Near Net Shape Forming Using Semi-Solid Metal Forming

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PRESENTATION OUTLINE

1. The Semi-Solid Metal Forming Processes
2. Thixocasting
3. Rheocasting
4. Applications of SSM Forming
5. The CSIR Process
6. Conclusion + Video
INTRODUCTION

1. THIXOFORMING
2. RHEOCASTING
LIQUID

Solidus temperature

SOLID

Ambient temperature

SEMI-SOLID

Globular structure formation

RHEO

Liquidus temperature

• CASTING
  Known since 3000 BC

• SEMI-SOLID METAL CASTING/FORMING
  Known since 1973 AD

• HOT FORMING
  Known since 3500 BC

• COLD FORMING
  Known since 4000 BC

• CASTING

THIXO

Known since 4000 BC
Thixocasting

SSM FEEDSTOCK

SSM FORMING PROCESS
## Disadvantages of the Thixocasting Process

<table>
<thead>
<tr>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>• High cost of feedstock material compared to normal foundry alloys</td>
</tr>
<tr>
<td>• In order to meet production rates multiple induction heating stations are required which requires high capital expenditure</td>
</tr>
<tr>
<td>• The scrap produced cannot be recycled on site and is also devalued significantly</td>
</tr>
<tr>
<td>• The feedstock is supplied in specific lengths, which means there would be additional scrap created by off cuts.</td>
</tr>
<tr>
<td>• During reheating oxidation of the billet surface occurs therefore dies have to be designed to remove oxides during the forming process.</td>
</tr>
<tr>
<td>• During reheating there are liquid metal losses from the billet prior to casting.</td>
</tr>
</tbody>
</table>
Rheocasting

Standard Ingot

Liquid

Semi-Solid

Solid

Furnace

NRC Slurry

Casting

Trim

Recycle Offal Back To

Cool

Transfer

Liquid Metal

Semi-solid metal with round grain structure

High Pressure Die Casting
Rheocasting Processes

- New Rheocasting Process (NRC) – UBE
- Semi-Solid Rheocasting (SSR) – MIT
- New Semi-Solid Casting – Hitachi
- Sub-liquidus Casting (SLC) – JLH Technologies & THT Presses
- Slurry on Demand (SoD) – AEMP
New Rheocasting (NRC) - UBE

Contech – USA
Citation – USA
Intermet – USA
Stampal - ITALY

Stampal - producing engine brackets for Fiat PUNTO
50000 pcs per month
Semi-Solid Rheocasting – MIT

Processed Alloy, as-cast

Reheated to 585°C
Hitachi Process

Electromagnetic stirring system at shot sleeve
SLC Process

Metal suitable for sub-liquidus casting resides within area defined by diameter “A”.

Small supply gates

Gate plate

Metal suitable for SSM processing

Over-cooled metal

Water cooled shot piston

Water cooled shot sleeve
## Advantages and Disadvantages of Rheocasting

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost of material same as standard casting alloys</td>
<td>Hydrogen Absorption</td>
</tr>
<tr>
<td>Semi-solid state achieved direct from liquid.</td>
<td>Process consistency</td>
</tr>
<tr>
<td>Oxidation reduced – reduced oxide entrapment.</td>
<td></td>
</tr>
<tr>
<td>Reduced loss of metal during reheating.</td>
<td></td>
</tr>
<tr>
<td>SSM scrap can be recycled in house.</td>
<td></td>
</tr>
</tbody>
</table>
Advantages of Using The SSM Forming Methods

- High wall thicknesses and different wall thicknesses can be designed
- Low gas porosity due to laminar filling and good airing
- Low solidification porosity due to a high solid fraction proportion \( (f_{\text{solid}} \sim 50\%) \)
- Production of thin walled components
- Allows for the casting of wide range of alloys inclusive of high strength wrought alloys.
- Joining by LASER, MIG or WIG welding possible
- Heat treatment from T0 - T7 possible
- Near netshape or netshape parts production
- Improved tool life
## Applications For SSM Forming

<table>
<thead>
<tr>
<th>Properties</th>
<th>RC</th>
<th>TC</th>
<th>SC</th>
<th>HPDC</th>
<th>LP casting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shrinkage Porosity</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Blow hole</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Segregation</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>2</td>
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<tr>
<td>Mechanical Properties</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Wrought alloy Application</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Hot Tearing</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Metal Fluidity</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Casting Cycle Time</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Die Life</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Product Cost</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>25</td>
<td>22</td>
<td>15</td>
<td>13</td>
<td>17</td>
</tr>
</tbody>
</table>

Key: (3) Excellent, (2) Good, (1) Some what poor, (0) Poor
# Examples of Applications of SSM Forming

<table>
<thead>
<tr>
<th></th>
<th>Master Break Cylinder</th>
<th>Fuel Rails</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Manufacturing Process</strong></td>
<td>PM</td>
<td>SF</td>
</tr>
<tr>
<td><strong>Annual Production (millions/yr)</strong></td>
<td>2.8</td>
<td>1.0</td>
</tr>
<tr>
<td><strong>Part Weight (lbs)</strong></td>
<td>1.7</td>
<td>0.98</td>
</tr>
<tr>
<td><strong>Min. Wall Thickness (mm)</strong></td>
<td>6.3</td>
<td>3.2</td>
</tr>
<tr>
<td><strong>Leak rate (%)</strong></td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td><strong>Machining Steps</strong></td>
<td>18</td>
<td>5</td>
</tr>
</tbody>
</table>

PM – Permanent mould  SF – Solid Forging

Winterbottom, W L
Applications of SSM Technology in the Automotive Industry

• BRAKE CALIPERS
• CLUTCH CYLINDERS
• SUSPENSION ARMS
• WHEELS
• PISTONS
• KNUCKELS

• ENGINE MOUNTS
• PULEYS
• ROCKER ARMS
• BELT COVERS
• MOTOR HOUSINGS
• SPACE FRAMES
Thin walled structural parts in doors A-Pillar

Door AUDI A3
Rear seat cover BMW R 1200 C motor bike

Condition:  As cast

Specification:  Perfect surface, low porosity
Component for AUDI A6 V8 Energy Management System for Bumpers

The Specification:
• No machining necessary
• High strength and elongation in condition T6
• Assembling forces > Material yielding strength
Weldable Thixoforming Components
AUDI A3 4-Door model:
A-pillar
Rear door hinge AUDI A2
Thixoforming parts lead to weight optimized solutions with a weight saving of 40-50% in comparison to steel designs.
Alfa Spider 2.0/16V

Rear suspension arm
Techno-Economic Analyses

Comparison of production costs for an A356 engine bracket, cast by different processes by Stampal, Italy
(SSM Rheo process is evaluated as 100%)
The CSIR Rheocasting System

- Induction heating/stirring coils
- PLC control unit
- Controls for air cooling
- Cups for processing billets
Assemblage of the Semi Solid Metal slurry maker
Temperature and power profiles of 7 continuously rheocast 60 mm billets with production rate one billet/min. The maximal temperature gradient is 5°C.
Seven continuous cast billets 60 mm diameter and 180 mm length, casting No p1.
The last one has been “kitchen knife tested”
Longitudinal section and two kitchen knife tests of the 90 mm billets
Microstructure of a 60mm diameter billet – average grain size 68 µm and shape factor 1.43

Microstructure of a 90mm diameter billet – average grain size 85 µm and shape factor 1.52
Microstructure's Homogeneity in 6 positions of a 60 mm billet
The CSIR Rheocasting System
Industrial Prototype
Proposed SSM Production Cell to be Established at ASC
Conclusions

• The SSM forming technology has demonstrated that it will be a competitive process for the manufacture of high quality, high volume components for the automotive industry in particular. The new slurry approaches to SSM forming has made the process economically viable.