
Abstract: To aid in understanding die wear when stamping AHSS, a study to characterize the contact pressure distribution in drawbeads during stamping had been undertaken. As direct measurement of contact pressure for a drawbead is not feasible during metal flow, a combination of experimental and Finite Element (FE) simulation techniques were used to determine the contact pressure distributions and the maximum contact pressure for a number of different conditions. Testing was conducted using the Drawbead Simulator (DBS) for two different bead configurations. The materials in this investigation were 0.7mm and 0.8mm EG BH210 and EG DP500. Static Implicit FE analyses were conducted with ABAQUS Standard using 2D plane strain continuum elements. A combined hardening model in conjunction with strain rate effects was used to describe material behavior as it flows through the drawbeads. Trends for the maximum contact pressure as a function of drawbead radius, material yield strength and thickness were generated.


Abstract: Advanced High Strength Steels (AHSS) are currently being considered for use in closure and structural panels in the automotive industry because of their high potential for affordable weight reduction and improved performance. AHSS such as dual phase steels are currently being used in some vehicle platforms. From a manufacturing perspective, stretch flanging during stamping is an important deformation mode requiring careful consideration of geometry and the die process. This paper presents some geometric and process guidelines for stretch flanging AHSS. Hole expansion experiments were conducted to determine the failure limit for a sheared edge condition. Effects of punching clearance, prestrain and prior strain path on hole expansion were explored in these experiments. In addition, dynamic explicit FE calculations using LS-DYNA were also conducted for a typical stretch flange by varying some key geometric parameters. The experimental and FEA results were then analyzed to yield process and geometric guidelines to enable successful stretch flanging of AHSS. This study has been focused on BH210 and DP500 steel products.


Abstract: An automotive underbody cross member was selected for one of the NUMISHEET’05 industrial benchmark to assess springback prediction capability of engineers around the world using various software. Binder and addendum were generated according to production intent process. Iterative design and draw simulation were performed on the part and addendum geometry to remove wrinkles and splits. Castings were poured and machined. Six different types of materials ranging from A15182-0 to DP965 were used in the production of the benchmark panels and three of these materials were included in the official benchmark data release.

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Draw panels were trimmed on a trimming fixture using laser and scanned with a whitelight optical device. Springback shapes at selected cross sections were recovered on the scanned data and original CAD data. In addition, major/minor and thickness strains were also measured at these sections. (Example materials: steels, aluminum.)

M. Huang and J. Brouwer, “Characterization and Control of the Springback of Advanced High Strength Steel”, MS&T ’05, Pittsburgh, PA, 2005.

Abstract: The shape deviation of Advanced High Strength Steel (AHSS) has proven to be a major problem in various automotive applications. The main cause of this shape deviation is the springback, in addition to the twist and part geometry constraints. In order to better understand and control the springback, conceptual curves were proposed for the angular springback and sidewall curl characterization. Based on the results of extensive laboratory experimentation using the channel draw test, the characterization curves for the steels EDDS, HSLA350, HS440, DP590, and DP980 were established. It is shown that within a 1mm to 23mm range of the tooling radii, the angular springback increased almost linearly with the “tooling radius to sample thickness” (R/t) ratio, while the curvature of sidewall curl increased rapidly to its maximum inflection point and then gradually decreased. The experimental results showed that the tooling radius was the determining process parameter for controlling the springback; the tooling radius also set the roles for the drawbead restraining force. For instance, when the ratio R/t was equal to or less than two, the angular springback and sidewall curl was significantly reduced without any drawbead restraining forces. The drawbead restraining forces’ effects on the springback increased with an R/t ratio that was greater than three; whereas it seemed to have a small effect on the sidewall curl. A difference in metal thickness, however, resulted in a dramatic change in the sidewall curl but relatively little effect on the angular springback. The characterization curves and findings provided a design guideline for tooling and process engineers to control the springback of AHSS in stamping productions.


Abstract: FEA simulations have been successfully applied to various sheet metal forming processes to predict formability issues such as fractures, wrinkles, and thinnout; however, they have not achieved the same level of success in the springback predictions. As the former mainly dealt with stretch and the latter with bending, we contemplated that a fundamental underlying problem in the FEA springback predictability may lie with the thin shell theory, as it allows the thickness stress to be neglected and only uses an in-plane stretch and shear to balance the out-of-plane loads. A study was conducted to investigate the problem with channel draw test. Two steels, DP590 and HSLA350, were formed and simulated with same set of tooling and process conditions except for two different drawbead setups, i.e. with and without drawbead restraining force. Two different deformation modes, stretch bending and bending, were produced as a result. The testing and FEA results showed that the FEA simulation could not properly and accurately predict the bending strains. Also, it tended to underpredict the bending deformation while overpredicting the stretch. These findings proved that the inability of thin shell element to predict the bending strain is a major cause for the problematic and inaccurate FEA springback simulations. In order to correctly solve the springback problem with FEA simulations, the thin shell element formulations must be improved to include through thickness stress.


Abstract: To further the application of Advanced High Strength Steels (AHSS) in automotive body and structural parts, a good knowledge and experience base must be developed regarding the press formability of these materials. As a first step towards accomplishing this goal, the American Iron and Steel Institute, in collaboration with the United States Department of Energy, jointly funded under the Technology Roadmap Program, a study by ArcelorMittal Research Laboratories to characterize the formability of AHSS using simulative laboratory tests. Splitting limits under different conditions and springback behavior of several grades of conventional high strength steels (HSS) such as bake-hardenable and HSLA steels, advanced high strength steels (AHSS) such as dual-phase and TRIP steels, and ultra-high strength steels (UHSS) such as recovery-annealed and tempered martensitic steels were characterized. This paper presents important trends and interpretations of the data on relevant intrinsic mechanical behavior, splitting limits, and springback behavior of mild, conventional HSS, AHSS, and UHSS steels.

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Abstract: Hot-dip coated dual-phase steels, with tensile strengths of 490 and 590 MPa, have been developed and are being successfully applied in several automotive structural applications. The tensile properties are achieved through alloying with manganese and molybdenum. This paper compares some performance aspects viz., strain-hardening, shearededge stretching, stretch forming, drawing and bake-hardening of these dual-phase steels to other high-strength (HSLA and C-Mn) and advanced-high-strength (TRIP) steels. The spotwelding behaviors of the dual-phase steels are also described.


Abstract: Bending under tension is an important deformation mode during stamping and has been observed to limit achievable ductility for high strength steels. This paper presents experimental results from Angular Stretch Bend (ASB) testing, which has been used to characterize bending under tension behavior for several conventional, advanced high strength steels and ultra-high strength steels. Steels that were studied include Bake Hardenable steels, High Strength Low Alloy (HSLA) steels, Dual Phase (DP) steels, Transformation Induced Plasticity (TRIP) steels, and tempered martensitic steels. Failure heights were determined under sample lockout conditions for different punch radii. By comparing absolute formability measured by the failure height, the results can be used to provide material formability ranking for different R/t ratios. In addition, strain distributions were analyzed to provide bending under tension forming limits for the different steel grades. This information will be useful in the development of die design and processing strategies for high strength sheet steels.


Abstract: In an effort to optimize outer body panel steel utilization with respect to dent resistance performance and weight reduction, the automotive industry continues to investigate the application of higher strength steels. Most recently, dual phase steel has been recognized as a very promising material substrate for outer body panel application, due to its inherent formability and final part performance attributes. This paper presents a comprehensive study of ArcelorMittal’s new electrogalvanized dual phase “DI-FORM 500” product, which was specifically designed to meet automotive exposed quality standards. It reviews the mechanical properties, aging characteristics, formability, dent resistance, weldability and fatigue strength of this product, along with a representation of its application advantages to the automotive industry, in terms of part performance, weight savings and cost avoidance.


Abstract: Advanced High Strength Steels (AHSS) are being aggressively explored by the automotive industry all around the world for cost-effective solutions to accomplish vehicle lightweighting, improve fuel economy, and consequently reduce greenhouse emissions. Because of their inherent high strength, attractive crash energy management properties, and good formability, the effective use of AHSS such as Dual Phase and TRIP steels, will significantly contribute to vehicle light weighting and fuel economy. To further the application of these steels in automotive body and structural parts, a good knowledge and experience base must be developed regarding the press formability of these materials. This project provides data on relevant intrinsic mechanical behavior, splitting limits, and springback behavior for several lots of mild, conventional HSS, AHSS, and UHSS (ultra-high strength) steels supplied by the member companies of the Automotive Applications Committee (AAC) of AISI. Two lots of TRIP600, which were supplied by Thyssen Krupp Stahl were also included in the study. Since sheet metal forming encompasses a very diverse range of forming processes and deformation modes, a number of simulative tests were used to characterize the forming behavior of the steel grades. In general, it was found that formability as determined by the different tests decreased with increasing tensile strength. Consistent with previous findings, the formability of TRIP600 was exceptionally good for its tensile strength. Detailed trends and conclusions are presented for each test in the study.

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Abstract: The effect of forming strains on the fatigue behavior of automotive mild steel, interstitial free steel, was studied after being prestrained by balanced biaxial stretch and plane strain. In the long life region, higher than $5 \times 10^5$ reversals, prestrain improves fatigue resistance. In the short life region, prestrain reduces fatigue resistance. At even shorter fatigue lives, the detrimental effect of prestrain diminishes. For plane strains, the fatigue behavior is anisotropic. In the direction perpendicular to the major strain, the steel exhibits much better fatigue resistance than in the direction parallel to the major strain.