

# APPLICATION OF CAD/CAE TO OPTIMIZING EXTRUSION DIE FOR DYL8812-3 ALUMINUM ALLOY PRODUCT

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## ABSTRACT

This paper presents the application of CAD/CAE for optimizing extrusion dies for the DYL8812-3 aluminum alloy product. It focuses on using Siemens NX for die design and QForm-Extrusion for simulating aluminum profile extrusion. Due to the non-uniform material flow, the profile passing through the die orifice may bend, twist, or deform. The QForm-Extrusion software features a specialized interface for quick die geometry import and automatic finite element model generation. It can also recognize die bearing zones, convert them into parametric form, and enable modifications and optimization, helping users achieve the most uniform distribution of longitudinal velocity. Additionally, the software provides a comprehensive analysis of die stress and deflection. With parallel computing, simulation time is significantly reduced. Numerical simulation using Qform software has optimized the bearing length and aluminum runner width of the DYL8812-3 extrusion die.

**Keywords:** Simulation, optimization, die design, aluminium extrusion.

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## 1. INTRODUCTION

Due to many advantages, aluminum and its alloys are widely used in many different fields such as: industrial equipment, transportation, construction, and interior decoration,... all over the world [1, 2].

Previously, when designing a die, then proceeding to die fabrication, and subsequently testing it, if it was not satisfactory, it would go back for design

refinement, causing increased costs and time in the die fabrication and testing process. In recent years, simulation software for the aluminum extrusion process (Qform) has emerged, allowing designers to input designs into simulation software. If deemed unreasonable, they can return to refine the design and simulate again. The simulation process replaces the fabrication and trial process. This reduces costs and time significantly [3, 4].

QForm-Extrusion is a specialized software used to simulate the extrusion process of aluminum profiles, developed by QuantorForm Ltd. This software is based on a versatile metal deformation simulation program that the company has developed for over 20 years. Model verification has been carried out through predicting load, material flow modeling, aluminum bar temperature, and die deformation, using special model experiments and multiple case studies in the industry conducted by software users worldwide [5-7]. A comprehensive analysis of the software's accuracy has been conducted in the International Extrusion Performance Evaluation Tests by comparing simulation results with precisely arranged actual experiments. The results show that the software performs very well [8-10].

The application of CAD/CAE to optimize extrusion die design is a solution that shortens die design time and improves die quality [11-14].

This paper will present the application of CAD/CAE to optimize the design of an extrusion die for DYL8812-3 aluminum alloy products.

## 2. DESIGN OF THE DIE

### 2.1. Basis of die design

A typical extrusion die set consists of a mandrel, die plate, and backer (Figure 1).

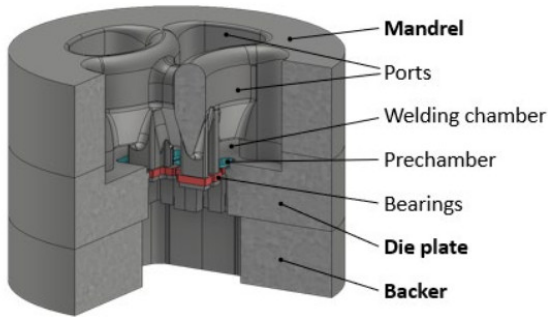


Figure 1. Simplified representation of porthole die set for aluminium profile extrusion [14]

**2.1.1. For Mandrel**

Mandrel has the function to divide the stream and guide aluminum into the die, creating the geometric shape and internal surface for the profile. Depending on the structural shape of the product, the designer creates the geometric shape of the aluminum guiding holes as well as the arrangement of the holes on the BG. In principle, uniformity must be created across the entire aluminum pressing surface and must match the type of billet. The arrangement of bridges between the holes must be sufficiently sturdy during extrusion, typically around 35 - 45mm for a 7" machine, and it is preferable to place the aluminum connection points in corner positions or less critical surface areas. The surface of the aluminum guiding inlet must have an outer diameter smaller than that of the billet. Since HOLLOW dies are more complex than SOLID dies, careful calculation of the volume of aluminum for each position must be done, and the aluminum chamber must be arranged to match the characteristics of each die, typically the height of the aluminum chamber is about 12 - 20mm, so the base of the bearing also has a similar size depending on the structure and dimensions of the profile [1, 2].

If during the design, the detail is too large while making the billet small, a tapered angle for the aluminum guiding holes must be created, depending on the type of die, different taper angles will be created, usually < 250. When designing a die with two symmetrical details, it is common to design with two aluminum chambers separated by a ridge in the middle about 7 - 12mm high to ensure an even distribution of aluminum flow across the entire die [1, 2].

**2.1.2. For Die plate**

Die plate has the function to create the geometric shape of the outer surface of the profile. Depending on the size and shape of the profile, when designing, the size and shape of the aluminum chamber must be chosen

appropriately. The assembly size between BG and DIE is +0.05. From the profile dimensions, an offset of 3.5 - 4mm is made for the milling process to reduce excess material for the EDM process; the depth of the milling process depends on the length of the bearing and the height of the aluminum chamber (if any). The length of the bearing aligns with the aluminum guiding holes and the geometric shape of the profile; however, the bearing length depends on the flow of aluminum long bearings flow slowly, while short bearings flow quickly [1].

**2.2. Design of the die**

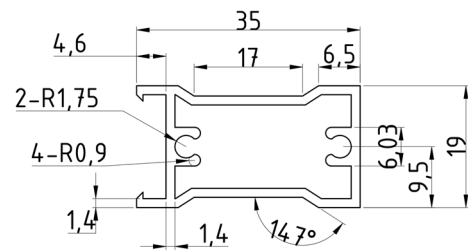


Figure 2. Product profile drawing

**Step 1: Determine the size of the die door**

Enlarge the product cross-section drawing by 1.01 to get the actual size of the die door (the shrinkage of aluminum is 1%) [1].

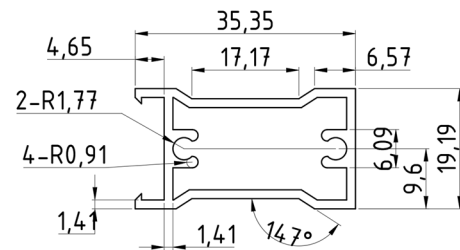


Figure 3. Form of Frame Door

**Step 2: Calculating the number of die cavities**

Using Siemens NX software, the calculated Sprofile is: Sprofile = 174.76mm<sup>2</sup>.

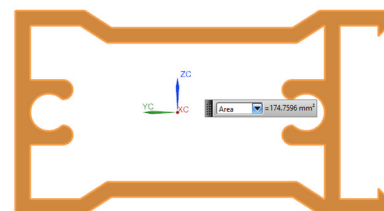


Figure 4. Cross-sectional area of the product

Choose N = 2 we have:

$$K = \frac{S_{container}}{N \cdot S_{profile}} = \frac{3.14 \times 77.5^2}{2 \times 174.76} = 54$$

The coefficient K is in the range of  $40 \div 80$ . Therefore, the design option of 2 die openings is reasonable.

**Step 3:** Arrange the profile and die diameter

The die has 2 openings, arranging the product symmetrically on both sides

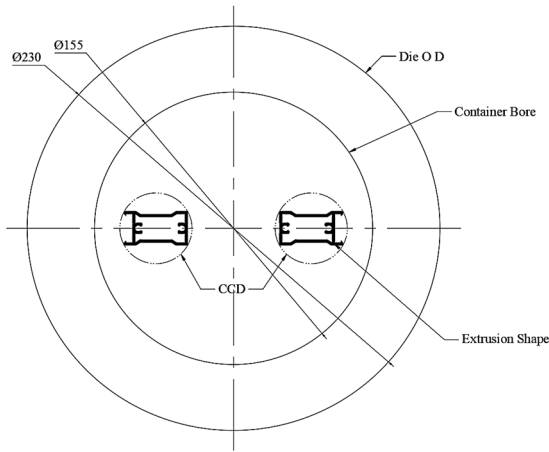


Figure 5. Arrangement of the profile and related diameters

which: CCD is the contour of the detail profile. Container bore is the core diameter of the die chamber (container). Die O.D is the outer diameter of the die.

**Steps 4, 5, 6:** Determine the outer cylinder dimensions  $\varnothing \times L$  of the core die (Mandrel),  $\varnothing \times L$  of the die cavity (Die plate): The core die has dimensions  $\varnothing 230 \times 84$  (mm). The die cavity has dimensions  $\varnothing 230 \times 70$  (mm).

**Step 7:** Design the aluminum guide holes

The product contour is circular, so we choose the option of 4 aluminum guide holes. The aluminum guide holes must be completely within the boundary circle

$$\varnothing = 155 \times (80\% \div 95\%) = 140\text{mm} \text{ (155mm is the diameter of the container) [1].}$$

For the 6" machine, the reasonable width of the die bridge is from  $(20 \div 35)$  mm, choose 25mm.

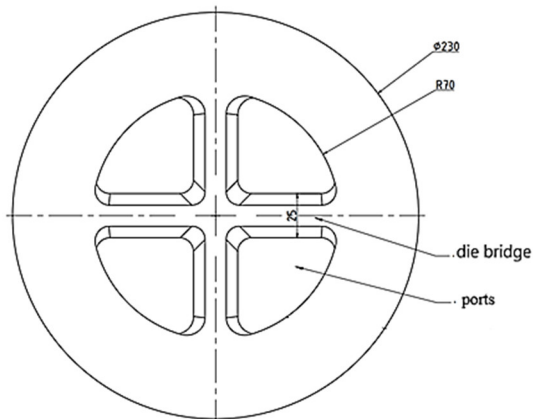


Figure 6. Position of die bridge and aluminum guide hole on the die

**Step 8:** Design of the die bridge [1]

Reasonable width of die bridge  $(20 \div 35)$  mm, choose a 25mm bridge, beveled and corner as shown in Figure 7.

**Step 9:** Bearing design

Adjustments to dies to edit or change metal flow ratios are done by changing the amount of die metal at places on the holes, understood as width, height, and bearing length. By increasing and decreasing the length of Bearing at some special locations; Reducing the Bearing length, the flow rate is increased and vice versa increases the bearing length, the flow rate decreases.

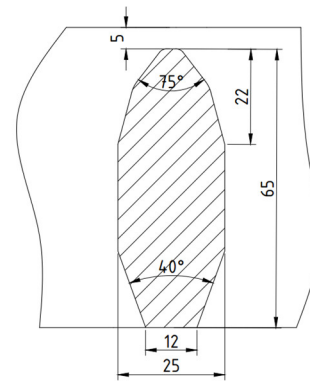


Figure 7. Shape of die

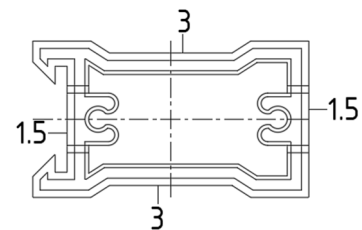


Figure 8. Bearing design

**2.3. Simulation of die design optimization**

The proposed approach to optimal technology design includes several steps (Figure 9).

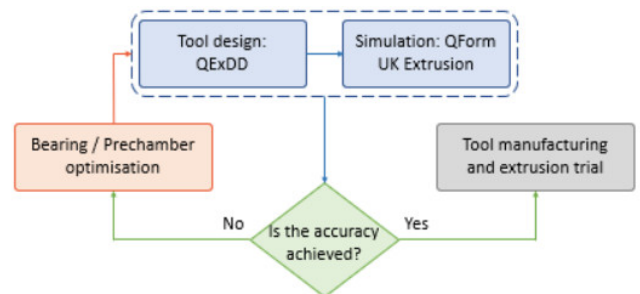


Figure 9. Graphical representation of the optimisation integration of CAD and CAE [14]

**2.3.1. The first die's design**

With important parameters shown in Figure 10. Simulation parameters are shown in Table 1.

Table 1. Simulation parameters

No.	Simulation parameters	
1	Aluminum material	A6063
2	Workpiece dimensions: Length L = 500; diameter $\varnothing = 155$	
3	Die materials	SKD61
4	Container temperature, (°C)	420
5	Workpiece temperature, (°C)	450
6	Die temperature, (°C)	490
7	Ram speed, (mm/sec)	5mm/s

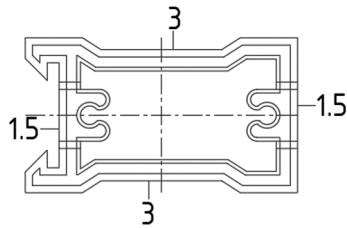


Figure 10. Bearing length drawing for the first time

The results of the product flow simulation are shown in Figs. 11, 12.

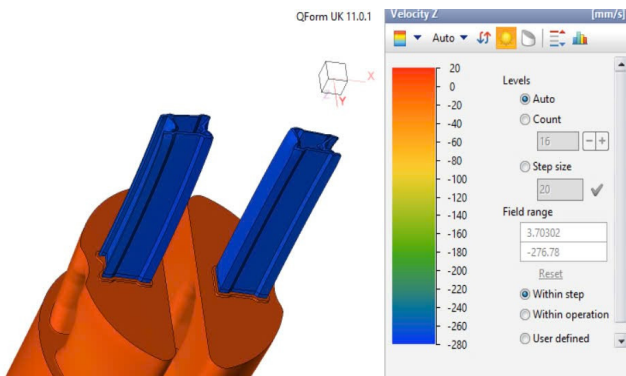


Figure 11. The speed of the first simulation flow

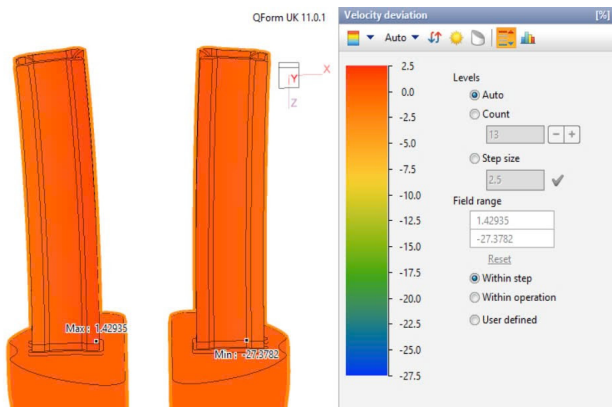


Figure 12. Dark velocity deviation

According to the results of simulation of the product flow uneven, the head of the product is still dented and not straight. Therefore it tends to be bent to the sides.

**Conclusion:** The die is not satisfactory, so the die needs to be adjusted, simulated and optimized the design parameters.

**2.3.2. Intermediate die design**

Based on the first simulation fruit, we need to adjust the die design to balance the flow of the product. The main parameters need to adjust the die design are circulated in Figure 13.

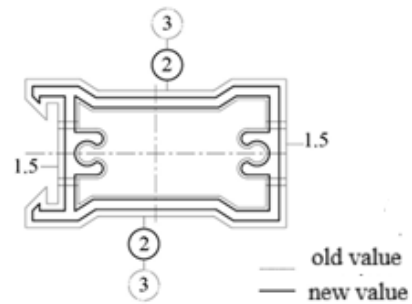


Figure 13. Next bearing length drawing

After adjusting, conducting simulation steps with the input variables similar to the first time we have the result of simulating product flow shown in Figure 14.

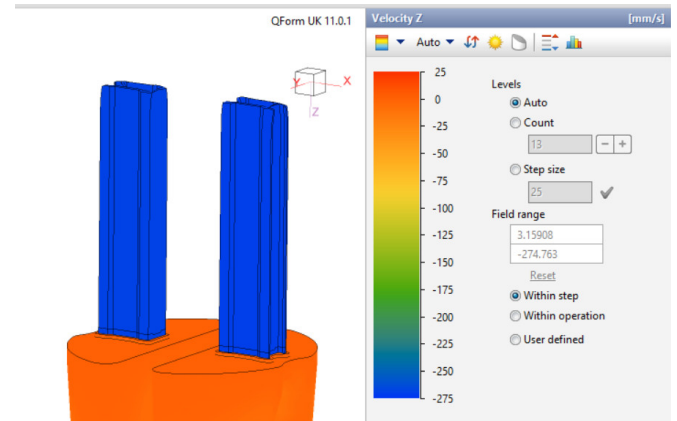


Figure 14. The speed of the intermediary simulation

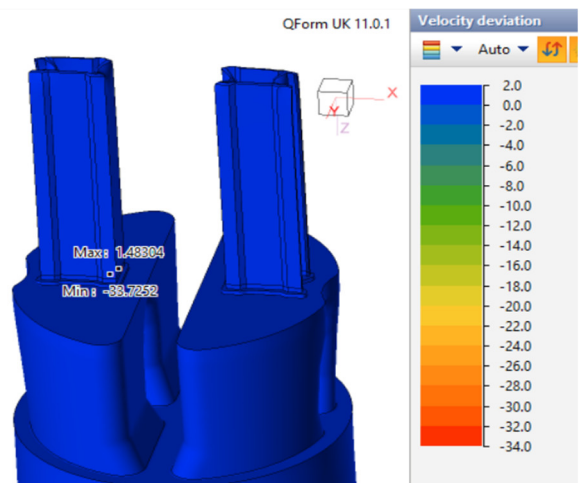


Figure 15. Maximum velocity deviation

According to the results of simulation of the product flow is still uneven. The part of the round border is still pulled inside. Therefore it will tend to dent the border.

**Conclusion:** Based on the simulation results, we need to continue adjusting the die design at the top of the die door so that the product flow is uniform.

**2.3.3. Die design last time**

The main parameters need to adjust the die design are circulated in Figure 16. After adjusting, conducting simulation steps with the input variables similar to the first time we have the result of simulating product flow shown in Figures 17, 18.

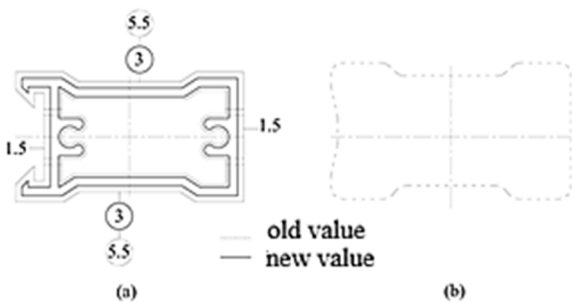


Figure 16. (a) Bearing length drawing (b) the last width of aluminum

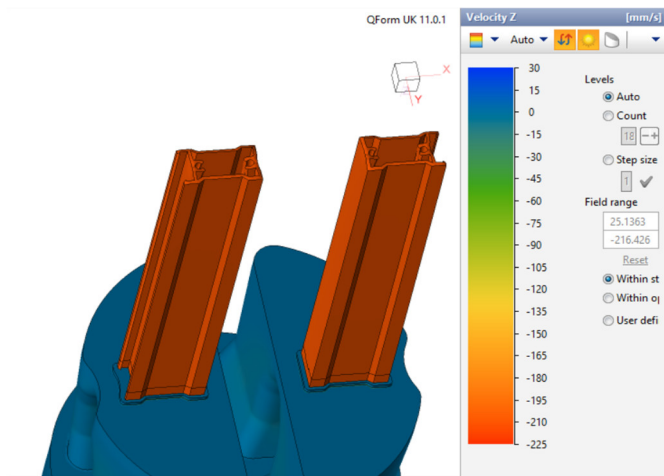


Figure 17. Last simulation flow velocity

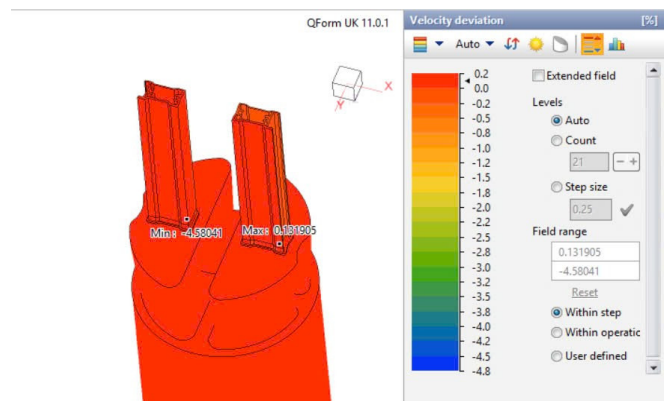


Figure 18. Maximum velocity deviation

According to the results of simulating the flow of the product is quite uniform at the points. Therefore, the die design has guaranteed technical requirements for balancing metal flow after some simulation and adjustment of die designs.

**Conclusion:** Balanced metal flow is one of the important factors to ensure product quality when pressed. Therefore, when proceeding to optimize the die structure, the die must first design to ensure the balance of the flow.

Based on the simulation results, we see that the design dies have been satisfactory.

**2.4. Drawing**

Figures 19 ÷ 21, respectively, is the drawing of the die.

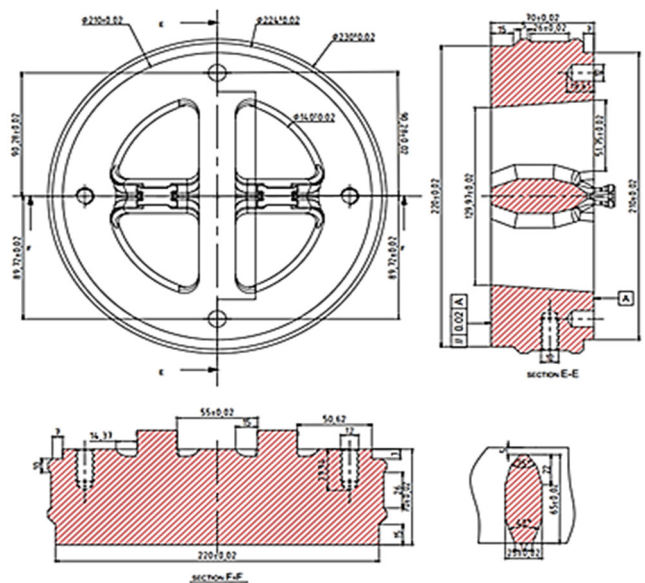


Figure 19. Mandrel drawing

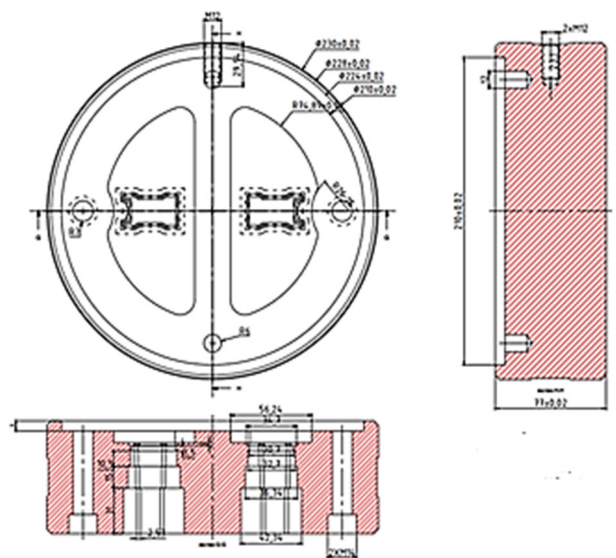


Figure 20. Die plate drawing

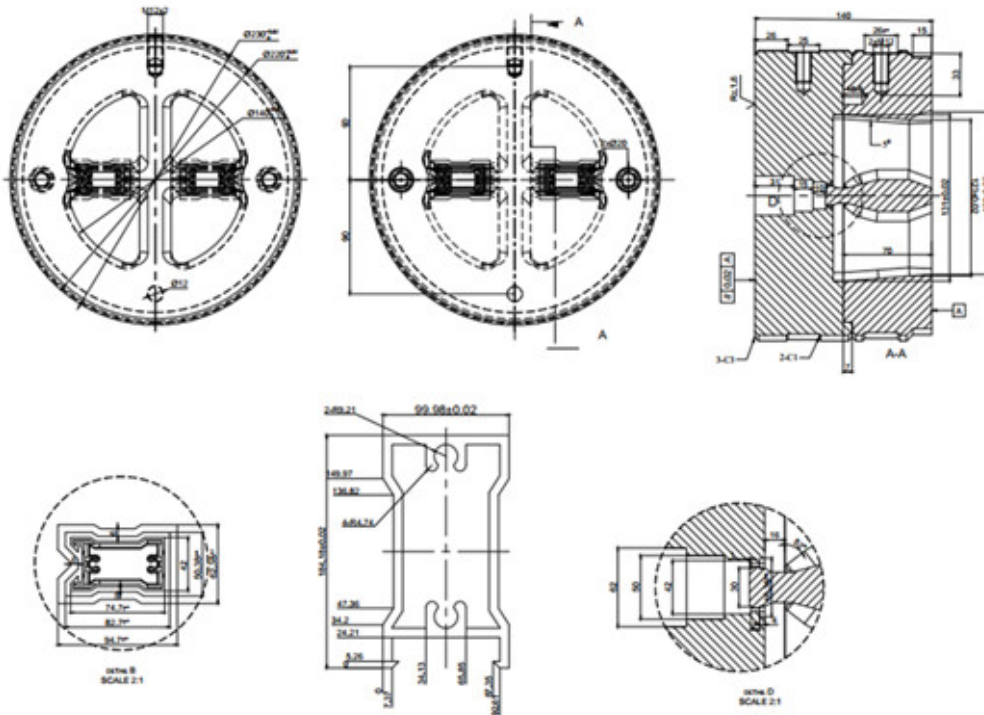


Figure 21. Die drawing

### 3. CONCLUSION

The application of CAD/CAE to the die design process has resulted in an optimally structured extrusion die for DYL8812-3 aluminum alloy products. Research results can be found to reduce design and manufacturing costs by using Qform software to simulate aluminum extrusion process.

By assessing the simulation results, the designer not only develops in theory but also quickly optimize the geometric parameters of the die and the technological parameters of the extrusion process. The number of die design revisions during the application of CAD/CAE to optimize the die design depends on the designer's experience.

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