

NUMERICAL AND EXPERIMENTAL INVESTIGATIONS ON FORMABILITY FOR LIGHTWEIGHTING OF AN AUTOMOTIVE FUEL TANK

ABSTRACT

In this highly competitive environment, one of the most important tasks for all the automotive companies is to manufacture lightweight products to reduce the overall weight and the cost. This also results in increased fuel economy and reduced emissions. The body panels and other sheet metal parts constitute about 30-40% of the total weight of an automobile in the case of a four-wheeler and 30-35% in the case of a two-wheeler. Different sheet metal forming processes such as deep drawing, stretching, and bending are extensively used for manufacturing body panels and many other critical sheet metal parts for automobile applications. Some of the common examples are fuel tank, oil sump, B-pillar, front and rear fenders, etc. The success of sheet metal forming or stamping process of a complex automobile part depends on the ability of the sheet metal to undergo the required deformation, referred to as formability, without excessive thinning, necking, wrinkling, or fracture under the imposed forming conditions.

Different strategies for lightweight construction of a two-wheeler are proposed in the present thesis by exploring different methods to reduce the weight of critical sheet metal parts such as the fuel tank. A fuel tank is one of the most critical parts of an automobile because it contains gasoline which is a highly volatile liquid. Manufacturing a fuel tank is a critical process because it involves large plastic deformation of the sheet metal during forming. In view of this, in the present work, a two-wheeler fuel tank has been selected for formability investigations to explore the feasibility of manufacturing the fuel tank successfully with reduced weight. To achieve this, **three different strategies have been explored**, namely, reducing thickness and/or changing the steel grade, manufacturing the fuel tank with lightweight Al alloys, and using hydroforming technology to manufacture the fuel tank.

In the first part of this work, formability of a two-wheeler fuel tank has been investigated to explore the feasibility of reducing thickness and/or changing the steel grade in order to reduce the weight and improve fuel efficiency. Formability analysis has been carried out using numerical simulations on 0.8 mm thick sheet of Extra Deep Drawing (EDD) steel which is being used to manufacture the fuel tanks. Simulations were carried out using

AutoForm software to find out the minimum initial sheet thickness which can be formed successfully without necking/failure. The effect of blank holding force and friction coefficient was also analyzed. Experiments were carried out to validate the predicted results such as strain distribution and thinning in the formed components. By reducing the thickness to the minimum possible (0.70 mm), it has been found that the weight of the product can be reduced by nearly 12.5%. Simulations have also been carried out by changing the grade from EDD to Interstitial Free (IF) steel. Due to the superior drawability of IF steel, it has been found that thickness can be further reduced to 0.65 mm which is expected to result in 19% reduction in the weight of the component. Both the predictions have been validated by the actual press trials.

The future lightweight vehicle is likely to use a combination of available lightweight materials which have the potential to replace steel for various structural and other parts. An Al-intensive vehicle is one of the most potential ways to achieve vehicle weight reduction. In view of this, **in the second part of the work**, numerical simulations have been carried out to explore the feasibility of forming a two-wheeler fuel tank by using two different Al alloys, AA5052 and AA5754 (both 1 mm thick), commonly known for their ability to work harden and good properties. Due to their inferior formability when compared to EDD steel, successful forming could not be achieved. Experimental press trials also confirmed the predictions from the simulations. However, it was found that the fuel tank could be successfully formed in the case of AA5754 when the initial blank thickness is increased to 2 mm. Even with enhanced blank thickness, it would yield significant weight reduction in the case of this component.

Presently, the fuel tank of a two-wheeler is manufactured in two parts (upper left and upper right) which are welded after forming in a single die. Fuel tanks with large depth require multiple drawing steps. Apart from additional costs due to tooling, welding, and finishing operations, problems such as failure at joints and leakage are possible. These problems can be overcome by exploring innovative ways to manufacture a fuel tank. In view of this, the possibility of manufacturing a two-wheeler fuel tank with large depth as a single part by hydroforming technology has been explored using FE simulations in **the third part of this thesis**. The effect of peak pressure and clamping force on formability of 0.8mm thick EDD steels sheets has been studied in hydraulic bulging and the results obtained from simulations and lab scale experiments were in good agreement thus verifying the simulation

methodology. Formability of the fuel tank with large depth has been studied in FE simulations by single stage and two stage hydroforming processes. It was found that a fuel tank with a large depth could be formed successfully as a single component by two-stage hydroforming with intermediate annealing thus eliminating the need for forming two separate parts followed by joining. It is expected to result in 42 % weight saving when compared to the conventional forming.

Keywords: Lightweighting, Formability, Deep drawing, Hydroforming, FE simulation