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TOPIC
MOLD DESGIN PRODUCT
PLASTIC CUP

BACHELOR THESIS

PLACE 2024

VGU
Vietnamese-German University

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MOLD DESIGN PRODUCT PLASTIC CUP

A Thesis Presented by

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Submitted to the Examination Board RUB University Bochum,

Vietnamese - German University

in fulfillment of the requirements for degree of



BACHELOR OF SCIENCE IN
MECHANICAL ENGINEERING

APRIL 2023



Major: Mechanical Engineering

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ME2017

MOLD DESIGN PRODUCT PLASTIC CUP



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ABSTRACT

Small steps that lead to the molding industry was first made at the end of 1800 when Sir John Wesley Hyatt composed the first symbol plastic injection mold to create the plastic billiard balls, the mold concept at that time was very simple, their design is used a basic plunger to inject plastic into the mold through a heated cylinder [1]. Following that, until 1903, the molding process was improved by two German scientist Arthur Eichengrün and Theodore Becke, their scope is finding a material which is less-flammable, and they have developed the soluble forms of cellulose acetate. This type of powder is easy to apply in injection molded. Then in 1919, Arthur Eichengrün developed the first injection molding press. Keep following years, in 1930s the molding industrial have meet the new kind of material it's called thermoplastic material like polyvinyl chloride, polystyrene, and polyolefins [2]. Over time, the plastic manufacturing industry has experienced significant growth and expansion, they are not target to the simple and normal product, they aim to create the hightech and complex product.

Plastic injection molding has become one of the most crucial industry in the era of civilization. It contributes directly to a variety of manufacturing industries such as automobile, telecommunication, airplane and so more. Due to its wide range of applications, plastic molding has developed into different types in order to be suited for a variety of products. Gradually, from create a large scale products to smaller scale products such as cellphones housing, microchips, plastic electrical board parts and many more.

With the development personal items such as laptop frame, plastic charger cover. In this research, a conceptual design of a plastic injection molding product is generated in order to create a plastic parts to minimize the manufacturing costs and serve for the daily life using.

ACKNOWLEDGEMENT

As my research and prototype design to be succeeded, I would like to express my greatest gratitude to my supervisor Dr. Nguyen Quoc Hung for your great support. Your enthusiastic spirit motivated me during the time of the making of this project and your way of teaching always making me feel warm and welcomed in Vietnamese German University.

Also, this thesis would not be possible without the massive support from the engineer at Vietnamese German University and also my second supervisor, Mr. Do Van Duyen. At the beginning of this thesis, I was like walking through thick fog, but with your fantastic support as well as your contribution during the ideation and manufacturing of the product, everything is clearer for me and finally, I could find myself walking on the right track, and finish my thesis in time.

I am deeply grateful for the support and motivations that I received from my supervisors. Thank you all for your greatest support.

My family also plays an important role for the success of my thesis, without the great support from my parents, it would be impossible for me to finish my studying career. The unconditional love from them has given me power to achieve what I want, and my capability in anything.

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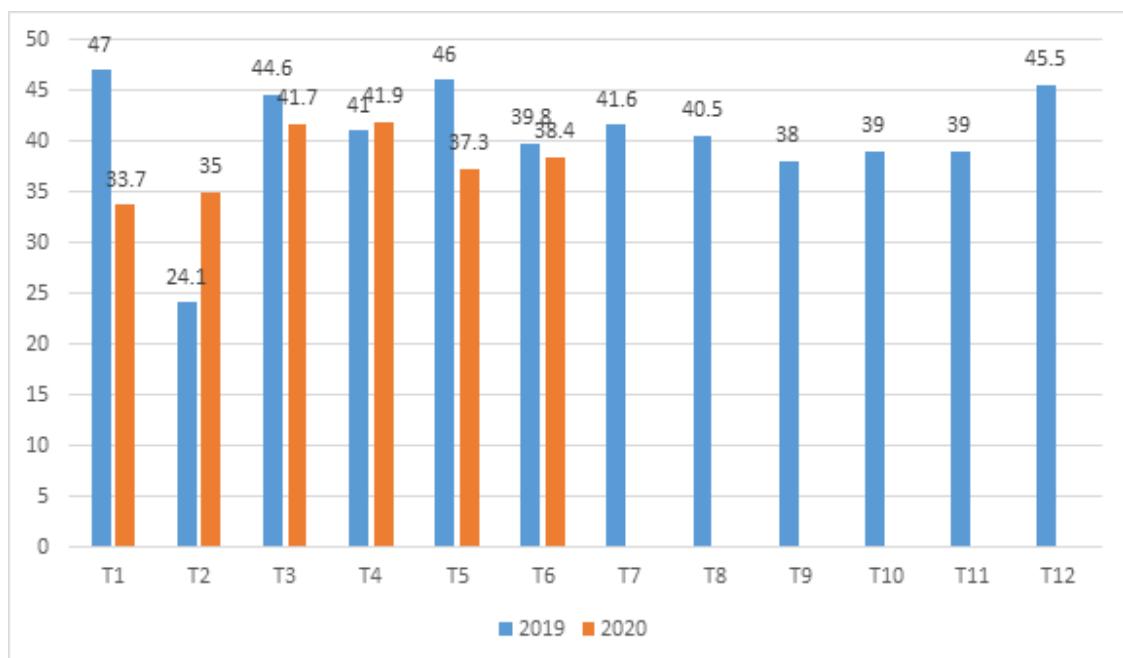
CHAPTER I: VIETNAM PLASTIC INDUSTRIAL

1.1 Overview of Vietnam's plastic industry

1.1.1 Current status of the plastic industry in Vietnam

Against the backdrop of global and domestic economic disruptions to supply chains, production, and business activities due to the COVID-19 outbreak, many sectors and industries are facing many difficulties, including economic sectors, especially the plastics industry. However, the plastics industry maintains a steady growth momentum entering 2020, and business activities are growing well. From 2016 to 2020, Vietnam's plastics industry has not only adapted to the rapidly changing pace of global production but also successfully integrated many modern technologies. In addition to keep the growth stable and move toward in potential export markets such as the United States, Japan, the European, South Korea and China, Vietnamese plastic products are also being promoted in other markets.


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The plastic products' export turnover in the EU market in 2019-2020 (Unit: thousand USD)

Exports of plastic products were estimated at \$300 million in July 2020, up 3.6% from June 2020 and up 2.3% from the same period in 2019. Exports of plastic products were estimated at \$1.9 billion in the first month of the year, down 0.4 percent compared to the same period in 2019.

According to statistics, the export value of plastic products in June 2020 reached 289.7 million US dollars, an increase of 10.7% over May 2020 and a 2.7% increase over the same period in 2019. The total turnover of plastic products in Vietnam in the first six months reached US\$1.6 billion in 2020, down 0.9% from the same period in 2019.

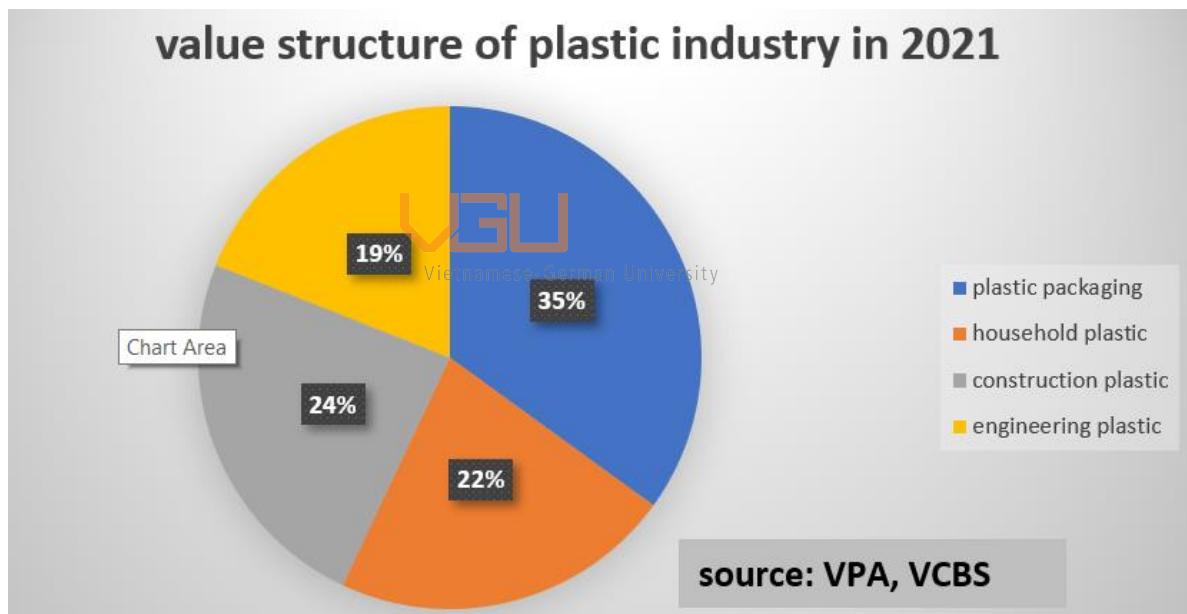
The plastics industry is developing speedily, which is considered as a booming of Vietnamese economy. This growth comes from a large market with high potential since Vietnam's plastics industry is just starting its journal of comparing itself to the world as well as variety of this country's plastic products can be served in different fields. In term of some aspect of life you can see there are plastic products for packaging, plastics for building materials, plastics for daily life, high-tech plastics, etc. According to Decision 2992/QD-BCT on the Guidelines and Targets for the Development of the Plastics Industry to 2020 Aiming at 2030, approved by the Ministry of Industry and Commerce, the plastics industry will continue to be prioritized for development and given priorities in taxation and capital. Through that, the plastic industry will receive incentives such as:

- Up to 85% of the total investment capital with Priority Payment is loaned to invest in sample production.
- Taxes are exempt for the first 4 years for high-tech factories investing in difficult socio-economic condition areas..
- Products of the plastic industry strive to reach 12.5 million tons by 2020 and export turnover to reach \$4.3 billion with a growth rate of about 15%.

The structure of the plastic industry still maintains the largest proportion of packaging plastic. According to the Vietnam Plastics Association (VPA), the

structure of the plastic industry there are four main segments: household, packaging engineering, and construction plastics. Packaging plastic accounts for the 37.43% making this segment maintains the largest proportion over the years..

This structure has changed slightly compared to the previous period, when the proportion of construction plastic was relatively high, 30% in the years 2000-2005. However, the downturn of the real estate market in 2008 reduced the proportion of construction plastic components to 21% and the current rate to 18.25%. According to the plastic industry development plan for 2020, the plastic industry will restructure the plastic product group to reduce the proportion of packaging and household plastic products, and gradually increase the proportion of plastic building materials and plastic products.



- **Plastic packaging segment:** This segment maintains the largest proportion in the structure of Vietnam's plastic industry with products such as food packaging, construction packaging, pet packaging, plastic bags, etc. Following the general trend of the world, the group of environmentally friendly recycled PET bottles and plastic bags will achieve a high growth rate in the coming years compared to other product lines. According to technology, materials, and market, the plastic packaging segment can be further divided into:

- **Plastic bag:** This is the only product with export sales exceeding 200 million USD in the first 6 months, accounting for 28.4% of total export sales of the plastic industry. Plastic bags are one of the leading plastic products exported to markets such as Japan, the UK, and Germany. The main raw material for the production of plastic bags is PE plastic beads. However, the export of this product line faces difficulties, especially in the US market with anti-dumping tax regulations on plastic bags from Vietnam and the European market when tax restrictions are imposed. Anti-dumping is applied. Reduce the use of plastic bags and replace them with biodegradable packaging.
- **Soft food packaging:** Vietnam's soft packaging market is divided into two segments: single film flexible packaging and complex flexible packaging. Packaged food and consumer goods are the main consumer markets for flexible packaging. The main raw material of this segment is PP plastic. Because it does not require much capital and technology, this segment accounts for most of the packaging group. In addition, due to technological limitations, most packaged food and consumer goods companies tend to use third-party packaging services, leading to the great growth potential of this market. for domestic and foreign enterprises.
- **Construction packaging:** The main products are lightweight PP plastic cement bags and kraft paper. The potential of this sub-sector depends on the development of the construction and real estate industries.
- **PET Packaging:** Although the market size of the PET packaging segment in Vietnam is only 50% of that of the soft packaging segment, this segment represents the position of domestic companies. PET packaging can be divided into 3 main segments: Preform - PET bottle, label, stopper - and is considered as a supply industry for canned goods, beverages, consumer goods, and chemicals. The rapidly increasing demand for packaging products in these sectors has led to the strong growth of the PET packaging market in recent years.

➤ **Household plastic products:** household products such as tables and chairs, cabinets, toys, and tableware, ... accounting for more than 29% of the output value of the plastic industry. Vietnam's household plastics currently account for 90% of the domestic market, but are mainly popular products with low-profit margins, while high-end products with high-profit margins belong to FDI companies. and foreign companies such as Lock & Lock of Korea. Many household plastic products produced by Vietnamese enterprises have also been exported to many countries around the world, but the achieved value is not high due to the low competitiveness of the segment. Old machinery and outdated technology make the quality of plastic products of domestic companies not high and less competitive. Most of the products are very simple and have low standards, so the added value is not high. Many companies have not dared to invest in high-tech machinery and equipment, most of them use old machinery imported from China. In addition, more than 80% of domestic plastic enterprises operate on a household scale, producing from input materials to finished products, so they cannot rely on specialized outside resources. Besides, the high-end plastic market has a wide coverage, in addition to production capacity, it is also necessary to have a promotion strategy and professional services, while domestic enterprises are weak in this technique.

➤ **Construction plastic segment:** The main products of this industry group include uPVC, HDPE pipes, plastic doors, ceiling tiles, and furniture mainly for construction needs. The growth rate of this segment is forecasted to increase due to the recovery of the real estate market and the increasing number of projects. Construction plastic market share only accounts for 18.2% of the whole industry, however, the growth rate of the construction plastic segment is quite high 15-20%/year, so the growth potential is still very large. Currently, 180 companies are operating in 02 segments: plastic pipes for construction and plastic construction materials. The main raw materials of this product group are PVC, PP, and HDPE plastic beads.

- **Technical plastic:** including products that are plastic equipment used in the assembly of automobiles, motorcycles, and plastic electronic equipment, accounting for 15% of the output value of the product. Although the number of companies is limited, the total output of this segment accounts for 20% of the total output of the plastics industry and mainly serves the domestic market.

Years \ months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
2022	520	340	530	535	490	490	495	470
2021	380	260	430	400	410	440	490	410

Export turnover of plastic products in 2021 - 2022 (Unit: Million USD)

Source: General Department of Customs

plastic export market structure in 2022

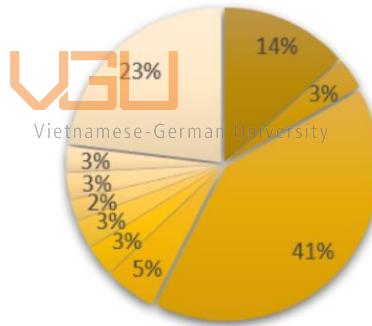


Chart Area

■ Japan ■ Germany ■ United States ■ South Korea ■ Cambodia ■ Netherlands ■ England ■ China ■ Indonesia ■ Others Countries

In the first 8 months of 2022, the US is still a big market for plastic products exported from Vietnam, reaching US\$1.56 billion, accounting for 41.4% of the total plastic products export turnover. Compared to the same period in 2021, export sales of plastic products to the US increased by 40.7%. The US market is the market where plastic bags remain subject to anti-dumping duties. Therefore, the export sales of plastic bags to the US account for a very modest proportion. On the other hand, plastic sheets, foils, and film products are the products with the greatest potential in the US market. This potential export item should focus on promoting export to this market. In addition to plastic bags, the US also imports many

products such as canvas, household plastic, and plastic products used for transportation and packaging. The demand for the import of plastic products in the EU market is still high, and the enterprises also have good import ability, especially the demand for plastic pipes. In addition, Vietnamese goods entering the European market are not subject to 8%-30% anti-dumping duties like other Asian countries such as China. This is a welcome event for Vietnamese plastics companies to increase exports to this market

Japan was the second largest plastic products market in 8 months, reaching USD 514.7 million, accounting for 13.4% of the total plastic products export sales. Compared to the same period in 2021, export sales to the Japanese market increased by 14.8%. Japan is a very potential market for the export plastic industry when the annual demand for plastic products in this market is about 8 billion USD. Some of the most exported plastic products to this market are plastic bags, household plastic products, canvas offices, and school supplies. This is one of the very fastidious markets with many strict regulations on the quality of goods, while some Vietnamese enterprises have not been able to meet the standards, mainly due to a lack of information. and experience. However, this is still a very potential market and Vietnamese businesses are also trying to promote trade to penetrate deeply into this difficult market.

1.1.2 Difficulties encountered

Raw materials are in short supply, most have to be imported. Despite the strong development in recent years, the plastic industry is still mainly known as the economic and technical industry of plastic processing, because it has to import nearly 80% of its raw materials. To be more specific, this industry currently needs about three and a half million tons of raw materials namely PP, PE, PCV, PS, beside hundreds of other adjuvant chemicals every year. However, at present, the plastic industry can only handle about 900,000 tons of raw materials, chemicals, as well as additives supporting for the whole industry's needs (about 20-25% of raw materials), since the industry of petrochemical industry has not yet developed.

The project to build a domestic industrial data system has not yet been developed. A new Dung Quat polypropylene factory with a capacity of 150,000 tons/year will be commissioned in three plastic chemical zones in Nghi Son (Thanh Hoa), Dung Quat (Quang Ngai) and Vung Tau (Ba Ria) from August - 2010. PVC Plastic is manufactured in two factories Phu My Plastic and Chemical Company and TPC Vina Plastic and Chemical Company with a capacity of 390,000 tons. View in the water only about more than 900,000 a whole lot of data for the network fragmented, and so far, there is no accurate system of the number of recycling companies.

A lack of initiative in the procurement of raw materials reduces the competitiveness of domestic companies, and it is difficult for export companies to use tax incentives based on regulations on the origin of goods. In addition, global price fluctuations for plastic resins will greatly affect the business results of plastics companies. Exchange rate fluctuations also have a strong impact on plastics companies that import input materials



It is forecast that Vietnamese plastics companies will need around 8 million tons of raw materials to service their manufacturing activities by 2022. If the raw material source is not proactive soon, it will create a major block for companies' ability to accomplish their production as well as raise their competitiveness in the scenario that Vietnam has been and is involved in signing of several bilateral and multilateral free trade agreements.

Our Technology is still not caught up with the world, we are now self-study and improving day by day. Technologies of Vietnam used to manufacture plastic products include:

- Injection Technology: This is the technology used for manufacturing plastic components as well as parts for the electronics, electrical, motorcycle, and automotive industries. In Vietnam, up to 3,000 types of injection molding machines have been recently used.
- Blown Extrusion Technology: This blown film technology produces all kinds of plastic packaging materials from film used in the technology of

blowing PE, PP, and film bags (PVC lamination). At present, many plastic companies use extrusion blow molding technology, with many pieces of types of equipment imported from other countries, with varieties generations, to produce plastic packaging products.

- Plastic production technology using Profile bars (Profile Technology): In Vietnam, this technology is used to produce products such as PVC drainpipes, PE water supply pipes, aluminum-plastic pipes, optical cables, doors, PVC, picture frames, roofing, and wall covering.

However, these technologies also have many disadvantages such as energy consumption, environmental impact, and not yet competitive product quality. 60-70% of the machines are new and are mainly imported from the Asian market. However, products from these markets, especially China, have lower prices, but are still quite simple and have not reached the level of complex technologies, such as those of Germany, Italy, and Japan. Modern new technologies in 8 plastic processing industries are already present in Vietnam, typically technologies for the production of plastic electronic circuits, DVDs, CDs, 4-layer bottles, PET bottles, and laminated films.

Plastic resin prices grew high earlier this year, due to the oil prices increase, but have recovered. Most resins are refined, made from crude oil and natural gas, and a few biological plastics are made from corn or other biological products, so the price of plastic pellets is highly dependent on fluctuations in oil and natural gas prices. The plastic packaging industry accounts for the largest proportion and uses PP and PE as raw materials, so these are the two types of plastic beads with the largest consumption and import demand.

1.1.3 Vietnam plastic industry outlook in 2022

The export of goods from plastic industry in 2021 has brought nearly 5 billion USD and is expected to keep growing over 20% in 2022 thanks to the expanding industry scale and receiving many big orders. The production size of the plastics industry is growth booming thanks to the huge investment activity by not only FDI

companies but also domestic companies. The global plastic industry is now in the race to achieve the aim of green production and environmentally friendly product. Vietnam has become a manufacturing base and receives many orders from major import markets

Regarding data from the government's import-export department, the COVID-19 pandemic has negatively impacted the global market across many economic aspects. However, Vietnam's plastic product exports still brought in substantial revenue—nearly \$4.93 billion in 2021. This figure is impressive compared to the growth of many other export sectors. Based on these data, it indicates a promising forecast for the Vietnam plastics industry in 2022. Many international terms and rules have been complied with to untangle complex and antiquated laws and provisions, creating a friendly and open market.

Currently, investors from Thailand, Korea, and Japan have bought stakes in many plastics companies in Vietnam. In 2021, SCG Group (Thailand) completed the acquisition of a 70% stake in two packaging and household plastic companies from Duy Tan Plastic Company (sales of nearly VND 5,000 billion) for US\$280 million. Previously, SCG Group also spent nearly US\$89 million to buy a 94% stake in Bien Hoa Packaging Company (SOVI), a company founded in 1968 with annual sales of nearly VND2,000 billion.

By 2022 the new trend of plastic products is using biological plastic, based on the export of green-tech plastic bags to the EU and US markets is also enjoying high sales and strong growth thanks to companies that are ahead of the trend of manufacturing green products with products made from natural, bio-based plastic bags meet the environmental protection needs of the people of these countries.

Although the picture of plastic companies' first quarter business results is bright, there is still a gray area. Difficulty in sourcing plastic resin materials, because some companies believe that revenue and profit decreased mainly because the general market demand has not recovered after the Covid-19 pandemic, in addition to the high price of plastic resin materials and other factors like shipping costs and management costs both increased due to the impact of global political instability

With the above difficulties, in addition to overcoming them through proactive procurement of raw materials and increasing the financial "buffer", companies would like more supportive policies from the managing authority, such as tax incentives, loans, premises... as well as support trade connections for companies to achieve more breakthroughs.

1.2 Introduction to Thesis topic

1.2.1 Orientation to choose topics

It can be said that the household plastic industry is one of the plastic production segments that attract a lot of investors, and the household plastic market is a very exciting one. In household plastic products, plastic cups are one of the most basic and intimate items in every person's daily life no matter where in the world. produces product lines that are compact, durable, and environmentally friendly.



Figure 1.2.1.1: Plastic cup in our daily life



Figure 1.2.1.2: disposable cup versus the reusable cup



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When considering plastic cups at home, in the office, or at events, it's important to weigh the pros and cons of disposable versus reusable options. Each type has its strengths, and the best choice often depends on factors such as budget, quality, and usability requirements. Disposable cups are usually more economical and convenient for one-time events, while reusable cups, though initially more expensive, can be cost-effective in the long run and more environmentally friendly. The design features and materials used also play a significant role in determining the cup's overall performance and suitability for specific uses. People intent to use the reusable plastic cups then the disposable plastic cup cause reusable plastic cup have a lot of advantage and benefit when using them in daily life: like they hard to have the deform when impact with other objects, they are more environmentally friendly, safe for hot and cold drinks containers and last but not least they have the long service life. See the benefit and the huge contribute of the reusable plastic cup in daily life, I decided to choose reusable plastic cup will be the main subject to conduct the study for our article in design injection mold.

1.2.2 Objects and scope of research of the topic

- Understand the meaning of the mold design
- Design a plastic product
- Apply the NX program to design the mold for the plastic product.
- Simulation of the machining process

1.3 Basic concept of injection molding

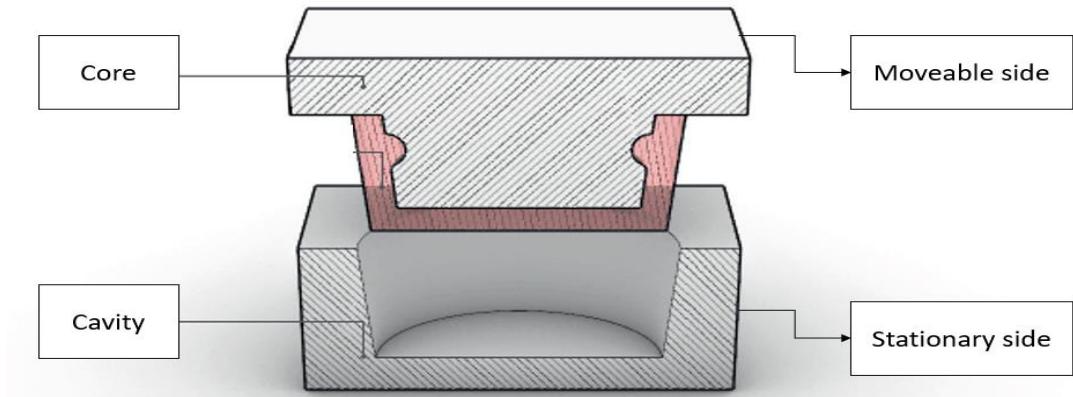
1.3.1 *Injection Mold Concept*

Injection molding is a homogeneous multi-component system used to shape molten plastic into the desired product after it has solidified.

The size and texture of the mold depend on the size and shape of the plastic product. The number of products required is also an important factor to consider as short-term production requirements do not require multi-cavity molds or specially designed tooling. These additional requirements greatly affect the mold structure as well as the product cost

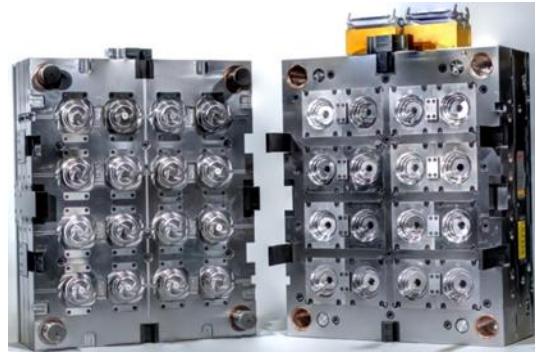
Injection molding is divided into 2 main molding components:

- The stationary part (the cavity) is the part that does not move during the entire injection molding process. This part attaches to the fixed wall of the plastic injection molding machine and connects to the machine's plastic injection nozzle system, the plastic will be fill directly to the mold cavity space through the nozzle and runner system.
- The moving part (the core), this part has the function of closing the mold to press the product and opening the mold to get the product. The moving part is fixed on the wall of the moveable side of the machine, the plastic injection machine is connected with the mold removal system to bring out the product through the ejection system provided in the mold.



1.3.2 Types of injection molds

Mold Cavity:

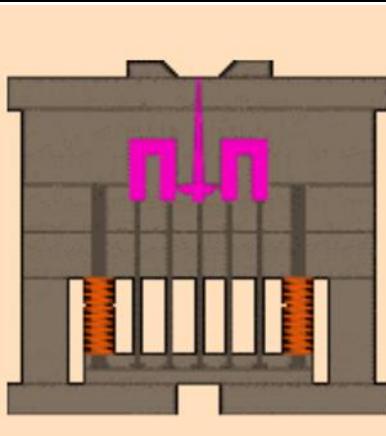
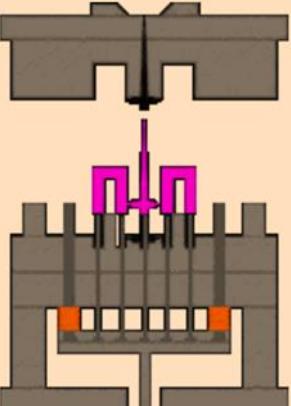
Number of cavity	Picture
single cavity	 <p>A photograph showing the components of a single cavity mold. It includes a moveable side plate with a core, a stationary side plate with a cavity, and a core pull system consisting of a rod and a lock plate.</p>
Multi cavity	 <p>A photograph showing two components of a multi-cavity mold. Each component contains four separate mold cavities, arranged in a 2x2 grid. The components are made of metal and show complex internal structures for each cavity.</p>

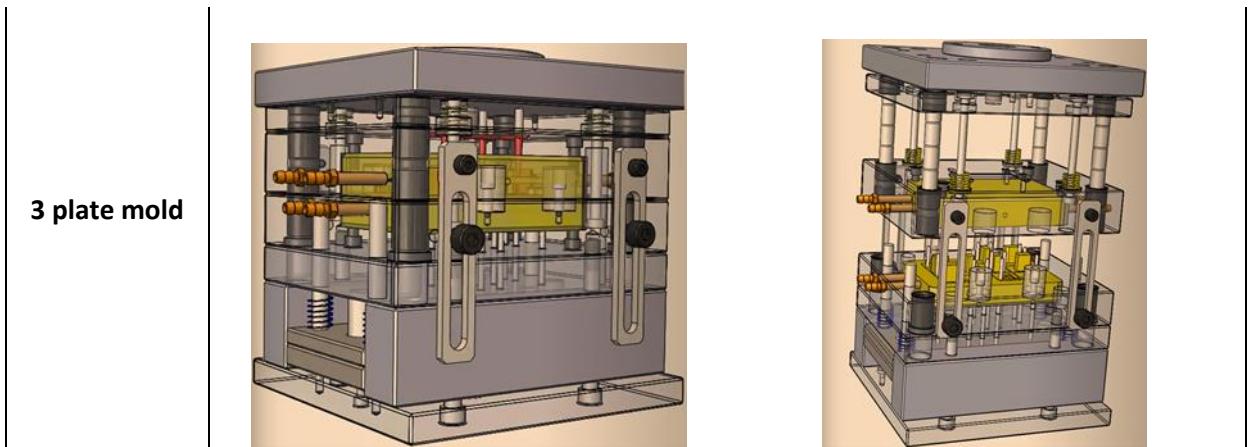
The feeding system of the mold is a crucial part of the injection molding process. This system is responsible for directing the flow of molten plastic from the nozzle of the injection molding machine to the cavity of the mold. There are two main types of feed systems: the cold runner system and the hot runner system.

Hot runner is a system of channels that are heated by an electrical system. This part is used in plastic injection systems and its main task is to keep the temperature of the liquid plastic stable during processing. It is an indispensable fixed part of the injection mold. The mold temperature is controlled by a controller which helps to form a stable temperature during the injection molding of plastic products.

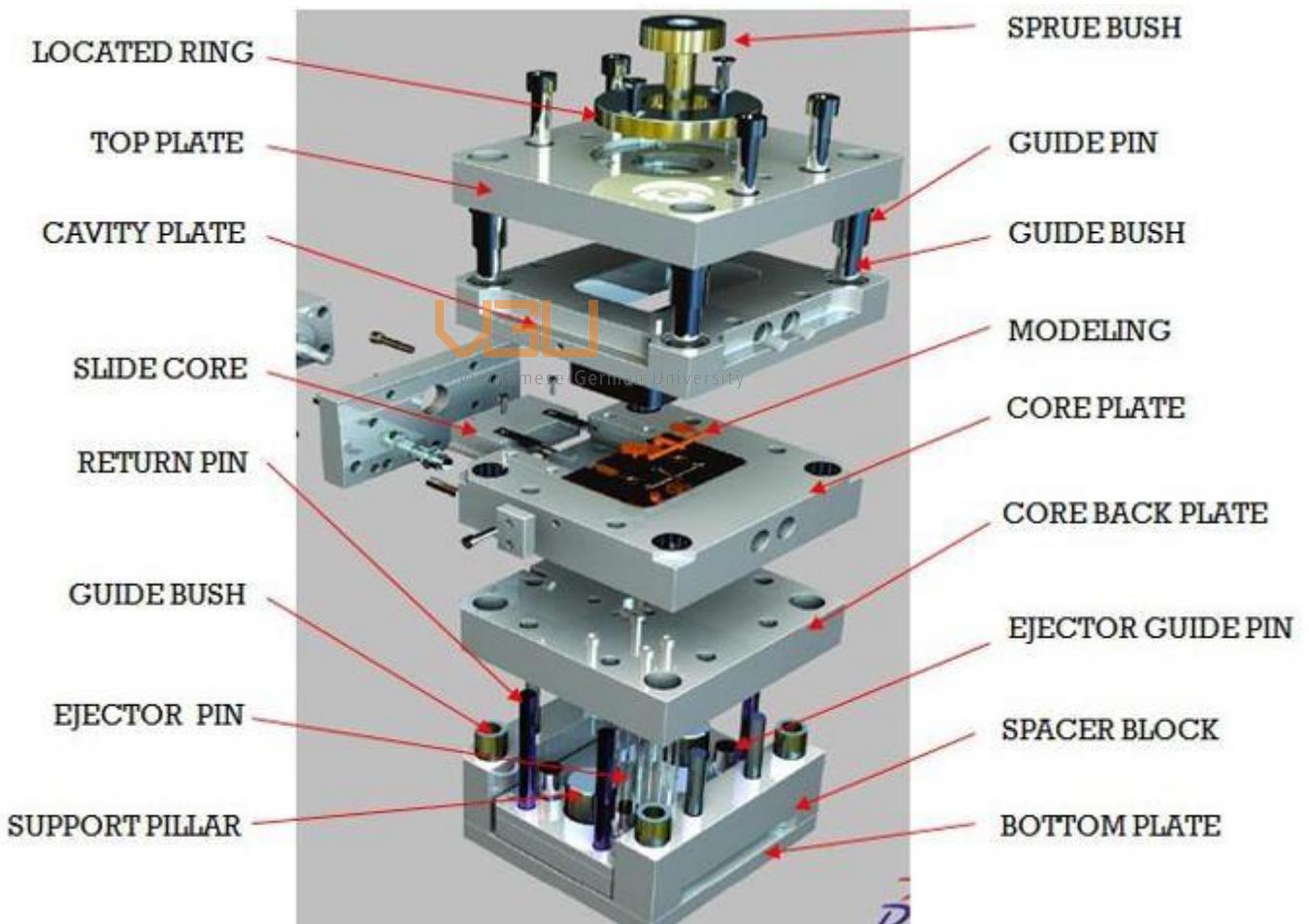
The "Cold runner" type is a mold in which both the product and the runner are cooled and solidified before being removed from the mold. There are many types of such molds with different structures, including two-plate molds where the product and runners can be removed from the same opening, for three- plate molds product and runner cannot be take out from the same opening.

- Mold opening

Mold opening	Picture
2 plate mold	 



1.3.3 General structure of a set of molds

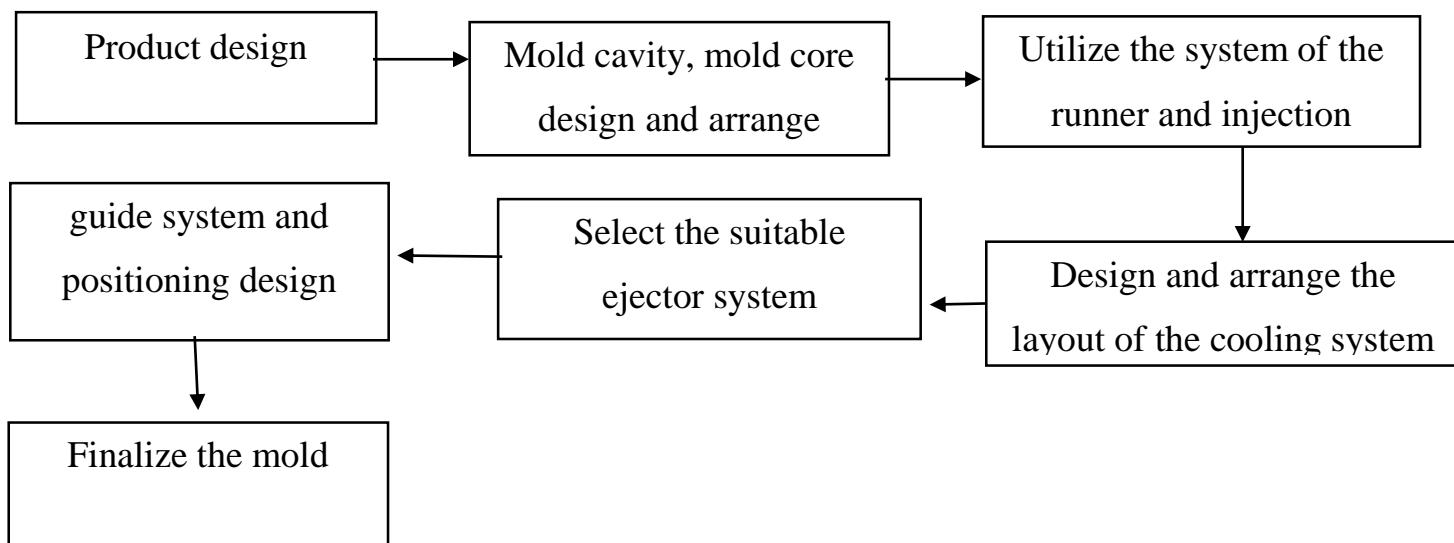


In addition to the cavity (stationary) and the core (movable) molds, the mold set contains many other parts. These parts are assembled to form the basic systems of the mold, including:

- System of guidance and positioning: including all guide pins, guide bush, location rings, positioners, return pins, etc., which are responsible for keeping the correct working position of the two mold parts when coupled together for precise molding.
- The system of filling the plastic into the mold cavity: will include the gate, the runner, and the sprue bushing, these components are responsible for supplying plastic from the injection machine's nozzle into the mold cavity.
- Injection Mold Ejector System: This includes components such as ejector guide pins, return pins, space plates, ejector plates, retaining plates, and support pillars. They are responsible for pushing the product out of the mold after pressing.
- Slide Core System: This system, which includes the slide core, slide insert, transform core, angular pin/angular cam, hydraulic cylinder, etc., is used in the direction of the mold's opening to remove pieces that are undercut and cannot be removed.
- Mold Exhaust System: Contains ventilation holes that are responsible for bringing out the remaining air in the mold cavity, creating ideal conditions in mold cavity when fill in the plastic easier and reduce the risk for the product not to blister (air bubble) or burn.
- Cooling system: composed of water pipes, grooves, heat pipes, connectors, etc., which is responsible for stabilizing the temperature inside the mold when operate and shape the form of product by cooling down it quickly.

1.4 Basic steps of design a mold

Mold design is one of the most important stages in the production of plastic products. Based on the product design and product material we can optimize the basic concepts and standards for the mold structure. Follow the process strictly we can be easy to mitigate the risk and failure that can happen to our product desire.



1.4.1 Design for the production

Before designing the mold, the first stage begins with the collection of information and specifications related to the plastic product to be injection molded. Therefore, it is necessary to evaluate the function and usage of the product. These activities include determining the geometry, dimensions, tolerances, and location of the injection port and ejector. Furthermore, understanding the important properties of the part material is also important, this will help you to design the components inside the mold reasonable and accurate.

1.4.2 Material viscosity

The material property plays an important role on the structure of the racking system like choose what the type of injection port and the design for the cooling system, it's will decide the shape of the plastic products after molding process. In mold design, Viscosity is a key component in mold design, influencing multiple aspects. They include the amount of pressure needed to inject the material into the mold, the size and form of the injection port and channel system to facilitate easy material

flow into the mold, and the vent hole's depth to release any trapped air in the mold cavity.

1.4.3 Thermal properties of materials

The cooling effect during injection molding will depend on how well the plastic substance absorbs and dissipates heat. When plastic materials are subjected to high temperatures over an extended length of time, they become somewhat temperature sensitive. The relationship between injection molding temperature (the greatest and lowest temperatures at which a material may be safely pressed) and the amount of time that passes before deterioration starts at this temperature must therefore be understood. For instance, low temperatures and brief elapsed times are frequently used for injection molding of thermosensitive plastic materials. On the other hand, low heat-sensitive materials require longer elapsed times at high temperatures during pressing, which increases the significance of the mold cooling system design.



1.4.4 Shrinkage of the material

Another important characteristic to be considered during injection molding is material shrinkage. Each plastic material has a shrinkage factor assigned to it that determines the full size of the insert in the mold to produce the desired final size of a product after it is removed from the mold. To simplify shrinkage estimation for mold sizing, the table below lists the shrinkage factors of some thermoplastics.

Materials	Shrinkage value (%)
Polyethylene (PE)	1.5-6.0

Polypropylene (PP)	1.0-3.0
Polyvinyl chloride (PVC)	0.1-0.5
Polystyrene (PS)	0.2-0.6
Polycarbonate (PC)	0.5-0.8
Acrylonitrile butadienstyrene (ABS)	0.3-0.8
Polyamide (PA)	0.6-2.0

Mold shrinkage rate is an important factor in determining the technical tolerance of both the mold and the final product. Typically, the tolerance of the mold is 1/10 of the tolerance of the product. For example, if the tolerance of the mold is 0.02 mm, the tolerance of the product will be 0.002 mm. To determine the appropriate tolerance for your mold, you can refer to the DIN 16742-2013 standard. This will help you choose the tolerance based on the plastic material of your product and the desired accuracy.

In reality, predicting shrinkage for cavity and core sizing is not a simple task. Many factors need to be guaranteed so that the final shrinkage result can be more accurate. If we have any changes in product design features, it will create a chain reaction to the shrinkage. Additionally, the variation of temperature in the mold can create fluctuations in the shrinkage process and impact to the injection molded part. The key solution to prevent the uncontrolled shrinkage we need to obtain as much information and seek for advice as detailed as possible from the mold experience designer and suppliers' material report document to accurate shrinkage prediction.

CHAPTER II, INTRODUCTION OF NX SOFTWARE AND THE BENEFIT OF NX IN PLASTIC MOLD DESIGN

2.1 What is NX Mold Design?

2.1.1 Definition

NX Mold Design is a professional mold design software that provides a rich library system and simple object management and control functions, helping to reduce design and machining time and cost. Mold design integrates cutting-edge technical expertise with useful production automation to cover every stage of the process, from assembly planning to design. NX mold design handles even the most intricate designs and offers cutting-edge features to guarantee quick response to design modifications and adherence to all quality standards.

2.2 Features of NX Mold Design software

2.2.1 Tools for the mold design process

- Product Analysis: Import geometry and drawings using transformed data. It is easy to design and change the design, meet the designer's wish, and achieve the processing purpose.
- Mold cavity/core development: automatic calculation of cavity/core partitions. Rapid parting surface design. Supports automatic hole-making to nest complex sliding designs (side core ejection system). Automatic collision checking of the system after the design process is complete.
- Mold structure: includes mold/core layout, part system, and base mold library for prototyping and mass production with multiple cavities. It is based on a standard parts storage library, and its parameters can be easily changed without programming. The side core system design includes the added quick push system. Additionally, it allows for the insertion of cooling channels, air pipes, nozzles, and other commonly used components.
- NX's mold design process includes several powerful features to streamline cavity/core development, including automatic drafting, combined orifice plate generation, 3D annotations, and hole tolerances. These features make it

easier than ever to design molds with precision and efficiency. As a result, NX provides mold design documentation that meets the highest standards and exceeds expectations.

- Capabilities beyond NX mold design: Siemens PLM's whole range of products may offer the most feature-rich solution suite, assembly models, and comprehensive solution suite...
- Design changes update: mold design can be constantly developed and updated along with the product design; as the product design changes, the speed of mold replacement will be breakneck.

2.2.2 reusable standard

- Input data: Reuse existing configurations such as project templates, materials, tools, and design processes to accommodate new templates. Accelerate and optimize mold design through standardized processes and components.
- Output data: automatic  generation of bills of materials, 2D drawings, mold textures, and CNC toolpaths.
- Parts can be reused: User-specific parts can be used and imported in the customization field. Developing these own parts can also reuse the structure of the base mold.

2.2.3 Design foundation

- Product analysis: use mold wall thickness measurement, bevel angle calculation, cutting area detection, and radius evaluation functions.
- Analytical Instruments: Validate mold designs in an assembly environment, calculate positional safety clearances, analyze strength, and detect sharp corners. Electrodes are required for analysis. Extend tool life.

2.2.4 Comprehensive solution in NX

- *Design Change Management:* Graphically compare design versions for similarities and differences. Exchange design versions, control the transfer of changes, and update related features, drawings, and toolpaths.
- *Process and Data Management:* Supports team-oriented, where teams of multiple design engineers work on a template simultaneously, which will help team members work on the same page and seamlessly keep up with design changes (if any). Synchronization and product distribution within NX software is one of the software's strengths.
- *Production integration:* manufacturing automation, molds are designed and created using machining programs on NX software

2.3 NX product mold design content

2.3.1. Mold Design



- Calculation of shrinkage factor
- channels and nozzles
- Automatically generate 2D drawings
- Create a parting surface path
- Insert subparts and hole tables
- Create a parting surface
- Create bill of materials
- Create cavity/core, cutting area
- Standard configuration, reusable orifice plate, tangential EDM
- cooling water line
- propulsion system
- change design
- Connection cavity
- Concept Design

3.2. Provide standard details

- Supports basic shaping of standard units: DME, Futaba, HASCO, LKM, Meusburger, Omni, PCS, Progressive, Rabourdin, Strack, Superior, and Universa.
- Basic detail systems (Injection, Ejection, Cooling, Sliders/Lifters, Rails, Locks, Pins, Screws, Springs, Struts) supported for standard units: DME, Futaba, HASCO, National, Meusburger, Omni, Progressive, Rabourdin, Strack, Yates.
- Basic detail management



CHAPTER III RESEARCH PRODUCT CHARACTERISTICS AND SELECT SUITABLE PRODUCTION MATERIALS

3.1 CONCEPT DESIGN OF THE COFFEE CUP

- Plastic coffee cups are familiar items that can be found easy in every household in our lives
- A coffee cup will consist of 2 parts
 - + The body of the cup
 - + The handle of the cup
- The coffee cup is designed in a monolithic form.

3.1.1 Requirements for details of plastic coffee cups

- When designing a plastic cup, it is important to consider the feel of the handle against the skin. A slight roughness can provide a better grip.
- The materials used to make the coffee cup must be safe, non-toxic, and non-irritating to the skin of the users.
- Good durability and **easy cleaning** are also important factors to consider when designing a coffee cup..



3.1.2 Some types of cup on the market



Ceramic cup



Stainless steel cup



Plastic cup

3.1.3 Product material selection

PLASTIC RESIN IDENTIFICATION CODES						
1	2	3	4	5	6	7
PETE	HDPE	PVC	LDPE	PP	PS	OTHER
Polyethylene Terephthalate	High Density Polyethylene	Polyvinyl Chloride	Low Density Polyethylene	Polypropylene	Polystyrene	Other
						
Recyclable	Recyclable	Recyclable at specialist points	Recyclable at specialist points	Recyclable	Recyclable at specialist points	Not easily recyclable

Through learning about the properties of plastics commonly used to make household products and the required specifications for plastic cups, we chose the material used to make plastic drinking cups, which is PP plastic, because it has outstanding and suitable advantages that bring the best results to the product, ensuring all the product characteristics requirements. Below is the amazing advantage of the PP (Polypropylene) material.

PP plastic has the full name of Polypropylene, with the chemical formula $(C_3H_6)_n$. PP plastic beads are one of the primary and most popular plastic beads on the market today.

PP plastic granules are hard, solid but not brittle, electrically insulating, impermeable, temperature-resistant, chemical-resistant, anti-deformation, transparent - through light. In addition to the above characteristics, PP plastic is also easy to process and it makes the PP plastic affordable in molding, so the products made of this plastic are very diverse and rich in patterns, providing consumers with a variety of choices. Especially PP plastic beads price is extremely reasonable and easy to find the supply source.

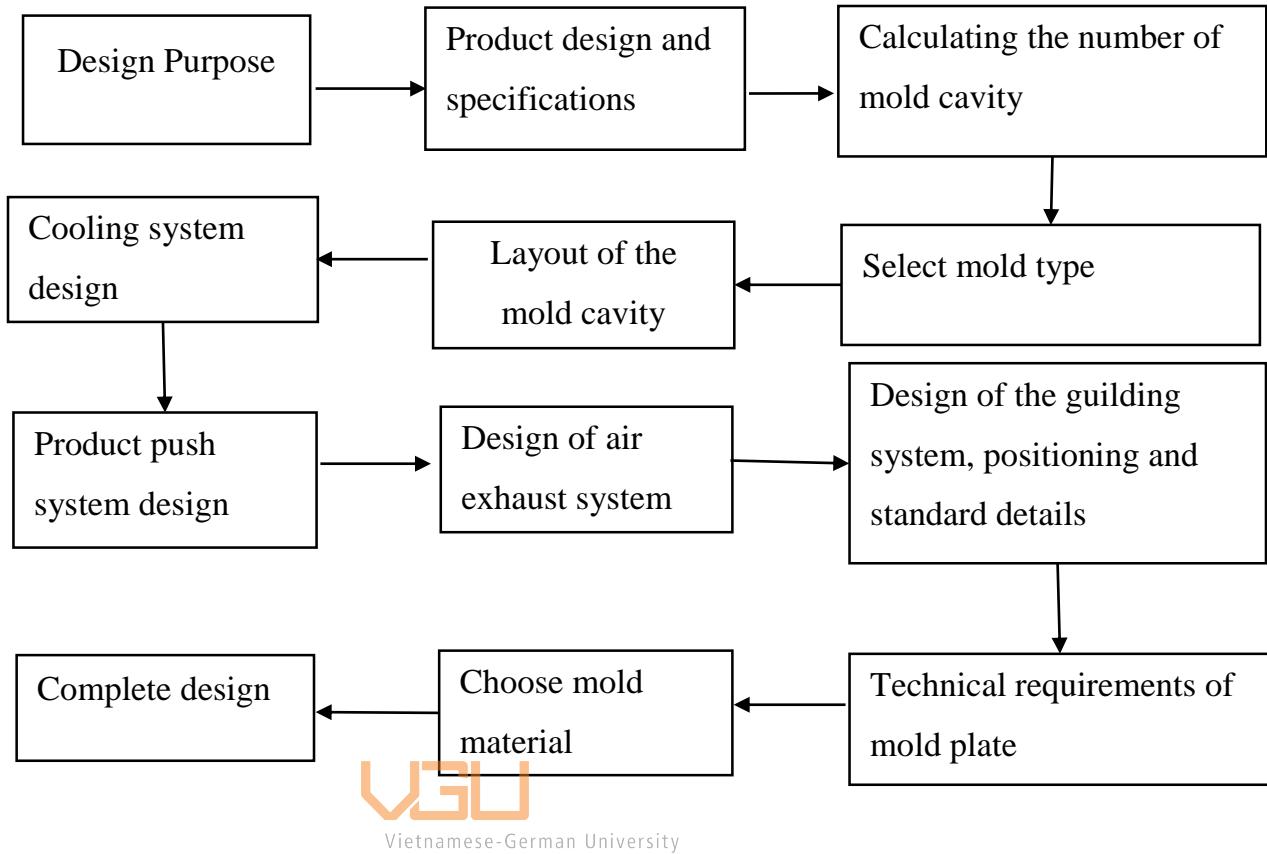
The end users will have a lot of concerns about the PP plastic like: does it safe to use as a food or liquid carrier plastic? Can it be recycled after use? These two concerns make PP plastic an excellent choice for molding. Firstly, it is highly

durable and chemical resistant, making it suitable for a wide range of applications. Secondly, it is safe for use with food, including medication bottles, dairy containers, and food storage boxes due to its high heat tolerance and low toxicity. Additionally, it is safe for use in the microwave and dishwasher, making it a convenient choice for everyday use.



CHAPTER IV. CALCULATION AND DESIGN OF COFFE CUP MOLD

4.1 MOLD DESIGN PROCESS



4.1.1 Actual Design Purpose.

As mentioned above, plastic cups are an indispensable item in the house, a necessary item in every family.

Plastic cups are made entirely from high-quality PP plastic with high hardness, durability and do not contain substances harmful to users' health.

Diverse in design and form

I think designing a plastic drinking cup product as a graduation project is a great idea. This project not only aims to deeply understand injection mold design but also brings a benefit to our university by creating a welcome gift for freshers or a souvenir for each advertising campaign. Using plastic cups instead of ceramic cups will make it easier to carry without any concern about fragility.

As a student with a long affiliation with Vietnam-Germany University, I have come to appreciate the memories and friendships that I have made with like-minded individuals. One of the ways that the Vietnamese and German

communities express their shared spirit and culture is through the enjoyment of beer, often shared among friends to celebrate special occasions or to unwind after a long day of work. As a student, I would love to have a VGU-branded cup to not only share our university's reputation but also to serve as a reminder of the memories I have made during my time here.

4.1.2 Product design and specifications.

With the development of modern technology, technical drawings no longer need to be drawn by hand as before. With the features supported by the software, we can draw faster and easier and increase our productivity. Mold design have a lot of software that support in designing but NX software is the most power to design drawings.

We proceed to design products on NX 12.0 software through the following steps:

- Choose a design environment
- Product design.
- Products standards:

✓ Ensure the cosmetic spec to meet the design like the product size and shape accuracy.
- ✓ The product surface should be clean and shiny, free of cracks, burrs, and dents
- ✓ The hardness of the product affects the material used for injection molding; it should be neither too hard nor too elastic.
- ✓ The product material is non-toxic, colorless, odorless, tasteless, and harmless to human health. Because the material of the product is PP plastic
- ✓ Product Specifications.

4.2 Product Design Research

After conducting the research not only with students and staff of our university but also for the office workers from a variety company, we have acknowledged the desire for a plastic cup for the desk workers.

4.2.1 Product desire volume

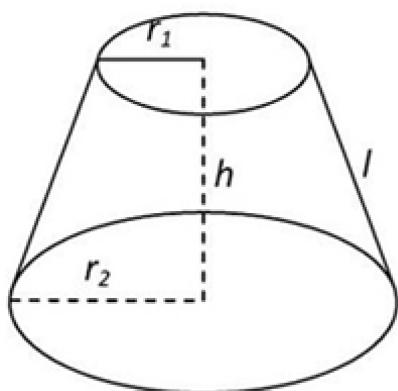
- People often intentionally drink a lot of water in the morning and they usually choose a plastic cup with a volume of around 500- 580ml, This amount of water can be used for about an hour and a half to two hours, with such a reasonable amount of volume, office workers and students can reduce the time spent getting out of their seats and going to get water.

- Through many ergonomic studies, scientists have proven that in order for a person working at a desk to maintain a stable concentration and relaxation of muscles, it is recommended to take a short break and do some stretching or light exercises to promote blood flow and reduce the risk of developing health issues related to prolonged sitting. So, a small walk to refill the cup full of water can help you hydrate and relax in a short time to gain more effective concentration in work as well as study.

- So based on the above desire for the cup I calculate the ideal parameter of the plastic cup as below:



- For the brim radius of the cup: 45mm
- For the height of the cup: 121mm
- For the bottom radius of the cup: 33 mm



$$V = \frac{1}{3} \pi (r_1^2 + r_1 r_2 + r_2^2) h$$

Based on the formula, the actual volume of the cup will be 582 mL. This size fits our scope for the target audience, which includes students and office workers.

4.2.2 Product Design Shape

- Plastic cups with lids are also a great solution for keeping your workspace dry and free from accidental spills. Consider investing in a reusable plastic cup with a secure lid to keep you hydrated without risking damage to your work materials.
- The design of the plastic cup will include a handle to make it easier to hold. This will limit contact with the cup when it may contain boiling water or steam condensation on the side, thereby avoiding burns and preventing hands from getting wet. Wet hands could damage a stack of papers or cause accidental spillage due to the heat. These small details can save a day of hard work.
- Regarding the design of the plastic cups, they will be transparent to increase aesthetics and allow for easy quantification of the remaining water level. This not only helps with active hydration, but also enables users to identify any foreign objects in the cup, such as insects, dirt, or unusual watercolor.
- To promote the school's reputation, plastic cups with the school's logo can be used by students to show uniformity and highlight the school's signature. These cups can also serve as a souvenir for students, exchange students, and visitors.



Figure 4-1: Product concept of 3D plastic drinking cup.

No	Parameter concept	Plastic cup
1	Density (D)	0.91g/cm ³
2	Mass (m)	580g
7	Volume (V)	582ml
3	Thickness	2 mm
4	Mold Shrinkage Rate (%)	1.6 %
6	tolerance	±0.57

Data Table 4-2: Product parameters

4.2.3 Mold Cavities.

- When designing a mold for a plastic cup, it can be helpful to refer to information from small and medium enterprises that produce household appliances. This information can aid in calculating the number of cavities needed in the mold to optimize the design and production process. Calculate data:

- Quantity: 55,000 (pieces/year).
- The goal is to produce a product in 40 seconds, during an 8-hour workday, for approximately 300 days per year.
- The estimated amount of waste is 5%.

We have the formula: $n = \frac{L \cdot K \cdot T_c}{T_m} = \frac{55000 \cdot 1 / (1 - 0.05) \cdot 40}{8.3600 \cdot 300} = 0,2625$
(number of cavity)

Symbols and unit:

- n: Minimum number of cavities in the mold
- L: Number of products in a product batch
- K: Waste-scrap coefficient (%) [K = 1/(1-k)]
- k: scrap rate (depends on each company) (%)
- Tc: cycle time for injection (s)
- Tm: Time required to complete 1 batch of products (days)

⇒ We can choose to design the mold with 1 cavity.

4.2.4 Locate the injection port.

The designer has two options to locate the injection port: choose by experience or use the Easy Fill Advanced Environment in NX software.

Based on the size, parting surface, volume, and position of the nozzle of the product, a 3-plate mold was chosen for the analysis position above. The 3-plate mold has the advantage of a lower mold cost and less plastic material; otherwise, we would have to add labor to cut the injection port.

4.2.5 Layout of the mold cavity.

Due to the calculation is the single cavity, we can set the mold lay out for the core plate and cavity plate like below figure:

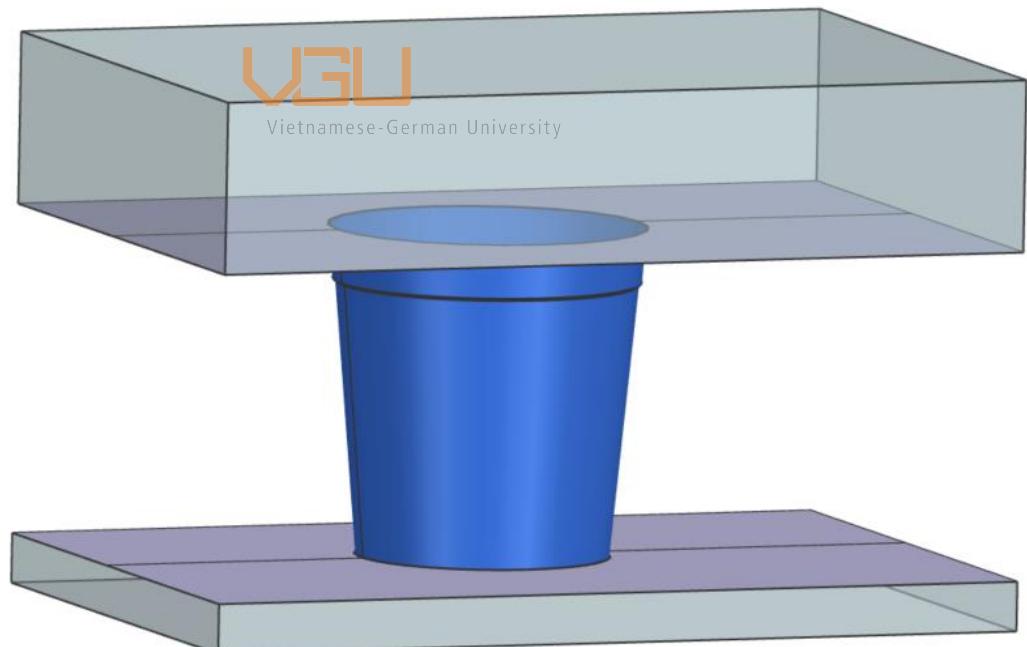


Figure 4-5 : lay out of the mold core and cavity.

The product has the physical parameter: 45*121*33

- Parameter of Core plate: 150*210*40.
- Parameter of Cavity plate: 150*210*40.

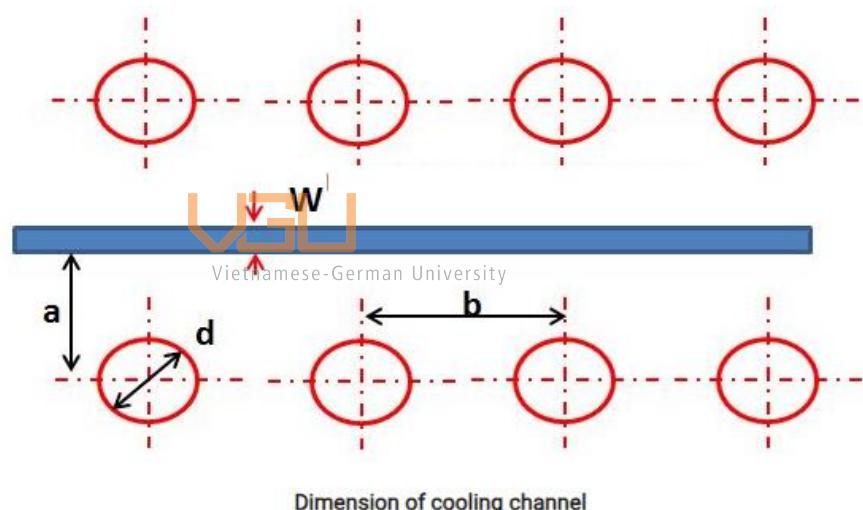
4.2.6 Design for the cooling system

❖ Purpose:

- Keep the mold at a stable temperature to ensure even cooling of the plastic material.
- Rapid cooling should be avoided to prevent deformation and waste.
- Reducing cycle time can increase production capacity.

❖ Dimension of cooling channel:

It is suggested that the thicker the cooling channel is the thicker the wall. The following picture illustrates this relation.



W: thickness of product (mm)	2 mm	2~4 mm	4~6 mm
d: Diameter of cooling channel (mm)	8~10 mm	10~12 mm	12~14 mm
b: Distance between two cooling channels	2~3d		
a: Distance from cooling change to product	2~2.5d		

Picture 4-6: Parameter and position of cooling channel .

- ✓ $W = 2 \text{ mm}$ (actual thickness of the product 1.8mm)
- ✓ $d = 8 \text{~} 10 \text{ mm}$. Choose $D=8 \text{ mm}$.

- ✓ $a = (2\sim 2,5) \times d = (2\sim 2,5) \times 8 = 16\sim 20\text{mm}$.
- ✓ $b = (2\sim 3) \times d = (2\sim 3) \times 8 = 16\sim 24\text{ mm}$

We have a channel diameter of 8mm, so the minimum water flow $Q = 2.84$ (liters/minute)

❖ Product cooling time:

Cooling time is affected by the following factors:

- Product thickness
 - Melting temperature of plastic
 - Mold temperature
 - Coolant

We have the formula to calculate the cooling time:

$$t_c = \frac{h^2}{a_{eff} \times \pi^2} \times \ln\left(\frac{4}{\pi} \times \left(\frac{T_{melt} - T_{mold}}{T_{eject} - T_{mold}}\right)\right)$$

In which: h The product thickness: $h = 2,0 \cdot 10^{-3}\text{(m)}$

T_{eject} The assigned part ejection temperature: $T_{eject} = 65^\circ\text{C}$

T_{mold} Mold temperature $T_{mold} = 40^\circ\text{C}$

T_{melt} Injection melt temperature: $T_{melt} = 180^\circ\text{C}$

a_{eff} Thermal diffusivity $\alpha = 0,096\text{ (mm}^2/\text{s)}$

Material	Thermal Diffusivity (mm ² /s)	Thermal Diffusivity (mm ² /s)
PP (Polypropylene) at 25 °C	0.096×10^{-6}	0.096

Based on the above data we have the cooling time for product as below:

4.2.7 Propulsion system.

There are many ways to get products such as:

- + The worker will take the product, inspect the product, and cut the glue tail after each injection molding cycle. Usually applied to large products, difficult to arrange the ejector system in the mold, or the operator needs to carefully check the quality of the extruded product.
- + Apply automation like robot arms.
- + Use product push system (best practice)

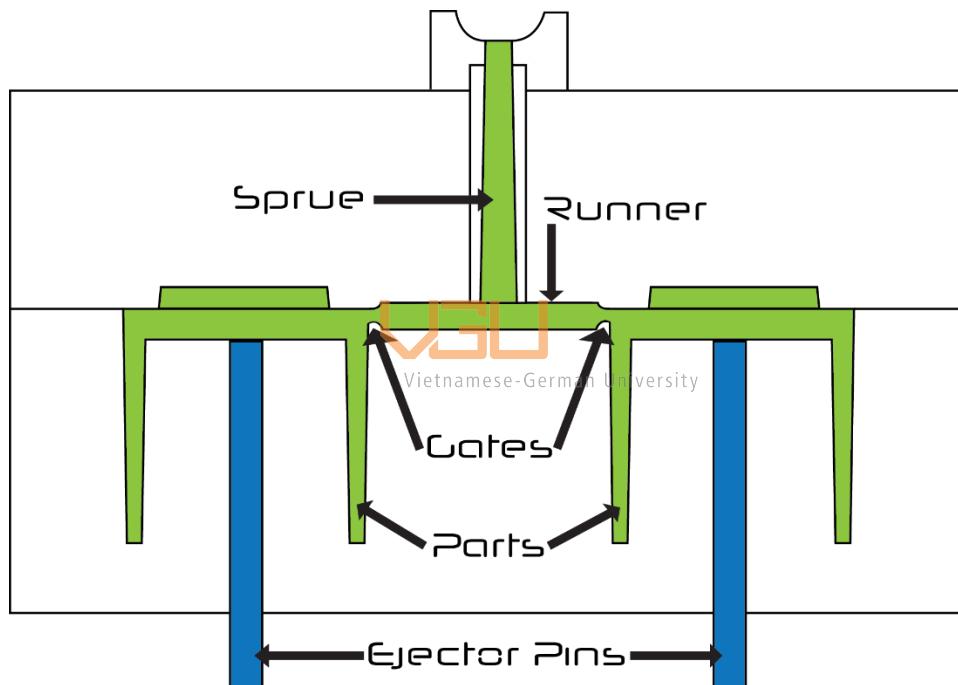


Figure 4-7: relation and position of Propulsion system

❖ Concept of Mold eject product:

After the product in the mold has cooled, the mold is opened. At this time, due to the vacuum, the product is still stuck in the mold. After cooling, the product easily shrinks, so a push system is needed to push the product out.

The ejector pin hardness is about 40-45HRC. It is precision machined and installed according to the shaft system and has good wear resistance. Since

the injection molding process cycle is very small, the guide bearing does not have self-lubricating properties, so it should be worn easily, to get a long service life it will need to be often maintained.

By this method, the product can be removed easily without affecting the shape or aesthetics of the product.

❖ General principles:

After the plastic material has been filled into the mold cavity and gone through the cooling process, the press will open the mold. The machine's push shaft will push the two sides of the mold and begin to eject the product by many related components like using ejector pins, ejector blades, ejector tubes, release plates, and other details. The product is then released and separated from the mold cavity.

During the ejection process, the ejector plate compresses the mold spring. When the push shaft of the press returns to its original position, the force acting on the push plate is no longer there. At this time, the spring compression force will help the push plate return to its original position, return pins have play the main role in this process.

❖ Sprue bushing design and function

Every mold has a sprue. This is the contact point between the machine and the mold. The sprue has a concave spherical seat where the molding machine nozzle tips seats off. It is important that the nozzle tip and the sprue seat have the same radius. If they do not mate properly, then the material will leak at this point and parts will be inconsistent. From here, the molten plastic travels through the sprue where it enters the runner system. There are exceptions, on large parts the sprue can also act as gates and runners. This is called direct sprue gating.

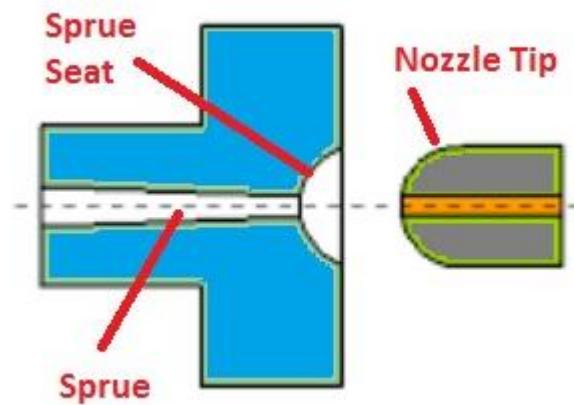


Figure 4-7.1: relation and position of Sprue and Nozzle tip

The size of the sprue depends on several factors, including the volume of material needed for the product, the thickness of the product's walls, and the type of plastic material used. The sprue length must match the thickness of the mold plates, and it is designed to have a reasonable length so that the plastic flow will not lose pressure along the way.

❖ Sprue calculation:

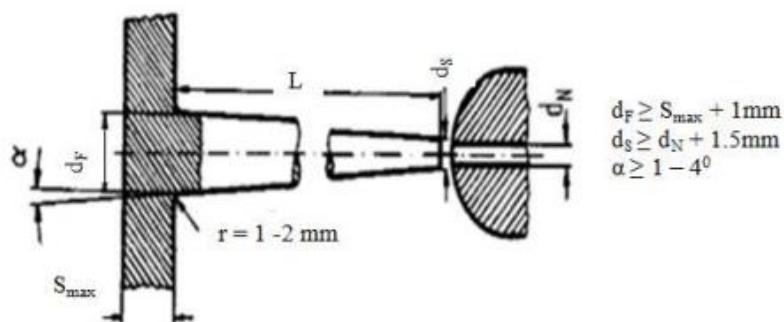


Figure 4-7.2: Sprue specification

We have $S_{max} = 2mm$, $d_N = 1mm$, $\alpha = 1 - 4^\circ$

$$\Rightarrow d_F \geq S_{max} + 1mm \geq 3mm$$

$$d_s \geq d_N + 1.5mm \geq 2.5mm$$

We can follow the sprue standard to have $d_F = 6\text{mm}$, $d_s = 3\text{mm}$, $\alpha = 1^\circ$.

❖ Gate

Due to the product structure and the mold design is single cavity, we can choose the direct injection gate - sprue gate. This type of gate is one of the most popular that you can see used for the most simple molding. The main purpose of this gate is let the sprue feeds the material to cavity molds directly with minimum pressure drop.

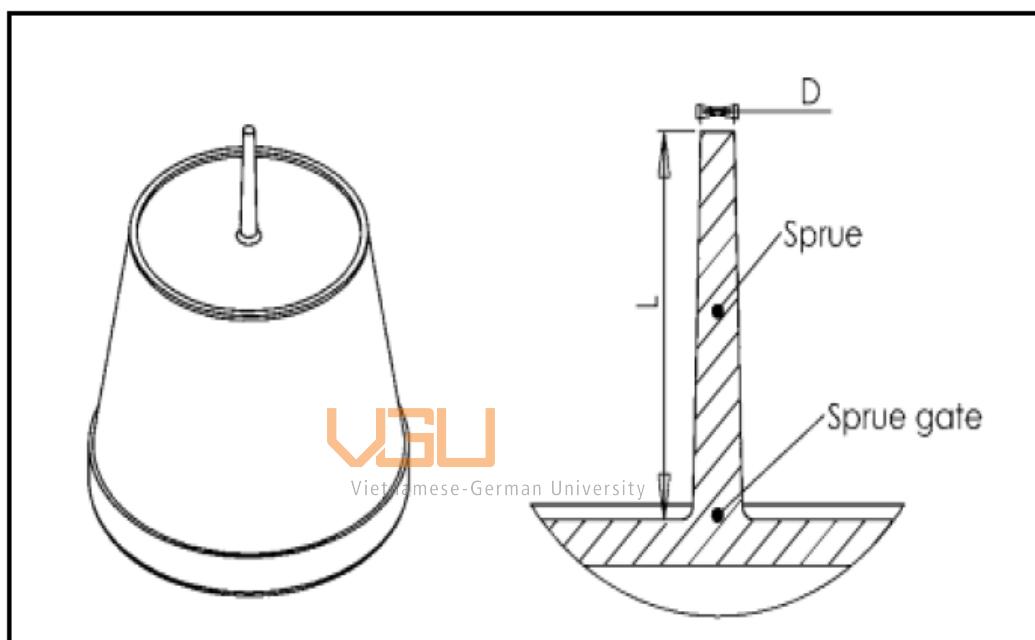


Figure 4-7.2: Sprue gate design concept

For the calculation: Sprue diameter is depend on nozzle of injection

The diameter of the sprue orifices must be 1-2 mm larger than the nozzle exit one.

In order to make the product demolded easier from cavity, it is suggested to give taper at the sprue from orifice diameter to produce about 1-3 degree.

In general the diameter of the gate much greater than the thickness of the product

❖ Calculation of propulsion system:

- Ejector space

After the product is removed, the ejector system must return to its original position to avoid the ejector pin damaging the mold cavity. Therefore, the return pin is needed. The return pin and ejector pin are located on the push plate. The push plate is under great pressure, so the push plate must also have an appropriate length.

The push-in distance should be 5-10 mm greater than the height of the product removed from the mold by the following mold in the direction of mold separation. However, the push distance should not be too long, and the ejector pin should not be too small, as pushing too far can weaken the propulsion system.

Product surface (cm ²)	Ejector plate thickness (mm)
5	12
10	15
25	20
50	30
100	50

4-7.2 : Ejector pin standard board

b) Push Pin

Products with high walls or deep ribs stick tightly in the mold, so push pins must be placed near these locations to easily push the product out of the mold. The farther the pin location is from these ribs, the weaker the force is on it and there is a risk of piercing the plastic surface at the push pin location before the product exits the mold.

For flat and compact products, we choose straight round push pins.

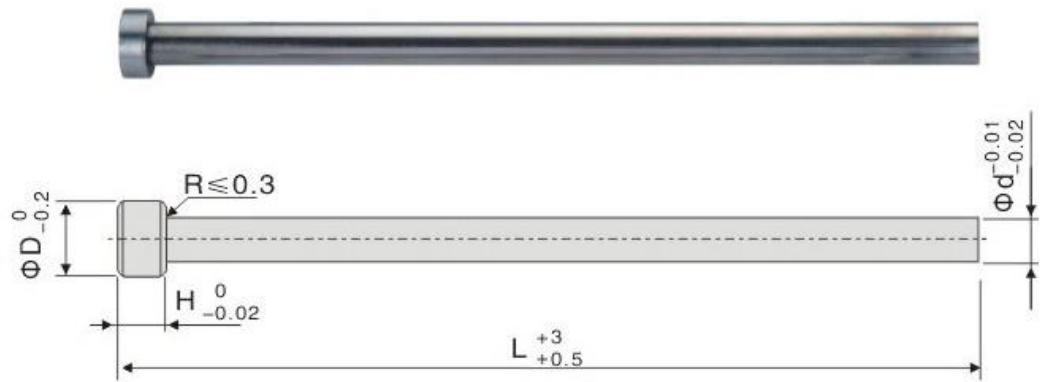


Figure 4-7.3. Straight round push pin standard

4.2.8 Air release system in plastic injection molds.

❖ General principles:

There is always air inside the mold, which needs to be expelled when the plastic fills the mold. This air must be released quickly during the filling process. Therefore, the  exhaust system provides multiple paths for the air trapped in the mold cavity to escape quickly and easily. The design of the exhaust system needs to allow air to escape easily, but not allow molten plastic to pass through.

Note that if the exhaust system is not designed properly, the air will not be released quickly enough, and the plastic will become trapped. This can cause air pockets, burn marks, weld line and short shot in the finished product, which weaken the product and make it more likely to fail.

❖ Defect types on plastic products:

- + Air Pocket

Reason: The raw material has high moisture content but is not dried before being put into plastic injection, leading to the formation of air bubbles in the flow and shaping inside the product.

The plastic pouring port, injection stem, and processed plastic channel have low gloss, are rough, and easily form air bubbles when molten plastic

passes through. Any air bubbles can mix into the flow and form into the product wall or product exterior.

The plastic mold design is not optimized to allow air to escape through the channels and poor venting may keep the air inside the mold, leading to air blockage.



Figure 4-8.1. Abnormal cosmetic of the products

+ Short shots

A short shot occurs when a plastic injection molded component is incomplete because the molten plastic has not filled the entire mold cavity. In other words, there is a portion of the part where there is no plastic. Create the products abnormal appearance. Abnormal cosmetic of the products.

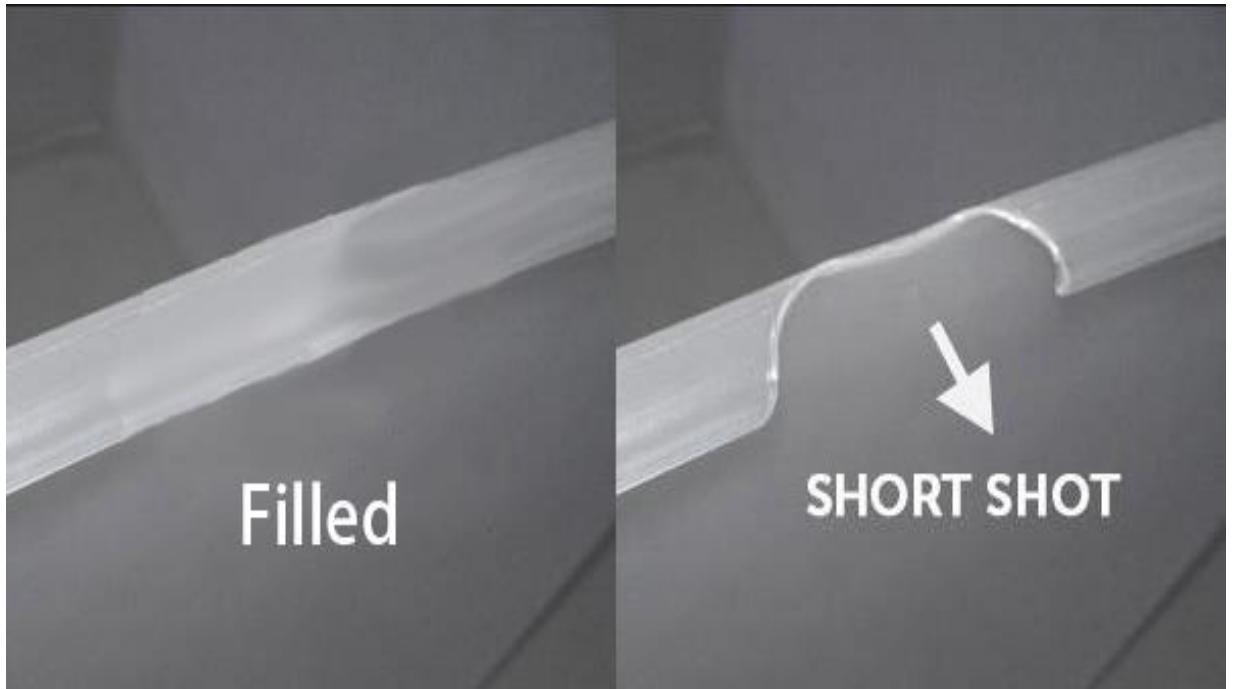


Figure 4-8.2 Short shot product.

❖ Type of air vent:

- + Vents on Parting Plane
- + Vents around Ejector Pins
- + Vents in Dead Pockets.
- + Vents through the cooling system...

❖ Vents on Parting Plane

The first choice for an air outlet is to place it on the parting surface because it is easy to process and clean. These grooves are the bridge between the mold cavity and the outside environment, helping air escape from the mold cavity.

The structure of the air vents on parting plane consists of two parts: the leading groove and the exit groove. The leading groove is located near the injection point and helps guide air to the exit groove. The exit groove is located near the end of the mold cavity and provides a path for the air to escape from the mold. These grooves should be designed to be as short and straight as possible to help the air escape quickly and efficiently.

❖ Leading groove (vent channel):

located at the beginning of vent and near the mold cavity. It must be designed to prevent material from flowing into the vents during the filling process. The depth at the beginning of the leading groove is usually small to prevent molten plastic from flowing out. The depth required may vary depending on the viscosity of the plastic being used. In this case the Plastic we used is the PP the vent thicknees will be 0.015 mm (d)

Plastic	Glanvill (1965)	Rosato (1986)	Menges (2000)
Low viscosity materials: PP, PA, POM, PE	0.08	0.1	0.015
Medium viscosity materials: PS, ABS, PC, PMMA	0.2	0.3	0.03

4-8.3. Recommended vent thicknesses (mm)

The width of the groove has no limit but is usually in the range of 3.175-12.7mm,
→ W= 4 mm



The length of the groove from the: $0,762\text{mm} < L < 3,175\text{ mm} \rightarrow L = 3.5\text{mm}$

We have guide grooves placed around the part, the total circumference of the vent channel = 30% of the part circumference.

$$n * C_{\text{vent}} = 30\% * C_{\text{part}}$$

We have n = the numbers of vents, C_{vent} : circumference of the vent channel, C_{part} : part circumference

$$+ C_{\text{vent}}: 2 * (L + W) = 2 * (3.5 + 4) = 15 \text{ mm}$$

$$+ C_{\text{part}}: 2 * R * \pi = 2 * 33 * 3.14 = 207.24 \text{ mm}$$

$$n = 30\% * 207.24 / 15 = 4.148$$

So the numbers of vent channel will be 4 vents

❖ A relief slot, or exit groove, is designed to allow air to escape from the vent. It should have a depth and width greater than the vent channel to

reduce pressure and allow air to escape completely. The recommended size for the relief slot is usually 20 times the depth of the vent channel.

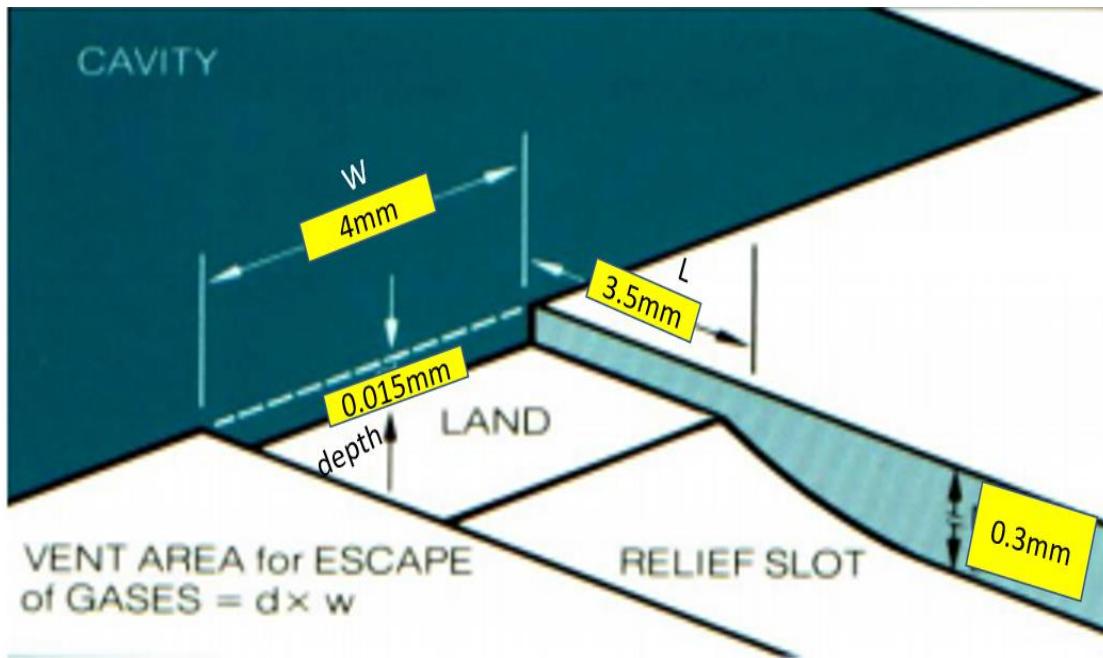


Figure 4-8.4. Design vent on parting plane

4.2.9 Mold guiding and locating system.



The main function of the guide pin and guide bush is to align the rear mold with the front mold. The guide pin is located in the mold core plate and the guide pin is located in the mold cavity plate

The length of the guide pin must be longer than the highest part to avoid damage during mold closing, especially during assembly.

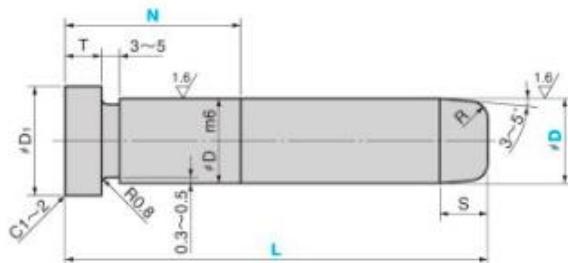
For the guiding pin material we can use SUJ-2- this type of steel is very common used in injection molding, especially for the guiding pin due to its wear resistance.

Guide Pin

FLANGE TYPE

RoHS

RGPA



Material : SUJ2
 (B1 52100)
 Hardness : HRC58 or more
 Induction Hardened

D	D m6	T	D1	S	Catalog No.	D	L (Increments of 5mm)	Press fit area N (Increments of 1mm)
20	20		25			20	75~200	8~100
25	-0.020 -0.033	25	30			25	105~300	8~120
30	30		35			30	130~350	8~130
35	35		40			35	155~400	
40	-0.025 -0.041	40	45			40	155~450	10~200
50	50	12	55	8		50		12~200



Order

Catalog No. RGPA D L N
 RGPA 25 - 200 - 50

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Figure 4-9.1. Guide Pin specification

We select the guide pin size according to mold shell standards:

D=25mm, D₁=30mm, L= 130 mm

Guide Pin quantity: 4

4.2.10 Mold making materials.

The following requirements are the basic standard and the design concepts of choosing the right mold materials:

- Mold durability, surface quality when machining the material
- The type of plastic will be sprayed into the mold, because there are types of plastic that are harmful to the mold cavity

- Number of products according to demand
- Abrasion resistance and corrosion resistance
- Deformation during heat treatment
- Calculating cutting technology
- High aesthetics.
- Low price

For our mold shell we would choose the SC45 steel- due to it's durability from the wear resistance characteristic of this steel, and this is the common material that may mold shell apply. For the mold cavity we will use P20 steel, this type of steel is in one of the common material apply in mold cavity design because of it magnificently versatile, low-alloy tool steel that is characterized by good toughness at moderate strength levels.

4.3 Choose plastic injection machine.

An injection molding machine is a vital tool in the process of plastic production, which functions by injecting molten plastic into a mold's cavity. This molten plastic, when in liquid state, possesses a high degree of memory, and applying the appropriate injection pressure is essential to fully fill the mold's core. This pressure acts on the core's contact surface, exerting a force that tends to displace the movable plate from the fixed one. To counteract this, pressure is applied onto the mold. The machine's pressure has to be greater for larger molds to prevent the movable plate from being pushed out during the filling of the mold cavity.

Therefore, choosing the right machine with the appropriate pressure is crucial, as it optimizes both the design process and the investment in machinery.

For plastic products, surface quality and shape accuracy are two crucial considerations. The main factors influencing these two parameters are pressing force (F), working stroke of the pressing screw (L), pressing speed (Q), and the duration of one working cycle of the pressing screw (t). These parameters must be calculated and selected according to the machine's operating criteria and the

press screw parameters to achieve the required surface quality and shape accuracy.

Plastic type	Injecting pressure (kgf/cm ²)	Plastic temperature(°C)	Mold temperature(°C)
Polyetilen(PE)	600 – 1400	180 – 300	15 – 75
Polypropylene(PP)	600 – 1400	200 – 300	40 – 60
Polyvinylchlorid(PVC)	1000 – 1500	150 – 180	35 – 65
Polystyren(PS)	700 – 1700	180 – 315	20 – 60
Polycarbonat(PC)	800 – 1500	280 – 320	82 – 125
Acrinitrile butadienstylen(ABS)	700 – 1500	200 – 280	40 – 85
Polyamid(PA)	800 – 1500	230 – 300	20 – 90

4-3.1 Pressing properties of some types of plastic

The press force is determined as follow:

$$F = p \cdot A_{\text{inter}}$$

We have : $p = 600 \text{ kgf/cm}^2$

$$A_{\text{inter}} = 2 \cdot 10,6 \cdot 6,95 = 147,34 \text{ cm}^2$$

$$\Rightarrow F = 800 \cdot 147,34 = 117872 \text{ kgf} = 120(\text{ton})$$

Because the pressing force is 120 tons, we choose the Haitian HtF-120X press with the parameters

CHAPTER V. MOLD DESIGN ON NX 12.0 SOFTWARE AND ANALYZE THE RESULTS

5.1 Mold design using Unigraphic NX12.0 software.

5.1.1 Mold separation using the Mold Wizard mold design environment in Unigraphic NX software.

To create the mold for the plastic cup, follow these steps:

Open the 3D model interface of the plastic cup product built in Chapter 4.

Navigate to the Mold Wizard mold design environment.

In Mold Wizard, you will find a material library system and a library of available mold components. Select the appropriate materials and components for your mold.

The software will automatically calculate and update the corresponding shrinkage coefficient based on the selected materials.

Ensure that the mold is created with the correct shape and dimensions, and that the designed product is not deformed or lacking in size.

Please note that it is important to consult with a professional in the field of mold design to ensure the accuracy and quality of your mold.

When designing plastic cup products, we recommend using PP (Polypropylene) plastic material with a shrinkage rate of 1.6%.



Figure 5-1: Mold Wizard toolbar.



In the Mold Wizard, initially select the icon to create the project and select the material.

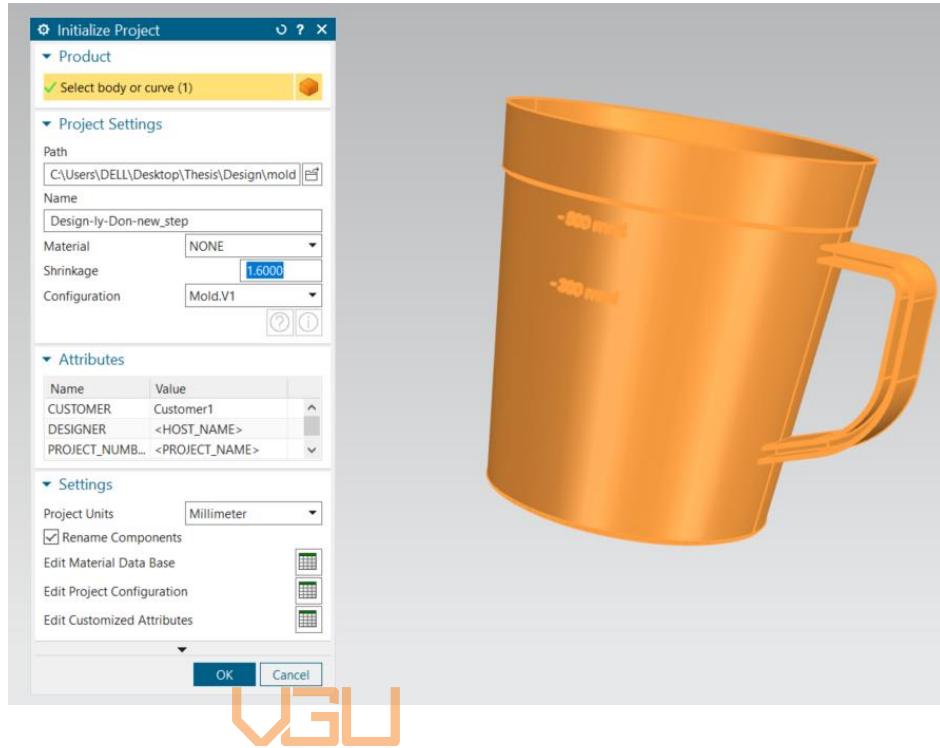


Figure 5-2: Create the mold project and choose the shrinkage.

Choose (Mold CSYS) Choose the origin coordinate and direction of product withdrawal. Click on Product Body Center and Lock Z Position.

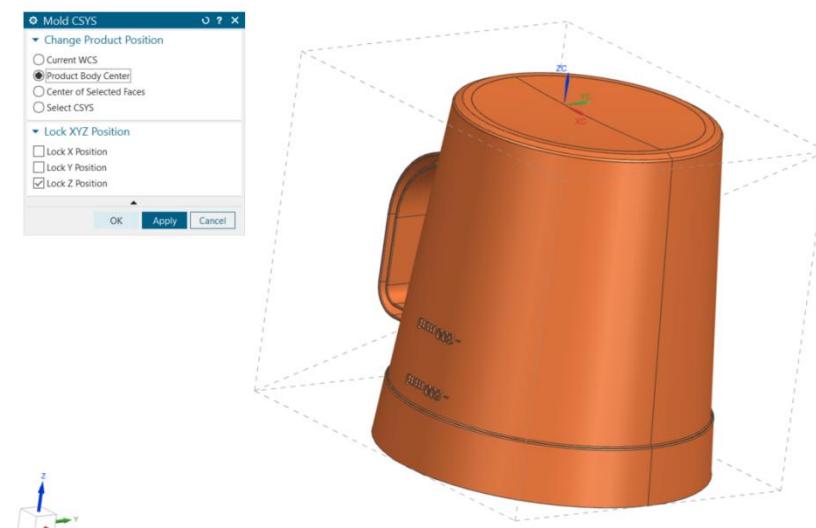


Figure 5-3 : Choose the origin and product eject gate

Choose  (Shrinkage) Multiply the shrinkage factor of the product.

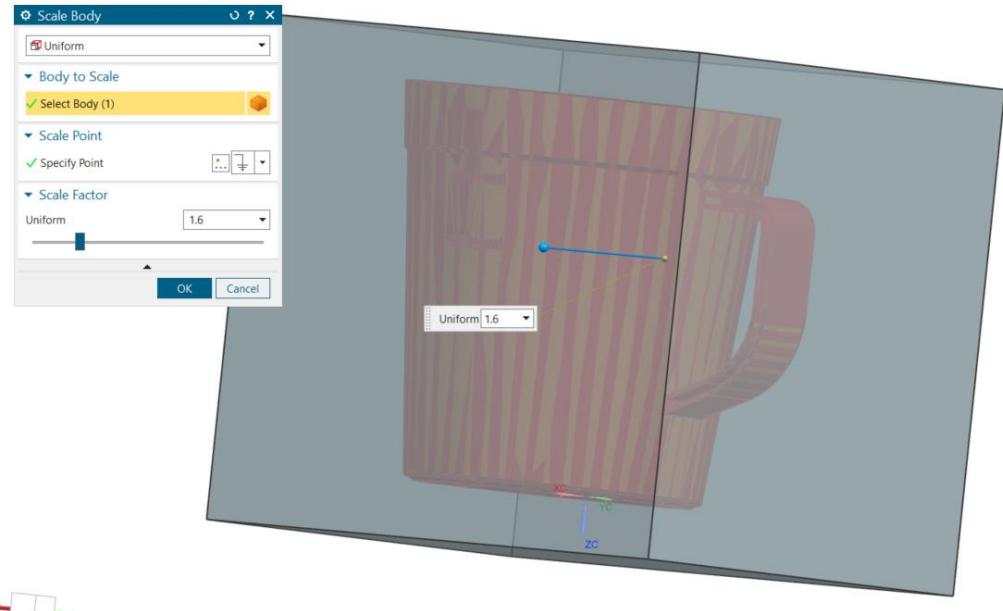


Figure 5-4 : Set The shrinkage rate =1.0016 .

Choose  (Workpiece) Create X, Y, Z envelopes for the Mold Plate

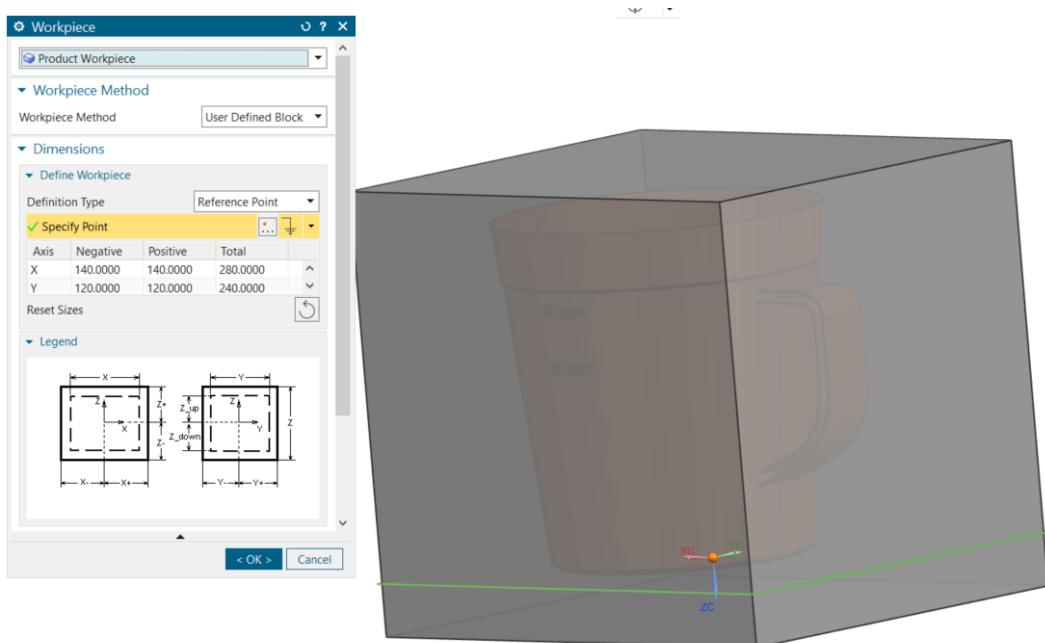


Figure 5.5 : Workpiece (X, Y, Z) for the mold.

Choose  (Check regions)/Calculate-NX will help to calculate the parameter and shrinkage direction based on the Z+

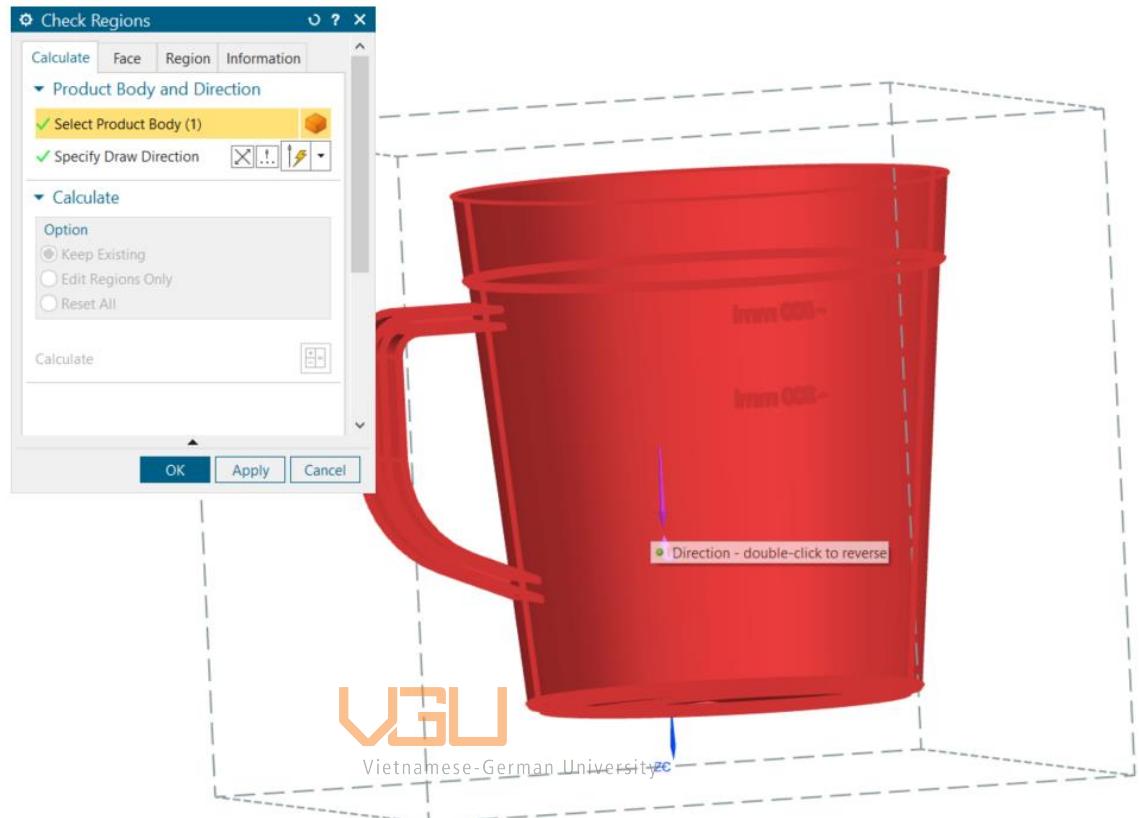


Figure 5-6 : Preliminary calculation of products..

Next step we choose this symbol  (Check regions) and click on Face category, to check the draft angles of product surface and undercut area.

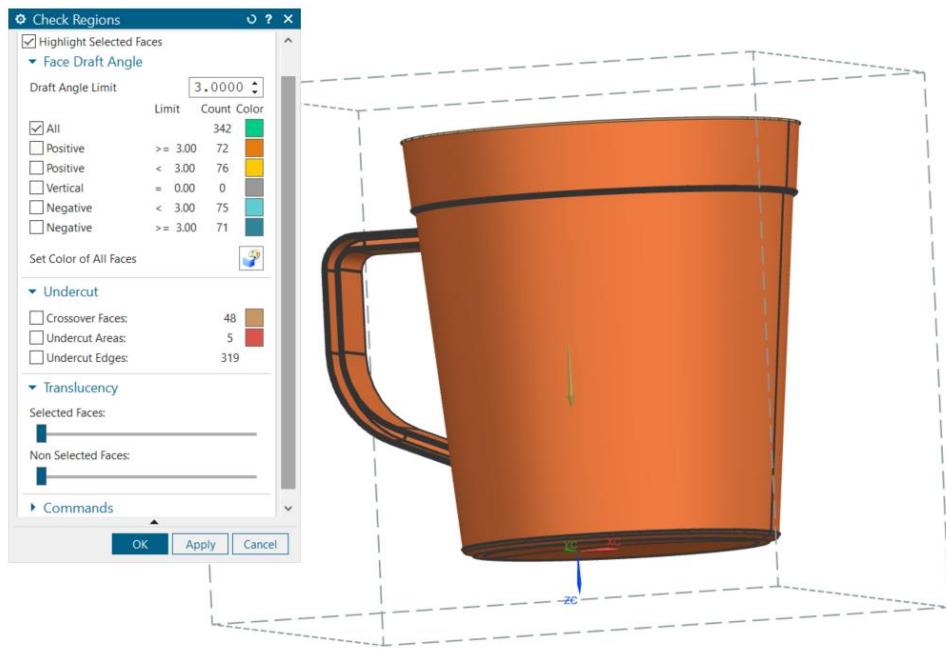


Figure 5-7 : check the draft angle of the product.

After check the product Face we continue to check Regions by click on  (Check regions) and choose the Regions category, this will help the users to identify which area belong to the Cavity Regions and Core Regions.

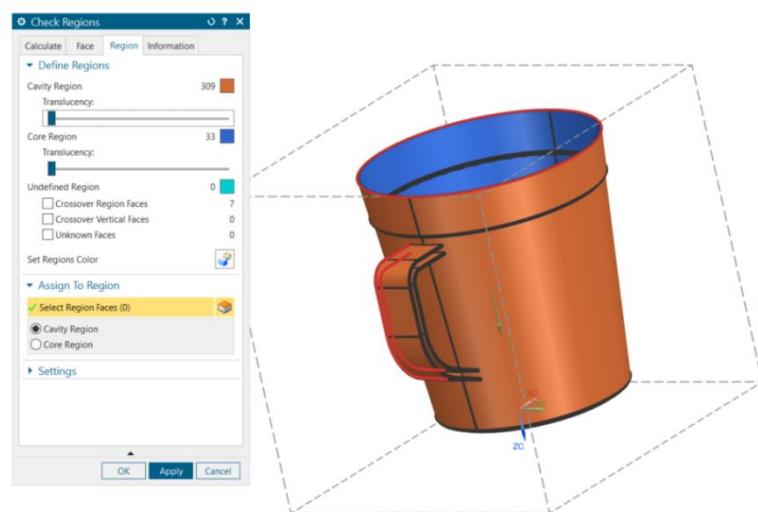


Figure 5-8 : Divide product aspects into Cavity Regions and Core Regions.

Choose symbol  (Define Regions) this will help to create parting lines and slide positions (if any).

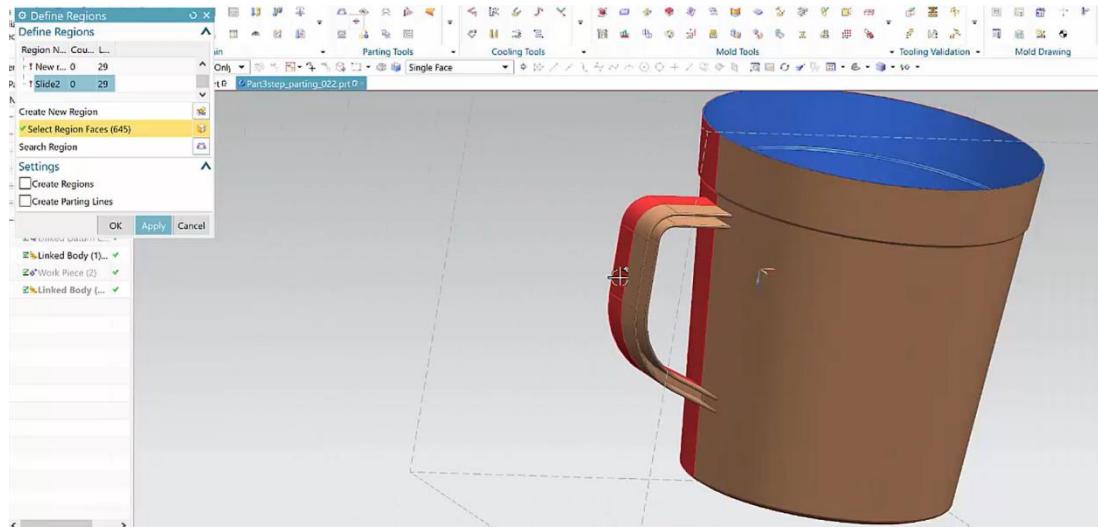


Figure 5-9 : parting line sketch .

Choose  (Design parting surface) this category will help designer pick the rational parting surface of the product

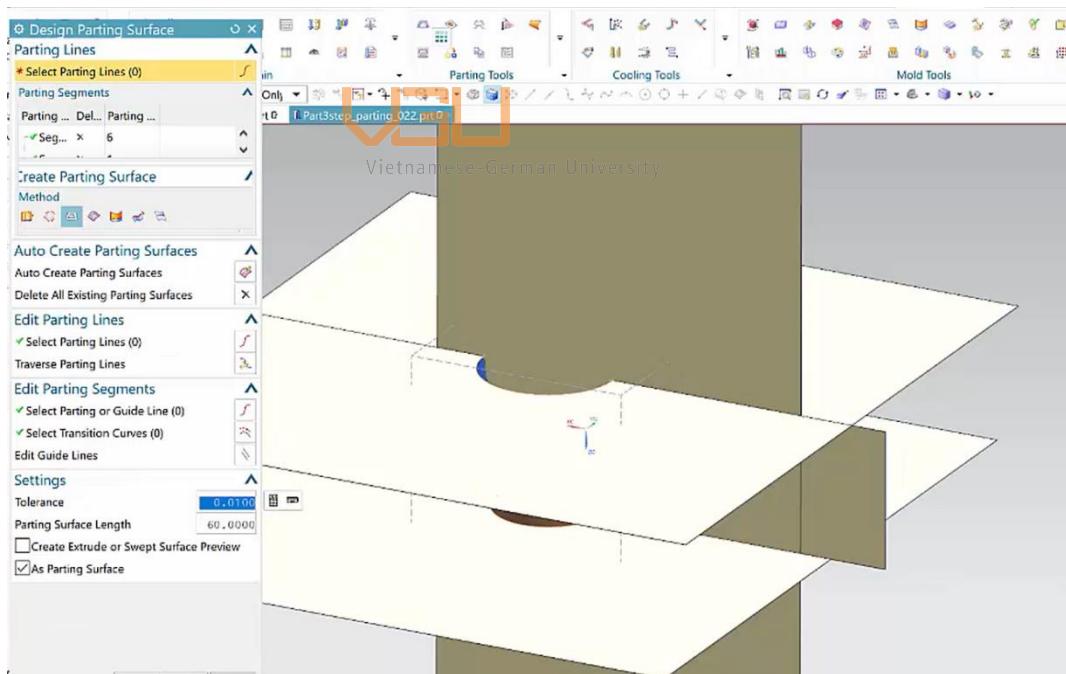


Figure 5.10 : Create parting surface for the product

 (Fill Surface) full fill the open area of the product

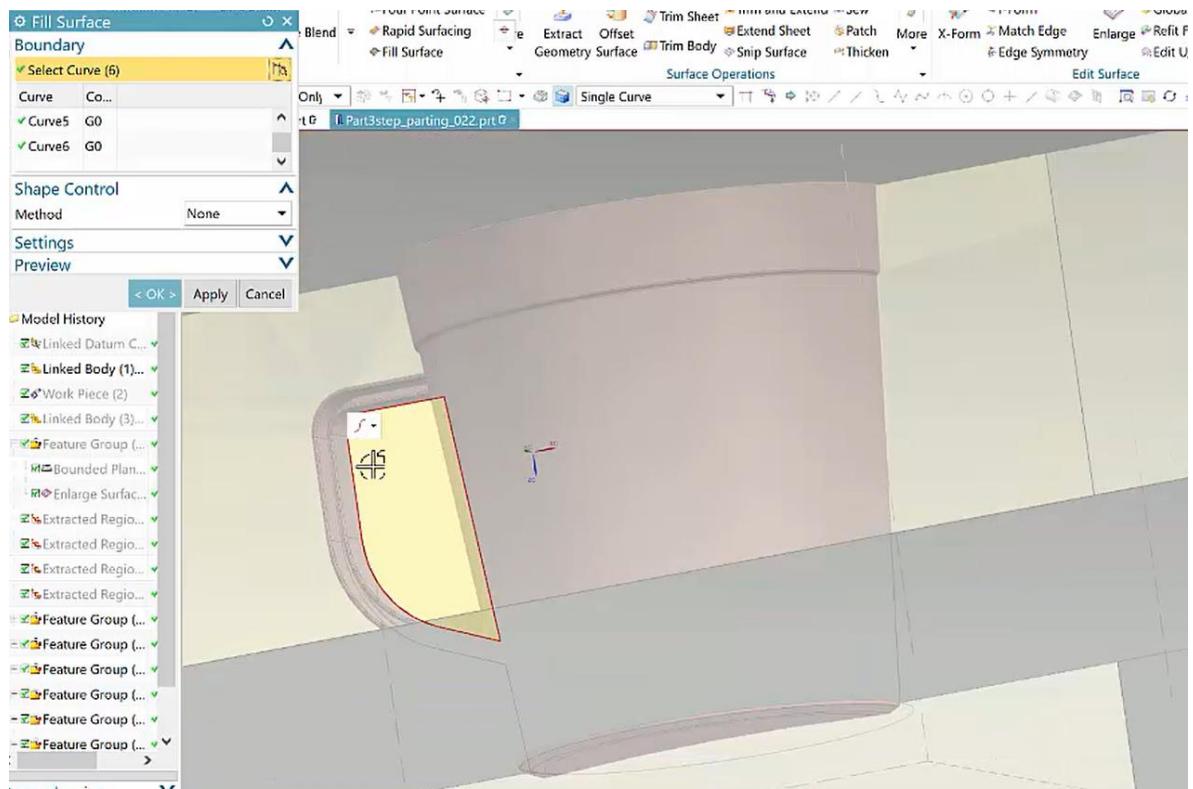


Figure 5-11: Fill surface apply on the open area of the product

Next we choose the  (Define Cavity and Core) this section will help to create the cavity and core of our mold design, for our product the cavity will have 2 slide this will help to solid our cup handle.

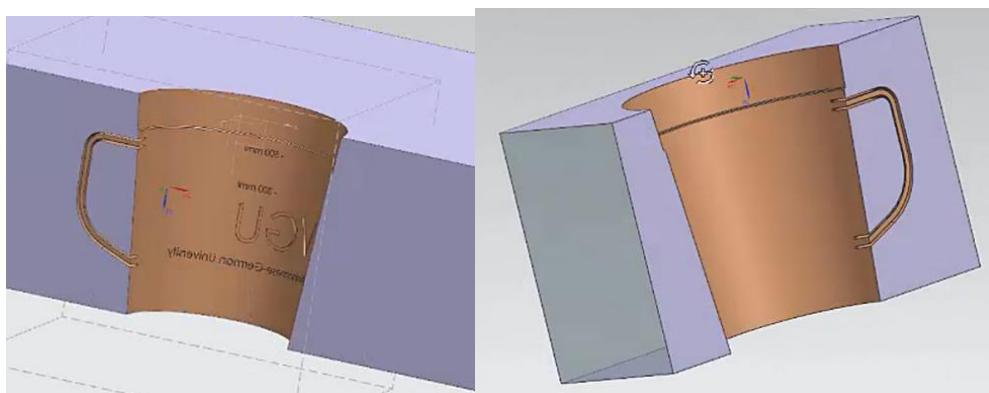


Figure 5-12: right side and left side of the cavity

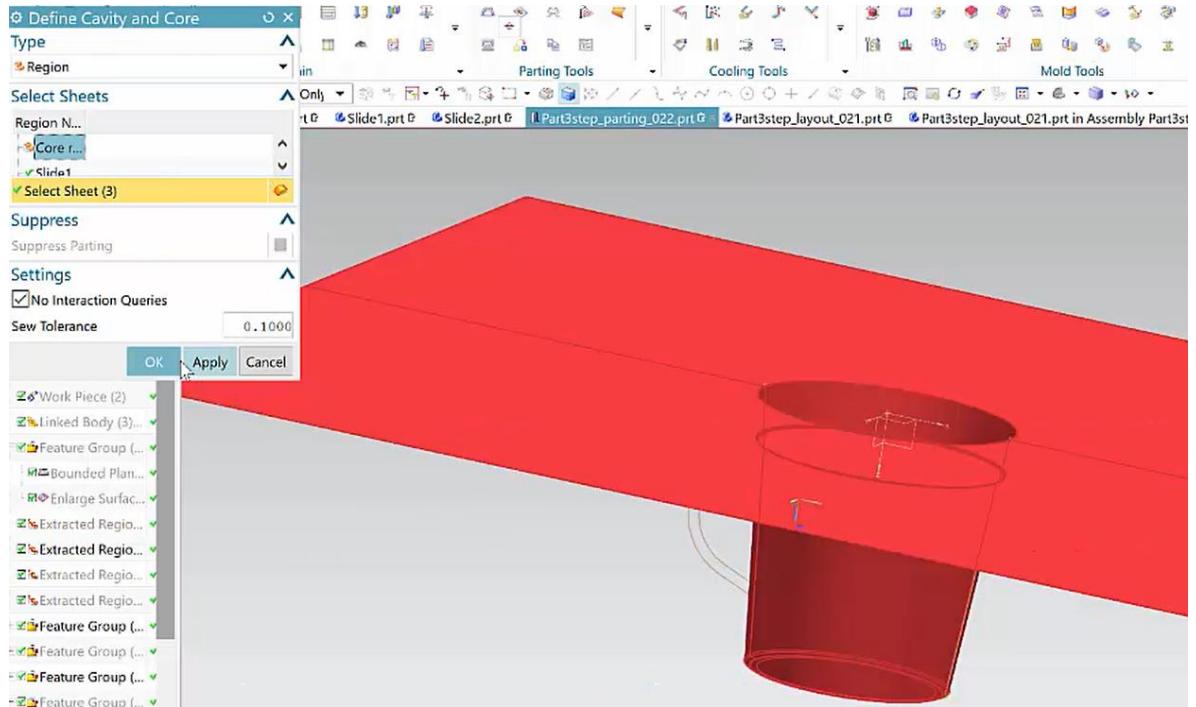


Figure 5-13: Core of the mold

5.1.2 Design a mold for product using Unigraphic NX software.



5.1.2.1 Design mold shell using Mold Base Library

In the Mold Wizard environment select (Mold Base library)/FUTUBA_DE

Select the mold size so that the mold shell does not affect the mold core and ejector pin positions.

We have the thickness of the static and dynamic mold cores as calculated as 40mm; 40mm respectively, so we give A=33mm; the product height is 121 mm, so the plate eject range should be 120mm,

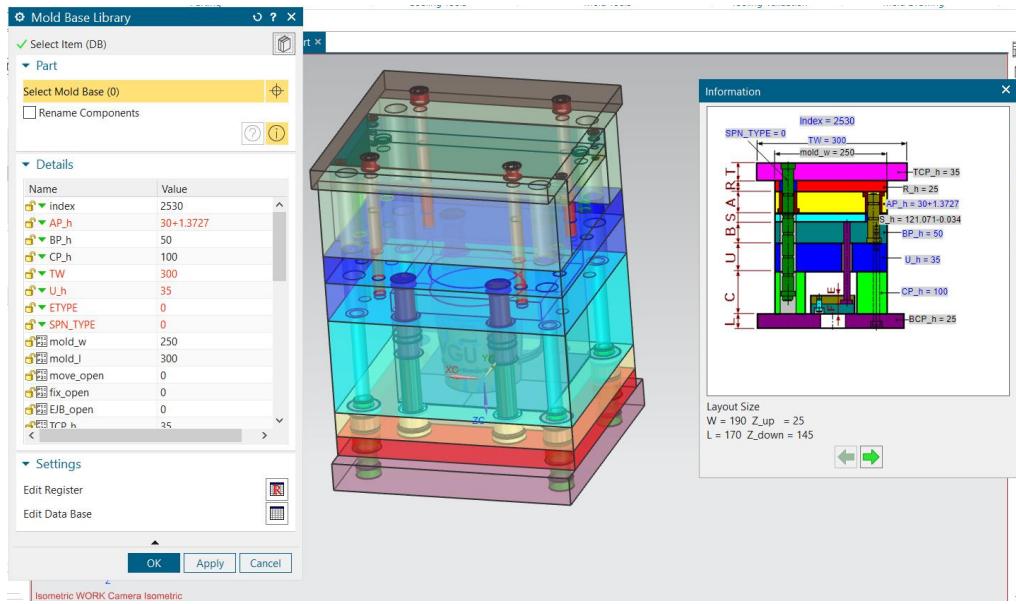


Figure 5-14: design mold base

Create a cavity containing a static mold cavity and a moving mold cavity:

Choose symbol  (Pocket) on the tool bar in Mold Wizard, remove the static mold block and the moving block of the surround surface of the mold core.

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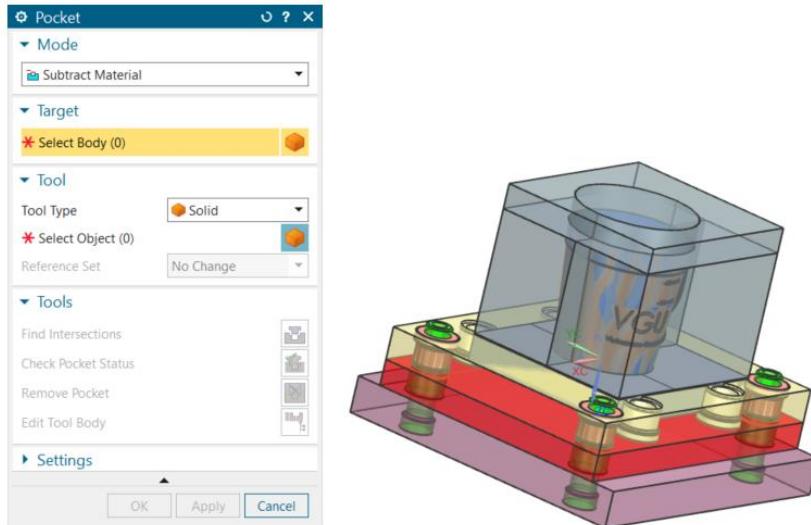


Figure 5-15: Create pocket for the mold

5.1.2.2 Design the Locating Ring, Sprue Bushing and Return Spring using the library Standard Part Library.

Choose  (Standard Part Library) on Mold Wizard tool bar, than search for the Misumi standard part catgeory.

Locating ring design: Select Locating Rings in the MISUMI folder. Select LRBS type and fill in the parameters: D=60mm;T=10mm.

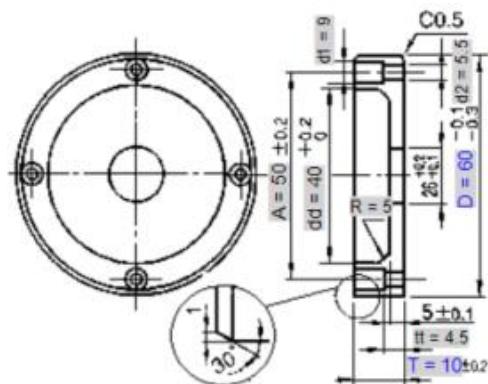


Figure 5-14: Locating ring parameter.

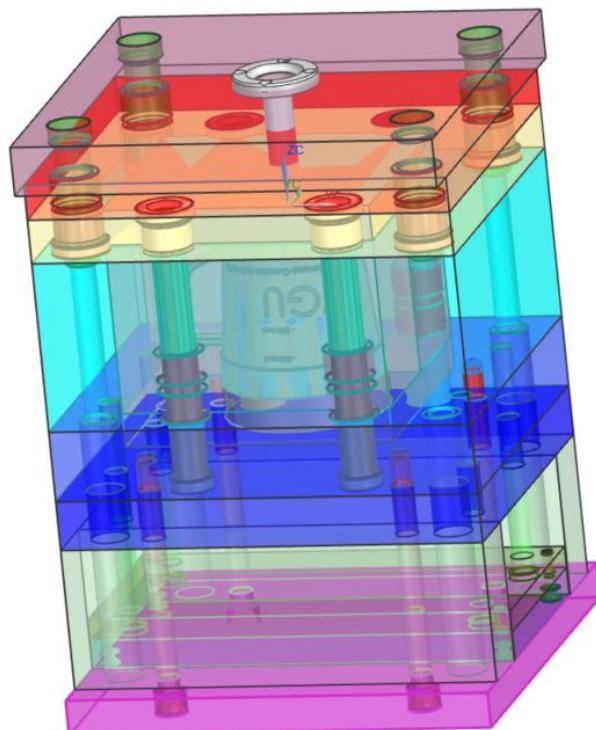


Figure 5-16: Locating ring design

Plastic bushing design: Select Sprue Bushings in the MISUMI folder. Select type and fill in the parameters: $d = \text{ mm}$; $P = \text{ mm}$; $A = {}^\circ$; $L = \text{ mm}$. When designing or choosing a sprue bush, the ball radius of the sprue should be bigger than the radius of the nozzle

Return spring design: Select Coil Springs in the MISUMI library. Select SWF style with the parameters $D=40\text{mm}$; $L=80\text{mm}$;;



CHAPTER VI. CONCLUSION

Thanks to the development of computers science and current software technologies that growth booming that lead to the mold design process is becoming easier, with higher accuracy and increased automation. Countries with advanced industries such as German, Japan, US , Taiwan... have developed a combined model that integrates various techniques and technologies to produce high-quality molds, catering to a wide range of technological fields. The model combines the use of advanced software for design and simulation, precision machinery for mold production, and stringent quality control processes to ensure the production of high-quality, reliable molds.

The thesis topic helps us understand clearly how plastic injection molding can be applied in manufacturing. It starts from releasing the product concept design to choosing the type of plastic material needed to create the product. From there, we can decide on the structure of the mold. The purpose of the thesis product is to be applied at VGU. This will enable both older and new university students to have something to remember and be proud of their university.

The graduation thesis has successfully accomplished the necessary tasks. Through this process, I have gained a more profound and extensive understanding of plastics, mold design, and the application of software in mold design and processing. However, due to my limited qualifications, practical experience, and research time, there may be unavoidable shortcomings. I eagerly anticipate the evaluations and suggestions of teachers and peers

REFERENCE

[1] History of injection molding, “Plastic Injection Molding: A Brief History”, 2023 [Online]. Available: <https://www.wundermold.com/what-history-plastic-injection-molding/> [Accessed: 27 10 2023].

[2] History of injection molding, “History of injection molding timeline”, 2023 [Online]. Available: <https://www.xometry.com/resources/injection-molding/plastic-injection-molding-history/> [Accessed: 27 10 2023].

[3] Plastic industry market news, 2022 [Online]. Available: <https://vpas.vn/thong-tin/ban-tin-thi-truong.html> [Accessed: 29 10 2023].

[4] Gelston, J. (2016) 8 tips for picking a gate location, 8 Tips for Picking a Gate Location. AIM processing. Retrieved from: <https://www.aimprocessing.com/blog/8-tips-for-picking-a-gate-location>.

[5] Food Grade Plastic: Which Plastics Are Safe For Food Storage, 2022 [Online]. Available: <https://www.palmetto-industries.com/safe-food-grade-plastic/> [Accessed: 02 11 2023]

 Vietnamese-German University

[6] Plastic injection mold cooling system design, 2019 [Online]. Available: <https://mechanicalengblog.com/plastic-injection-mold-cooling-system-design/> [Accessed: 02 11 2023]

[7] Mold material for plastics injection, 2018 [Online]. Available: <https://mechanicalengblog.com/mold-material-for-plastics-injection/> [Accessed: 03 11 2023]

[8] Plastic type and it's characteristic, [Online]. Available: <https://moldviet.net/Tai-Lieu/step8/index82.php> [Accessed: 03 11 2023]

[9] Beaumont, J.P. (2019) Runner and gating design handbook tools for successful injection molding. Munich: Hanser Publishers.

[10] Williams, J. (2019) Injection molding cooling time: A breakdown, Injection Molding Cooling Time: A Breakdown. Design World. [Online]. Available:

[https://www.designworldonline.com/injection-molding-cooling-time-a-breakdown/.](https://www.designworldonline.com/injection-molding-cooling-time-a-breakdown/)

[Accessed: 11 11 2023]

[11] Jackie (2020) The types of mold base for plastic injection mold, What Are the Types of Mold base? Ecomolding. [Online]. Available:

<https://www.injectionmould.org/2019/03/23/the-types-of-mold-base/>. [Accessed: 15 11 2023]

[12] 2 Plate Mold Or 3 Plate Mold: The Difference [Online]. Available:

<https://prototool.com/2-plate-mold-or-3-plate-mold/> [Accessed: 15 11 2023]









