



## BLANK OPTIMIZATION FOR HOT STAMPING PROCESS

Ahmad Zakaria, M. Azuan Zaudin and Azman Senin

Institute of Product Design and Manufacturing, Universiti Kuala Lumpur, Kuala Lumpur, Malaysia

E-Mail: [dzakaria@iprom.unikl.edu.my](mailto:dzakaria@iprom.unikl.edu.my)

### ABSTRACT

Boron alloyed steel is usually used in manufacturing of automotive part by hot stamping. Due to its unique properties, this material is comparatively expensive. Therefore an optimized size and shape of the blank is important in order to avoid material wastage after stamping operation. In this study, a blank for an automotive part called Front Impact Beam (FIB) was used as a case study. The objective was to minimize the material wastage after trimming to within +2mm. The effect of different blank sizes on the final stamped part is investigated by using commercial CAE software. The constraints considered in this study include minimum wrinkles and springback or distortion. Finally an improved blank optimization algorithm is developed.

**Keywords:** blank optimization, hot forming, finite element analysis (FEA).

### INTRODUCTION

Stamping is one of the cheapest ways to mass produce sheet metal parts. The operation commences with a pre-cut blank placed on top a lower die prior to being drawn to the cavity by its upper die. The stamped part produced is an exact replica of the die. For drawn or formed parts, trimming is usually required to remove the excess materials. These are called scraps. Depending on the parts, some may produce fewer scraps while other may generate as much as 60% scraps.

Many techniques have been proposed on scrap reduction methodology which in the past done experimentally via trial and error method. In progressive die design for instance an optimization of strip layout process has been largely automated and incorporated in commercial software. Orientation of the blank is arranged such that distances between blanks and the edge width are minimised [1]. In many cases scrap control in forming or drawing unsymmetrical part is complex due to non uniform material flow during forming [2]. As a result, material which passes through a corner or a bead will flow rather slowly compared to unrestricted material which resulted in wrinkles or thinning out.

Implementation of blank optimization algorithm is achieved by numerical simulation in conjunction with forming simulation software [3, 4]. It begins with an initial blank geometry. After forming the final part is compared with the required geometry tolerance. If the total shape error is less than the error allowance, then blank geometry will be modified [5], the procedure is repeated until the desired part edge geometry is met. The algorithm is given in Fig. 1. Khalili *et al* [6] introduced a new approach by applying Response surface method with reduced basis techniques in an attempt to reduce many variables involved in blank optimization. The implementation of blank optimization is by

The above discussion mainly involved cold stamping, however in the case of hot stamping where a

blank is heated up to 850 to its austenitic phase. It is then simultaneously stamped and quenched. Therefore in this case, the material flow is governed by a combination of thermo-mechanical and microstructure evolution [7]. The justification for maximized percentage material utilization is becoming evident as the raw materials for hot forming is comparatively expensive.

In this study, a new blank optimizing algorithm is proposed based on formability and uniform trimming allowance criteria. A 2mm allowance is given for a laser trimming process.

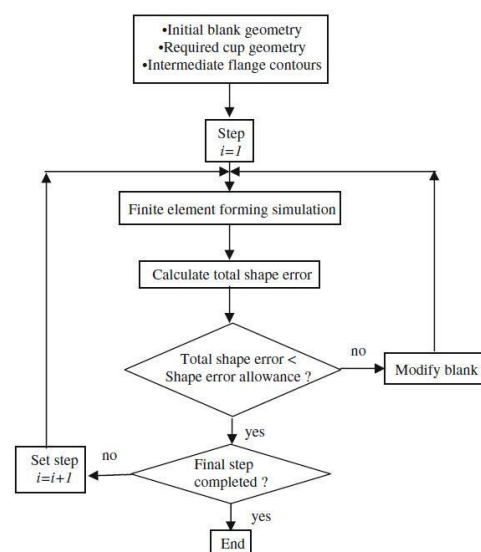


Figure-1. Multi-steps blank optimization [5].

### INTRODUCTION TO HOT STAMPING PROCESS

Saab Automobile AB was the first company to adopt this technique in 1984 to produce hardened component. The number of hardened parts manufactured



by this method has been increased tremendously every year. The final part becomes hardened as a result of rapid quenching. The formation of martensite in turn causes distortion and springback. However in general the size of distortion and springback is small [7] when compared to defects produced by cold stamping. The prediction of quench distortion has been investigated [8] by numerical method with less than 7% error.

### THE PROPOSED ALGORITHM

Figure-2 shows the proposed algorithm. It starts with an initial blank shape generated manually or other means. In addition it is assumed the blank can safely be drawn without any defects. The blank is virtually formed and formability result is analysed using commercial CAE software. The next step is to ensure the formed part does not possess any defects such as excessive thinning, wrinkles or slits. Finally, the part shape is compared with the reference geometry trimming allowance. If it is outside this tolerance then the original blank is offset by 2mm all round. The procedure is iterated until minimum scrap allowance is achieved.

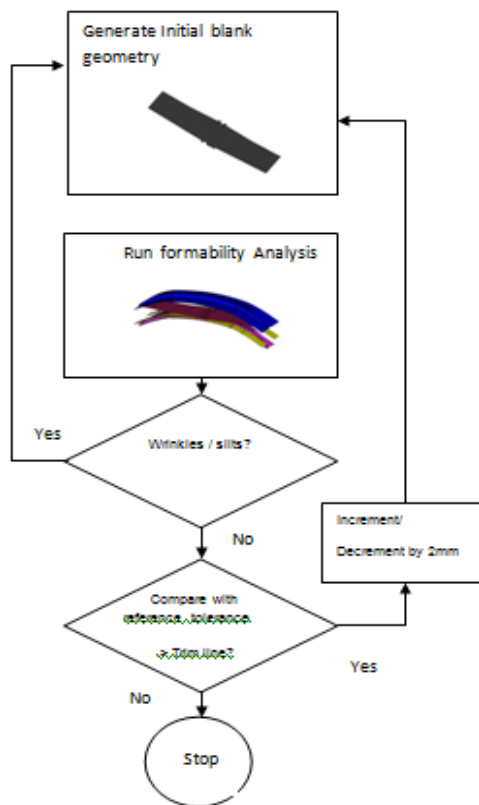


Figure-2. Proposed algorithm.

### METHODOLOGY

In this present work, an automotive part as shown in Figure-3 called front impact beam was used as a case study. It is to be hot stamped using Boron alloyed steel.

Altair Hyperworks modules were employed throughout this numerical simulation process. The blank provided by industry was first utilized as an initial blank shape. Virtual hot stamping was performed by Hyperform 13.0. The blank initial blank temperature was set at 810°C and the tool temperature at 75°C. Hot forming Material LAW80 [9] defines the strain rate dependency by this relation:

$$\sigma = \sigma_y \left(1 + \frac{\dot{\epsilon}}{C}\right)^{\frac{1}{P}} \quad (1)$$

Where  $\sigma$  is the initial yield stress

$\sigma_y$  is the yield stress

$\dot{\epsilon}$  is the strain rate

C and P are the strain rate parameters

The final part geometry is compared against the target trim line. The procedure was repeated every 2mm offset between the edge of original blank and the target trim line. The amount of scrap is recorded for each iteration. The whole procedure is depicted in Figure-4.



Figure-3. Front impact beam.

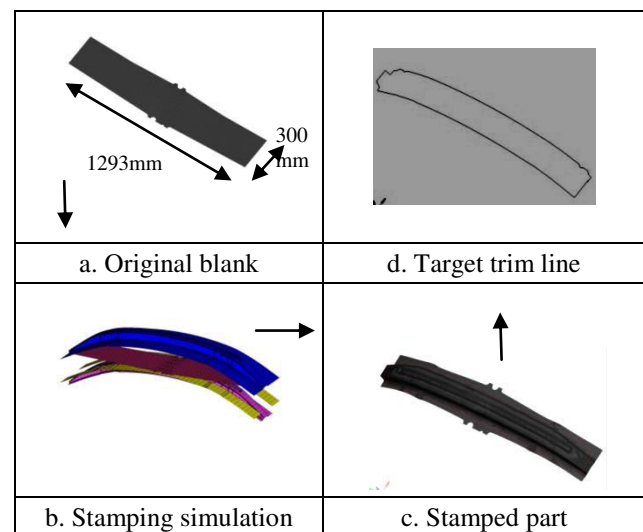


Figure-4. The methodology.

### RESULTS AND DISCUSSIONS

Figure-5 compares actual scrap produced by the original blank shape with the simulated scrap. They look fairly similar. Figure-6 shows the scrap shapes resulted



from first to fourth iterations. For the initial blank size, the resulted scrap weight is 3.98kg, after 3<sup>rd</sup> iteration the scrap is reduced to 3.873 kg. However on the 4<sup>th</sup> iteration the scrap becomes disjointed due to insufficient material. Therefore in this case, an optimum scrap is achieved at the 3<sup>rd</sup> iteration. The results also show that there is no significant effect on the formability by reducing the blank size area.



a. Actual scrap



b. Simulated scrap

**Figure-5(a).** Actual scrap and simulated scrap.

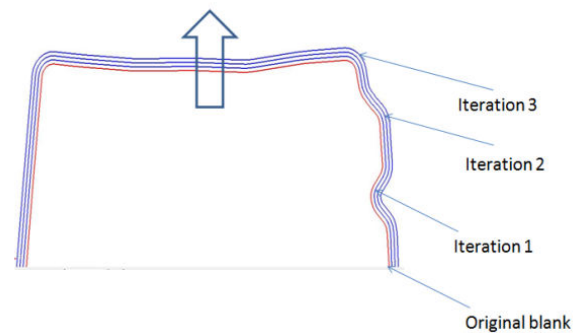
Iteration 1	Iteration 2	Iteration 3	Iteration 4
1 <sup>st</sup> 2mm	2 <sup>nd</sup> 2mm	3 <sup>rd</sup> 2mm	Disjointed scrap

**Figure-5(b).** Scraps evolution by decremental method.

Initial blank	Incr 1	Incr 2	Incr 3	Incr 4	Incr 5	Incr 6

**Figure-6.** Scrap evolution by incremental method.

The same algorithm was also evaluated by the incremental method where the initial blank was generated by conventional blank development. The scrap evolution is illustrated in Figure-6 and Figure-7. In this case, the convergence criterion is set when the minimum scrap width is 2mm subjective.

**Figure-7.** Incremental method.

## CONCLUSIONS

The new proposed blank optimizer algorithm reduces the scrap by 5.4 %. The above example shown was based on decremental reduction of the scrap area. The incremental enlargement technique can result in the same minimum scrap wastage percentage if the initial blank is more or less within the trim line. Further work is being undertaken to validate this result against the actual die try out since the proposed methodology did not consider other factors such as the existence of the guide pin and the nesting design of the blanking die.

## ACKNOWLEDGEMENTS

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