



Section 4 – Glossary

Advanced High-Strength Steel (AHSS): A series of high-strength steel types with novel metallurgy and processing compared to conventional high-strength steels. This results in different combinations of higher strength levels, improved formability, and/or increased crash energy absorption.

Aging: A change in material property or properties with time.

Angular change: Springback resulting from a change in radius at the punch with a resulting change in flange position usually described as a springback angle.

Anisotropy: Variations in one or more physical or mechanical properties with direction in the sheet metal. Related terms are normal anisotropy, planar anisotropy, and plastic strain ratio.

Austenite: Normally not found in steel at room temperature, austenite is a homogeneous phase consisting of a solid solution of carbon in the gamma form of iron. It is formed when steel is heated to temperature above the upper critical point. Rapid quenching of the austenite will produce martensite.

Bake Hardening steel (BH): Any high-strength steel that increases in strength as a result of a combination of straining and aging at a temperature and time typical of the automotive paint cure cycle.

Bake hardening: Generally means a change in mechanical properties created during a typical automotive paint bake cycle.

Bend: A simple bending process to reduce the sidewall curl because the sidewall does not undergo one or more sequences of bend and unbend.

Binder: Alternatively called a blank holder or holddown. The part of a forming die that holds the blank by pressure against a mating surface of the die to control metal flow and prevent wrinkling.

Burr: The rough cut edge of metal.

Carbon equivalent: Various equations using percent concentrations of carbon, manganese, chromium, molybdenum, and sometimes other elements to predict the weldability of a given steel.

Carbon Manganese steel (CM): High-strength steels primarily strengthened by solid solution strengthening.

Clinching: Mechanical joining systems where the punch forces the two sheets of metal to spread outward in the die and interlock.

Complex Phase steel (CP): A steel with very fine microstructure of ferrite and higher volume fractions of hard phases that are further strengthened by fine precipitates.



Computerized forming simulation: More accurately defined as computerized forming process development, where the forming of a stamping is accomplished in the computer without construction of hard tooling. Used to determine if the initial product design can be formed, evaluate various product and process design options, and obtain additional production requirements such as maximum required press load.

Cup drawing: A press forming operation in which a cup shaped (often cylindrical) part is produced from a sheet metal blank (often circular in shape).

Curl (sidewall): Springback resulting from metal moving over a radius. Curl is characterized by an average radius of curvature.

Die clearance: The space, on each side, between the punch and die.

Draw bead: A ridge constructed around a portion of a die cavity to partially restrain metal flow. A groove in the mating blankholder allows die closing. Sometimes called a die bead.

Draw: A conventional forming operation with continuous blankholder force.

Dual Phase steel (DP): A steel consisting of a ferrite matrix containing a hard second phase in the form of islands.

Elastic deformation: Deformation which will return to its original shape and dimensions upon removal of the load or stress.

Elastic limit: The maximum stress to which a material may be subjected and yet return to its original shape and dimensions upon removal of the stress.

Elongation: The amount of permanent extension in a tensile test or any segment of a sheet metal stamping.

Embossing: Displacing a section of metal a minor amount without noticeable reduction in sheet metal thickness or metal flow from surrounding sheet metal.

Engineering strain: The unit elongation given by the change in length divided by the original length. Sometimes called the nominal strain.

Engineering stress: The unit force obtained when the applied load is divided by the original cross-sectional area. Sometime called the nominal stress.

Erichsen test: A test in which a piece of sheet metal, restrained except at the centre, is deformed by a spherical punch until fracture occurs. The height of the cup at fracture is a measure of ductility. Similar to the Olsen test.

Filler metal: Available in the form of rods, spooled wire, or consumable inserts to improve the quality of the welded part.

Form: A forming process that allows the flange to be created in the last stage of forming and the sheet metal undergoes only a slight amount of bend-unbend deformation.



Form-draw: A forming process in which the blankholder force is applied from the middle to last stage of forming.

Forming Limit Curve (FLC): An empirical curve showing the levels of different combinations of biaxial strain beyond which failure (local necking) may occur in sheet metal forming. The strains are given in terms of major and minor strains measured from deformed circles previously imprinted as circles into the undeformed sheet metal.

Gas Metal Arc Welding (GMAW): An arc welding process that uses a continuously fed consumable electrode and a shielding gas. Common GMAW processes are MIG (metal inert gas) welding and MAG (metal active gas) welding.

Heat Affected Zone (HAZ): A zone paralleling the weld zone where a change in properties has taken place as a result of the heat generated by the welding process.

Heat balance: The phenomenon in resistance spot welding of balancing the heat input during the weld based on the gauge and grade of steel.

High-Strength, Low Alloy steel (HSLA): Steels that generally contain microalloying elements such as titanium, vanadium, or niobium, which increase strength by grain size control, precipitation hardening, and solid solution hardening.

High-Strength steel (HSS): By International Iron and Steel Institute definition, any steel product whose initial yield strength is specified between 210 and 550 MPa or whose tensile strength is specified between 270 and 700 MPa.

Hole expansion: A formability test in which a tapered (usually conical) punch is forced through a punch or drilled and reamed hole forcing the metal in the periphery of the hole to expand in a stretching mode until fracture occurs.

Hybrid joining: Combining adhesive bonding with resistance spot welding, clinching, or self-piercing riveting to increase the strength value.

Isotropic steel (IS): A ferritic type of microstructure modified so the delta r value is equal to zero to minimize any earing tendencies.

Instantaneous n-value: For some AHSS the n-value changes with strain. For these steels, the n value is plotted as a function of strain. The n value at any specific value of strain is called the instantaneous n-value.

Interstitial-Free steel (IF): Steels with very low amounts of carbon and nitrogen to which are added small amounts of elements such as titanium or niobium to combine with the remaining interstitial elements such as carbon and nitrogen to remove their strengthening effects.

Local elongation: Elongation measured over a very short gage length is controlled by the microstructure, particularly the frequency of interfaces between islands of hard martensite and the soft matrix of ferrite. Local elongation is measured by a conical punch hole expansion test and given the symbol λ .



Limiting Draw Ratio (LDR): An expression of drawability given by the highest drawing ratio (blank diameter divided by punch diameter) attained in a series of tests such as the Swift Cupping Test.

MAG: see Gas Metal Arc Welding (GMAW).

Martensitic steel (Mart): During processing the microstructure is transformed almost entirely to hard martensite.

Major strain: Largest principal strain in the sheet surface. Often measured from the major axis of the ellipse resulting from deformation of a circular grid. Usually called major stretch in the press shop.

Metal gainer: A preformed area of the stamping that creates lengths of line used to feed metal into an area that normally would be highly stretched and tear. Likewise, a post-formed area of the stamping created in an area of the stamping that has excess metal and normally would generate buckles.

Mid-Frequency Direct Current (MFDC): MFDC has the advantage of both unidirectional and continuous current.

Microstructure: The different phases and structure of metals are shown when a flat ground surface, highly polished, and etched (different etchants for different phases), is magnified and observed in a microscope. A picture of the microstructure is called a photomicrograph.

Mild steel: Low strength steels with essentially a ferritic microstructure and some strengthening techniques. Drawing Quality (DQ) and Aluminium Killed (AKDQ) are examples and often serve as a reference base because of their widespread application and production volume.

MIG: see Gas Metal Arc Welding (GMAW).

Minor strain: The principal strain in the sheet surface in a direction perpendicular to the major strain. Often measured from the minor axis of the ellipse resulting from deformation of a circular grid. Usually called minor stretch in the press shop.

Multiple stage forming: Forming a stamping in more than one die or one operation. Secondary forming stages can be redraw, ironing, restrike, flanging, trimming, hole expansion, and many other operations.

n-value: A term commonly referred to as work hardening exponent derived from the relationship between true stress and true strain. Except for AHSS, the n value usually is a constant for a given steel.

Overbend: Increasing the angle of bend to compensate for springback angular change. Upon springback from overbend, the part will match part print.

Plastic deformation: Upon exceeding the elastic limit of the sheet metal, a permanent or plastic increment of deformation is created.



Plastic strain ratio (r): A measure of normal anisotropy is defined by the ratio of the true width strain to the true thickness strain in a tensile test.

Post-annealing: An annealing cycle given to a stamping or portion of the stamping to recrystallize the microstructure and improve the properties for additional forming operations.

Post-stretch: A stretch process added to near the end of the forming stroke to neutralize sidewall curl and/or angular change resulting from the stamping process. Active lock beads, lock steps, or other blank locking methods are used to prevent metal flow from the blank while generating a minimum of 2% additional sidewall stretch at the end of the press stroke.

Quasi-static: Traditionally refers to the strain rate during a tensile test, which is very slow compared to deformation rates during sheet metal forming or a crash event.

r value: The ratio of true width strain to true thickness strain. Often called the plastic strain ratio.

Residual stresses: Elastic stresses that remain in the stamping upon removal of the forming load. Sometimes called trapped stresses because the final geometry of the stamping does not allow complete release of all elastic stresses.

Restrike: A secondary forming operation designed to bring the stamping to part print by correcting for springback or any other cause of dimensional variation.

Retained austenite: With proper chemistry and heat treating, some austenite can be retained at room temperature. With sufficient cold work, the retained austenite will transform into martensite.

Sheared edge stretchability: Reduced residual stretchability of an as-sheared edge due to the high concentration of cold work and work hardening at the sheared interface.

Shrink flanging: A bending operation in which a narrow strip at the edge of a sheet is bent down (or up) along a curved line that creates shrinking (compression) along the length of the flange.

Simulative formability tests: These tests provide very specific formability information that is significantly dependent on deformation mode, tooling geometry, lubrication conditions, and material behaviour. Examples include hemispherical dome tests, cup tests, flanging tests, and other focused areas of formability.

Springback: The extent to which metal deviates from its designed or intended shape after undergoing a forming operation. Also the angular amount a metal returns toward its former position after being bent a specified amount.

Strain gradient: A change in strain along a line in a stamping. Some changes can be very severe and highly localized and will have an accompanying increase in thickness strain.

Square lock bead: A square ridge constructed around a die cavity to completely restrict metal flow into the die.

Strain rate: The amount of strain per unit of time. Used in this document to define deformation rate in tensile tests, forming operations, and crash events.



Stretch flange: A bending operation in which a narrow strip at the edge of a sheet is bent down (or up) along a curved line that creates stretching (tension) along the length of the flange.

Tempering pulse: A post weld heat treatment or post annealing to improve the weld fracture mode and the weld current range.

Tensile Strength (TS): Also called the ultimate tensile strength (UTS). In a tensile test, the strength calculated by dividing the maximum load by the original cross-sectional area.

Terminal n-value: The n-value at high strain levels, which is a parameter influencing the height of the forming limit curve. In the absence of an instantaneous n-value curve, the terminal n usually is measured in a tensile test between 10% stretch and maximum load or ultimate tensile strength.

Total elongation: A parameter measured in a tensile test used as a measure of ductility. Defined by the final gage length minus original gage length divided by the original gage length and times 100.

Transformation Induced Plasticity steel (TRIP): A steel with a microstructure of retained austenite embedded in a primary matrix of ferrite. In addition, hard phases of martensite and bainite are present in varying amounts. The retained austenite progressively transforms to martensite with increasing strain.

True strain: The unit elongation given by the change in length divided by the instantaneous gage length.

True stress: The unit force obtained when the applied load is divided by the instantaneous cross-sectional area.

Twist: Twist in a channel is two cross-sections rotating differently along their axis.

Ultimate Tensile Strength (UTS): See Tensile Strength.

Ultra-High-Strength steel (UHSS): By International Iron and Steel Institute definition, any steel product whose initial yield strength is specified at 550 MPa or greater or whose tensile strength is specified at 700 MPa or greater.

ULSAB-AVC: UltraLight Steel Auto Body – Advanced Vehicle Concepts. Information is available at www.worldautosteel.org.

ULSAC: UltraLight Steel Auto Closures. Information is available at www.worldautosteel.org.

Work hardening exponent: The exponent in the relationship $\sigma = K\epsilon^n$ where σ is the true stress, K is a constant, and ϵ is the true strain.

Yield Strength (YS): The stress at which a steel exhibits a specified deviation (usually 0.2% offset) from the proportionality of stress to strain.