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“ANALYTICAL EVALUATION OF FORMING LOAD AND PRESS CAPACITY FOR A D2 TOOL STEEL FORMING DIE OF AN AUTOMOTIVE OIL PAN”

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ABSTRACT

This study evaluates the forming load and press capacity required for a forming die used to manufacture an automotive oil pan from 1.20 mm thick SAE 1008/1010 low-carbon steel sheet. The oil pan has an approximate length of 438.15 mm and width of 352.50 mm. The forming die consists of a punch and die block made of D2 tool steel and top and base plates made of mild steel, with a top plate of 730 mm × 620 mm × 50 mm. The forming load was estimated analytically from the effective forming perimeter, sheet thickness, and a representative forming stress. The effective forming perimeter was calculated as 1581.30 mm and, with a representative forming stress of 300 MPa, the basic forming force was 569.27 kN (58.03 ton). A 25% design allowance was applied to account for variations in material, friction, alignment, and forming conditions, giving a design forming force of 711.59 kN and a required press capacity of 72.54 ton. A standard 100-ton press, with a nominal force of 981 kN, was therefore selected, giving a calculated capacity utilization of 72.54% and a nominal margin of 27.46%. A sensitivity analysis showed that the 100-ton press would remain adequate for forming stresses up to about 414 MPa or sheet thicknesses up to about 1.65 mm, other parameters being unchanged. The load path through the press ram, top plate, punch, sheet, die, base plate, and press bed was also examined, and the average nominal contact pressures on the plates were found to be low. The results provide a calculation-based foundation for press selection and forming-die development for automotive oil-pan manufacturing, and they identify the finite element analysis of the die assembly and experimental validation as the next steps.

Key Words: Automotive oil pan; forming die; sheet-metal forming; forming force; press capacity; press tonnage; D2 tool steel; SAE 1008/1010 steel; load transfer.

I. INTRODUCTION

Sheet-metal forming is widely used in the automotive industry because it produces components with consistent dimensions at comparatively high production rates. Components such as body panels, covers, brackets, engine and transmission parts, and oil pans are manufactured by pressing a flat sheet into the required shape with a punch and die. The die controls the deformation of the sheet, and the quality of the formed component depends on the design, material, accuracy, and stiffness of the tooling [1], [2]. An oil pan is a shallow container attached to the lower part of the engine or transmission housing. It holds lubricating oil, provides a sealing and mounting interface, and must retain its shape in service, so the forming operation must deliver accurate dimensions and a reliable sealing flange [5].

The forming die considered in this work consists of four main components: a top plate, a base plate, a forming die block, and a punch. The punch and die block are in direct contact with the sheet and experience repeated loading and wear, so they are made of D2 tool steel, which is selected for its high hardness, wear resistance, and dimensional stability [6]. The top and base plates mainly support the tooling and transfer the load, and they are made of mild steel,

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which is economical, readily available, and easy to machine. During the forming stroke the press ram pushes the punch into the die cavity and the sheet undergoes plastic deformation and takes the shape of the oil pan. The die must be strong and rigid enough to carry the forming load without excessive deflection that would misalign the punch and die. A key step in the design of a forming die is the determination of the forming load, because it governs the selection of the press. If the press is too small, the operation overloads the machine and the die; if it is too large, capital and operating costs rise unnecessarily. The forming load depends on the sheet thickness, material strength, component geometry, friction, clearance, and blank-holder conditions [1]–[4]. For preliminary design, it can be estimated analytically from the deformed perimeter, the sheet thickness, and a representative stress, and a design allowance is added to cover practical variations. Finite element simulation of forming and springback provides more detailed information, but it requires material data and computational effort [7], [8]. The present study applies the analytical approach to a specific oil-pan forming die, evaluates the required and selected press capacity, and examines the load path through the die assembly, in order to provide a calculation-based basis for press selection and die development.

II. PROBLEM IDENTIFICATION

Forming a flat steel sheet into an oil pan involves considerable plastic deformation. If the die geometry is improper, the material unsuitable, or the forming force excessive, defects such as wrinkling, tearing, excessive thinning, springback, and dimensional variation may occur, and the die components may be damaged [5]. The press used for the operation must therefore have a capacity that exceeds the forming load with a suitable margin, while the die assembly must transfer that load to the press bed without excessive deformation. At the design stage, however, the forming load is not known exactly. It depends on the effective forming perimeter, the sheet thickness, and the representative forming stress, all of which carry uncertainty, and the practical load is further affected by friction, alignment, tolerances, and local forming conditions.

The problem addressed in this study is to determine the forming load and the required press capacity for the oil-pan forming die in a systematic and traceable way, to select a standard press with an adequate margin, and to understand how sensitive this selection is to the assumed forming stress and sheet thickness. In addition, the structural arrangement of the die, comprising the plates, die block, and punch and the path by which the load reaches the press bed, must be examined so that the suitability of the die design can be judged.

III. RESEARCH OBJECTIVE

The main objectives of the present study are as follows:

- To study the geometry, material, and manufacturing requirements of the automotive oil pan and to define the design inputs for the forming operation.
- To describe the forming die assembly, comprising the top plate, base plate, die block, and punch, and the materials selected for each component.
- To determine the effective forming perimeter and the basic forming force from the sheet thickness and the representative forming stress.
- To apply a design allowance and calculate the required press capacity, and to select a suitable standard press.
- To evaluate the capacity utilization and nominal margin of the selected press, and to examine its sensitivity to forming stress and sheet thickness.
- To examine the load path through the die assembly and the nominal contact pressures on the structural plates, and to identify the further analysis required.

IV. MODELING AND SIMULATION

4.1 Methodology

The methodology is based on the dimensional requirements of the component, the material characteristics, the estimation of the forming load, and the comparison of the calculated requirement with standard machine capacities. The component geometry and manufacturing requirements are studied first, and the CAD model of the oil pan and the forming die is developed in SolidWorks. The effective forming perimeter is then determined from the principal dimensions of the component, and the forming force is calculated from the perimeter, sheet thickness, and representative forming stress. The force is converted to tonnage and a design allowance is applied, after which the required capacity is compared with standard press capacities and the next standard rating above the requirement is selected. The sequence can be summarized as: component study → material identification → CAD modelling → die design → forming perimeter → forming force → press tonnage → design allowance → required press capacity → standard press selection → capacity evaluation.

4.2 Governing relations

The effective forming perimeter P_e is taken from the principal length L and width W of the component as a preliminary geometric approximation:

$$P_e = 2(L + W) \quad (1)$$

The basic forming force F_f is estimated from the perimeter, the sheet thickness t , and the representative forming stress σ_f , and is converted to tonnes of force using 9.81 kN per tonne:

$$F_f = P_e \times t \times \sigma_f \quad (2)$$

$$T_f = F_f / 9.81 \quad (3)$$

A design allowance A is applied to obtain the design forming force and the required press capacity, and the utilization of the selected press is the ratio of the design force to the nominal press force $F_{\text{press}} = T_{\text{selected}} \times 9.81$:

$$F_d = F_f(1 + A) \quad (4)$$

$$T_{\text{required}} = F_d / 9.81 \quad (5)$$

$$\eta = (F_d / F_{\text{press}}) \times 100 \quad (6)$$

The perimeter-based relation is a preliminary approximation. The actual forming perimeter differs because of corner radii, ribs, local contours, and flanges, and the relation does not explicitly include blank-holder force, friction, draw depth, or strain hardening, which are covered here by the design allowance [1]–[3].

V. DESIGN OF FINNED ENGINE CYLINDER MODELS

The forming die assembly consists of a top plate, base plate, forming die block, and punch. Figure 5.1 shows the arrangement of the tool, and Figure 5.2 shows a sectional view with the guide pillars, punch holder, die back plate, and press bed. The top plate is the upper structural member and transfers the force from the press ram to the punch; it must be stiff enough to avoid bending that would misalign the punch with the die block. The base plate supports the die block and transfers the forming reaction to the press bed. The die block provides the cavity against which the sheet is formed, and the punch presses the sheet into the cavity and produces the oil-pan profile. The principal dimensions of the components, taken from the CAD model, and the materials are listed in Table 5.1.

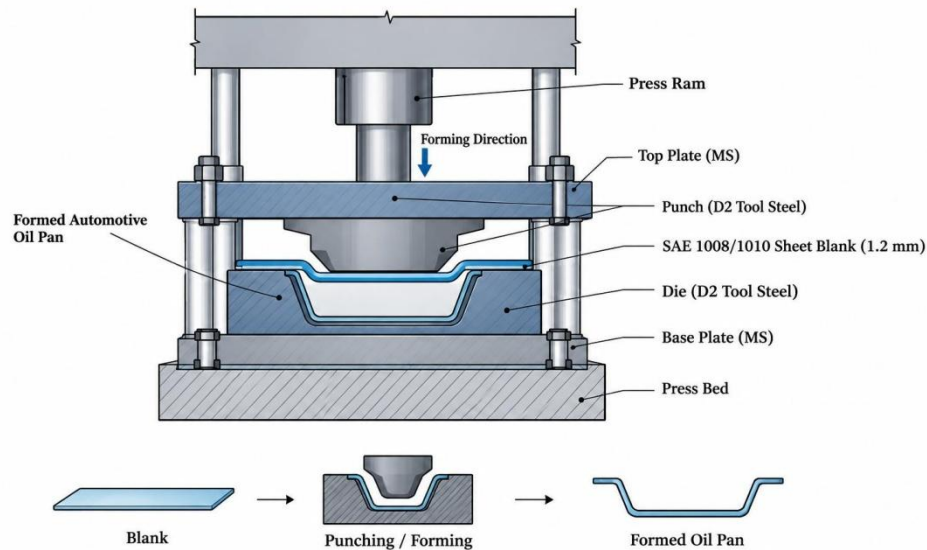


Figure 5.1 Process and components of the automotive oil-pan forming die

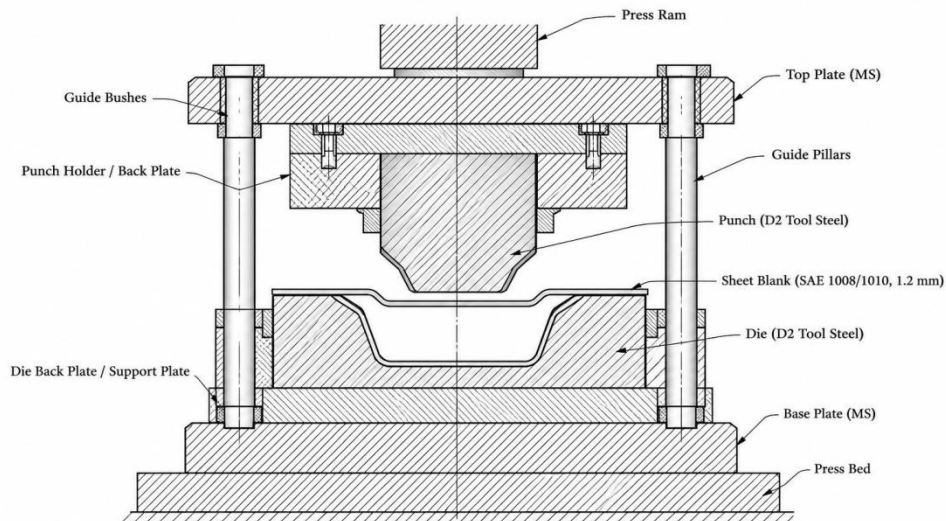


Figure 5.2 Sectional view of the forming die assembly

Table 5.1: Components and materials of the forming die

Component	Material	Size (mm)	Function
Top plate	Mild steel	730 × 620 × 50	Transfers press load to punch
Base plate	Mild steel	730 × 620 × 60	Supports die; transfers reaction to press bed
Die block	D2 tool steel	530 × 450 × 160	Forms sheet; wear resistance
Punch	D2 tool steel	Follows oil-pan profile	Applies forming force; accuracy

The design input parameters used in the calculation are given in Table 5.2. The oil pan has a length of 438.15 mm, a width of 352.50 mm, and a formed depth of 12.7 mm, with an approximate capacity of 12 quarts. It is formed from 1.20

mm thick SAE 1008/1010 low-carbon steel. A representative forming stress of 300 MPa and a design allowance of 25% are adopted for the preliminary evaluation.

Table 5.2: Design input parameters

Sr.	Parameter	Value
1	Component	Automotive oil pan
2	Component length, L	438.15 mm
3	Component width, W	352.50 mm
4	Formed depth	12.70 mm
5	Sheet thickness, t	1.20 mm
6	Sheet material	SAE 1008/1010 low-carbon steel
7	Representative forming stress, σ_f	300 MPa
8	Design allowance, A	25%
9	Selected press capacity	100 ton

VI. RESULT AND DISCUSSION

6.1 Forming load and required press capacity

Using Equation (1), the effective forming perimeter is $2(438.15 + 352.50) = 1581.30$ mm. From Equation (2), the basic forming force is $1581.30 \times 1.20 \times 300 = 569\,268$ N, that is 569.27 kN, which corresponds to 58.03 ton. Applying the 25% design allowance gives a design forming force of 711.59 kN and a required press capacity of 72.54 ton. The allowance therefore raises the requirement by about 14.51 ton, which shows that selecting a press on the basic force alone would not represent the complete design requirement. The next standard capacity above 72.54 ton is 100 ton, and the nominal force of the selected press is $100 \times 9.81 = 981$ kN, which exceeds the design force of 711.59 kN. The results are summarized in Table 6.1 and compared in Figure 6.1.

Table 6.1: Summary of calculated results

Sr.	Parameter	Result
1	Effective forming perimeter	1581.30 mm
2	Basic forming force	569.27 kN
3	Basic forming tonnage	58.03 ton
4	Design allowance	25%
5	Design forming force	711.59 kN
6	Required press capacity	72.54 ton
7	Selected press capacity	100 ton
8	Nominal press force	981 kN
9	Press capacity utilization	72.54%
10	Nominal capacity margin	27.46%

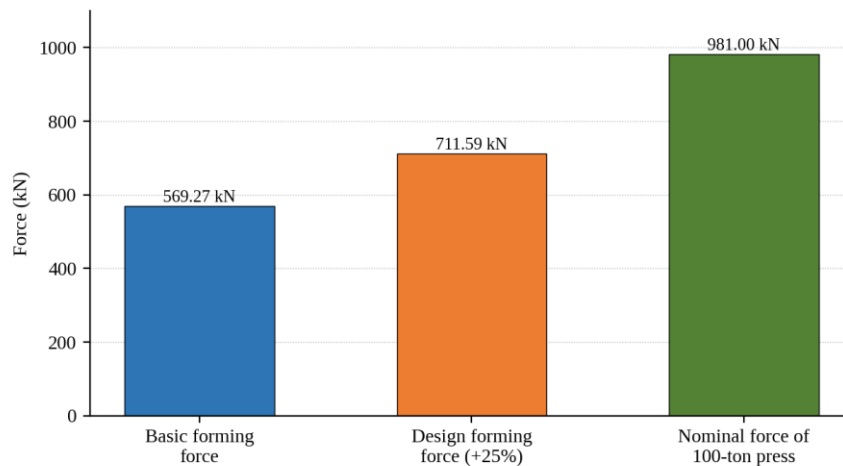


Figure 6.1 Basic forming force, design forming force, and nominal force of the selected press

6.2 Capacity utilization

The calculated utilization of the selected press is $(711.59 / 981) \times 100 = 72.54\%$, leaving a nominal capacity margin of 27.46%. This margin is in addition to the 25% allowance already included in the design force, so the press is not expected to operate near its rated limit for the conditions considered. The margin also provides room for factors that the preliminary relation does not capture explicitly, such as blank-holder force, local thickening, and tooling wear over the life of the die. Since the design force is expressed as a fraction of a nominal rating, it should also be remembered that presses are normally rated for full load near the bottom of the stroke, so the forming load should be checked against the press load–stroke characteristic when the machine is finally chosen.

6.3 Sensitivity to forming stress and sheet thickness

Because the representative forming stress is an assumed value, its influence was examined by repeating the calculation for other stresses and sheet thicknesses, with the perimeter and allowance unchanged. Table 6.2 gives the required press capacity, and Figure 6.2 shows the variation. The required capacity increases linearly with both stress and thickness. At the 1.20 mm thickness, the design force would equal the nominal force of the 100-ton press only if the forming stress reached about 414 MPa, which is 38% above the adopted value, and at 300 MPa the thickness could increase to about 1.65 mm (38% above the specified value) before the nominal capacity is reached. The 100-ton selection is therefore robust to moderate errors in the assumed stress, but it would not remain adequate for a 1.5 mm sheet at 400 MPa. The forming stress should therefore be confirmed from tensile tests on the actual sheet [9], [10].

Table 6.2: Required press capacity (ton) for different forming stresses and sheet thicknesses

Forming stress (MPa)	t = 1.0 mm	t = 1.2 mm	t = 1.5 mm
250	50.37	60.45	75.56
300	60.45	72.54	90.67
350	70.52	84.63	105.78 *
400	80.60	96.72	120.89 *

* exceeds the capacity of the selected 100-ton press

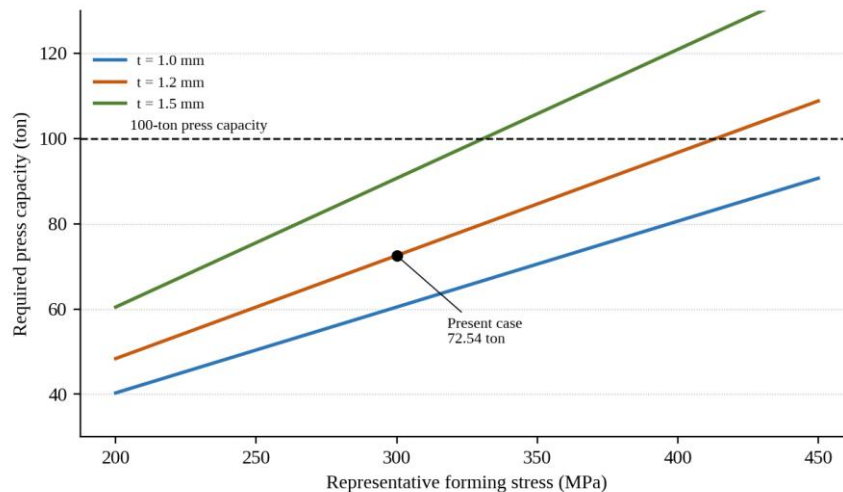


Figure 6.2 Required press capacity as a function of forming stress and sheet thickness

6.4 Load transfer and structural arrangement

During the forming stroke the load is transferred along the path: press ram → top plate → punch → sheet material → die → base plate → press bed. The top plate distributes the force from the ram to the punch assembly, the punch applies the forming force to the sheet, and the die provides the reaction and controls the final geometry. The reaction then passes through the die block and base plate to the press bed. The punch and die block are made of D2 tool steel because they are the working elements in contact with the sheet, while the plates are made of mild steel because their function is structural.

As an indicative check of the structural plates, the design force of 711.59 kN was divided by the full face area of the top plate (730 mm × 620 mm) and by the footprint of the die block (530 mm × 450 mm), giving average nominal pressures of about 1.57 MPa and 2.98 MPa, respectively. These values are very small compared with the yield strength of mild steel, which is of the order of a few hundred MPa, and with the strength of hardened D2 tool steel. They are, however, averages over the entire plate area. The actual contact areas between the ram and top plate, and between the punch and the sheet, are smaller, and local stresses around holes, edges, and the die cavity will be higher. The structural integrity of the die assembly has therefore been assessed here through the calculated load, the load path, the dimensions, and the material selection, and a finite element analysis of the plates, die block, and punch is required to determine the local stress, deformation, and factor of safety.

6.5 Limitations

The results apply to the conditions studied. The forming force was obtained from a perimeter-based relation using the principal dimensions of the component, so ribs, corner radii, flanges, and local contours of the actual die are not included, and the relation does not model the deformation mode, blank-holder force, friction, strain hardening, or springback explicitly. The representative forming stress of 300 MPa was assumed, not measured. The formed depth of 12.7 mm is small, and the capacity quoted for the oil pan (12 quarts) should be checked against the internal volume of the final geometry. The calculation was not validated against measured press loads or finite element simulation. These limitations are addressed through the design allowance and the capacity margin, but they should be removed in future work by simulation and trial forming [7], [8].

VII. CONCLUSION

The forming load and press capacity for an automotive oil-pan forming die were evaluated analytically. For a component of 438.15 mm × 352.50 mm made from 1.20 mm thick SAE 1008/1010 steel sheet, the effective forming perimeter was 1581.30 mm and, with a representative forming stress of 300 MPa, the basic forming force was 569.27 kN (58.03 ton). A 25% design allowance increased the design force to 711.59 kN, corresponding to a required press

capacity of 72.54 ton, and a standard 100-ton press with a nominal force of 981 kN was selected. The calculated utilization was 72.54%, leaving a nominal margin of 27.46%. The sensitivity analysis showed that the selection remains adequate for forming stresses up to about 414 MPa or sheet thicknesses up to about 1.65 mm, but not for a thicker or stronger sheet such as 1.5 mm at 400 MPa. The load path from the press ram through the top plate, punch, sheet, die, and base plate to the press bed was identified, and the average nominal pressures on the plates were found to be low, with D2 tool steel used for the working components and mild steel for the structural plates. The study therefore provides a calculation-based foundation for press selection and die development for oil-pan manufacturing. Future work should include finite element analysis of the die assembly for stress, deformation, and factor of safety, determination of the forming stress from tensile tests, simulation of forming and springback, and validation by trial forming and measurement of the press load.

REFERENCES

- [1] W. F. Hosford and R. M. Caddell, *Metal Forming: Mechanics and Metallurgy*, 4th ed. Cambridge University Press, 2011.
- [2] T. Altan and A. E. Tekkaya, *Sheet Metal Forming: Fundamentals*. ASM International, 2012.
- [3] Z. Marciniak, J. L. Duncan, and S. J. Hu, *Mechanics of Sheet Metal Forming*, 2nd ed. Butterworth-Heinemann, 2002.
- [4] S. Kalpakjian and S. R. Schmid, *Manufacturing Engineering and Technology*, 7th ed. Pearson, 2014.
- [5] O. M. Ikumapayi et al., review of the deep-drawing process and its applications in manufacturing, 2022.
- [6] J. R. Davis, Ed., *Tool Materials*. ASM International, 1995.
- [7] S. W. Lee and D. Y. Yang, "An assessment of numerical parameters influencing springback in explicit finite element analysis of sheet metal forming process," *Journal of Materials Processing Technology*, vol. 80–81, pp. 60–67, 1998.
- [8] L. Papeleux and J.-P. Ponthot, "Finite element simulation of springback in sheet metal forming," *Journal of Materials Processing Technology*, vol. 125–126, pp. 785–791, 2002.
- [9] *Metallic Materials — Tensile Testing — Part 1: Method of Test at Room Temperature*, ISO 6892-1, International Organization for Standardization.
- [10] *Standard Test Methods for Tension Testing of Metallic Materials*, ASTM E8/E8M, ASTM International.