HDF – fast Hot Die forming by active material blank feeding

The revolution in extreme lightweight metals forming

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Shown member was developed and manufactured by Dr. Amborn in the mold of his previous HEATform GmbH
About the HoDforming GmbH...

• HoDforming GmbH focusses especially on high-temperature forming - at best possible advanced temperature - of metals such as high strength aluminium or magnesium.

• HoDforming GmbH offers a unique and cost efficient HOT-Die forming technology which is proven in high volume production.

• The forming tools as well as the blank are advantageously tempered and the blank is actively feeded into the cavity.
Why forming in hot condition...
HDF Technology Portfolio

HDF – Hot Die Forming

HDF-H

- Hollow bodies (e.g. tubes)
  - HDF-H\textsuperscript{Al}
  - HDF-H\textsuperscript{Mg}
  - HDF-H\textsuperscript{St}

HDF-F

- Flat products (e.g. sheets)
  - HDF-F\textsuperscript{Al}
  - HDF-F\textsuperscript{Mg}
  - HDF-F\textsuperscript{St}

components based on

- Aluminium
- Magnesium
- Steel
HDF-H principles e.g. tube

A tube is heated up to an temperature profile, then is placed into an adequately heated die and sealed at both ends.

The positioning of material under hot gas pressure with material supply pushed in from both ends defines the final (local) tube thickness.

A tube is blown up by putting it under gas pressure and deformed with material supply pushed in from both ends (= constant volume!)

The tube is finally calibrated under the inner hot gas pressure, achieving the final shape and exact tool dimensions.

Gas pressure  →  Axial force
Schematic HDF-F process

- Positioning of sheet
- Closing the tool
- Initialize gas pressure

- Constant gas pressure
- Piston moves up further, increasing gas pressure
- Controlled material intake

- Increase gas pressure
- Piston moves up words, reducing gas volume
- Controlled material intake

Optional:
The sheet rims are fixed, no material intake possible! The piston motion generates final shape (incl. small radii), increasing gas pressure to smoothen surface wrinkles.
Effect of temperature on stress/strain behavior of ENAW5083 (Al-Mg-Mn) alloys

1. Increase of formability
2. Decrease of forming load

Effects of Temperature and Strain Rate on Strength and Formability:

- \( R_{p0.2} \downarrow \)
- \( r\)-Wert \( \rightarrow \)
- \( n\)-Wert and \( A_{\text{uniform}} \downarrow (\downarrow) \), but \( A_{\max} \rightarrow \)
- due to \( m \rightarrow ! \)
High Temperature Flow Stress in Al Alloys

Quantitative description:

\[ k_f = \frac{1}{\alpha} \cdot \sinh^{-1}\left( k \cdot \varphi_v^{m_1} \cdot e^{m_2 \cdot \varphi_v} \cdot Z^{m_3}\right) \]

Zener–Hollomon parameter

\[ Z = \varphi_v \cdot e^{R \cdot T} \]

Heat transfer contributions:
- Radiation
- Convection
- Friction
- Heat conductivity
Hot Forming Mechanisms in Al-Mg alloys

Superplastic Forming (SPF)
Utilizes GBS deformation

Quick-Plastic Forming (QPF)
Utilizes the transition region between GBS and SD deformation; considered a “Hybrid” process

Solute-Drag Forming (SDF)
Utilizes SDF deformation

Warm Forming (WF)
Utilizes deformation from SDF well into PLB-creep

Ref. Eric M. Taleff
The University of Texas at Austin
HoDforming characteristics I

• **Ability to form every metal component** - which is not formable in cold condition

• **Ability to form a hollow body or a component made from a sheet blank** - in every condition

• **low forming forces** - 10 times less than cold formed are needed

• **stable forming process** - almost no scrap

• **CO₂ friendly** - due to no required pre-heat treatments and low forces

• **Cost efficient process** - low cost forming dies

• **low or high component volume** - can be produced cost effective

• **thin sheets - complex geometries**, small radii or sharp edges
HoDforming characteristics II

- **wrinkle free components** - due to the possible high gas pressure
- **reduction of welding connections** - less parts needed
- **possibility to form tailored blanks**
- **complex components** - with a defined wall thickness distribution less than 20%
- **A-Class surface** and eye-catching shapes possible
HoDforming is able to offer ...

• a working technology with a **permanent HOT-Die** at **best possible advanced temperature** which is already proved by high volume production.

• a forming of **metal sheets and blanks at best possible advanced temperature**

• an **actively feeding of the blank into the cavity**

• an efficient process where components can be produced in **less than 20 seconds cycle time**

• forming of the blank **by gas** as **forming medium or by punch** or in combination of both
HDF-Technology Portfolio for forming...

**Materials:**
- HDF-H: Aluminium, Magnesium, Steel, Brass, Copper, Titanium, ...
- HDF-F: Aluminium, Magnesium, Steel, Brass, Copper, Titanium, ...

**Areas of application:**
- HDF-H: Automotive, Aviation, Energy, Design and Interior, ...
- HDF-F: Automotive, Aviation, Energy, Design and Interior, ...

**Surface quality:**
- HDF-H: up to Class A surfaces
- HDF-F: up to Class A surfaces

**Stage of development:**
- HDF-H: patents granted, approved in high-volume production
- HDF-F: patent applied, high-volume production in preparation

**Process temperature:**
- process runs at the best advanced temperature
HDF-H „Die temperature“ in °C...

The already high volume proved HDF-H process uses a permanent “Hot-Die” (at best possible advanced temperature).

<table>
<thead>
<tr>
<th>Material</th>
<th>Temperature Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminium</td>
<td>480 – 550 °C</td>
</tr>
<tr>
<td>Brass</td>
<td>620 – 850 °C</td>
</tr>
<tr>
<td>Mild Steel</td>
<td>900 – 960 °C</td>
</tr>
<tr>
<td>Ferritic Stainless</td>
<td>950 °C</td>
</tr>
</tbody>
</table>

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HDF means that the **blank can be actively feeded** in the cavity....

- **HDF-H**: absolutely friction free
- **HDF-F**: low determined friction
HDF is a **time efficient** process where components can be produced in

- **HDF-H**: less than 40 sec. cycle time
- **HDF-F**: less than 20 sec. cycle time
HDF uses **gas and/or a punch** as forming medium

**HDF-H**
- **A-Class components:** should be formed by gas pressure
- **Structure components:** can be formed by punch
- **Wrinkle free structure components:** should be formed by punch and gas

**HDF-F**
HDF-F\textsuperscript{Al} Limits of conventional cold forming

- **Cold forming limit:** High-strength aluminium alloys
- **Cold forming limit:** Standard aluminium alloys
- **HDF-F\textsuperscript{Al}:** All aluminium alloys = thinning of \(\sim 20\%\)
Potential HDF - Products (HDF ENAW Xxxx)...

320 % forming ratio
Potential HDF - Products (HDF-H & HDF-F ENAW 7xxx)...

Example (already produced):
- Aluminium alloy ENAW 7020
- Formed after bending in one step.
- Blank is actively feded
- Formed at SHT
- Forming ratio up to 250 %
- Controlled wall thickness

- Forming aluminium and magnesium alloys in one step
- Forming of ENAW 7xxx alloys without any heat treatment
- No spring back effect
- High accuracy
- Wrinkle free
- Controlled wall thickness
- Using of Tailor Welded Blanks (TWB) or Tailor Rolled Blanks (TRB)
- Using different Aluminium and Magnesium alloys connected in tailor welded blanks
- Using of material reinforcements within process
Potential HDF-F - Products B-Pillar (e.g. ENAW 7075)...

- Blank will be coated with special lubricant
- Blank will be heated up (e.g. two heating stations for sheet thickness >2 [mm])
- forming the B-Pillar by punch
- cooling rapidly down in fixed position
- probably a heat treatment T73651 could be necessary due to the stress corrosion cracking (SCC or hydrogen cracking), see treatments for screws with > 400 MPa
HoDforming at a glance...

- **HoDforming** is a technology for advanced aluminum, magnesium, steel and metals forming
- All advantages of the forming capabilities can be realized for extremely light weight constructions
- The innovative technology is able to realize extreme light weight products in a most efficient way, as e.g. relevant in the automotive industry
- Realizing of forming complex geometries in combination with high strength alloys
- New possibilities to optimize the crash worthiness of the products
- Cycle time for the main automotive products is less than 30 seconds
- Forming ratios up to 200%
- Small radii as well as sharp edges possible
- Class A surface realisable
- Active blank material feeding in the cavity
Thank you for your attention

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