

TUESDAY, AUGUST 24, 2004, P.M.

SESSION 32: INTERNATIONAL SYMPOSIUM ON MATERIALS FOR FUEL EFFICIENT AUTOMOBILES

FORMABILITY

Sponsor: Iron and Steel, The Metallurgical Society of CIM

Room: ALBION C

Chairmen: D. WILKINSON, T. PETRIC and M. JAIN, McMaster University, Hamilton, Ontario, Canada

PAPER 32.1 — 14:00 (KEYNOTE)

MICROMECHANICS MODELS FOR ENGINEERED AUTOMOTIVE MATERIALS.

M-J. PINDER, University of Virginia, Charlottesville, Virginia, U.S.A.

Micromechanical techniques play an important role in identifying optimum material architectures for use in engineered structural components. These techniques have been successfully employed for a long time in investigating the potential of advanced materials concepts in the aerospace industry. They can also be easily adapted to the identification of material-based solutions for increasing automobile fuel efficiency through better stiffness-to-weight ratios in stationary and moving components, and improved heat and wear resistance. In this talk, several user-friendly micromechanics models developed for NASA will be discussed with the focus on their applicability to the design of optimal structural components for automotive applications.

PAPER 32.2 — 14:30

STRAIN ACCOMMODATION AND DAMAGE DEVELOPMENT IN A DUAL-PHASE STEEL.

Y. OSOSKOV, L. GUTKIN, M. JAIN, D.S. WILKINSON and D. EMBURY, McMaster University, Hamilton, Ontario, Canada

The availability of high-strength materials with enhanced formability is of vital importance in the development of fuel-efficient automobiles. In this study, strain accommodation and damage development in ferritic-martensitic dual-phase steel DP600 have been investigated in different deformation modes (uniaxial tension, biaxial tension, plane strain). The macroscopic plastic deformation progressed in a steady and uniform manner until necking and did not exhibit significant planar anisotropy. On the basis of loading-unloading microhardness experiments, the strain accommodation by both structural constituents was analyzed, and the macroscopic plastic behaviour was modeled. The work hardening of martensite and its unloading spring-back were much higher than those of ferrite. The dominant form of damage development was found to be microvoid coalescence along martensite bands parallel to the sheet surface. The microvoid nucleation occurred by decohesion at either ferrite-martensite interfaces or between adjacent martensite regions.

PAPER 32.3 — 14:50

AA6111 SHEET BENDABILITY PREDICTION USING A THREE-DIMENSIONAL DAMAGE PERCOLATION MATERIAL MODEL.

O. ORLOV, M. WORSWICK, University of Waterloo, Waterloo, Ontario, Canada,
B. LIEVERS, K. PILKEY, Queen's University, Kingston, Ontario, Canada, and
D. LLOYD, Alcan International, Kingston, Ontario, Canada

A three-dimensional damage percolation material model is used to predict damage evolution and bendability of AA6111 sheet. The role of void/particle size and spatial (clustering) distributions on the formability and damage in aluminum alloy sheet during damage sensitive forming operations is addressed here. A multidisciplinary approach employing (i) statistical stereological methods to characterize the material particle fields from 2D metallographic sections; (ii) probability theory and known clustering characteristics to generate 3D particle fields; and (iii) damage percolation simulations to predict the progression of damage within the bulk material. Damage initiation is observed to occur primarily at larger particles and/or clusters, followed by catastrophic failure due to the coalescence of several neighboring clusters.

COFFEE BREAK — 15:10 – 15:30

PAPER 32.4 — 15:30

SURFACE ROUGHNESS IN DC CAST AA6111 ALLOYS.

V. OSWELL, D. EMBURY and D.S. WILKINSON, McMaster University, Hamilton, Ontario, Canada

Aluminum alloys, such as AA6111, hold great promise for automotive applications. However, they are prone to the development of surface roughness during forming. This can lead to unacceptable surface finish for skin sheet

applications. We are therefore studying the development of correlated surface roughness phenomena in such alloys. Most previous research has focused on the dependence of roughness development on grain size, sheet thickness, amount of strain, tensile orientation with respect to rolling direction and texture of the material. Our current research and this presentation considers the relationship between strain hardening rate and surface roughness development over a range of strain, temperature and temper conditions in DC cast AA6111.

PAPER 32.5 — 15:50

FABRICATION OF SEAM WELDED ALUMINUM TUBE FOR HYDROFORMING.

P. MARTIN, D. BARAGAR, G. SHEN and D. DOLAN, CANMET, Ottawa, Ontario, Canada

Fabrication of aluminum tubes using roll forming and welding is an interesting alternative to tube extrusions for hydroforming. This technology is well developed for low-carbon steel but it is much less understood for production of aluminum tubes. It is a complex process since it involves good control over the roll forming conditions to minimize work hardening and optimization of the welding operation to avoid fracture at the weld during hydroforming. This paper describes results of an investigation of fracture during tube expansion of 5052 and 5754 aluminum seam welded tubes for hydroforming. Seam welded tubes were produced in laboratory by press forming of tubular blanks and pilot-scale tube high frequency induction welding. The effect of property mismatch between the weld and base metal has been investigated. The material work hardening was obtained by roll forming of sheet blanks in the 0-temper and H32 temper condition. The weld microstructure properties were varied by using different welding conditions. In this study a new test method has been used to simulate tube expansion using a jig to stretch tube coupons. The new technique has been used to evaluate weld integrity and forming property of the tubes. Significant workhardening can be present in base metal without causing weld fracture during tube expansion. The workhardening increases the yield strength mismatch between base metal and weld. Annealing contributes to reduce the hardness of base metal leading to more uniform deformation during tube expansion. As a result weld fracture occurrence is reduced. The study showed a significant deformation of the welds during tube expansion. Weld thinning can be as significant as parent material thinning before fracture. To avoid fracture at the weld joint good formability and high yield strength welds is needed. It has been shown that thinning of the weld can be reduced by minimizing the width of the weld joint.

PAPER 32.6 — 16:10

INSTRUMENTED BENDING AND HYDROFORMING OF DP600 TUBE.

A. BARDELICK, D. OLIVEIRA, J. DYMENT, S. WINKLER and M.J. WORSWICK, University of Waterloo, Waterloo, Ontario, Canada

The use of high strength steel alloys in hydroforming applications is attractive to the automotive industry because of the potential for improvement in fuel efficiency due to weight savings. The current research focuses on the effect of tube bending parameters, in particular centre-line-bend radius to tube diameter (R/D) ratio on the hydroformability of 76.2 mm (3") diameter DP600 tube. A fully instrumented servo-hydraulic mandrel-rotary draw tube bender is used to accurately control bend process parameters, such as pressure die boost, mandrel position and clamp load. Bending R/D ratios of 1.5, 2.0 and 2.5 are considered and the degree of corner fill during hydroforming that can be achieved after bending is assessed. Numerical models of the bending and hydroforming process are developed and compared to results from experiments. Novel formability criteria, such as stress-based forming limit diagrams are considered to account for strain path effects between processes.

PAPER 32.7 — 16:30

MODELING OF FORMABILITY OF AUTOMOTIVE SHEET METALS.

K. INAL, K.W. NEALE and A. ABOUTAJEDDINE, University of Sherbrooke, Sherbrooke, Québec, Canada

Applications of crystal plasticity theory to the numerical modeling of sheet formability are considered. In particular, instabilities and localized deformation phenomena for automotive sheet metals subjected to various deformation modes are investigated. In-house finite element analyses based on a rate-dependent crystal plasticity model have been developed to simulate the large strain behaviour for specimens subjected to various deformation modes. In the formulation, plastic deformation of an individual crystal is assumed to be due to crystallographic slip. Modeling of the polycrystalline aggregates is carried out at various scales. These formulations account for initial textures, as well as texture evolution during large plastic deformations. The results of simulations for automotive sheet metals are discussed, and in certain cases comparisons are made with experimental results. The effects of various parameters such as initial texture, multi-phases and strain paths on formability are discussed.

PAPER 32.8 — 16:50

EFFECT OF CRYOGENIC TREATMENT ON THE MECHANICAL PROPERTIES OF STEEL(4340) AND ALUMINUM ALLOY(7075)

S. ZHIRAFAR, Mechanical and Industrial Engineering, Montréal, Québec, Canada

Over the last few years, interest has been shown in the effect of very low temperatures during the heat treatment cycle on the performance of the steels. "Cryogenic Tempering" the process of deep-freezing materials at Cryogenic

temperatures (-196 C), has been reported to optimize the mechanical properties of some steels, normally tool steels, being treated. This paper reports on experiments carried out to determine the hardness, toughness and durability of cryogenically treated Steel (4340) and Aluminum alloy (7075) as compared to those conventionally treated.