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# A Blank Optimization by Effective Reverse Engineering and Metal Forming Analysis

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Finite element methods allow us to better understand the complex plastic deformation behaviour of a sheet metal component during forming. The purpose of the present work is to optimise the current 1535 × 1600 × 1.2 mm blank sheet of a commercial vehicle engine tunnel bottom using finite element simulation without violating safety and efficiency. The goal of this communication is to look at methods of finite element simulation that are used to solve the related problem. For generating the CAD data of the forming tools, a reverse engineering technique has been adopted. The formation simulation is performed using the commercially available PAMSTAMP explicit solver-based program. The blank holder force was increased by around 15 % (from the current force of 350 kN to 400 kN) while measuring the reduced blank width. The optimised blank sheet's simulation results have been compared to the current blank, ensuring that the optimised blank is appropriate for the bottom portion of the engine tunnel without any defects or failures being produced. In the application of sheet metal formation, finite element techniques have always enabled us in weight savings and cost-saving of automotive components.

**Keywords:** Engine tunnel bottom, FEM, Simulation, Sheet metal forming

## Introduction

All automobile industries worldwide are very keen to substantially reduce the vehicle's weight under strict fuel economy regulations without compromising the safety and quality of the vehicle. To minimize the overall vehicle weight by following various techniques such as blank optimization, using high strength steels and FRP, sheet metal has a crucial role.[1] It is not so simple for the automotive industry to incorporate all these techniques, so companies use finite element analysis before implementing the shop floor in the current scenario.

For the study of sheet forming operations, finite element analysis (FEA) is anticipated to be an effective instrument for industrial users. It is widely used to model 3-D sheet metal forming processes in the automotive industry in the tooling design section.[2] The 3-D finite-element modeling (3DFEM) is now shifting from research labs to commercial practice for a few days.[3] Automotive companies are in various stages of accumulation of knowledge through the regular use of their codes to produce different panels.[2] The industrial objectives of finite element simulation of sheet metal forming processes[4] have three main goals at present: (a) time reduction, (b) cost reduction, and (c) product quality improvement.

The latest working sheet metal optimization method has been used to reduce the blank size of the existing engine tunnel bottom section. The engine tunnel bottom part (Fig. 1) is from M/s Ashok Leyland. The new blank dimension is 1520 X 1600 X 1.2 mm, configured without compromising safety and efficiency from the dimension of 1535 X 1600 X 1.2 mm blank size. Since M/s Ashok Leyland does not have their CAD data of the forming tools, reverse engineering technology has been used to solve it. This communication aims to look at methods of finite element simulation that are used to solve the related problem of industry creation, and this can provide a researcher with valuable information for further development of methods of finite elements.

## CAD Model Development

For any FEA, the CAD model is fundamental, and proper CAD geometry of the forming tools such as die, punch, blank holder, and a blank outline is needed for the forming simulation.[5] In the current work, reverse engineering (RE) technique[6] develops CAD data of the forming tool surfaces because M/s

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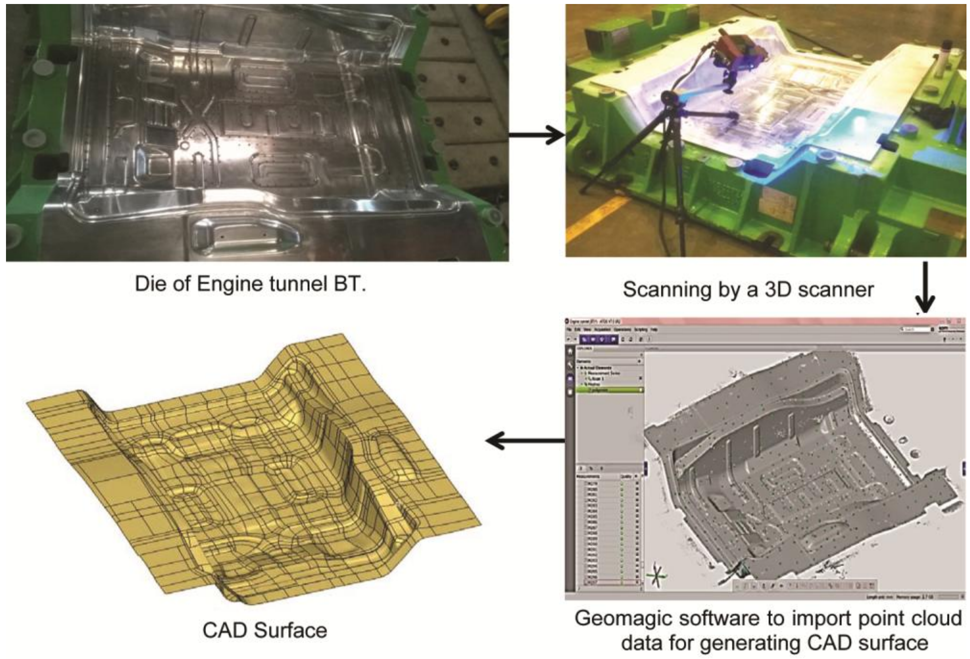


Fig. 1 — Reverse engineering for CAD model generation by using a 3D scanner

Table 1 — Material properties have been used for analysis

| Material | Density Kg/m^3 | Poisson ratio | Modulus of elasticity (MPa) | YS (MPa) | K (MPa) | n | R-bar |
|---|---|---|---|---|---|---|---|
| AU09 | 7850 | 0.3 | 210E3 | 165 | 608 | 0.22 | 1.65 |

Ashok Leyland does not have the forming tools' CAD data. Reverse engineering (RE)[7] is a powerful instrument to create a CAD model from a physical component's 3D scanned point cloud data. For the 3D scan and generation of the physical components' point cloud data, a 3D optical blue-ray ATOS scanner was used (Fig. 1). After a 3D scan, the CAD surface in the GEOMAGIC software was created. Geomagic software is a powerful tool for processing very detailed geometric surface data from the point cloud. This software will erase all the noises during the 3D scanning process and catch the tiny and sharp edges that have been missing during the scanning process.

With the ATOS optical blue-ray scanner's assistance, the 3D scanning was carried out at the M/s Ashok Leyland Pantnagar facility. This flexible optical measuring system is based upon the triangulation principle. Fringe patterns are projected on the 3D surface and captured by the two cameras, using fringe patterns to create a polygon mesh of the target's surface. With varying positions and angles, the entire surface of the die was captured. The point cloud data was exported in STL file format after capturing the whole surface and then imported into Geomagic software for CAD surface development by removing all the noises and extra surfaces captured during 3D scanning. The CAD surface has been stored in IGES format and used during the modeling of forming tools in finite element analysis (FEA). The material properties used for the study of the FEA are mentioned in Table 1.

## Finite Element Analysis

Excessive blank sizes in some components are used through the absence of design definition and information designers' development, which increases the weight and cost of the vehicle and significantly decreases the vehicle's mileage but may optimise the raw material or say blank size to reduce the overall consumption of material and scrap with the aid of numerical modeling of sheet metal forming. This work's main objective is to understand the formability of the bottom portion of the engine tunnel with the current blank size and refine the blank dimensions based on that. This contributes to raw material consumption savings.

### Forming Tools FEA Setup in PAMSTAMP

Finite element software such as PAMSTAMP is used to simulate the bottom portion of the engine tunnel after designing the CAD model of the die.[8,9]

The punch and blank holder were removed from the die face by applying sufficient clearance (blank thickness + 10% of the blank thickness). In a double-action mechanical press, the part is pressed, so the FEA instrument set up considers a double-action press configuration, as seen in Fig. 2.

As rigid bodies, the forming instruments such as die, punch, and blank holder are considered, while the blank is considered deformable.[10] Four nodes of quadrilateral shell elements define the deformable blank, and during the forming simulation, the adaptive mesh formulation was considered. Adaptive meshing has helped to build simulation at the specified location where, due to variance in the geometry profiles, mesh refinement is required. In this field, where the local error is large, smaller elements are used.

**Load and Boundary Conditions**

It is essential to define the boundary condition after defining the forming tool's FEA model because the FEA solver cannot solve the problems without limiting it. The FEA model behaves like a dummy part in space or a solid body. We have to describe the limitations and the loads or velocity in the boundary state. Since the forming process is a double operation, the die is entirely restricted; only Z-direction translation is permitted for punch and blank holder. Tool speeds are greater than the real value to reduce the cost of computing. The current job's punch speed is 10 m/s against the real value (0.5 m/s). Numerical results offer a small difference between accelerated and accurate tool speed simulation.[11]

**Material Model**

Using the rigid material model, die, punch, and blank holder are described. The model of Anisotropic Elastic-Plastic characterises blank sheet metal. This is the material model most widely used in PAMSTAMP

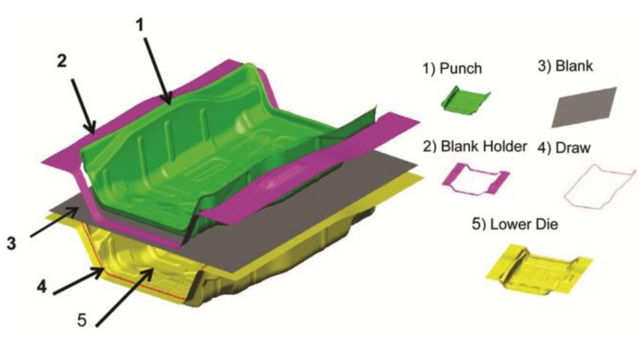


Fig. 2 — Process set up informing simulation software PAMSTAMP

for sheet metal forming applications. Most materials tend to match the grains in the operating direction preferentially on certain crystallographic planes. Consequently, the slip mechanism is oriented, which allows for smoother deformation in some directions than in others. Such a disorder generates plastic anisotropy. Anisotropic means that the properties inside the sheet are different in different directions. The mechanical properties, such as yield strength, tensile strength, and work hardening rate, can be influenced by this crystallographic orientation.

Sheet metal anisotropy is measured by a quantity called the Lankford parameter or coefficient of anisotropy. This coefficient is determined by a single-axis metal strip tensile test.[12] It is defined as the ratio of true width strain ($\in_w$) to the true thickness strain ($\in_t$).

$$r = \frac{\in w}{\in t}$$

where; r = Anisotropy coefficient

Usually, the anisotropy ratio[13] is the average of strain ratios measured in the rolling direction of the sheet in three different orientation parallel ($r_0$), transverse ($r_{90}$), and at 45° ($r_{45}$)

$$\bar{r} = \frac{r_0 + 2r_{45} + r_{90}}{4}$$

where, $r_0$ is the strain ratio in the longitudinal direction.

$r_{45}$ is the strain ratio measured in 45° to the rolling direction.

$r_{90}$ is the strain ratio in the transverse direction.

In the present work, the average anisotropy of 1.65 ($\bar{r}$) is considered for the sheet metal blank, and Hill's 1948 material has been used for solving the anisotropy problem. The following equations define Hill's 1948 material model.[14,15]

$$\sigma_{Hills48} = \sqrt{\frac{1}{2}}[H(\sigma_{11} - \sigma_{22})^2 + F(\sigma_{22} - \sigma_{33})^2 + G\sigma 33 - \sigma 112 + 2N\sigma 122$$

where, $\sigma_{11} = \sigma_{22} = \sigma_{33}$ = Principle yield stresses

$\sigma_{12}$ = Shear stress

F, G & N = Hill's coefficient

F=G=1 at N=3, the yield surface is equivalent to vonMises one H+G = 2

## Results and Discussion

By repositioning the optimised blank and some improvements in the forming process parameters, the blank size of the M/s, Ashok Leyland engine tunnel bottom part has been optimised from 1535 mm to

1520 mm in width. The blank holding force has been increased from 350 kN to 450 kN for processing parameters, and the coefficient of friction is considered to be 0.12 for all the contact body). In Fig. 3 the dimension and location of the current and optimised blank from the mid-plane drawn between the die are shown. The existing blank (1535 mm in width) was kept on the die by moving 7 mm from the middle plane in the Y-direction in the initial state. We suggested keeping the optimised blank (1520 mm in width) by moving 5 mm from the middle plane in the Y-direction, which helps the material flow smoothly within the die during formation.

Compared to current blank results, the final optimised blank results have been validated since this project's main aim is to optimise the blank size without affecting any surface defect and altering the component's formation defect. In both the current and recommended blanks, the thinning is almost the same, this has been shown in Fig. 4 and it also shows that the material flow is uniform in both

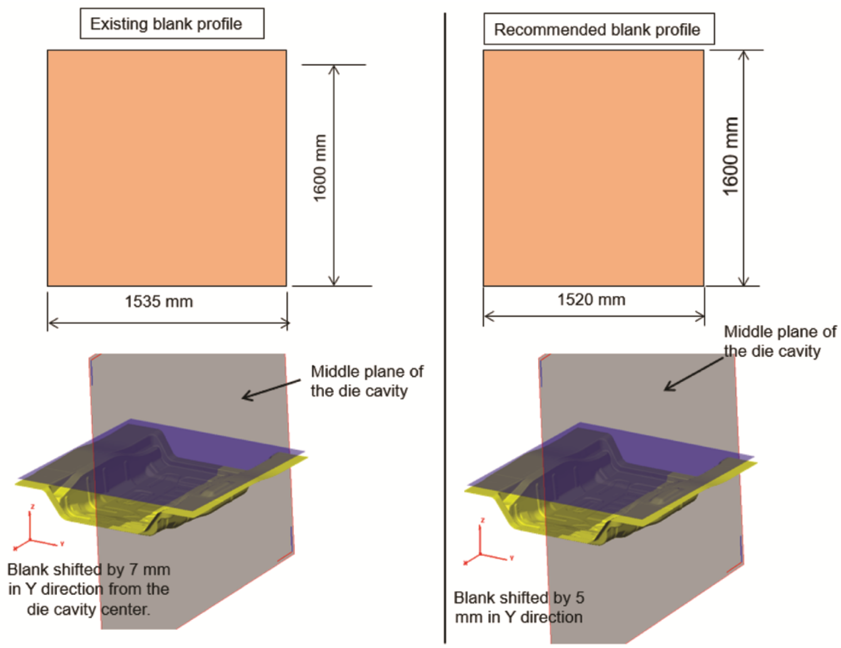


Fig. 3 — Process set up informing simulation software PAMSTAMP

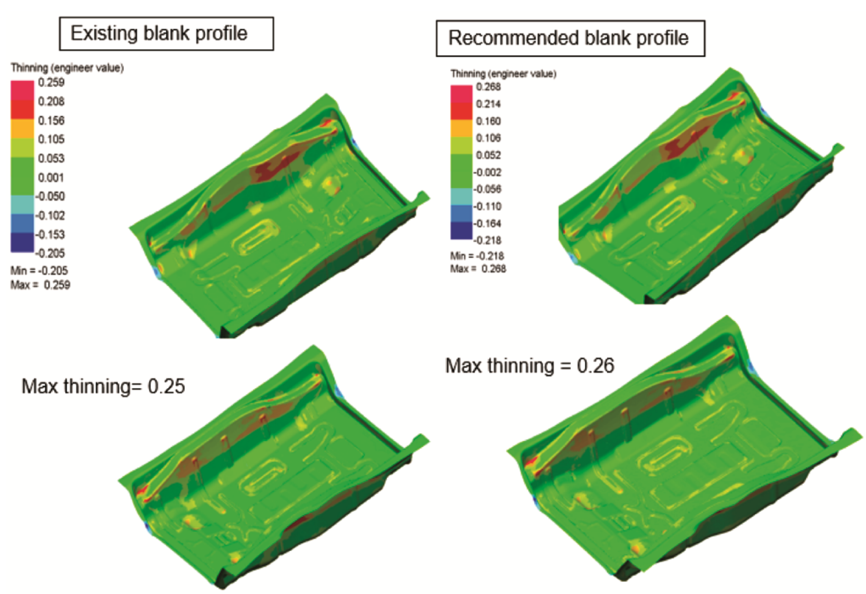


Fig. 4 — Thinning contour plot of Existing and Optimized blank

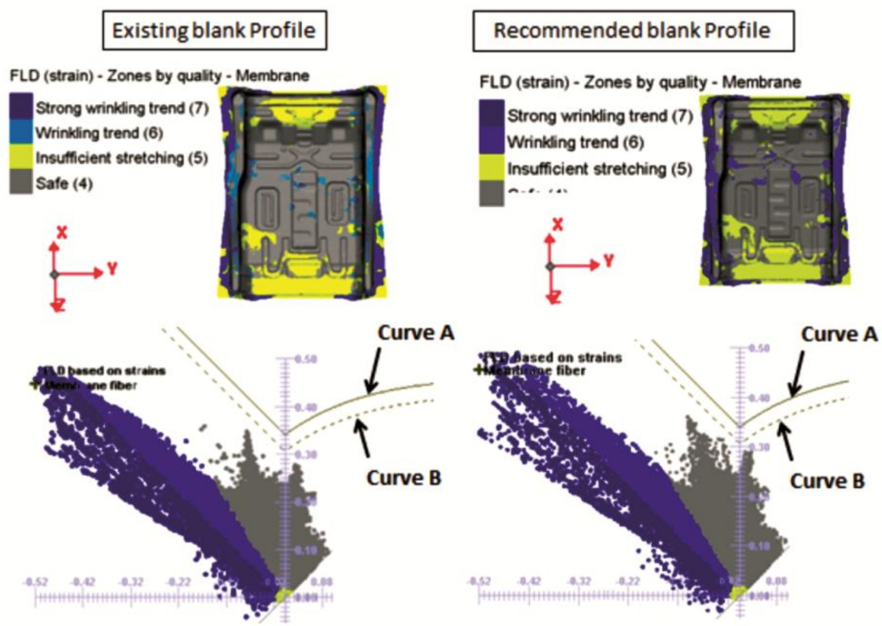


Fig. 5 — FLD plot of Existing and Optimized blank

the blanks. The Forming Limit Diagram (FLD) is commonly used for specific materials in the sheet metal industry to describe the degree to which drawing, stretching, or some combination of drawing and stretching will deform them. There are different FLD generation methods, but the FLD was created in Fig. 5 based on the setup of the Nakajima test. The vertical axis (Y) is a major strain, while the horizontal axis (X) is a minor strain. In Fig. 5, the top-most curve 'A' reflects the real forming limit curve (FLC). Failure (crack or excessive thinning) in the component will reflect any strain combination on an element beyond this curve.

The next curve B reflects a 10 percent strain offset protection margin from the real FLC, curve A. It is ensured that all strain combinations of major and minor stains on a part should be below curve B for all practical use. This means that the element is in a safe zone. The vertical axis diagram's left side represents the draw zone. The plane strain is defined by any strain combination near the vertical axis, and the right side of the vertical axis curve represents the stretch or bi-axial zone. In Fig. 5, both components' wrinkling patterns are found to be the same and all the combination of strains is below the curve B, which indicates that both components are in the safe zone (existing & recommended). So, we can easily claim that the recommended blank has enhanced the material's use without compromising the component's quality and protection.

## Conclusions

The current analysis of blank optimization of the engine tunnel's bottom was performed to decrease the blank weight by 1%. Still, the relationship between Tata Steel and Ashok Leyland is more fruitful. For both firms, it's a win-win situation from a cost and quality point of view. The ATOS 3D blue ray surface scanning method has produced the CAD model of the forming tools, and the tool used for numerical prediction is specifically based on PAMSTAMP. A slight wrinkle tendency was observed for both blanks (Existing and Recommended) in this review. Therefore, M/s Ashok Leyland was advised to perform tests with an optimised blank dimension of 1520 × 1600 × 1.2 mm. The blank holder force was increased by approximately 15% (from the current force of 350 kN to 400 kN), and computational calculations showed that the product was computationally acceptable for vehicles after all this adjustment.

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## Conflict of interest:

The authors declared no conflict of interest.

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