Advanced Manufacturing Technologies that Enhance Steel’s Contribution to Mass Efficient Automotive Body Structures

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Advanced Manufacturing Technologies to Enhance Steel’s Contribution to Mass Efficient Architecture

- Presentation planning
  - Superior combination of technical material and advanced manufacturing
  - An unchallengeable steel/process combination
- Program, business and vehicle targets
  - The driver for initial material selection
  - Consulted in final material decisions
Typical objectives of a vehicle program (short list)

- **Program (Vehicle) Targets:**
  - Architecture, mass, cargo and passengers, pricing (affordability)

- **Business (Enterprise) Targets:**
  - Capital investment, manufacturability, recyclability and sustainability

- **Vehicle (Performance) targets:**
  - Crashworthiness, ride, handling, NVH (noise, vibration & harshness), fuel efficiency, EV range
What Can Steel Do?

• Focus on mass efficient structures for automotive architecture within the context of program targets and objectives

• Internal Innovations
  o Steel grade development
  o Application modeling

• External Innovations
  o Pre-process steel treatment technology
  o Advanced steel forming/manufacturing technology
Equilibrium Phase Diagram

- A range of equilibrium solid solution phases can be observed in this unique alloy system.
- Controlled Non-equilibrium processing (fast heating and/or rapid cooling) can precisely modify and combine these phases to create new steel grades.
- That’s what drives tailored innovation in steel grade design.
Automotive Steel Grade Development

C-Mn, Interstitial Free

What: Carbon and Manganes alloy variations, mainly
How: Strength supported by these alloys, degas tech
Why: Evolutionary start point, common manufacturing
Result: Formable alloys for structural and deep drawing

Circa 1960

Martensitic, Press Hardened

What: Elevated strength levels with Carbon/Mn base chem
How: Micro-alloy additions and precipitation mechanisms
Why: Increased strength with lower Carbon for weldability
Result: Expanded range of steel property windows

Circa 1990

Complex or Multi-phase grades

What: Martensite based high strength steel components
How: Uniform rapid cooling technology,
Why: Provide strength rqmts, achieve complex parts
Result: Complex very high-strength Hot stamped parts

Circa 2000

HSLA

What: Steel using the Fe-C phase system for dual phases
How: Precise inter-critical anneal process / fast cool tech
Why: Good Ductility at strengths above HSLA
Result: New windows of higher strength, cold stamping

What: Elevated strength steel with even more ductility
How: Post quench reheating for selective alloy partitioning
Why: Cost efficiency in forming, replace Hot stamping
Result: Broke paradigm of high strength is less formability

Circa 1980

Dual Phase

Circa 2010

3rd Gen AHSS - partitioned

2020 +
Global Formability Diagram for Steel

Conventional Steels

HSLA Grades

AHSS (1) Grades

AHSS (2) Grades

Gen 3 AHSS Grades

3rd Gen AHSS (TBF, CFB, QP)

IF

IF-HS

Mild

TRip

BH

C-Mn

HSLA

FB

CP

DP

MS, PHS

C-Mn, Interstitial Free

Martensitic, Press Hardened

Complex or Multi-phase grades

Source: WorldAutoSteel
American Steel is the Lowest Emitting in the World

Recyclability of Steel Generates High Recycle Rates

• Recyclability versus the quantity recycled

• Steel is continuously recyclable nearly all automotive scrap steel is, in fact, recycled!
Application Modeling that Supports Efficient Use of Steel Grades

**Resistance Spot welding**
- **What**: Standard joining method for matl combinations
- **How**: Testing and validation at diff weld parameters
- **Why**: Assure good joints with complex stack-ups
- **Result**: Wide application in assembly process

**Constitutive and fracture modeling**
- **What**: Forming limit dependence on deformation history
- **How**: Strain data acquired from multiple coupon tests
- **Why**: Improves FLC correlation to physical reality
- **Result**: Enhances forming simulation, Virtual designs

**Integrated Computational Material Engg**
- **What**: Material designed to desirable properties
- **How**: Linking material models at multiple scales
- **Why**: Steel grades designed to matl expectations
- **Result**: New steels designed by integrated models

**Non-linear strain path modeling**
- **What**: Forming limit dependence on deformation history
- **How**: Strain data acquired from multiple coupon tests
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**Strain monitoring by DIC**
- **What**: Image & camera system to measure metal strain
- **How**: Laser surface “markers” before/after forming
- **Why**: More accurate assessment of strain in stampings
- **Result**: Repeatable confirmation of forming strains

**Metal forming instrumentation**
- **What**: Apply Instrumentation tech to stamping
- **How**: Non-contact apps; Acoustic, vibration, thermal
- **Why**: Real time press automation/control and records
- **Result**: Increased matl understanding, press room eff
Process Modeling that Supports Efficient Design with New Steel Grades

- Coupon testing and analysis
- Use varying stress and strain conditions
- Establish global and local formability limits
- Construct comprehensive constitutive and fracture strain models
- Generate “material card”

- Development of robust FEA models
  - Specific forming evaluation (stamping simulation)
  - High and low speed crash energy management
- Conduct (minimal) validation process
  - High levels of simulation in vehicle/comp design
Pre-process Steel Treatments Enhance Manufacturing Options

Laser welded blanks

What: Dissimilar metal blanks joined pre-stamping
How: Two different sheets Laser welding process
Why: Adding strength or gauge in appropriate place ONLY
Result: Process and QA much improved, ubiquitous use

What: Expansion of two blanks to multiple
How: Precise blank tolerances met by supply
Why: Expansion of single welded blank concept
Result: Many applications in place, esp door rings

What: Coils rolled with planned modulating thickness
How: Rolling technology and control
Why: Apply extra metal ONLY where needed for mass out
Result: Applications on current vehicles, commercialized

What: Elimination of mech blanking, cut form coil by laser
How: Modern equipment supplied to blanking industry
Why: Extreme flexibility in blank shape for forming
Result: Disruptive tech now integrating to supply chain

What: Linear welds coil to coil or multiple
How: Special processing line
Why: Improve productivity of laser welding blanks
Result: Proven concept being adopted special applications

What: Prevent scale from heating, requiring removal
How: Applied coating or steel alloy resists scaling
Why: Prod efficiency, eliminates process step
Result: Lower cost, more productive Hot Stamping

Tailor Rolled coil

Multi piece Laser weld blank

Laser Blanking

Specialty coatings
Tool Box of Pre-Process Steel Treatments

LASER WELD PROCESS AUTOMATION

MULTIPLE BLANK LASER WELDING FOR HOT STAMPING

TAILOR ROLLED COILS (THICKNESS)
Advanced Steel Forming Technologies

**Forging and stamping**

**What:** The starting point, going far back in time  
**How:** Mechanical presses, progressive and unique dies  
**Why:** High rate part manufacturing  
**Result:** Traditional automotive part production

**What:** Forming long parts from tubes  
**How:** Water pressure in tube makes shapes, stops buckle  
**Why:** Effective for long thin varied section and bent parts  
**Result:** Numerous applications, A-pillar and roof rail

**What:** Forming complex parts with High-strength  
**How:** Heating blanks, pressing while hot, die quench  
**Why:** Enables complex parts with High strength  
**Result:** Many applications, technical improvements made

**What:** Innovations applied to hot stamping  
**How:** Differential cooling and welded blanks used  
**Why:** Parts get design strength where needed  
**Result:** Varied strength where needed for design intent

**What:** Enhancement to plain roll forming  
**How:** Equipment capable of varied section and 3D  
**Why:** More applications of low cost forming  
**Result:** Enable complex parts, roll stamping is cost saving

**What:** Pressurized gas forms part, versus stamping  
**How:** Heated metal formed by achievable gas pressure  
**Why:** Complex shapes, tube like parts efficient prod  
**Result:** Stronger parts than hydroform, flange option

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Examples of Advanced Manufacturing Technologies

- **ROLL STAMPING**: 3D Roll Forming, flexible RF, Profile bending, High Temp w/Accel cool

- **GAS HOT METAL FORMING**: Nodal architectures

- **PRESS HARDENING WITH VARIABLE IN DIE QUENCHING**

  - Initial profile
  - Die
  - Gas
  - Cooling duct
  - Part


Door beams, roof headers, cross-members and cross car beams

Fig. 16. B-pillar with tailored properties (Erhardt and Böke, 2008).
Advanced Manufacturing Technologies (available) Enhance Steel’s Contribution to Mass Efficient Automotive Structures

Many combinations of the above technologies can be used to achieve “right weighted”, mass efficient automotive structures with steel.
Conclusions

- **Vehicle program objectives** have a substantial role in the selection of automotive materials.

- Reality seeks to produce vehicles using appropriate material choices to meet these objectives.

- Future vehicles, with significant changes for electrification, will call for “right weighting” of material choices to ensure appropriate balance of the program imperatives.

- Technical advances with modern grades of steel and associated manufacturing technology innovations can provide mass efficient automotive body structures and components.
Thank You / For More Information

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