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DESIGN FOR MANUFACTURABILITY OF AUTOMOTIVE PART CONSIDERING FORMABILITY AND SPRINGBACK

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ABSTRACT

Sheet metals are used for most of the BIW and structural parts. The advantage of HSS materials is that relatively lesser thick metals can be used compared to medium strength steels, because HSS material's Yield Strength (YS) and Tensile Strength (TS) are higher. The basic challenge with HSS sheet is high spring back after forming. Due to higher range of YS, the usual forming tonnage may not be able to bring all areas of part into plastic zones. When compared to medium strength steels the area which is below YS will be more in a Stress-Strain diagram. This results in great amount of spring back. In the present study, the mechanism of metal forming is studied to understand the effects of forming parameters (draw ratio, punch radius, Die radius, degree of bend, etc.) and material properties like (Yield Strength (YS), Tensile Strength (TS), Elongation, Co-efficient of work-hardening; n-value, Anisotropy ratio; r-value). Forming Limit Diagram is widely used to understand the formability of a material. A computer aided metal forming software which is based on Finite Element Method, called Auto Form is used for forming simulation. The results of forming (thinning, wrinkles, cracks etc) and spring back are analyzed against material properties. Based on the results, the course of design changes to part are planned and implemented through CAD (Computer Aided Design) package. The modified part will be re-simulated using Forming tool without changing parameters. This final forming simulation helps to analyze the effect of design changes made. The design changes based on forming simulation results can be repeated if spring-back is not reduced. These iterative changes made to original Part design helps in the reduction of manufacturing time and saves cost of proving the part in real-time manufacturing..

KEYWORDS: Sheet Metal, Hss Material, Spring Back & Formability

INTRODUCTION

Sheet metal forming process is a plastic deformation in which the volume, energy of metal is conserved. Sheet metal is generally considered to be a plate with thickness. One of the most important processes in sheet-metal forming is deep-drawing. The major concern in sheet mzetal forming (especially High strength steel) is Springback. Springback is the dimensional change of the formed part after pressure of the forming tool has been released. It results from the changes in strain produced by elastic recovery. The elastic recovery is greater for the higher Yield Stress materials. So when designing any part for application of High Strength Steel materials, its springback behavior should deeply analyzed. Springabck bahaviour can be better analyzed based on formability results.

The principal difference between conventional steels and HSS is their microstructure. Conventional steels are single phase ferrite steels. HSS are primarily multi-phase steels, which contain ferrite, martensite, bainite, and/or retained austenite in quantities sufficient to produce unique mechanical properties. Some types of HSS have a higher strain hardening capacity resulting in a strength-ductility balance superior to conventional steels.

The improved capabilities of the HSS accentuate problems already existing with forming. These concerns include higher loads on presses and tools, greater energy requirements, and increased need for compensation and control. In addition, HSS have greater tendency to wrinkle due to lack of adequate hold-down and often a reduction in sheet thickness.

Obtaining knowledge and experience are needed for forming higher strength steels. In next sections the mechanical properties related to metallurgical properties are discussed for DP steel.

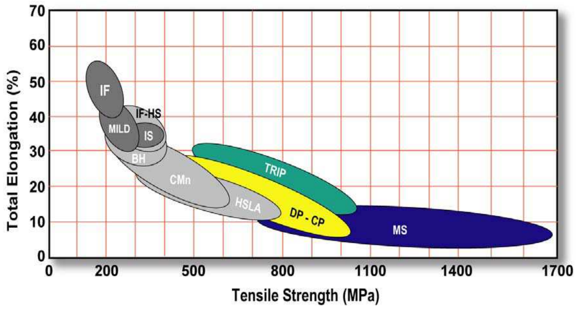
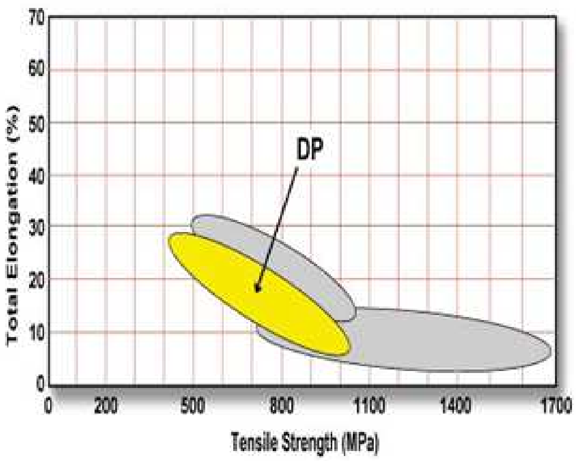


Figure 1: High Strength Steels (In Color) Compared to Low and Medium Steels (Dark and Light Grey)

Material Properties (Dual Phase (DP) Steel)

DP steels consist of a ferrite matrix containing a hard martensitic second phase in the form of islands. Increasing the volume fraction of hard second phases generally increases the strength. DP (ferrite plus martensite) steels are produced by controlled cooling from the austenite phase (in hot-rolled products) or from the two-phase ferrite plus austenite phase (for continuously annealed cold-rolled and hot-dip coated products) to transform some austenite to ferrite before a rapid cooling transforms the remaining austenite to martensite. Depending on the composition and process route, hot-rolled steels requiring enhanced capability to resist stretching on a blanked edge (as typically measured by hole expansion capacity) can have a microstructure containing significant quantities of bainite.



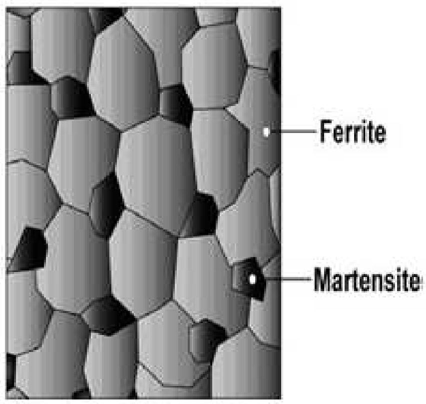


Figure 2: Islands of Martensite in a Matrix of Ferrite **Figure 3: Ferrite – Martensite DP**

Figure 2: shows a schematic microstructure of DP steel, which contains ferrite plus islands of martensite. The soft ferrite phase is generally continuous, giving these steels excellent ductility. When these steels deform, strain is concentrated in the lower-strength ferrite phase surrounding the islands of martensite, creating the unique high work-hardening rate exhibited by these steels.

The work hardening rate plus excellent elongation give DP steels much higher ultimate tensile strengths than conventional steels of similar yield strength. Figure 4 compares the engineering stress-strain curves for HSLA steel to a DP steel of similar yield strength. The DP steel exhibits higher initial work hardening rate, higher ultimate tensile strength, and lower YS/TS ratio than the similar yield strength HSLA. The DP 350/600 with higher TS than the HSLA 350/450

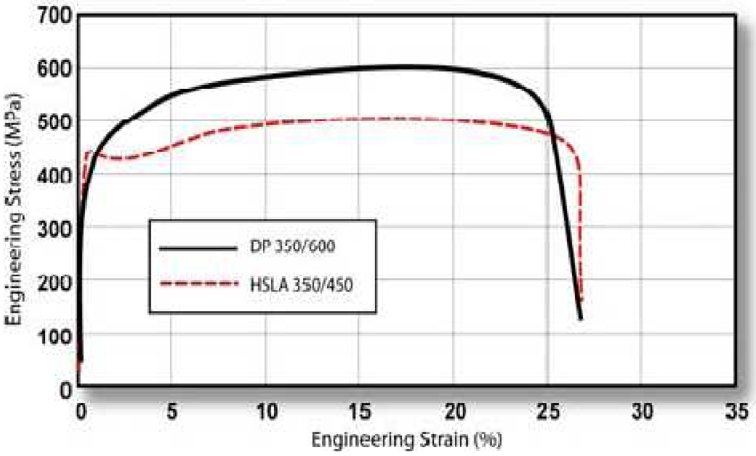


Figure 4: Comparison of the Engineering Stress-Strain Curves for HSLA Steel to a DP Steel

SOLUTION METHODOLOGY

Finite Element Simulation for Metal Forming

To simulate metal flow during deformation processes, the most promising technique is the finite-element method. The concept of the finite-element method is one of discretization.

The finite-element model is constructed using a number of finite points which are identified in the domain of the function, and the values of the function and its derivatives, when appropriate, at these points are specified. These points are called nodal points. The domain of the function is represented approximately by a finite collection of subdomains called finite elements. The domain then is an assemblage of elements connected together appropriately on their boundaries. The function is approximated locally within each element by continuous functions which are uniquely described in terms of the nodal point values associated with the particular element.

Numerical modelling of metal forming processes can be used to simulate metal deformation for complex processes. By using the finite element analysis method, simulation of design can helps to predict errors and modification can be done at early stage before the parts was fabricated and tested. Subsequently the labour cost and time lost can be reduced by gradually replacing manual trial-and-error design iteration.

Percentage Thickness Reduction

The problem described in Description of Problem is simulated using AutoForm and is taken as the initial model. Percentage thinning, Formability, Punch Force and FLD are plotted. Spring back of the part is also analyzed at various critical locations of the part (critical areas where other parts will be mating) for the result of DP600 material. Based on the initial results, sheet metal part's design is modified based on the formability and spring back nature. The results of formability and spring back after the part re-design are discussed in the later part

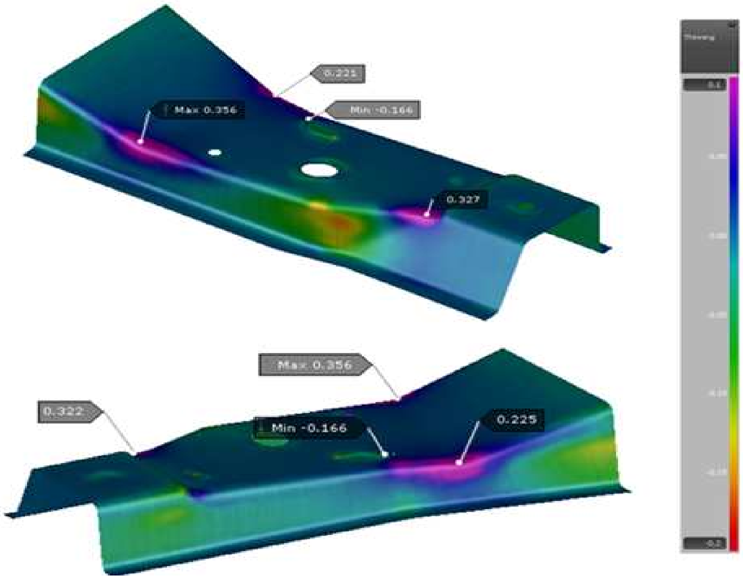


Figure 4: Percentage Reduction in Thickness for DP600 Material (Initial Design)

The major spring back is side-wall curling and angular changes. The source of these two types of spring back is same, i.e. uneven stress distribution in thickness direction. This can be reduced by reducing the thickness of part the, but if it is not a desired part change, the other method is to compensate for these changes in part geometry which is used to build the tools. Springback compensation is nothing but modifying the geometrical shape of part according to springback amount based on analysis results. This also called over-forming. Up on the release of elastic stresses brings the part dimensions back to part. In addition to spring back the lower radius of part is also changed. The other type of springback is twist in the ends (on the web of part). While analyzing the twist it is identified that the source of springback can be insufficient stretch at the ends (on web area) and along the length.

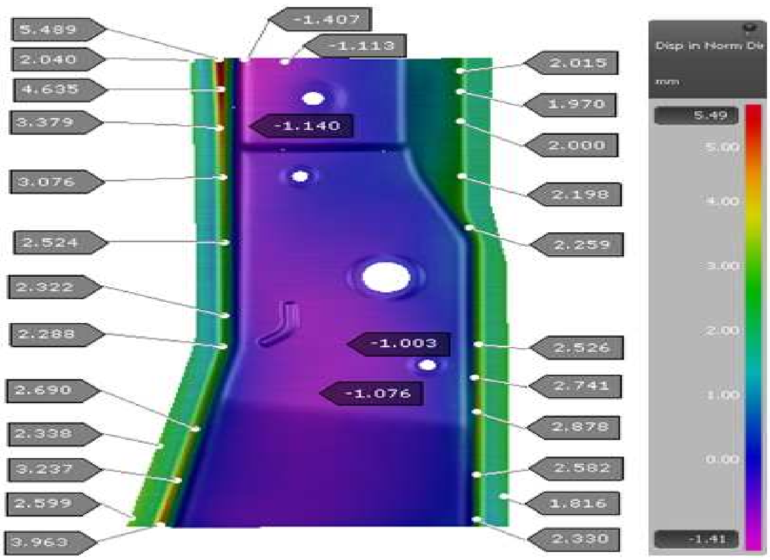


Figure 5: Spring Back at Different Locations for DP 600 Material (Initial Design)

Modifications on Part

The fillet radius at the top of part at ends is reduced. Stiffeners are added on both sides of walls. Beads are added in the centre of part for reducing the wrinkles.

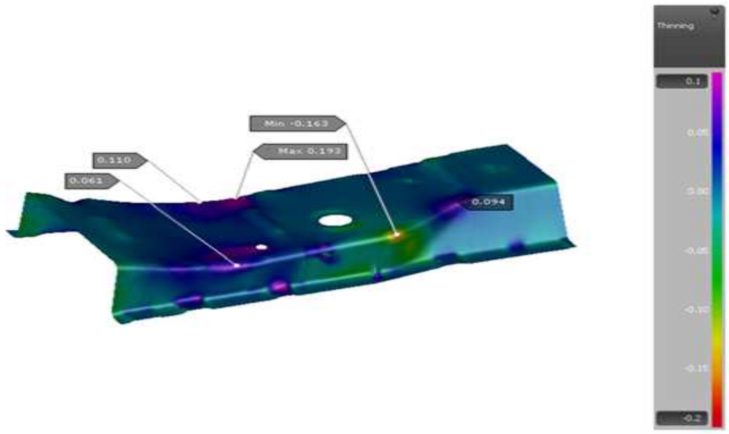


Figure 6: Percentage Thickness Reductions for DP600 Material (Modified Design)

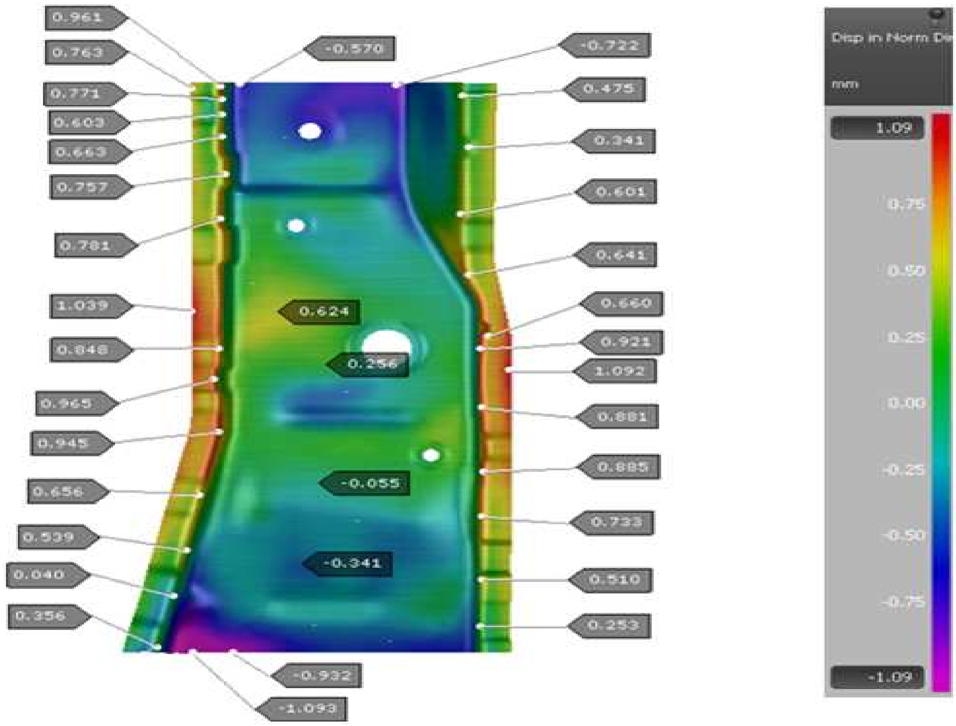


Figure 7: Spring Back at Different Locations for DP 600 Material (Modified Design)

CONCLUSIONS

It is evident from the study that understanding the material properties before testing for formability helps for better design of part for formability. And based on formability results, it is easy to understand the variables which cause the spring back behavior. By controlling these variables, it is possible to control the spring back in HSS parts.

Finite Element Method is a powerful tool for simulating metal forming and springback operations. The use of finite element simulation in the better understanding of forming operations is becoming more important as it provides a way to determine important parameters which will help for improving formability. It also helps to find the ways to modify the part geometry and make the part formable with fewer defects. This in turn saves time and cost of iterations at tool try-outs as it is possible to predict possible defects and problems in forming HSS parts.

From this study it is proven that forming of parts with HSS sheet is challenging due to its high springback behavior, but it is able by having a good understanding of material properties, study of the formability and spring back.

When designing the structural parts for High Strength Steels it is important to consider the following features in design to reduce the spring back.

Figure 8: Features in Design to Reduce the Spring Back

Wrinkles should be avoided whenever possible. Because they cause thickening in the region where wrinkles are formed, do not stretch sheet properly. This results in increase in springback.

When open channels are designed (like car under body of parts) it is required to add stiffeners at strategic locations. These Stiffeners Help To Lock In Elastic Stresses.

Scope for Future Study

- The current study is carried out considering no change in material properties and process parameters like Blank-holder force, friction etc. The current study is focused only on change of Geometry of part which helps during product development stage.
- There are more findings and better solutions can be found by studying for different process parameters like blank-holder force, change in friction, tool geometry, post-stretch operations etc.

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