L. Huang, M. Kuo, B. Yan, “AHSS Application in Roof Strength”, To be Published at SAE 2007.

Abstract: The new federal roof strength regulation requires higher roof strength within a specified intrusion to protect passengers in case an accident occurs. In addition, considering the fuel consumption and environmental friendliness, the OEM’s designers have to develop an efficient passenger compartment structure to meet the requirements with the minimum weight impact. In this paper, Advanced High Strength Steels (AHSS) are introduced as an enabler to support this challenging task. The advantages of different types of AHSS for vehicle crashworthiness are presented. The criteria to select materials to improve the roof crush performance are discussed in detail. Finally, a new steel design concept using dual phase steels with strength ranging from 590 to 980 MPa is introduced to illustrate how steels of different strength levels are used in the design. In this example, component geometry is modified to accommodate the formability of the AHSS; roll forming is used for several components when the steel of very high strength is used; laser weld blank is applied to further reduce weight. Furthermore, special reinforcements were designed which significantly improve the buckling resistance of the structure and boost the crush performance at the later stages of crushing. FEA simulation demonstrates that the new AHSS design is capable of meeting the new federal regulation. It is concluded that the AHSS is a very effective enabler in achieving increasingly stringent roof crush requirement. However, a holistic approach must be taken when steels of high strength is used, including optimized use of steel strength, strength and formability compromise, part geometry modification, new manufacturing processes and innovative design.


Abstract: New grades of steel, dual phase and TRIP, were developed offering superior combinations of strength and ductility, when compared to traditional higher strength grades. These steels, available up to 980 MPa minimum tensile strength, typically exhibit high ductility, excellent work and bake hardening characteristics, and high n-value. Dual phase and TRIP steels can be considered to replace, at lighter gauge, all HSLA grades for a lower mass, high performance application. These grades can be considered for energy absorption, intrusion minimization, and all parts requiring a good combination of high strength and ductility. Their mechanical properties are ideally suited for challenging hydroformed applications, such as frame and roof rails, B-pillars, cross car beams and front end structures.


Abstract: Drop tower axial crush testing was performed on hat section samples of various steel grades ranging in minimum tensile strength from 410 MPa to 1300 MPa. It was demonstrated that the energy absorption capability increases with the tensile strength of the steel. However, steels of very high strength, greater than 980 MPa tensile strength, exhibited a greater tendency for weld button pullout or material fracture, and thus limited energy the absorption capability. The effect of the closeout plate and the yield strength of the steel on energy absorption were also investigated. FEA simulations were performed and correlated to the experimental results. A flow stress based material criterion is introduced based on the analytical approach to compare the crush performance of steels.

Abstract: Nine different materials were selected for three 2005 Numisheet Benchmark studies. A set of standard material properties was measured using a common test method. Specification on the test method and procedure is described in this paper. The specific methods used in the determination of standard material properties, r-value, the forming limit curve and coefficient of friction are also provided.


Abstract: Increased public awareness of automotive safety and consumer demands for improved occupant protection has increased significantly over the last several decades and there is no end in sight for this trend. This increased focus on safety is also being driven by new regulations being issued by the National Highway Traffic Safety Administration (NHTSA), independent rating agencies such as the Insurance Institute for Highway Safety (IIHS). All these factors are driving automotive design engineers to utilize advanced high strength steels as a key enabler for maintaining structural efficiency without paying large penalties in mass or cost. This paper will focus on key areas of body structure crashworthiness (frontal crush, side impact, rear crush and roll over) as well as interior seat structures as some of the key areas for automotive safety. In each of these areas, recent developments in advanced high strength steels are offering innovative solutions to meet consumer expectations and regulations efficiently and without significant penalties in vehicle mass or the high costs normally associated with alternative material solutions. A materials strategy for steel use is proposed for the next generation of automotive body structures. This strategy takes into account several difficult to quantify factors such as current North American steel industry capabilities, typical automotive manufacturing constraints as well as cost and mass factors. Applications for Dual Phase (DP), Transformation Induced Plasticity (TRIP) and martensitic steels will be discussed in detail.


Abstract: Prediction of dent resistance of automotive closure panels using Finite Element Analysis (FEA) has increased in popularity as an effective screening tool to determine the optimum combination of material properties and thickness for a given exposed panel application. The analysis process typically includes formability analysis, the results of which are mapped onto a structural model for analysis of dent resistance. Although this method is general, allowing for consideration of the entire panel assembly and boundary conditions, the approach can be very time consuming especially when evaluating several combinations of material grade and thicknesses. This paper presents an alternative approach for the prediction of dent resistance. Using a number of screening simulations the most influential variables affecting dent resistance were determined. A rectangular bi-curved plate was used to approximate the panel assembly. A Design of Experiments (DOE) approach was then used to vary the geometry, thickness, mechanical properties and stretch imparted during stamping. Denting FEA was conducted on these rectangular plates, followed by statistical analysis of the results of the denting FEA. Predictive models for dent resistance based on the statistical analysis were developed for several steel grades. Comparison of the model prediction to actual test results yielded excellent agreement.


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: The production feasibility of a Mn-Si-Cr-Mo alloy grade of hot-rolled dual phase steel was demonstrated using standard hot strip mill processing. Coils of gauges between 1.8 and 6.0 mm were produced with standard run-out table cooling practice and coiling temperatures. The material has good in-coil property uniformity, a low yield-strength-to-tensile strength ratio compared to HSLA steels, and excellent formability (JIS total elongations typically in excess of 30%). It also has good hole expandability, weldability and fatigue resistance. Production material performed successfully in wheel disc production trials and seems suitable for manufacturing structural automotive parts.


Abstract: Traditional constitutive models can only describe a parallel or divergent stress strain response at different strain rates. This paper presents a new constitutive model that can describe convergent, divergent or parallel stress strain patterns. The new model is a modification to the popular Johnson-Cook model. By comparison with the Johnson-Cook model using high strain rate data of seven high strength steels, the new model is evaluated. The results showed that the new model could adequately describe the stress strain relation at high strain rates for the seven steels. In addition, an empirical relationship between the parameters in the new constitutive model and quasi-static tensile data has been developed based on the analysis of several high strength steels. The equation requires only quasi-static data as the input and is capable of estimating flow stresses at high strain rates. The calculated stress strain curves at high strain rates can be used as a first order approximation for design purposes when the experimental high strain rate data are not available. The empirical equation is also evaluated by comparing the errors with the Johnson-Cook model.


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: With interest in improving vehicle quality and customer satisfaction, Ford Motor Company initiated an effort aimed at improving dent resistance of closure panels. An investigation of various means of product improvement led to the recognition of dual phase steels, due to their inherent formability and strain hardening attributes, as the most appropriate steel panel for outer panel applications. ArcelorMittal’s new Electro-galvanized dual phase steel DI-FORM 500 (henceforth referred to by the generic designation, DP500), which meets 500 MPa minimum tensile strength, was specifically designed to meet automotive exposed quality standards. This paper compares the dent resistance performance of automotive door assemblies manufactured with both Bake Hardenable 210 (BH210) and DP500 door outer panels. Results indicate the achievement of significantly improved outer panel dent resistance through the use of the DP500 product. The excellent correlation of test results to predictions by a dent resistance model developed by ArcelorMittal is also reviewed.

Abstract: High strain rate performance is one of the attributes important for the advanced high strength steels (AHSS) because many of their applications are critical to crash management. A project has been conducted by ArcelorMittal to generate high strain data for a group of AHSS, including dual phase and TRIP steels. Since there was very little experience in high strain rate testing for steels and no standard testing methods and procedures are available, the project also evaluated the testing methods and developed a procedure for data processing. In this paper, testing results from two major testing methods: servohydraulic testing system and Split Hopkinson Bar (SHB, both tension and compression), are compared. The process of data reduction and curve fitting is presented. Finally, high strain rate properties of the AHSS tested are discussed.


Abstract: Fatigue property is one of the important attributes for the advanced high strength steels (AHSS) since most of the automotive applications are subjected to cyclic loading. Even for applications that were not fatigue critical, fatigue failure often becomes important due to reduced gages and hence increased stresses. Recently, ArcelorMittal has conducted a study to characterize the fatigue behavior of six AHSS: BH300, 440W, HSS590, DP600, TRIP590 and DP800 with HSLA350 as benchmark. In addition to the strain controlled fatigue tests, notched specimens were also tested to study the notch sensitivity of the AHSS.


Abstract: The effect of forming strains on the fatigue behavior of an 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 5x10^5 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.


Abstract: A systematic investigation of the combined effect of strain, strain path, panel radius and bake hardening was carried out for five different materials. A full factorial experimental approach with three variables (stretch, strain path and panel radius) was used to examine the effects of the individual variables and interactions of the variables. Experimental panels were formed and dent tested using a recently established guideline for dent testing. Several significant and interesting results were obtained from this experiment offering new insights into the phenomenon of dentability. It was found that the increase in dent resistance on baking was dependent on the radius of curvature of the panel, where the effect of baking was significantly higher for the high radius (low curvature) panel. In addition, dent resistance of non bake-hardenable steels seemed to be dependent on the strain path, whereas the dent performance of bake-hardenable steels seemed to be relatively independent of strain path. These results offer broad guidelines on the appropriate applications and stamping practices for bake-hardenable steels and non bake-hardenable steels.