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

Targets Related to Automotive Material Selection

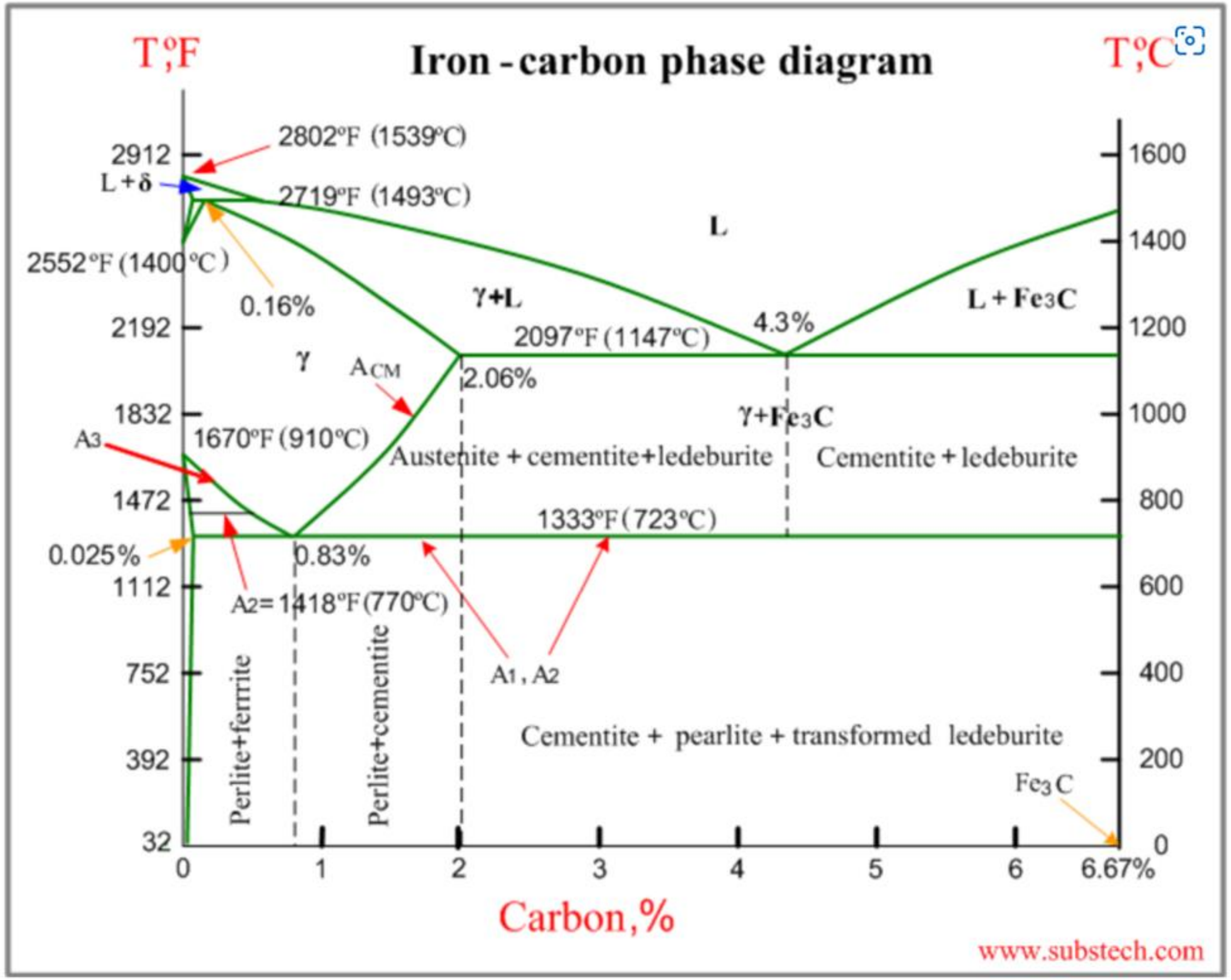
Typical objectives of a vehicle program (short list)

- 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
  - Steel grade development
  - Application modeling
- External innovations
  - Pre-process steel treatment technology
  - Advanced steel forming/manufacturing technology

Honorary Member of the Steel Grade Team



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

Circa 1960

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

HSLA

Circa 1980

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

Martensitic, Press Hardened

Circa 1990

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

Dual Phase

Circa 2000

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

Complex or Multi-phase grades

Circa 2010

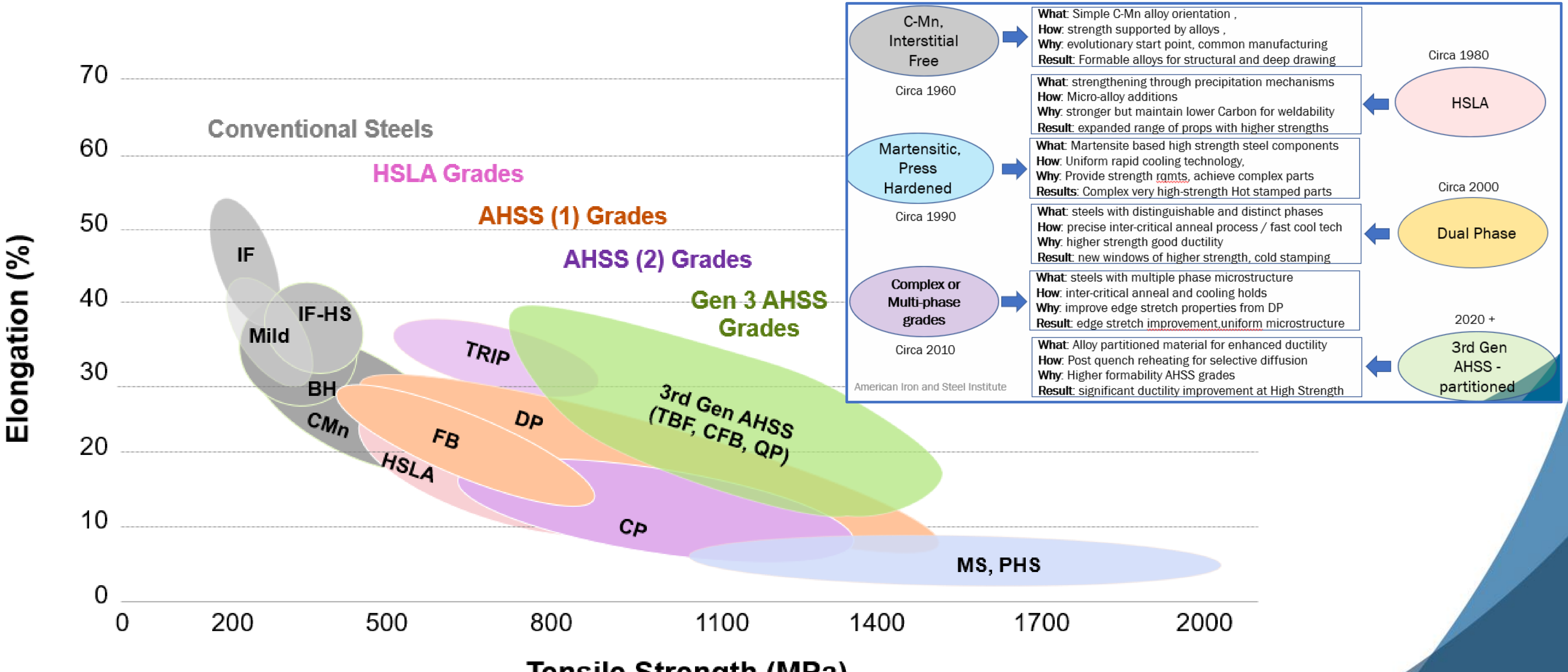
What: Steels with multiple phase microstructure
How: Precise inter-critical anneal with cooling holds
Why: Improve edge stretch and bending characteristics
Result: Enhanced forming, uniform microstructure

3rd Gen AHSS - partitioned

2020 +

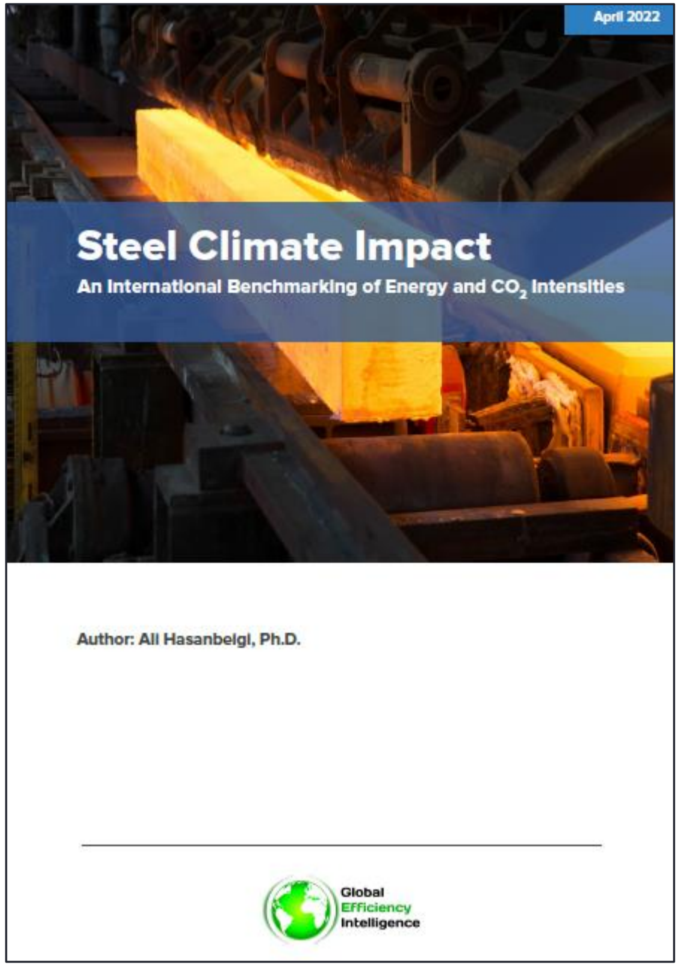
What: High Strength steel with even more ductility
How: Post quench reheating for selective alloy partitioning
Why: Cost efficiency in forming, replace Hot stamping
Result: Broke paradigm of high strength is less formability

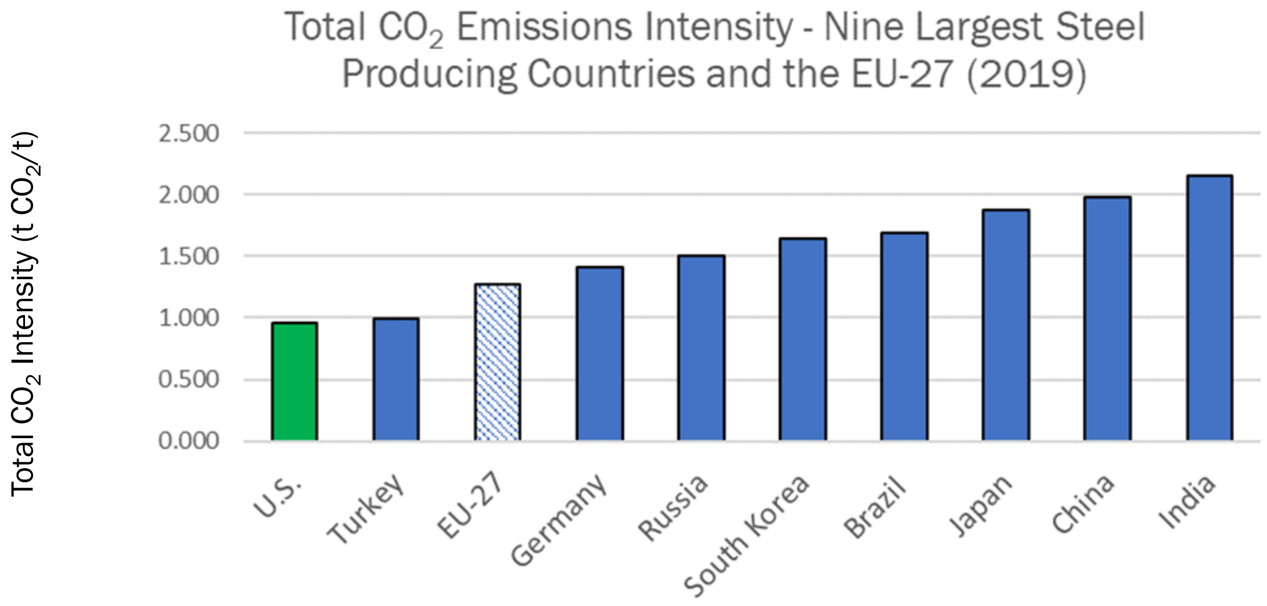
Global Formability Diagram for Steel



Source: WorldAutoSteel

American Steel is the Lowest Emitting in the World





<u>Adapted from:</u> *Hasanbeigi, "Steel Climate Impact: An International Benchmarking of Energy and CO_2 Intensities", Global Efficiency Intelligence, 2022.*

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

Non-linear strain path 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

Constitutive and fracture modeling

What: Material characterization
How: Coupon testing supports to analytical modeling
Why: Need for precise material files to conduct FEA
Result: Enhanced formability and crash simulations

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

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

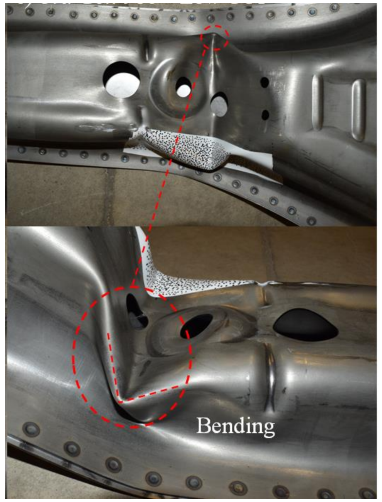
Metal forming instrumentation

What: Apply Instrumentation tech to stamping
How: Non-contact appls; 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
  - o Specific forming evaluation (stamping simulation)
  - o High and low speed crash energy management
- Conduct (minimal) validation process
  - o 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

Multi piece Laser weld blank

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

Tailor Rolled coil

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

Laser Blanking

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

Laser welded coil

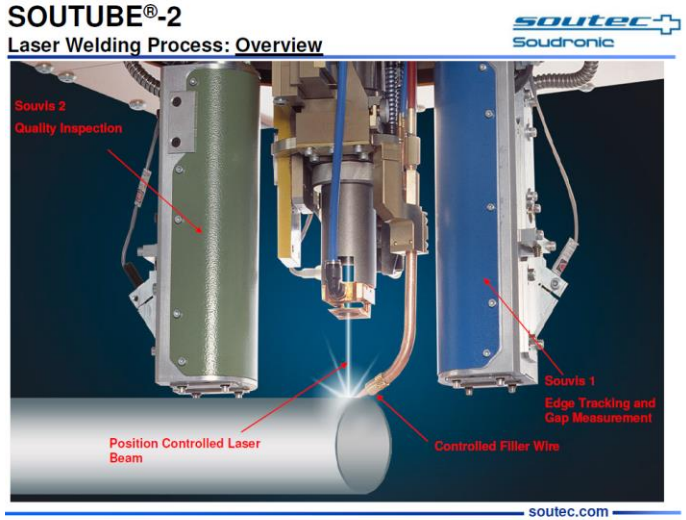
What: Linear welds coil to coil or multiple
How: Special processing line
Why: Improve productivity of laser welding blanks
Result: Proven concept being adopted special applications

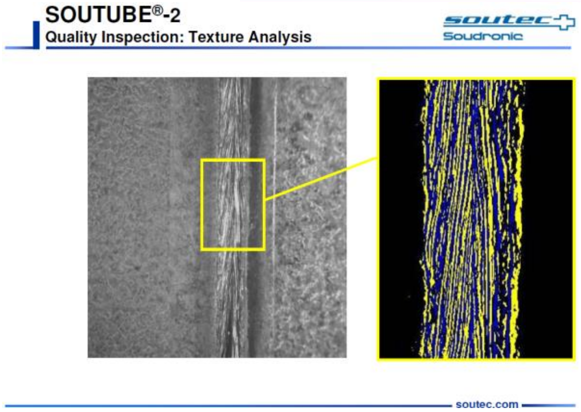
Specialty coatings

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

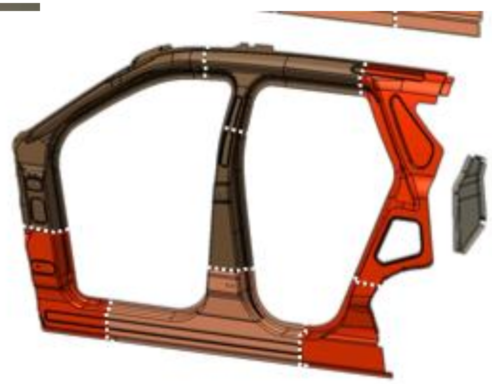
Tool Box of Pre-Process Steel Treatments

LASER WELD PROCESS AUTOMATION

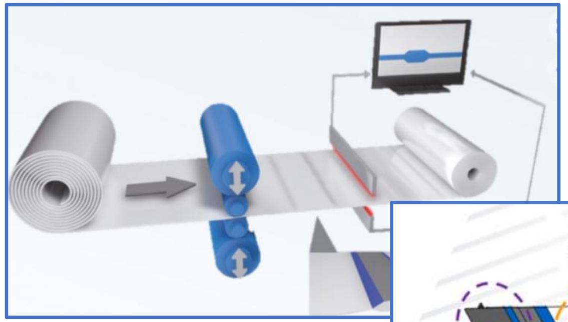


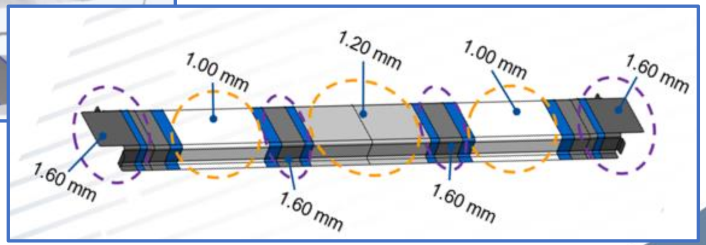


MULTIPLE BLANK LASER WELDING FOR HOT STAMPING



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

Hydroforming

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

(PHS) Hot stamping

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

PHS Var. quench, welded blanks

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

3D roll forming, roll stamping

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

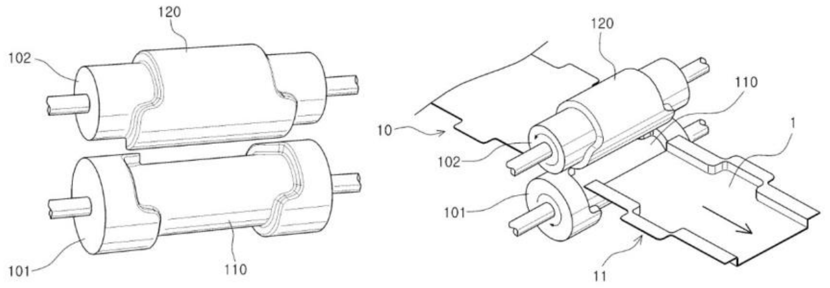
Hot metal gas forming

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

Examples of Advanced Manufacturing Technologies

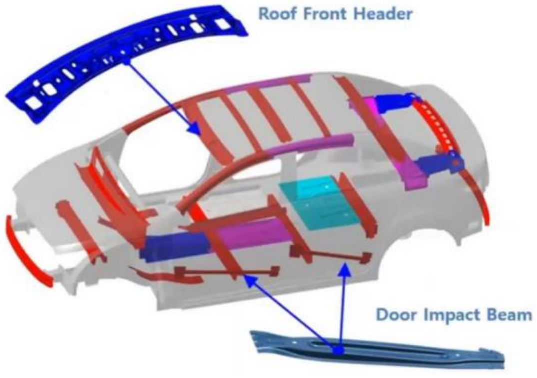
ROLL STAMPING

3D Roll Forming, flexible RF, Profile bending, High Temp w/Accel cool

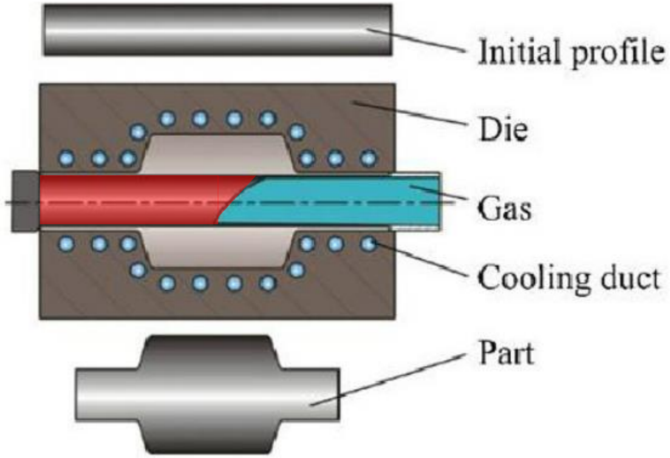


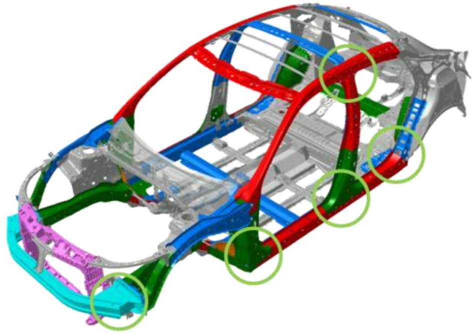
[“Apparatus for roll stamping,” Patent KR101417278B1 Issued to Don-Gun Kim and assigned to POSCO Co. Ltd.]

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



GAS HOT METAL FORMING





Nodal architectures

PRESS HARDENING WITH VARIABLE IN DIE QUENCHING

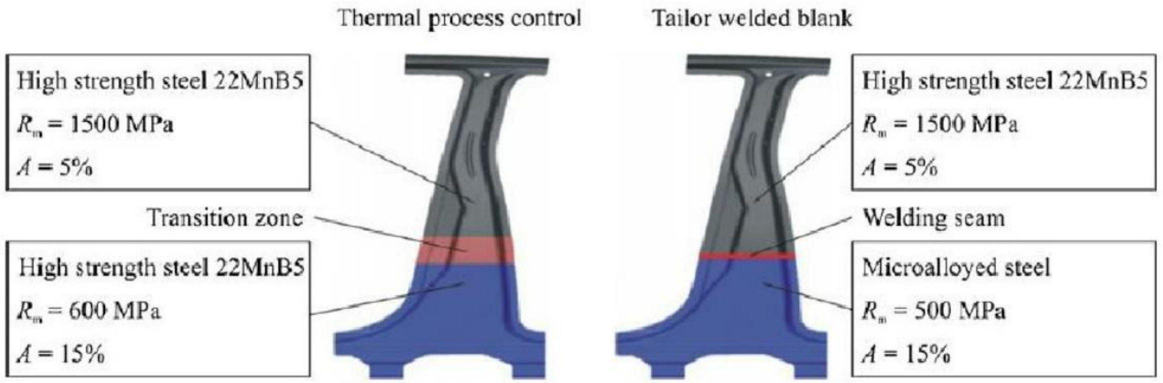


Fig. 16. B-pillar with tailored properties (Erhardt and Böke, 2008).

Summary

Advanced Manufacturing Technologies (available) Enhance Steel's Contribution to Mass Efficient Automotive Structures

C-Mn, Interstitial Free	Micro-alloyed HSLA	Martensitic, Press Hardened	Dual Phase	Complex or Multi-phase grades	Generation 3 partitioned	Modern Steel Grades
Resistance Spot Welding	Non-linear strain simulation	Fracture Mechanics	DIC monitoring of strain	Computational Material Design	Metal forming instrumentation	Advanced Modeling
Laser welded blanks	Multi piece Laser weld blank	Tailor Rolled coil	Laser Blanking	Laser welded coil	Specialty coatings	Pre-processing
Forging and stamping	Roll forming, Hydroforming	(PHS) Hot Stamping	PHS Var. Quench, welded blanks	3D roll forming, roll stamping	Hot Metal Gas Forming	Adv Mfg. Tech

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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