CHAPTER 1 INTRODUCTION

1.1 Scientific and Theoretical Problems

The global warming, energy consumption, high price of oil and gas and awareness of environmental issue have become the most important considerations in every industrial sector. In the automotive industry, much effort has been done to develop new vehicle concept with enhanced efficiency of fuel consumption. One effective solution is to design a light–weight car body structure, which can be achieved by replacing lower strength, relatively thick steel sheets with other higher strength, relatively thinner steel sheets. By applying such thinner gauge, higher strength steels to the vehicle, improved passenger safety can be also obtained due to increased ability for energy absorption. To realize the needs of the industries, steel makers have focused on developing advanced high strength (AHS) steels with enhanced properties. The AHS steels such as dual phase (DP) steel, transformation induced plasticity (TRIP) steel exhibit multiphase microstructures with an excellent combination between high strength and good formability. They can be used with reduced sheet thickness, but without deteriorating safety performance.

The AHS steels have been increasingly applied in the automotive industries due to their distinguished mechanical properties, on which the microstructures of these steels play an important role. Due to various constituent phases with distinct characteristics, the AHS steels exhibit sophisticated damage mechanisms that make the prediction of material formability difficult. By forming these steels, small post–necking deformation was observed or fracture could even occur before strain localization. Obviously, crack initiation can take place in the AHS steels prior to necking and induce a macrocrack at an early state. Therefore, a tool for predicting ductile crack initiation during cold forming of such multiphase sheet steels is required.

Originally, the forming limit diagram (FLD) is conventionally used in sheet metal forming industry for formability description and optimizing process. By the strain based FLD criterion, material formability is evaluated on the basis of localized necking. In case of AHS steel sheets, accuracy of the failure onset prediction could be definitely impaired, since macro−cracks could occur before necking occurrence due to early damage initiation. This is challenging for the forming limit description. Otherwise, industrial forming parts often exhibiting complex shape are usually manufactured in multi–step procedures, whereby influences of occurred non–proportional strain paths on the applied FLD could be problematic. As shown in many research works, the forming limit stress diagram (FLSD) is less dependent on the forming history and strain path. It can be used to describe necking occurrence of any kinds of drawn parts undergoing complex strain paths. In this work, FLDs and FLSDs were determined for the investigated AHS steel sheets and then applied to predict the formability behaviour of these steels.

As mentioned, the AHS steels basically exhibited complex damage mechanisms, which made the prediction of material formability difficult. On the microscopic scale, micro−cracks could initiate during an early state of deformation and restrict the forming limit of material. Hereby, failure was reached without any noticeable macroscopic localized necking. Improved failure criterion for such steel sheets is still required to evaluate both micro− crack initiation and macroscopic failure in order to obtain more precisely description of their forming behavior. Generally, fracture of these steel parts is ductile, for which stress triaxiality plays a decisive role. In this work, another failure criterion based on the relationship between local critical plastic strains at crack initiation and arising stress triaxialities was investigated. To determine the failure criterion of the investigated steel, forming experiments and corresponding FE simulations under various states of stress must be performed and evaluated. The obtained failure criterion was afterwards verified on both laboratory and industrial scale.

1.2 Objectives and scope

The aim of this work was to describe and predict formability behavior of the advanced high strength steels grade DP780, TRIP780, and JAC780Y by mean of experimental and numerical methods.

The methodological approaches of this work are introduced as following.

1. Anisotropic plastic behaviors of the AHS steels were investigated under different states of stress. Effects of yield criterion and hardening law on local stress and strain distributions of the steel samples were studied.

2. Forming limits of the AHS steel sheets were characterized by the conventional strain based criterion (FLD) and the stress based criterion (FLSD). Both criteria were determined by experiments based on the Nakazima test and theoretical calculations according to the M–K model. The obtained threshold curves were verified by the hole expansion test

3. Damage curves were developed for ductile crack initiation and plastic instability state. A hybrid experimental and numerical analysis was employed. Tensile test of notched samples were carried out in combination with the direct current potential drop (DCPD) method. Subsequently, FE simulations of the corresponding tests were performed for calculating stress triaxialities and plastic strain at crack initiation and instability state. The determined damage curves were validated by different experimental tests.