Main tendencies in the automotive industry

• Main driving forces
  - Customers' demand
  - Global competition on the world market
• Customers' requirements
  - More economical
  - Increased safety
  - Higher comfort
• Legal requirements
  - Environmental protection
  - More rigorous crash tests
• Meeting manifold requirements → mass reduction
  - Lower consumption
  - Less harmful emissions
  - Increased environmental protection
  - More economical vehicles

• Contradictory requirements
  - Lower mass – thinner sheets
  - More rigorous crash tests

→ solution: application of high strength materials

→ unfavorable consequences: reduction of formability

Development trends in sheet metal forming

• Development tendencies in sheet metal forming
  - Main developments
  - Application of conventional and high strength steels
  - Technological process developments
  - Hot Press Forming – Press Hardening
  - Definition, fundamentals and main types of Hot Press Forming Press Hardening Forming
  - Hot Press Steels (HPS) Materials and their mechanical properties
  - Application trends in the World of automobiles
  - Process characteristics
    - Microstructure controlled press hardening
    - Tailor Welded Hot Forming Blanks
    - Mass reduction potential of HPF
• Summary and Conclusions

Process developments in sheet metal forming

• Selected topics in sheet manufacturing
  - Sheet hydroforming
    - Laser forming
    - Tailor Welded Blanks
  - Hot forming
    - Incremental sheet metal forming
    - Superplastic forming
    - New joining technologies
    - Overall process control and monitoring
    - Integrated product and process development
Hot press forming (HPF) – also known as press hardening (PHF)
- a relatively new forming process
- recently developed particularly for the application of a special group of high strength steels in car body manufacturing in the automotive industry
- a unique metal forming processing technique
  - the material is heated up to a sufficiently high temperature to provide austenitic microstructure
  - then it is cooled down rapidly in the forming tool
  - at certain cooling rate diffusionless martensitic phase transformation occurs leading to significant increase of the strength parameters

Short history of Hot Press Forming
- 1977: Invented and patented by Erland Lundström
- 1984: First applied in the automotive industry by the SAAB in the car series 9000
- 1999: First application of 22MnB5 Manganese-boron alloy in France
- 2005: The first published results on the application of Tailor Welded Blanks (TWB ⇒ HWB) for hot forming
- 2008: The first application of galvanized Manganese-boron alloyed steel in car body making

Direct (a) and Indirect (b) process chain in Hot Press Forming
a) direct hot forming
b) indirect hot forming

Typical hot press formed parts in car body

Areas of ultra-high strength steel application in the body structure of a recent passenger car (Volkswagen Sharan)
Trends in the usage of PHS in the automotive industry

- In most European cars PHS is applied in the body side structure.
- In Asian cars PHS is less frequently used and if so usually in the body side structure.
- Some European carmakers use PHS as a strategic product for a wider range of parts.

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The martensitic steel family
“adjustable strength by carbon content”

- Hardness (strength) of fully quenched martensite increases linearly with the carbon content.
- Start temperature of martensite transformation (Ms) decreases with the carbon content.
- At higher carbon contents hardness (strength) increase reduced by the content of retained austenite.
- At approximately 2200 MPa tensile strength steel reaches its technical limit.

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Material Properties of Typical Hot Press Steels (HPS)

<table>
<thead>
<tr>
<th>Steel grade</th>
<th>Martensite start, To°C</th>
<th>Critical cooling rate, %/°C</th>
<th>Yield strength, MPa as delivered</th>
<th>Hardness (HV) as hot formed</th>
<th>Tensile strength, MPa as delivered</th>
<th>Hardness (HV) as hot formed</th>
</tr>
</thead>
<tbody>
<tr>
<td>8MnCrB5</td>
<td>-</td>
<td>-</td>
<td>447</td>
<td>751</td>
<td>520</td>
<td>882</td>
</tr>
<tr>
<td>20MnB5</td>
<td>450</td>
<td>30</td>
<td>505</td>
<td>867</td>
<td>657</td>
<td>1154</td>
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<tr>
<td>22MnB5</td>
<td>410</td>
<td>27</td>
<td>457</td>
<td>1010</td>
<td>608</td>
<td>1478</td>
</tr>
<tr>
<td>27MnCrB5</td>
<td>400</td>
<td>20</td>
<td>478</td>
<td>1097</td>
<td>638</td>
<td>1611</td>
</tr>
<tr>
<td>37MnB4</td>
<td>350</td>
<td>14</td>
<td>580</td>
<td>1378</td>
<td>810</td>
<td>2040</td>
</tr>
</tbody>
</table>

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The classic press hardening steel: 22MnB5 (EN 10083-3)

<table>
<thead>
<tr>
<th>Grade</th>
<th>C</th>
<th>Si</th>
<th>Mn</th>
<th>P</th>
<th>S</th>
<th>Cr+Mo</th>
<th>Ti</th>
<th>B</th>
<th>Nb</th>
<th>Heavy, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>22MnB5</td>
<td>0.25</td>
<td>0.40</td>
<td>1.40</td>
<td>0.025</td>
<td>0.010</td>
<td>0.30</td>
<td>0.10</td>
<td>0.048</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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Temperature profile and microstructure development during press hardening process

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Microstructure controlled press hardening

Conventional PH process
Reheating in γ phase
Martensitic phase transformation
Adopted micro-structure

Reduced reheating temperature
Reheating in α phase
Reduced carbon content
(good ductility, improved weldability)

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Microstructure controlled press hardening

- Cooling stop at elevated temperature
- Reducing in γ phase

Mach reduced carbon content (good toughness, weldability)

- Ms Ms
- Cooling stop at elevated temperature
- Reducing in γ phase

Press hardening in α+γ phases (22MnB5)

Advantages of dual phase press hardening:
- Realization of dual phase microstructure with significantly improved elongation
- Mechanical properties can be varied according to the reheating temperature
- Energy saving through reduced furnace temperature
- Reduced thermal loads on the coating material

Weight reduction potential of press hardening steel

Tailored properties for side impact behavior

- Defined deformation behaviour of B-pillar under side impact condition to minimize load on passenger by:
  - Tailored blank (product approach)
  - Tailored quenching (process approach)

Summary

- Press hardening technology has proven to be a good solution to problems of forming ultra-high strength steels.
- Press hardening allows raising the strength level up to around 2000 MPa enabling weight reduction of 20 to 30% without safety compromise and cost increase.
- The key for further improvements lies in a combined approach by process and alloy design.
- Bainitic microstructures provide very interesting application potential in the strength range of 700 to 1000 MPa.
- Nb microalloying provides a feasible solution to improve application properties of all press hardening and air hardening steels.

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Thank you for your kind attention!