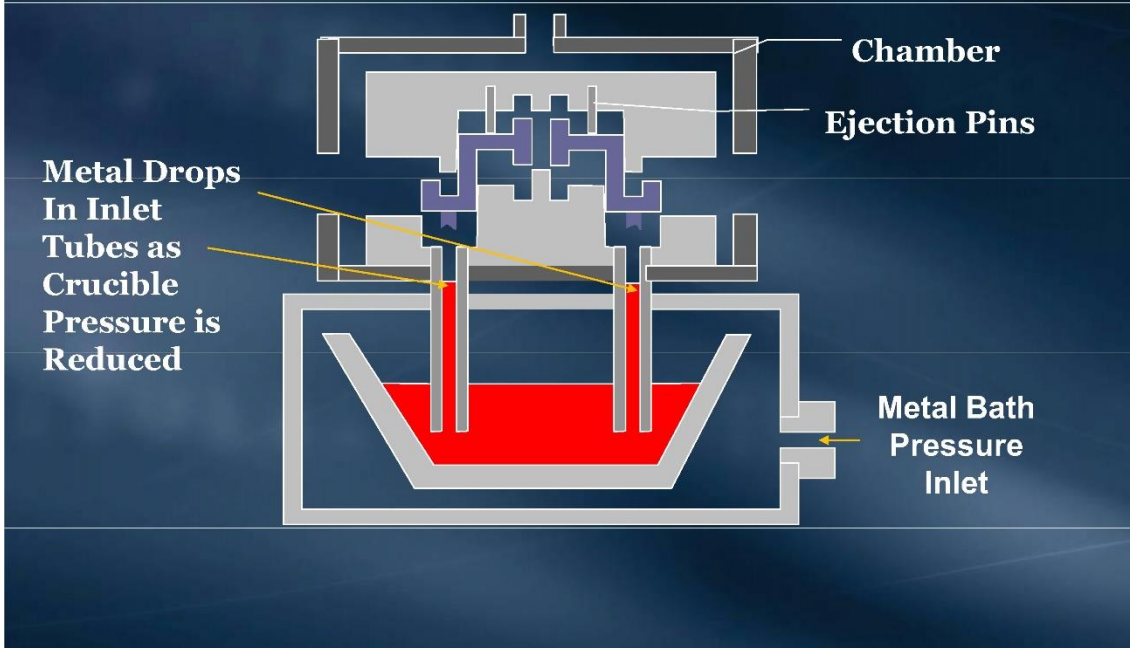

ACPC Process Step One: Mold is Closed at Atmospheric Pressure
Mold Chamber Pressure Inlet
Chamber
Part Cavity
Mold
Upper Mold
Lower Mold
Riser Fill Tubes
Molten Metal Bath
Metal Bath Pressure Inlet


ACPC Process Step Two: Apply Equal Pressures to Chamber and Metal Bath Initially
Mold Chamber Pressure Inlet
Vents
Chamber
Fiberglass Filters
Ceramic Filters
Metal Bath Pressure Inlet

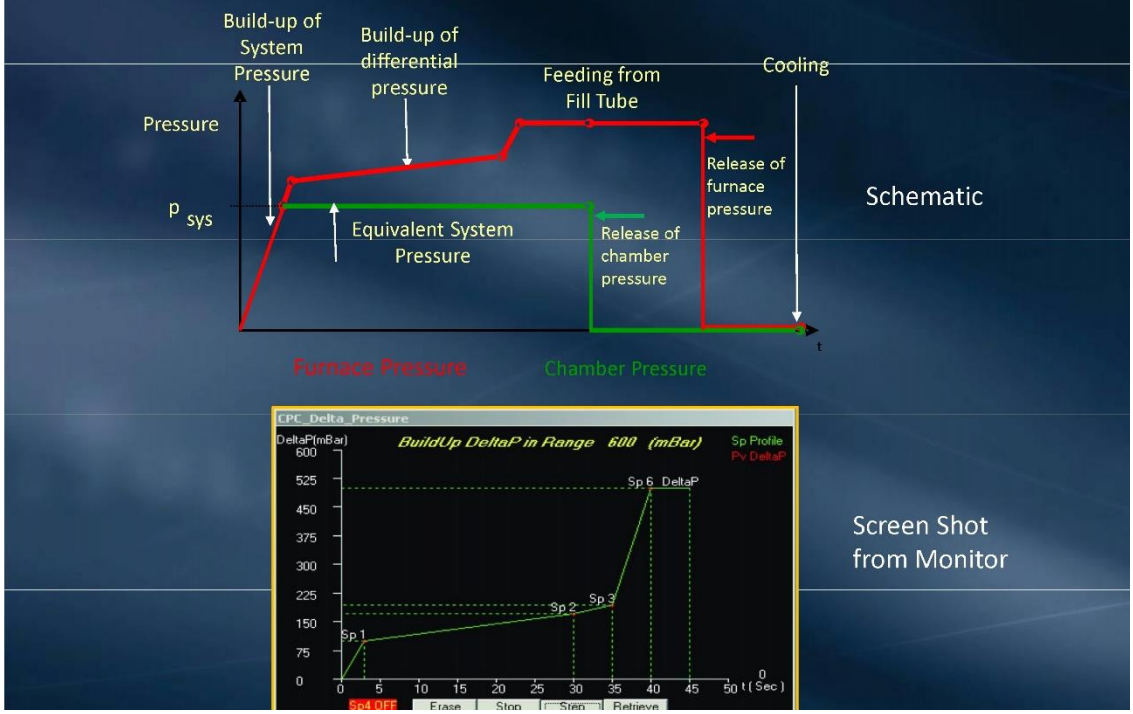

ACPC Process Step Three: Apply Greater Pressures to Metal Bath So Metal Fills the Mold While Pressure is Still Maintained in the Chamber
Pressure
Mold Chamber Pressure Inlet
Chamber
Metal Bath Pressure Inlet


ACPC Process Step Four: Totally Exhaust Chamber, Increase Bath Pressure, Part Filled, and Fill Tubes Continue to Feed Casting
Exhaust
Mold Chamber Pressure Inlet
Chamber
Riser Fill Tubes
Metal Bath Pressure Inlet

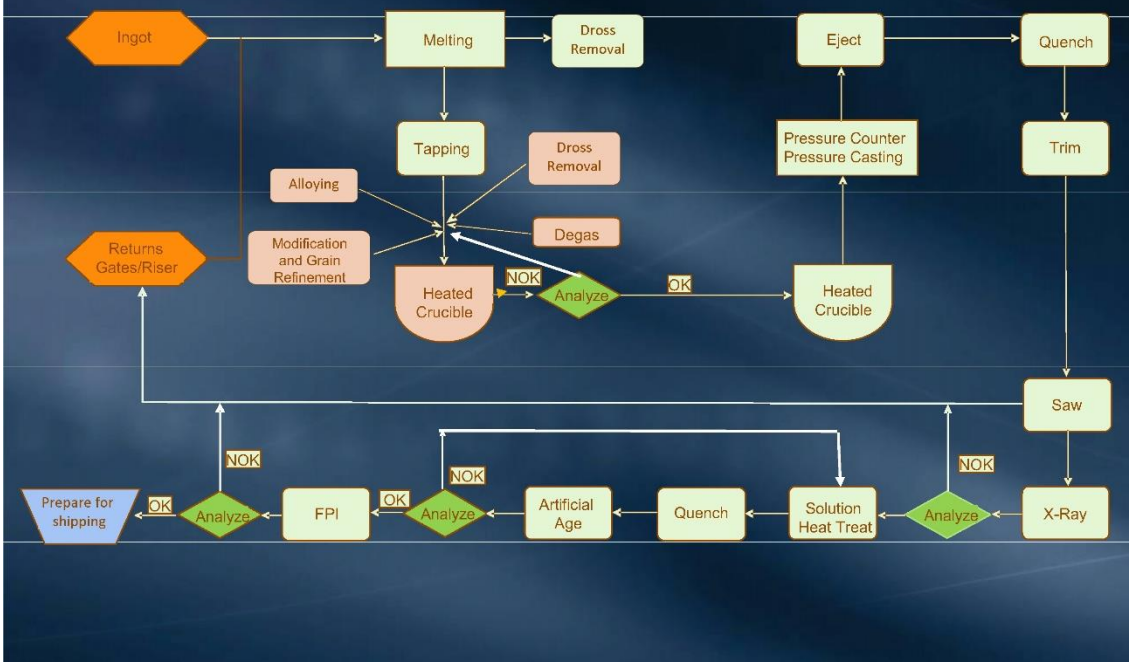
ACPC Process Step Five: Reduce Pressure on Bath, Metal Drops in Inlet Tubes Ready to Fill Next Mold, Mold is Opened, Part is Ejected and Removed



Advanced Counter Pressure Casting Pressure Changes



Advanced Counter Pressure Casting Process Flow



Advanced Counter Pressure Casting

Since that starting point, continuous improvements and advancements have been made with the CPC Group to the ACPC casting process

- Increased tie bar spacing and larger platen sizes to permit more parts per mold and larger components to be manufactured
- Increased number of cooling circuits to 96 from 64
- Larger and optimally designed crucibles to allow for fewer metal changeovers
- Improved mold cooling system
- Quick mold change system techniques
- More and improved controls and data collection capabilities
- Special access to back of mold for large cavities, plus tiltable movable molds for easier maintenance
- Ability to cast cored parts using either metal core pull techniques or sand cores

Advanced Counter Pressure Casting

Since that starting point, continuous improvements and advancements have been made with the CPC Group to the APCPC casting process

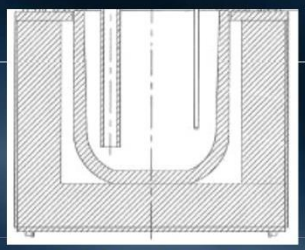
- Increased tie bar spacing and larger platen sizes to permit more parts per mold and larger components to be manufactured
- Increased number of cooling circuits to 96 from 64
- Improved mold cooling system

Latest CPC 1600-C96 Large Platen Machine

Increase to 96 Cooling Circuits with Improved Control and Monitoring

Advanced Counter Pressure Casting

- Larger and optimally designed crucibles to allow for fewer metal changeovers and more parts per mold

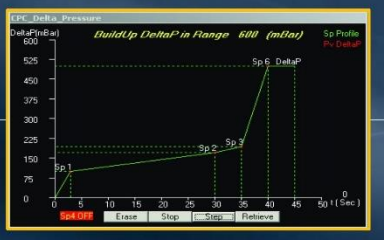


Straight wall crucible with 900kg capacity

Larger crucible provides space for more fill tubes

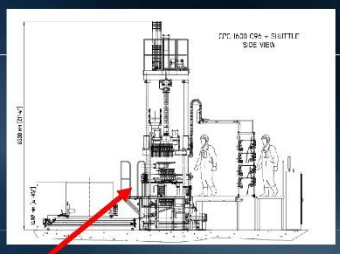
- Improved mold cooling system more and improved controls and data collection capabilities

Touch Screen Monitor Screen Shots



Advanced Counter Pressure Casting

- Special access platform to back of mold for large cavities, plus tiltable movable upper mold half for easier maintenance



Access Platform for Large Molds

Tiltable Upper Mold Half

- Quick mold change system techniques using shuttle system and quick disconnects

Advanced Counter Pressure Casting

- New Filter Concepts to prevent inclusions and fluid dross from entering the mold cavity

Fiberglass Screen Filter Which is Placed Between the Sprue (bottom mold half) and Sprue Spreader (upper mold half)

- Advanced tooling with integrated water cooling, plus the ability to cast cored parts either using metal core pulls or sand cores

Advanced Counter Pressure Casting

Keys to Producing Optimum Knuckles and Control Arms

- ✓ Prevent the formation of oxide films or folds
  - ➢ Counter Pressure in chamber results in non-turbulent flow, level filling and no films or folds forming
- ✓ Eliminate shrinkage
  - ➢ Extensive, selective water cooling of the mold and part, plus the continued pressure applied through the fill tube essentially eliminate shrinkage
- ✓ Eliminate inclusions
  - ➢ Removal of dross during metal preparation, along with using filters at the bottom of the fill tube and at the sprue inlet eliminate inclusions from entering the mold cavity
- ✓ Eliminate gas bubbles
  - ➢ Degassing the metal with Argon to specific gravities >2.60 gm/cc, non-turbulent metal transfer using the shuttle system, and use of Counter Pressure in the mold result in no gas entering or being formed in the mold cavity or part
- ✓ Modify or refine the eutectic silicon
- ✓ Refine the grain size
  - ➢ Both accomplished during metal processing by using calculated Strontium and TiB_2 additions and monitored by microstructural analyses

Advanced Counter Pressure Casting

- *The Results…*
  - These actions and their results have lead to the ACPC process presently being the most widely selected process worldwide for the production of high integrity aluminum steering knuckles and control arms
    - Over 90% of the casting machines now being produced by the CPC Group are now ordered to produce ACPC aluminum knuckles, control arms and other structural parts
    - There have been 11 ACPC plants constructed and placed in operation since the original plant in Stevensville, Michigan started production in 2001, and the building of at least another 3 plants has been announced
    - Plants are located in the United States, China, Korea and Germany, and consideration is being given to facilitizing in Brazil, India and Eastern Europe
    - Originally, most ACPC parts were conversions from steel and aluminum forgings, and ductile iron castings—however, now a large percentage of knuckles and control arms are being designed directly as aluminum castings, particularly those made using ACPC

Advanced Counter Pressure Casting

- *The Results from actual production parts…*

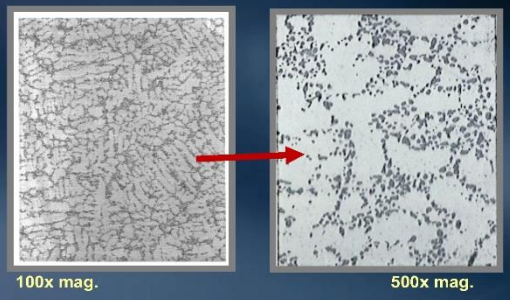
Typical ***In-Part*** Mechanical Properties and Hardness

- A356 - T6
  - UTS - 320-360 MPa
  - YS - 230-260 Mpa
  - %EL - 9-12 %
  - BHN - 92-102
  - SDAS - 20-35 microns

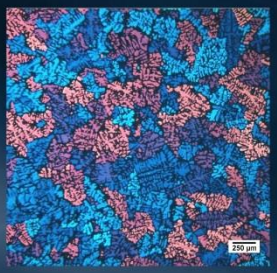
Results vary based on the locations selected for specimens, section thickness, water cooling and proximity to the inlet

Advanced Counter Pressure Casting

- Results from typical microstructure evaluations



Eutectic Silicon Modification
SDAS ~ 25-30 microns



Aluminum Grain Refinement
Grain Size ~ 250 microns

- Uniform distribution of microstructure
- Absence of porosity and oxides
- Small SDAS and fine Grain Size

Advanced Counter Pressure Casting

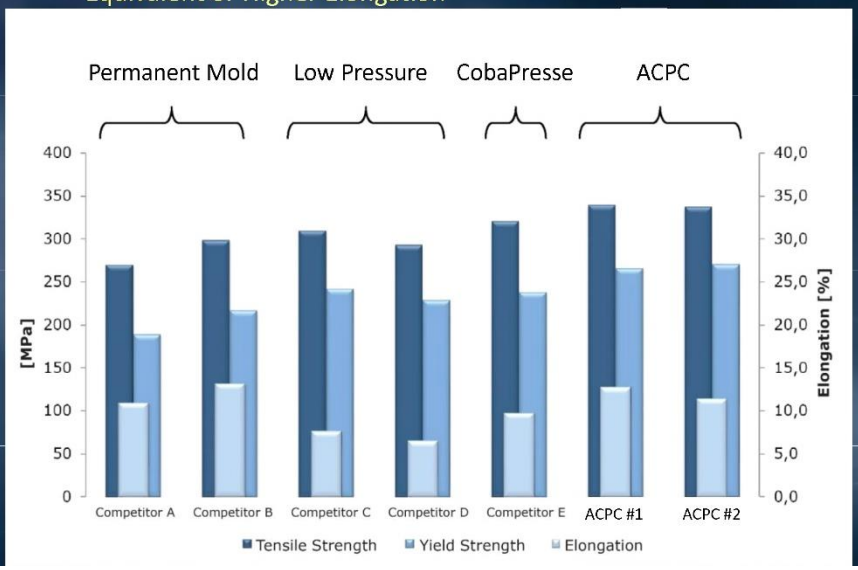
Process Assessment - Aluminum Steering Knuckles-Structural Castings

Attributes	Manufacturing Processes: Gravity Perm Mold	Low Pressure	ACPC	VRC/PRC	Squeeze Casting	RheoCast	ThixoCast	Forging
Properties								
UTS (Mpa) Tensile Strength	260	276	330	310	290	310	300	320
YS (Mpa) 0.2%Offset Yield	180	207	240	220	220	240	230	270
% Elongation	5	7	10	9	9	10	10	10
Fatigue (Mpa) $n=10^7$	70	75	90	85	90	100	100	110
Microstructure								
Grain Size[1]	1000 micron	800 micron.	250 micron	750 miron.	500 micron.	150 micron	150 micron	200 micron.
SDAS (dendrite)	40 micron	40 micron	25 micron	25 micron	15 micron	globular	globular	not applicable
Oxides (risk factor)	Moderate	Moderate	Very Low	Moderate	Moderate	Low	Low	Low , lap issues
ADVANTAGES	lower cost	extensive use, wheels	high quality, strength & ductility	quality & strength	quality & strength & history	high quality, strength & ductility	high quality, strength & ductility	high quality, strength & ductility
DISADVANTAGES	manual operator control, lower ductility, issues on tranquil filling	usually 1-on, issues on controlling filling and longer cycle times	limited number sources, but part design interchangeable with other processes	proprietary process & seal issues on dies cause seam defects	potential for oxides from die lube, eutectic segregation, equip & tooling cost high	limitation on current shot weight size, new process	High material cost using special billet and reuse of returns	Properties are often directional, reduced net shape potential and material/process cost is high
Process Info[2]								
Seconds/part	75	240	37	37	50	25	25	unknown
Pieces/mold	4	1-2	4	4	2	2	2	1-2
Typical Parts	rear knuckles, crossmembers	wheels, crossmembers, lower control arms	front & rear knuckles, lower control arms	knuckles, crossembers, lower control arms	front knuckles	upper control arms, ABS housings	upper control arms	upper control arms
Size Limits	1.5 meters	1.0 m	0.5-1.0 m	0.5-1.0 m	0.5 m	0.4 m	0.5 m	0.5 m
Cost & Investment[3]	1	1.1	1.2	1.3	1.4	1.4	1.5	2
Lead Time (weeks)[4]								
-Prototype	10	11	12	14	18	16	16	24

1. Note Grain Size depends on process additions and control, the data listed in table are from observations, va;ues for individual parts and sources may vary.
2. Process information represents **typical data** and is from benchmarking studies, results may vary from individiual sources and equipment..
3. Base set at 1.0 for Gravity Permanent Mold, individual part cost w ill vary by size, volume, material specification, etc.
4. This is estimated timing for parts from metal 'hard' tooling, assuming design freeze, and part not requiring pulls. Secondary processing, support equipment, etc. may take longer.

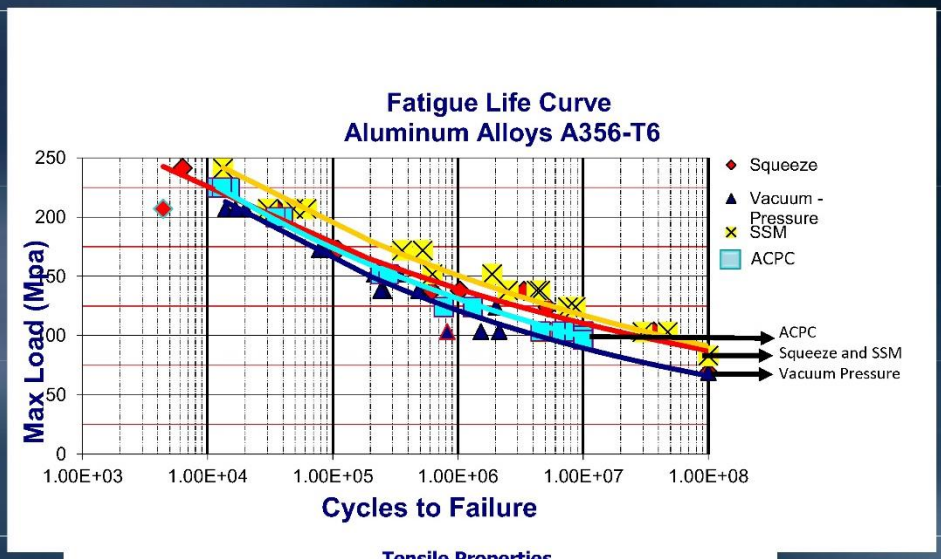
Advanced Counter Pressure Casting

- How does ACPC Compare to Competing Processes Used to Produce Aluminum Knuckles and Control Arms?
  - Higher Ultimate Tensile Strength
  - Higher 0.2% Offset Yield Strength
  - Equivalent or Higher Elongation



Advanced Counter Pressure Casting

- Comparison of Fatigue Life for Various Aluminum Casting Processes- USCAR Data



Tensile Properties

PROCESS:	SSM	Squeeze	VRC/PRC	ACPC
UTS (MPa)	307	312	323	325
Yield (MPa)	210	243	243	245
% Elongation	15.2	11.0	11.3	14.3

Advanced Counter Pressure Casting

- Examples of Aluminum Steering Knuckles Produced Using ACPC

Advanced Counter Pressure Casting

- Examples of Other Aluminum Structural Parts Produced Using ACPC

Lower Control Arm

Upper Control Arm

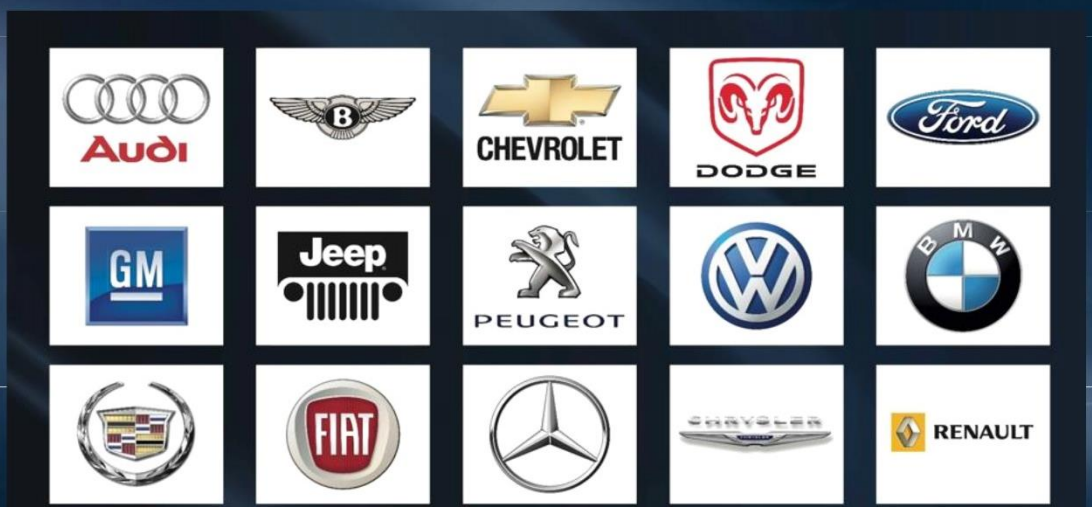
Suspension Yokes

Upper Control Arm

Structural Brackets

Advanced Counter Pressure Casting

- It is estimated by the CPC Group that over 50 million knuckles, control arms and other structural parts will be cast using the ACPC process in 2015
- Below are a number of "Western" OEM's that will have ACPC parts installed on their vehicles worldwide
- In addition, many Chinese OEM's are beginning to use ACPC components, or are in the prototype or design phase of implementation



Advanced Counter Pressure Casting

- ACPC Success Stories

High Volume Knuckle Conversion from Squeeze to ACPC Casting

High Volume Front Lower Control Arm Conversion from Ductile Iron to an Aluminum ACPC Casting

High Volume Front Lower Control Arm Conversion from a Welded, Multi-Piece Steel Stamping to and Aluminum ACPC Casting

High Volume Steering Knuckle Conversion from Ductile Iron to an Aluminum ACPC Casting

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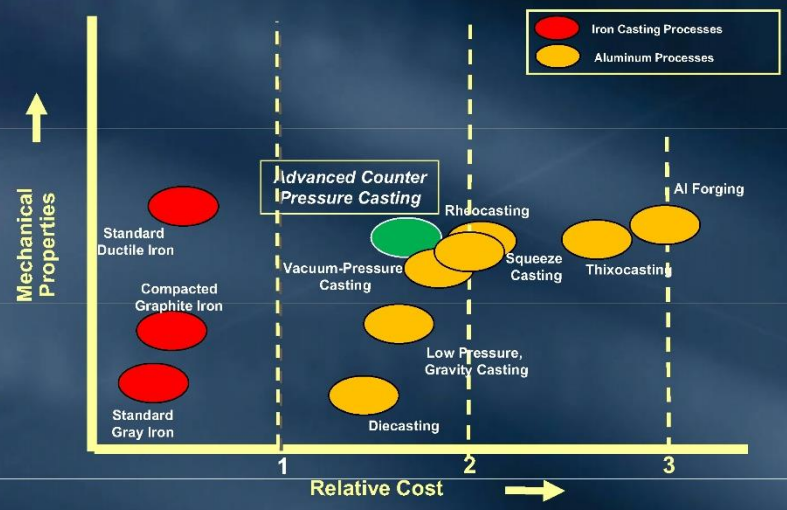
Casting Process/Material Continuum



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