Aluminum Castings;
Trends and Opportunities

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JLJ Technologies, Inc.  
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• Consultant, specializing in the technology of:
  – Light metal castings
  – Hypereutectic Al-Si alloys and bare-bore engines
  – Semi solid metal casting and the rheocasting process

• Clients include: automotive OEMs; commercial, automotive and aerospace foundries; foundry equipment suppliers
Will Provide a Brief Overview:

Aluminum Trends;
Alloys,
Products & Processes;
Foundry Challenges;
& Opportunities for Collaboration
The Castings Market; (N. America, basis - AFS Forecasts & Trends 2004)

- **All metals:**
  - 2004: ~12 MMT* (11.9 M vehicles)
  - *2008: growth to high of ~17 MMT/year* (14 M vehicles)
  - 2012: drop to ~14 MMT/year (12.7 M vehicles)

- **Aluminum:**
  - 2004: a reasonable year at ~2 MMT
  - *2008: growth expected to ~2.7 MMT/year*
  - 2012: some retraction to ~2.6 MMT/year

- *MMT = million metric tons*
Automotive OEM’s

- **Largest Light Metal Castings Market**
  - N. America Aluminum
    - 2004- 1.5 MMT*
    - 2008- 1.7 MMT
    - 2012- 2 MMT
  - N. America Magnesium
    - 2004- 80,000 MT
    - 2008- 200,000 MT
    - 2012- 230,000 MT

  - *MMT = million metric tons
US Automotive Aluminum Castings Opportunities
(% of vehicles employing)

- Cast aluminum engine blocks:
  - 2004 = 45% growing to 2008 = 65%

- Aluminum suspension castings:
  - 2004 = 30% growing to 2008 = 50%

- Cast aluminum wheels:
  - 2004 = 75% growing to 2008 = 85%

- Cast aluminum differential carriers:
  - 2004 = 30% growing to 2008 = 50%

- Cylinder heads, Transmission Cases & Intake manifolds remain flat or decrease
Other US Aluminum Casting Opportunities
(average % growth per year)

• Growth expected to exceed the general economy:
  – Marine +3.2%
  – Non-auto/light truck engines +2.4%
  – Heating and air conditioning +2.6%
  – Aerospace +2.3%
  – Instrumentation +2.3%
Other US Aluminum Castings Opportunities
(average % growth per year)

• Growth expected to lag behind the general economy:
  – Power tools  +1.2%
  – Meters and regulators  +1.1%
  – Household appliances  +1%
  – Office/Computer  -1.9%
The **SSM** Market

- The major potential market for SSM components is automotive.
- Die casting is projected to grow significantly in the next 8 years, and permanent mold even more-so – almost all growth in products (engine and structural) that could benefit from SSM.
- For high integrity structural castings:
  - 20% of the market could benefit *immediately* (0.1 MMT/year in 2004), and
  - 40% by 2012 (growth to >0.4 MMT/year by 2012).
The SSM Market

• For high integrity die castings:
  – >10% could benefit immediately by conversion to SSM (0.2 MMT/year in 2004), and
  – 40% by 2012 (growth to >1 MMT/year by 2012)

• Globally, the potential SSM market is estimated to grow from:
  – ~0.6 MMT/year now
  – to ~2.4 MMT/year by 2012,
  – if process capacity and prices support the market

• The key to growth will be piece cost and availability of product
Automotive OEM
Issues & Considerations

• Automotive:
  – The Largest Aluminum Castings Market
  – Placing Engineering/Design Demands on Suppliers
  – Placing Severe Pricing Pressures on Suppliers
  – Changing Loyalties
Automotive

- **OEM’s Placing Engineering/Design Demands on Suppliers (USA):**
  - Component & system designs now largely done by contractors and suppliers
  - Suppliers must provide full service
    - Design, testing, verification, launch, production & quality control
  - That capability is costly **BUT**
  - **OEMs do not necessarily acknowledge the cost or expect suppliers to recover cost in component pricing**
Automotive

• **Severe Pricing Pressures Placed by OEMs:**
  – OEM’s “shop” parts, regardless of the development source
  – They set a “market price”
  – They seek lowest bidders
  – Then negotiate down from there
  – + They require annual “productivity” give-backs
Automotive

• OEM Loyalty Issues:
  – “Contracts” are sometimes “one-way”
    • OEMs sometimes re-source if offered a better price, regardless of current contract
  – Full-service suppliers too often find themselves at a disadvantage to those with less capability and thus better prices
Automotive
-HOWEVER-

• **Automotive is the Largest Aluminum Castings Market**

• Suppliers *must* find a way to deal with issues; they *must*:
  – 1) Be **focused**; must seek to be the recognized expert in certain components or assemblies; *should not try to do everything*
  – 2) Be **smart**; should seek the business where they are *the best*
  – 3) Be **capable**; need to be full service in their specialty; *be the “go-to” source*
Automotive OEM’s; HOWEVER

- **Automotive is the Largest Aluminum Castings Market**
- Suppliers *must* find a way to deal with issues; they *must*:
  - 4) Be a good *supplier*; must be on-time, have low ppms and be *reasonably* flexible regarding releases, etc.
  - 5) Be *profitable*; must price products to include reasonable margins and with a full understanding of how to achieve required give-backs without creating losses
Aluminum Trends; Alloys, Products & Processes; Foundry Challenges; & Opportunities for Collaboration
Alloys

• **Old standbys will continue to dominate** for years to come
  – A356 (and similar) for suspension components & wheels
  – 319 and 380 (and similar) for drive-train components, housings, brackets and HPDC

• **Some specialty alloys will come and go** as the specialty need arises
  – Example: 390 for wear & stiffness (pistons, engine blocks, transmission components)
Alloys

• Issues “wanting” resolution:
  – Better elevated temperature property retention in alloys having strength & ductility suitable for structural applications
    • For under-the-hood, attachments to drive-train, etc.
  – Higher strength + ductility alloys
    • For structural applications
  – Alloys having suitable strength + ductility for large structural parts, but w/o T-6 treatment
    • Avoid costs of T-6 and avoid dimensional issues
Alloys

- Issues “wanting” resolution: SOLUTIONS:
  - Better elevated temperature properties – alloys containing Cu – 319, 354, 355
  - Higher strength + ductility alloys – A206-type
  - Alloys having suitable strength + ductility for large structural parts, but w/o T-6 treatment – Al-Mg alloys, Al-Zn alloys
  - Other opportunities – normally-wrought alloys and MMCs
  - Bottom line, existing alloys are yet to be fully challenged in new applications
Alloys

• Opportunities exist for new alloys too:

• ACRC Projects:
  – Semi solid alloys
  – i-select-Al™ selection software
  – Mg alloy solidification characteristics
Alloy, Product & Process Opportunities go Hand-in-Hand; New Product & Process Opportunities Always Include Challenges
Products and processes go hand in hand:

– **Weight** is often cited as a conversion driver
– **Product cost** is *always the bottom-line driver*;
  & that includes:
  • **Casting cost** (material content, net-shape capability, capital, tooling and conversion costs)
  • **Machining** (metal removal requirements - net-shape casting capability)

– **Process considerations that reduce cost are the keys to future success.**
Aluminum Trends; Alloys, Products & Processes; Foundry Challenges; & Opportunities for Collaboration
One Specific Challenge Example; 
Large Castings

• The Parts:
  – Engine blocks, lower crankcases, cross-members, sub-frames, wheels

• Technical Challenges:
  – Filling, feeding, heat treating, maintaining dimensions

• The Cost Challenge:
  – Make thinner, lighter, stronger, faster, closer to net shape
SSM, a Potential Solution?

- SSM Components are very much akin to Conventional HPDC:
  - Near Net Shape
  - Thin Sections (but also Thick, if needed)
  - Great Detail and Complexity, plus
  - Excellent Dimensional Control & Surface Finish
SSM, a Potential Solution?

- Yet, SSM Components are of Very High Integrity:
  - Sound, Heat-treatable, Good Mechanical Properties
  - Utilize High-integrity Alloys
    - Primary Alloys (A356, 354, 355, etc.)
      - Parts are Heat Treatable; T-5 (SSM Advantage) or T-6
      - Parts Have Good Strength/Ductility Combination
    - OR, Suitable Secondary (380, 333, 319, etc.)
      - Parts are Sound, Leak Free
SSM - INHERENT ECONOMICS

- **Near-Net-Shape**
  - Minimum (or No) Machining
  - Material Thrifting, Minimum Material Content
  - Viscous Metal Flow, Minimum Turbulence, Minimum Scrap

- **Low Energy Content During Casting**
  - Long Tool Life (2 to 5 Times Die or Squeeze)
  - Fast Cycles

- **T-5 versus T-6 Heat Treatment**
SSM Process: Rheo vs. Thixo

RHEOCASTING

Solidification

SSM Billets

Partial Remelting

THIXOCASTING

THIXOFORGING

MHD

Mechanical Agitation

GR

Advances & Opportunities for Collaborative Research & Development

December 13-14, 2004 — NPU, Xi’an, China
THIXOCASTING: 
the traditional BILLET approach

• **Billet Has Limitations**
  – Supplied in Limited # of Alloys
  – Process Run-around Cannot be Reused for SSM w/o First Being Processed Back Into Billet

• Billet is Relatively Expensive
  – MHD Billet Sells at a Premium Over Similar-Alloy Foundry Ingot

• Billet-related Costs Offset Inherent SSM Economic Advantages

• **Billet Cost has Driven Development of Slurry SSM Processing Routes**
Background

SSM Structure Formation

**Traditional Understanding:**

Form dendrites $\rightarrow$ Dendritic growth $\rightarrow$ Shear off dendrites $\rightarrow$ SSM Structure

**New Understanding:**

Form dendrites (copious nucleation) $\rightarrow$ Suppress dendritic growth $\rightarrow$ SSM Structure

$\Rightarrow$ Controlled nucleation & growth!
RHEOCASTING: The SSM Slurry Alternative

- Utilize Normal Foundry Alloys/Forms
- Re-Use In-Plant Process Run-Around
- Require only provision for Small Grains and Melt Temperature Controls
SSM Slurry Alternatives

- NRC® Process – Ube
- SSR™ Process – IdraPrince
- CRP
- SoD Process – Mercury Marine
- And Others
UBE: New Rheocasting (NRC) Process

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SSR$^{TM}$ Process

(R. Martinez, J. Yurko, and M.C. Flemings, 2001)

Advances & Opportunities for Collaborative Research & Development

December 13-14, 2004 — NPU, Xi’an, China
Continuous Rheoconversion Process (CRP); WPI

Mixing of Liquids in Reactor Creates Copious Nucleation of Tiny α Grains
Sub Liquidus Casting (SLC™); THT Presses

Pre-grain refined liquid is introduced into shot sleeve at just above liquidus temperature.
Sub Liquidus Casting (SLC™); THT Presses

- Globular Structure Develops as Grain Refined Melt Cools Under Controlled Thermal Conditions in the Shot Sleeve to Semi Solid Temperature
- Only Slurry of Appropriate Temperature is Direct-Gated into Die Cavity
SLC™

• SLC™ is a trademark of THT Presses, Inc., and stands for SUB LIQUIDUS CASTING

• SLC™ is a low-cost slurry route

• SLC:
  – Uses Foundry Ingot & Re-uses Run-Around
  – Requires no Pre-Development of Slurry or Billet
  – Product is Ejected Free of In-gates
SLC: Providing A Universe of Gating Possibilities for Large Castings

- **Large diameter shot sleeve**
  - 1000T and higher machines, 50-55 cm shot sleeves
  - Oval sleeve concept being developed

- **Large shot weights/volumes feasible**
  - 1000T and higher machines, 100 kg and larger shots
  - 200T machines, up to 20 kg shots
SLC: Ideal for Large Castings

• **Direct gating**
  – No runners
  – Short couple between biscuit and part
  – *Minimum need for shrinkage feeding* with SLC, *BUT*
  – SLC provides short and direct feeding paths to critical, shrink-prone areas

• **Minimum end-of-shot terminal pressure spike**
SLC Direct Gating
Direct Gating into Wheels
Cross-members, Sub-frames
SLC, Engine Block Gated into Bulkheads, similar to LPPM
SLC + CRP

• A natural marriage of two new concepts
  – SLC by THT Presses &
  – CRP by Worcester Polytechnic Institute
Continuous Rheoconversion Process (CRP); WPI

Mixing of Liquids in Reactor Creates Copious Nucleation of Tiny α Grains

- Superheat (ΔT)
- High nucleation rate
- Forced convection

Thixocasting - Solidify completely in cold crucible; reheat
Rheocasting - Solidify partially in heated crucible

Advances & Opportunities for Collaborative Research & Development
December 13-14, 2004 — NPU, Xi’an, China
Continuous Rheoconversion Process (CRP); WPI

- Nucleated α Grains Quickly Become Globules During Cooling to Semi Solid Processing Temperature;
  - As Slurry, for SLC
The ACRC at WPI
(Advanced Casting Research Center)

- Key current projects supporting casting industry growth:
  - Semi solid slurry development routes
  - Fluidized bed heat treatment
  - Improved melt cleaning & inspection methodologies
  - Improving alloy systems
    - Al-Si eutectic microstructure evolution
    - Mg alloy microstructure evolution
    - Alloys for semi solid processing
    - Die casting alloy selection software
Aluminum Trends; Alloys, Products & Processes; Foundry Challenges; & Opportunities for Collaboration
ACRC-NPU Collaboration

- Solidification studies, microstructure evolution and phase identification
- Alloy development and improvement
- Melt quality assessment
- Student exchanges
Conclusions

• **Automotive Aluminum Castings:**
  – A Huge Opportunity: *but*
  – OEM’s: A Challenge
  – Suppliers Must Find A Way To Meet That Challenge
  – Be Smart, Be Focused, Be Good & Be Profitable
Conclusions

• The next 4-8 years will provide substantial aluminum castings market growth opportunities

• Current alloys will continue to dominate, but opportunities will exist for new alloys, difficult-to-cast, normally-wrought, specialty alloys and MMCs
Conclusions

• Recent process developments can reduce piece cost and address needs, thus expanding product opportunities; Two examples:
  – SLC slurry SSM
  – Fluidized-bed heat treating
• University – Industry Alliances can help to overcome issues
• ACRC and NPU can collaborate
Aluminum Castings; Trends and Opportunities

Thank You!