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Effect of strain rate on the deformation behavior of dual phase steels and particle reinforced polymer composites

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Mechanical behavior of materials at high strain rates differs considerably from that observed at quasi-static or intermediate strain rates. In most cases, the flow stress (resistance to deformation) is observed to increase with increasing rate of deformation. In this work, the deformation behavior of high strength dual phase steels and particle reinforced polymer composites was studied at a wide range of strain rates. For the tests at high strain rates, split Hopkinson pressure bar (SHPB) technique was applied and further developed in terms of data handling, controlling of the tests, and specimen preparation.

The aim to reduce the fuel consumption by reduction of car weight has become one of the main goals of the automotive industry. One way to reduce the car weight is the use of thin, ultra high strength dual phase steels, which are protected against corrosion by hot dip galvanizing. Dual phase steels in automotive applications are mainly used in bumpers, door and roof beams and side impact protection beams. To simulate the behavior of these structures, whose important function is to protect the driver and the passengers in the case of a sudden impact, information on the behavior of the materials as a function of strain rate is needed. In this work, valuable new data on the compressive stress-strain response of four different hot dip galvanized dual phase steels was obtained in the strain rate range of $10^{-3}…10^{3}$ s^{-1}. This data can be used, for example, in structural analyses of automotive structures and components.

Another aspect of the dual phase steels that was studied in this work was the pre-strain and strain rate dependence of the so-called springback phenomenon. Springback is the amount of deformation that is recovered after the forming load is removed, *e.g.*, in deep drawing process. It has been found that in addition to the purely elastic deformation predicted by the initial elastic modulus, some extra amount of strain is recovered depending on the amount of plastic straining involved. This extra recovery of strain, usually referred to as anelastic strain or deformation, leads to an apparent Young's modulus, which usually has a smaller value than the initial Young's modulus. The anelastic behavior of the dual phase steels was studied by tensile tests made at different pre-strains and loading rates. The reasons for the observed changes in the apparent Young's modulus with increasing pre-strain and strain rate are discussed.

The studied particle reinforced epoxy and polyurethane based materials are used in paper machine applications as roll covers. The increasing speed of the paper web in modern paper machines sets new requirements for the dynamic stress-strain response of the cover materials. The roll cover material may be subjected to strain rates as high as 1000 s^{-1} at elevated temperatures and moist conditions, which means that the mechanical properties, such as stiffness of the roll cover, differ considerably from those measured at static conditions at room temperature. In this work, the compressive deformation behavior of the roll cover materials was studied at temperature and moisture conditions similar to real paper machine applications using servohydraulic materials testing machines and the SHPB technique. Also creep tests of different durations were performed. Moisture was found to have a more detrimental effect on the stiffness and strain rate sensitivity of the polyurethane roll covers than elevated temperatures.