



IJRTSM

INTERNATIONAL JOURNAL OF RECENT TECHNOLOGY SCIENCE & MANAGEMENT

“DESIGN AND PRELIMINARY MACHINE SELECTION OF AN INJECTION MOULD FOR AN ARMREST TOP PAD BASE PLATE USING CAD-BASED ENGINEERING CALCULATIONS”

Abhishek Gurjar¹, Dr. Gautam Singh²

¹ PG scholar, Department of Mechanical Engineering, SAGE University, Indore, Madhya Pradesh, India

² Assistant Professor, Department of Mechanical Engineering, SAGE University, Indore, Madhya Pradesh, India

ABSTRACT

This study presents the design and preliminary machine selection of an injection mould for an armrest top pad base plate, a ribbed plastic component used in office-chair armrests. The component has an overall plan size of approximately 180 mm × 70 mm, corner radii of 15 mm, two Ø5 mm through holes, a wall thickness of approximately 2 mm, a rib height of about 10 mm, and a mass of about 85 g obtained from the SolidWorks model. The study covers product design analysis, plastic and mould material selection, mould concept development, core and cavity design, gate and runner concept, cooling and ejection arrangement, selection of the mould components, and a three-dimensional assembly developed in SolidWorks. Engineering calculations gave an estimated shot weight of 105 g, a preliminary projected area of 126 cm², and a clamping force of 50.4–75.6 ton for clamping-force factors of 0.4–0.6 ton/cm². With a 15% design margin the design clamping force was 86.94 ton, and a 100-ton class injection moulding machine with an injection capacity of at least 150 g was selected for preliminary purposes. A supporting analysis showed that the 100-ton machine remains adequate for clamping-force factors up to about 0.69 ton/cm² or projected areas up to about 145 cm², and that the bounding-rectangle projected area is conservative by about 1.8%. The mould, consisting of seven principal plate components with a closed stack height of about 286 mm, provides a basis for detailed design, simulation, manufacture, and moulding trials. The results are design estimates intended to be verified against the final plastic grade, CAD model, and machine specifications, and the methodology can be applied to similar ribbed plastic components used in automotive and furniture applications.

Key Words: Injection mould; armrest top pad base plate; SolidWorks; core and cavity; clamping force; shot weight; machine selection; ejection system; cooling system.

I. INTRODUCTION

Plastic components are widely used in the automotive and furniture industries, electrical appliances, medical devices, and consumer products because they are lightweight, strong for their weight, corrosion resistant, and inexpensive to produce. Injection moulding is the primary process for the mass production of such components. Plastic granules are melted in the heated barrel of the machine, the molten plastic is injected under pressure through the sprue, runner, and gate into a mould cavity, and after cooling and solidification the mould is opened and the part is removed by an ejector system [1], [2]. The quality of the moulded part depends on the product design, mould design, material selection, injection pressure, cooling arrangement, ejection system, and process accuracy, so mould design plays a decisive role in dimensional accuracy, surface quality, repeatability, and production efficiency [3].

A mould consists of a fixed half, attached to the stationary platen of the machine, and a moving half, attached to the moving platen, with the cavity and core between them. The fixed half generally comprises the top clamping plate and cavity plate, and the moving half comprises the core plate, ejector system, spacer blocks, and bottom clamping plate.

<https://www.ijrtsm.com> © International Journal of Recent Technology Science & Management

The cavity forms the outer surface of the product, and the core forms the underside and detailed features. A faulty mould design may cause incomplete filling, flash, sink marks, warpage, dimensional variation, improper cooling, ejection difficulty, surface imperfections, and a long cycle time, and it may also waste material [3], [4]. Research on gate location and cooling [5], [6], the structure and thermal behaviour of moulds [7], warpage [8], and conformal cooling [9] shows that mould layout decisions strongly influence the result.

The component considered in this study is the armrest top pad base plate, a plastic part that supports the top pad in the armrest of an office chair and provides its mounting surface. It is a long, narrow part with rounded corners, two through holes, supporting surfaces, and a ribbed underside. These features determine the moulding direction, parting line, core and cavity design, hole-forming core pins, cooling layout, and ejection arrangement. The objective of the present work is to develop a suitable injection mould for this component using SolidWorks modelling and engineering calculations, and to make a preliminary selection of the injection moulding machine. In this work the term analysis denotes engineering calculations and CAD-based design evaluation; no flow or structural simulation was performed.

II. PROBLEM IDENTIFICATION

The armrest top pad base plate has rounded edges, through holes, thin sections, and a ribbed structure, all of which must be considered at the mould design stage. If the mould is not designed properly, the cavity may not fill completely, particularly in thin walls and ribs, and weld lines may form near the holes and ribs. Non-uniform cooling can cause differential shrinkage and warpage, ejection may bend, crack, or stick the part, misalignment of the core and cavity may impair product quality and mould life, and the cycle time may be longer than necessary. The ribs must be formed without sink marks, the holes require supported core pins, and the mould must be practical to manufacture, assemble, inspect, and maintain.

A second problem is the selection of the injection moulding machine. The machine must supply a clamping force sufficient to keep the mould closed during injection, and a shot capacity sufficient to inject the product and the runner system in one cycle. At the early design stage the final plastic grade, runner geometry, and injection pressure are not known, so these quantities must be estimated from the product weight and the projected area, with margins, and the sensitivity of the machine selection to the assumed values should be understood. The problem addressed in this study is therefore to develop a complete preliminary design of an injection mould for the armrest top pad base plate, covering product study, material selection, mould layout, component selection, engineering calculations, and machine selection, and to establish how robust the selection is to the assumptions used.

III. RESEARCH OBJECTIVE

The main objectives of the present study are as follows:

- To study the geometry and design requirements of the armrest top pad base plate and to identify its important features: holes, ribs, rounded corners, and wall thickness.
- To select preliminary materials for the plastic component and for the mould components.
- To develop the core and cavity arrangement, parting line, gate and runner concept, cooling arrangement, and ejection system.
- To calculate the product mass, shot weight, projected area, and clamping force, and to select a suitable injection moulding machine.
- To develop the complete mould assembly in SolidWorks and to select the major mould components.
- To examine the sensitivity of the machine selection to the clamping-force factor and projected area, and to verify the mould arrangement through CAD-based checks.

IV. MODELING AND SIMULATION

4.1 Design methodology

A design methodology was adopted that proceeds from the product to the mould and the machine. The product was first studied from the drawing and the SolidWorks model to identify its dimensions, holes, ribs, thickness, and mass. The design requirements were analysed, a preliminary plastic material was identified, and a mould concept with fixed and moving halves was developed. The core and cavity were designed according to the moulding direction, parting line, and draft, and the gate, runner, cooling, and ejection arrangements were considered. Engineering calculations were then carried out to obtain the shot weight, projected area, clamping force, and injection capacity, the mould components were selected, and the complete assembly was modelled in SolidWorks and checked for dimensional compatibility, alignment, ejection movement, and interference. The sequence is: product study → material selection → mould concept → core and cavity design → engineering calculations → component selection → CAD assembly → machine selection and verification.

4.2 Governing relations

The total shot weight W_s is the sum of the product weight W_p and the estimated runner and sprue weight W_r . The machine must have an injection capacity W_{req} greater than the shot weight with an allowance a of 25%:

$$W_s = W_p + W_r \quad (1)$$

$$W_{req} = W_s (1 + a) \quad (2)$$

The preliminary projected area A_p is taken as the product of the overall length L and width B , and the preliminary clamping force F_c is the projected area multiplied by a clamping-force factor P_f in ton/cm². A safety margin m of 15% gives the design clamping force:

$$A_p = L \times B \quad (3)$$

$$F_c = A_p \times P_f \quad (4)$$

$$F_{design} = F_c (1 + m) \quad (5)$$

The mould cavity dimension D_m is obtained from the product dimension D_p and the linear shrinkage S of the selected plastic as $D_m = D_p (1 + S)$. The shrinkage value depends on the plastic grade, thickness, flow direction, and moulding conditions and has not been assumed here because the final grade has not been confirmed. The bounding-rectangle projected area is an approximation, since corner radii and holes reduce the true projected area, and runner and gate areas add to the area under pressure.

V. DESIGN OF THE INJECTION MOULD

5.1 Product design

The armrest top pad base plate is a plastic part with a quadrilateral body, rounded corners, two through holes for fastening and assembly, and a ribbed underside that increases stiffness without wasting material. Its principal dimensions are given in Table 5.1 and shown in Figure 5.1. The rounded corners require accurate cavity machining and influence the flow of the plastic, the holes require supported core pins or inserts, the ribs influence flow, cooling, and ejection and may cause sink marks if too thick, and the thin sections increase flow resistance and require suitable gate positions and flow directions. The supporting and contact surfaces fit with the other armrest components, so warpage or dimensional variation in these regions would affect the assembly. The approved product drawing is treated as the controlling document for the final dimensions.

Table 5.1: Product design inputs

Sr.	Parameter	Value
1	Product	Armrest top pad base plate
2	Manufacturing process	Plastic injection moulding
3	Overall length	180 mm
4	Overall width	70 mm
5	Corner radius	R15 mm
6	Through holes	2 holes of Ø5 mm
7	Wall thickness	Approximately 2 mm
8	Rib height / depth	Approximately 10 mm
9	Product mass (SolidWorks)	85 g
10	CAD software	SolidWorks

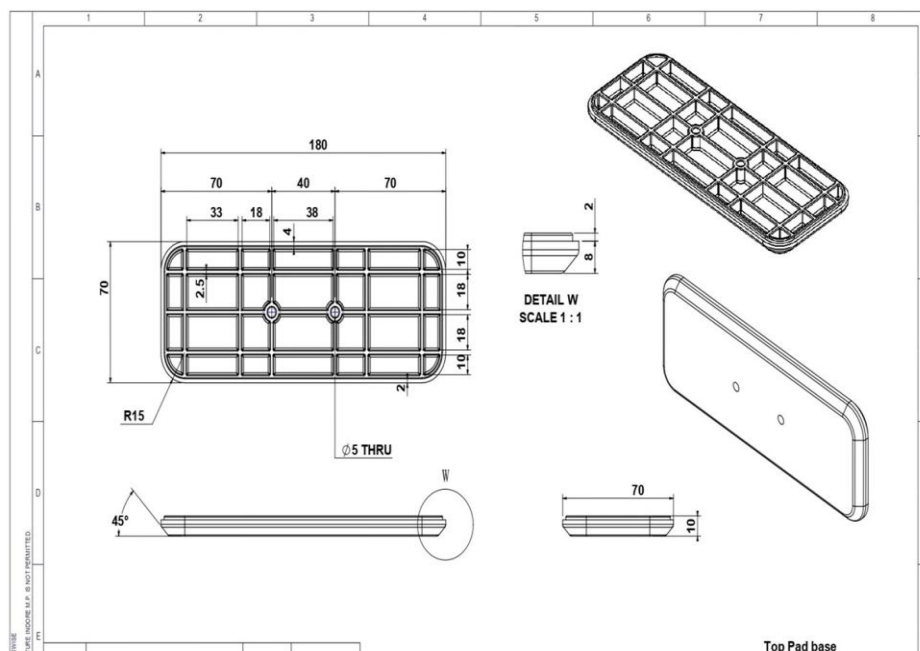


Figure 5.1 Dimensioned drawing of the armrest top pad base plate

5.2 Materials

The plastic material must have good flow, adequate strength and stiffness, impact resistance, dimensional stability, a good surface finish, controlled shrinkage, low moisture absorption, and acceptable cost. Among the common materials, ABS, polypropylene, polyamide, PC/ABS, and HDPE were considered, and ABS or another suitable automotive-grade thermoplastic was taken as the preliminary option because of its surface finish, impact resistance, dimensional accuracy, and ease of moulding. The exact grade must be confirmed from the manufacturer's datasheet, including density, melt flow rate, shrinkage, and processing temperatures. The preliminary materials of the mould components, selected according to function, are given in Table 5.2. Tool steel is chosen for the core and cavity inserts for hardness, wear resistance, and surface finish, pre-hardened mould steel for the core and cavity plates for strength and machinability, and mild or structural steel for plates that mainly provide support and mounting.

Table 5.2: Preliminary material selection for the mould components

Component	Preliminary material	Reason
Core and cavity inserts	Tool steel	Hardness, wear resistance, finish
Core and cavity plates	Pre-hardened mould steel	Strength, machinability
Ejector plates	Mild or medium-carbon steel	Strength, machinability
Spacer blocks	Mild steel	Structural support
Clamping plates	Mild or structural steel	Mounting and support
Guide pillars	Hardened alloy steel	Wear resistance, alignment
Guide bushes	Hardened or bearing-grade steel	Smooth movement

5.3 Mould concept and components

A standard two-plate thermoplastic mould with fixed and moving halves was adopted, with a single cavity in the initial concept. The moulding direction is that in which the mould opens: the outer surface of the part is formed by the cavity and the ribbed underside by the core, which allows easy removal, minimal undercuts, a simple parting arrangement, and a favourable ejector position. The parting line was chosen according to the product profile, ribs, holes, draft direction, and surface requirements, preferably in a non-functional region to reduce flash and visible marks, and a draft of 1° was applied to the vertical surfaces parallel to the opening direction. The cavity was developed by importing and orienting the product model, applying draft, creating the cavity block, subtracting the product geometry, and checking the surface, parting line, and runner connection; the core was developed similarly, with checks of the ribs, ejector locations, and interference with the cavity. The two holes are formed by core pins. The principal components and dimensions are listed in Table 5.3, and the exploded and assembled views are shown in Figures 5.2 and 5.3.

Table 5.3: Principal mould components

Component	Size (mm)	Qty	Function
Top clamping plate	250 × 245 × 25	1	Supports fixed half; mounts to fixed platen
Cavity plate	250 × 200 × 66	1	Holds cavity; forms outer surface
Core plate	250 × 200 × 70	1	Holds core; forms ribs and underside
Ejector retainer plate	250 × 115 × 15	1	Retains ejector pins
Ejector plate	250 × 115 × 20	1	Moves ejector pins
Spacer blocks	250 × 30 × 100	2	Ejector stroke space; support
Bottom clamping plate	250 × 245 × 25	1	Supports moving half; mounts to moving platen

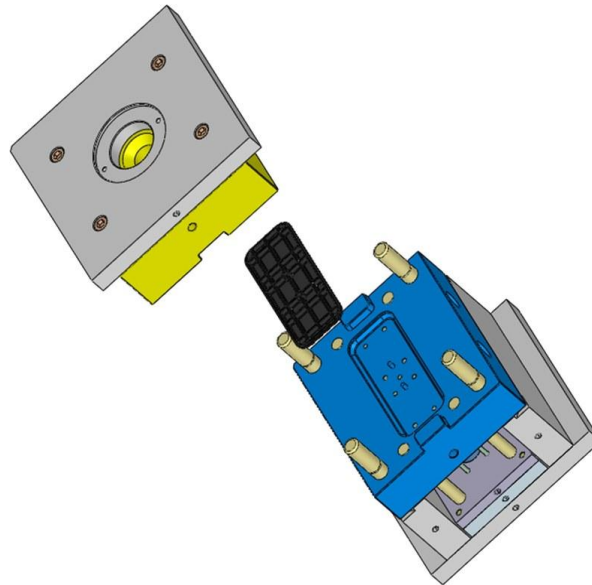


Figure 5.2 Exploded view of the injection mould

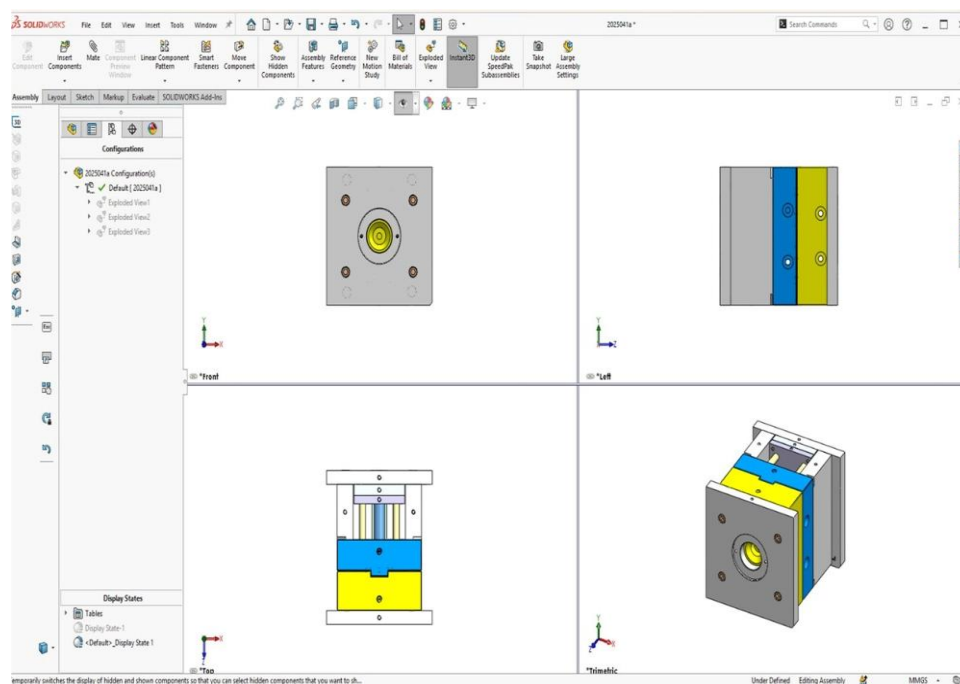


Figure 5.3 Views of the complete mould assembly

5.4 Gate, runner, cooling, and ejection

The runner system consists of a sprue, a main runner, a gate, and a cold-slug well if required, and the gate location is to be selected considering the wall thickness, flow length, appearance, weld-line possibility, air entrapment, product strength, and ease of gate removal [5]. Cooling channels are provided in the core and cavity plates with clearance from the ejector pins, screws, guide elements, and mould edges, so that heat is removed uniformly and warpage is reduced [6], [8]; a conventional channel layout is adopted in this study, and conformal cooling [9] is not considered. The ejection system comprises the ejector plate, ejector retainer plate, ejector pins, and return arrangement, with the pins acting on strong portions of the part and avoiding thin ribs and visible surfaces. Figure 5.4 shows the runner, gate,

cooling channel, and sprue arrangement. The final gate type and size, runner diameter, cooling channel diameter and pitch, and the number and size of the ejector pins have not been finalized, and a detailed ejection-force calculation has not been carried out; these are listed as preliminary CAD arrangements.

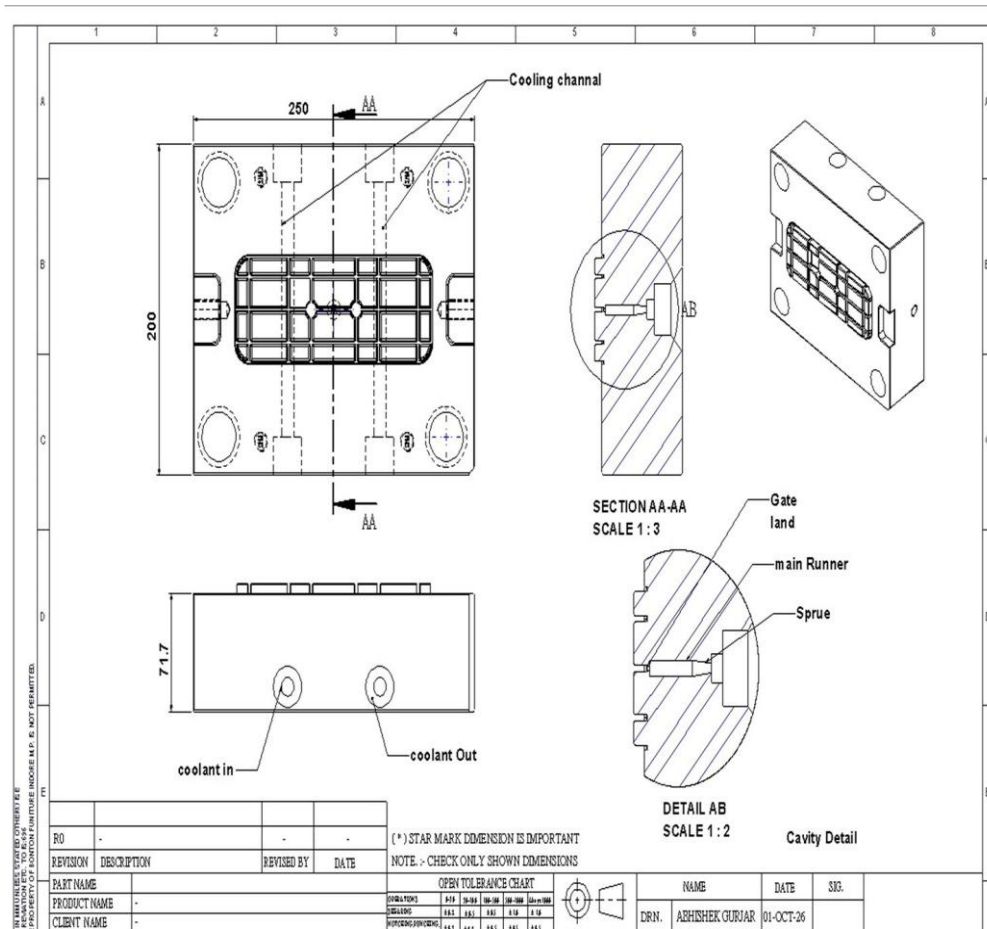


Figure 5.4 Runner, gate, cooling channel, and sprue arrangement of the mould

VI. RESULT AND DISCUSSION

6.1 Shot weight and injection capacity

The product mass obtained from the Mass Properties option of SolidWorks is 85 g. A preliminary runner and sprue allowance of 20 g was assumed, so from Equation (1) the total shot weight is 105 g. With a 25% allowance, Equation (2) gives a required injection capacity of 131.25 g, and a machine with a minimum injection capacity of 150 g was considered, which is 14.3% above the requirement; the shot then occupies 70% of the selected capacity. The runner allowance of 20 g is about 24% of the product weight and is an assumption, so the shot weight should be recalculated when the runner and gate design is finalized.

6.2 Projected area and clamping force

The preliminary projected area, from Equation (3), is $180 \times 70 = 12\,600 \text{ mm}^2$, that is 126 cm^2 . With clamping-force factors of 0.4 and 0.6 ton/cm², Equation (4) gives clamping forces of 50.4 and 75.6 ton, and, taking the higher value and applying the 15% margin of Equation (5), the design clamping force is 86.94 ton, or about 87 ton. A 100-ton class machine is therefore recommended for preliminary selection. The calculation is summarized in Table 6.1 and compared with the capacity of the machine in Figure 6.1. The design force corresponds to 86.9% of the nominal capacity of a 100-ton machine, leaving a nominal margin of 13.1% in addition to the 15% margin already applied; for the lower factor of 0.4 ton/cm² the design force would be 58.0 ton.

Table 6.1: Summary of engineering calculations

Sr.	Parameter	Result
1	Product weight	85 g
2	Estimated runner and sprue weight	20 g
3	Total shot weight	105 g
4	Required injection capacity (25% allowance)	131.25 g
5	Selected minimum injection capacity	150 g
6	Preliminary projected area	126 cm ²
7	Clamping force at 0.4 / 0.6 ton/cm ²	50.4 / 75.6 ton
8	Design clamping force (0.6 + 15%)	86.94 ton
9	Selected machine	100-ton class
10	Core / cavity plate thickness	70 mm / 66 mm
11	Product shrinkage	From material datasheet

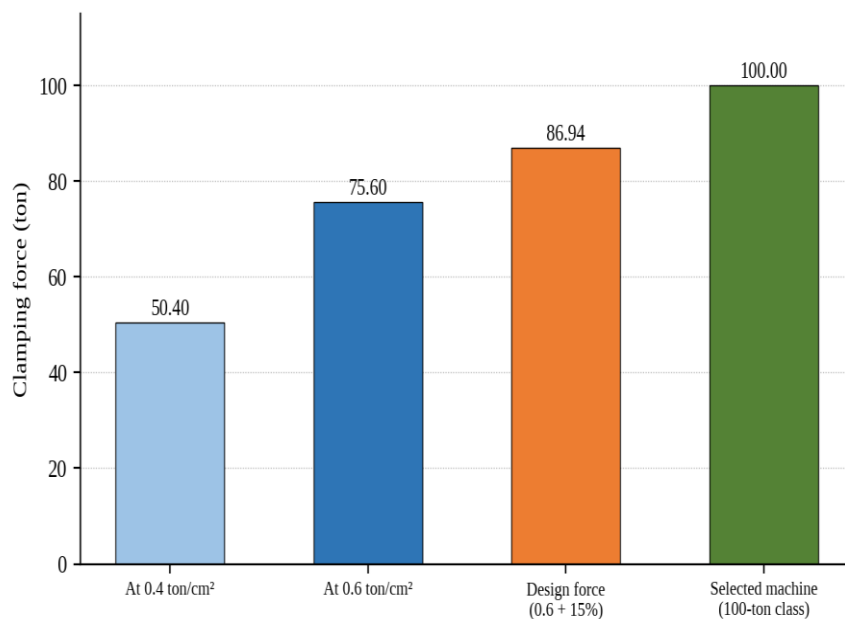


Figure 6.1 Preliminary clamping force compared with the capacity of the selected machine

6.3 Sensitivity of the machine selection

Because the clamping-force factor and projected area are estimates, their influence was examined by varying them while keeping the 15% margin (Figure 6.2). The design clamping force varies linearly with both. At the projected area of 126 cm² the 100-ton machine remains adequate for factors up to about 0.69 ton/cm², which is 15% above the value adopted, and at 0.6 ton/cm² it remains adequate for projected areas up to about 145 cm², which is 15% above the estimate. The selection is therefore robust to moderate errors in either quantity. It would not remain adequate if the clamping factor were raised to 0.8 ton/cm² for a thin-walled, long-flow-path part, which would give 116 ton, and the factor should therefore be confirmed from the plastic grade, cavity pressure, and machine data.

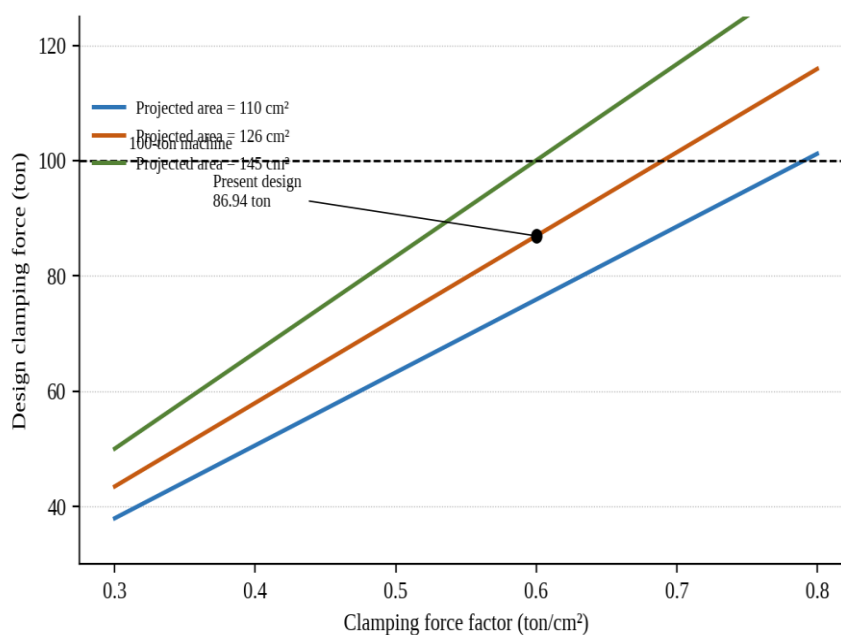


Figure 6.2 Design clamping force as a function of the clamping-force factor and projected area

6.4 Projected area refinement and mould dimensions

The bounding-rectangle projected area ignores the corner radii and holes. Subtracting the four corner losses, $(4 - \pi)R^2$ with $R = 15$ mm, and the two $\varnothing 5$ mm holes gives a projected area of about 123.7 cm², which is 1.8% lower than the rectangular estimate and would reduce the design clamping force to about 85.3 ton. The rectangular estimate is therefore slightly conservative, although the area of the runner and gate, which is not included, acts in the opposite direction. The core and cavity plates (250 mm × 200 mm) are about 4.0 times the projected area of the product, which leaves space around the cavity for cooling channels, ejector pins, guide elements, and fasteners. The closed stack height of the mould, taken as the sum of the bottom clamping plate (25 mm), spacer blocks (100 mm), core plate (70 mm), cavity plate (66 mm), and top clamping plate (25 mm), is about 286 mm, and the plan size is 250 mm × 245 mm; these values, together with the ejector stroke, must be checked against the platen size, tie-bar spacing, and daylight of the selected machine. The spacer blocks leave about 65 mm of free space beyond the combined thickness of the ejector plate and retainer plate (35 mm), which is ample for the product depth of about 10 mm plus clearance. Taking a steel density of 7850 kg/m³, the plates listed in Table 5.3 have a combined mass of about 97 kg, of which the core and cavity plates account for about 53 kg, which is useful for planning handling and mounting.

6.5 Design verification and limitations

The mould components were modelled as separate parts in SolidWorks and assembled into the fixed and moving halves, with an exploded view prepared to show the assembly sequence. The CAD assembly provides a clear representation of the mould structure and allows the component layout, alignment, mould opening direction, and ejector movement to be checked before manufacture. The verification checklist of the study shows that the product weight is obtained from CAD data, that the shot weight, projected area, clamping force, and machine capacity are preliminary, and that the component dimensions, core-cavity matching, interference checking, ejection movement, cooling arrangement, and final machine model remain to be verified, and that a practical mould trial is not included. The following limitations apply. The final plastic grade and shrinkage were not confirmed, the runner and sprue weight was assumed, and the projected area was based on approximate dimensions. No flow or thermal simulation was performed, and the injection pressure and cooling time were not determined. The plate thicknesses of 70 mm and 66 mm are preliminary CAD values, and no stress or deflection analysis of the plates was carried out, so their adequacy for the injection pressure and span between the spacer blocks should be checked. The results are therefore design estimates that provide a basis for detailed design, not final values.

VII. CONCLUSION

An injection mould was designed for an armrest top pad base plate of 180 mm × 70 mm with a mass of 85 g, using SolidWorks modelling and engineering calculations. The mould is a two-plate thermoplastic mould with seven principal plate components, a core and cavity arrangement with a 1° draft, core pins for the two Ø5 mm holes, and an ejector system in the moving half. The estimated shot weight is 105 g and the preliminary projected area is 126 cm², giving a clamping force of 50.4–75.6 ton and a design clamping force of 86.94 ton with a 15% margin, for which a 100-ton class injection moulding machine with a minimum injection capacity of 150 g was selected for preliminary purposes. The sensitivity analysis showed that the selection is adequate for clamping-force factors up to about 0.69 ton/cm² or projected areas up to about 145 cm², that the rectangular projected area is conservative by about 1.8%, and that the mould has a closed height of about 286 mm and a plate mass of about 97 kg. The study demonstrates a systematic approach for converting a plastic product design into a manufacturable mould design and machine selection, and it can be applied to similar ribbed plastic components used in automotive and furniture applications. Future work should confirm the plastic grade and shrinkage, finalize the gate, runner, cooling, and ejector design, carry out flow, cooling, and warpage simulation and plate stress and deflection analysis, verify the mould dimensions against the selected machine, and validate the design by manufacturing the mould and conducting moulding trials.

REFERENCES

- [1] D. V. Rosato and M. G. Rosato, *Injection Molding Handbook*. Springer.
- [2] T. A. Osswald, L.-S. Turng, and P. J. Gramann, *Injection Molding Handbook*. Hanser Publishers.
- [3] R. A. Malloy, *Plastic Part Design for Injection Molding*. Hanser Publishers.
- [4] J. P. Beaumont, R. Nagel, and R. Sherman, *Successful Injection Molding: Process, Design, and Simulation*. Hanser Publications.
- [5] H. Hassan, N. Régnier, and G. Defaye, “A 3D study on the effect of gate location on the cooling of polymer by injection molding,” *International Journal of Heat and Fluid Flow*, vol. 30, no. 6, pp. 1218–1229, 2009, doi: 10.1016/j.ijheatfluidflow.2009.06.005.
- [6] H. Hassan, N. Régnier, C. Le Bot, C. Pujos, and G. Defaye, “Effect of cooling system on the polymer temperature and solidification during injection molding,” *Applied Thermal Engineering*, vol. 29, no. 8–9, pp. 1786–1791, 2009, doi: 10.1016/j.applthermaleng.2008.08.011.
- [7] S. H. Tang, Y. M. Kong, S. M. Sapuan, R. Samin, and S. Sulaiman, “Design and thermal analysis of plastic injection mould,” *Journal of Materials Processing Technology*, vol. 171, no. 2, pp. 259–267, 2006, doi: 10.1016/j.jmatprotec.2005.06.075.
- [8] M.-C. Huang and C.-C. Tai, “The effective factors in the warpage problem of an injection-molded part with a thin shell feature,” *Journal of Materials Processing Technology*, vol. 110, no. 1, pp. 1–9, 2001, doi: 10.1016/S0924-0136(00)00649-X.
- [9] S. Z. A. Rahim, S. Sharif, A. M. Zain, S. M. Nasir, and R. M. Saad, “Improving the quality and productivity of molded parts with a new design of conformal cooling channels for the injection molding process,” *Advances in Polymer Technology*, vol. 35, no. 1, Art. no. 21524, 2016, doi: 10.1002/adv.21524.