# REKABENTUK DAN FABRIKASI MESIN PENYEMPRITAN BERSKALA KECIL

*(DESIGN AND FABRICATION OF SMALL SCALE EXTRUSION MACHINE)*

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1 would like to thanks all the technicians for their help, ideas and support with the designing and machining of the model and for all their aid while working in the laboratory and workshop. 1 would like to thank my friends also for helping me in designing and fabricating extrusion machine and help me to find out some necessary information and sharing the ideas regarding this project.

I would like to dedicate this work to my parents who guided through my studies and who cared for, loved and encouraged me. All contribution, collaboration, suggestion and advice will be appreciated and thanked for all whom involve in my project directly and indirectly.

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# ABSTRACT

This thesis is a project of design and fabrication of Small Scale Extrusion Machine. In development the machine, the principle of extrusion process need to study and understand to determine the components of the machine. Extrusion process is another method to form and shape metals and plastics beside the other process such as injection molding, blow molding and rotational molding.

The machine is designed to extrude raw materials such as plasticine and powder in certain shape where screw will rotate to force the raw material from feed hopper to shape-forming die. Design process start after know the functional of the components and the conceptual design of the machine. During design phase, the shapes and dimensions components will follow the guideline given by conceptual design.

After designing completed, the suitable materials is selected to fabricate the components. Many machines are used to fabricate the components that drill, lathe, milling and rapid prototyping machine. The machines used depend on the components to fabricate and the materials used. All components are assembled after fabrication completed to run extrusion machine by using motor. First run will evaluate the extrusion machine performance. Improvement and modification need to be done to the design if components are not functioning properly and effectively. Extrusion machine will run again until the performance is satisfied.

# ABSTRAK

Tesis ini merupakan projek merekabentuk dan fabrikasi mesin penyemperitan berskala kecil. Prinsip proses penyempritan perlu dikaji dan difahami untuk menentukan komponen-komponen yang terlibat dalam pembangunan mesin ini. Proses penyempritan adalah salah satu kaedah untuk membentuk logam dan plastik di samping kaedah-kaedah seperti penyuntikan acuan, tumbukan acuan dan perputaran acuan.

Mesin ini direkabentuk untuk menyempritkan bahan mentah seperti plastisin dan tepung dalam bentuk tertentu di mana skru akan berputar untuk memberi daya tekanan kepada bahan mentah ini daripada corong tuang sehingga ke acuan yang telah dibentuk. Proses merekabentuk bermula selepas fungsi-fungsi setiap komponen dan konsep rekabentuk mesin difahami. Semasa fasa rekabentuk, bentuk-bentuk dan dimensi-dimensi komponen-komponen perlulah mengikuti garis-garis panduan yang disediakan dalam konsep rekabentuk mesin.

Selepas proses rekabentuk siap, bahan-bahan yang sesuai dipilih untuk memfabrikasi komponen-komponen. Banyak mesin diperlukan untuk memfabrikasi komponen-komponen ini iaitu mesin gerudi, larik, pemilanan dan pencontohan sulungan. Mesin-mesin yang digunakan bergantung kepada komponen-komponen yang dimesinkan dan bahan-bahan yang digunakan untuk komponen-komponen itu. Semua komponen dicantumkan selepas proses fabrikasi siap untuk menjalankan mesin penyempritan yang direka dengan menggunakankan motor. Mesin penyempritan dijalankan buat kali pertama untuk menilai prestasi mesin. Penambahbaikan dan pengubahsuaian perlu dilakukan ke atas rekabentuk mesin sekiranya terdapat komponen yang tidak berfungsi secara baik dan efektif. Mesin penyempritan akan dijalankan sekali lagi sehingga prestasi mesin memuaskan.

# CHAPTER 1

## INTRODUCTION

Extrusion is a process for the continuous production of plastic and metal products such as tubing, pipe, film, sheet, coated wire, fiber, profiles and so on. Most extruded products have a constant cross section; however, it is also possible to make products with a nonconstant cross section. An example of the latter is extrusion blow molding, where a parison is extruded and subsequently, inflated with air in a mold to make a blow molded product. Another example is bump tubing used in medical applications. In this tubing sections of larger diameter are produced next to smaller diameter sections in a reproducible and repeatable fashion (1). Figure 1 gives one example of extrusion machine (2).

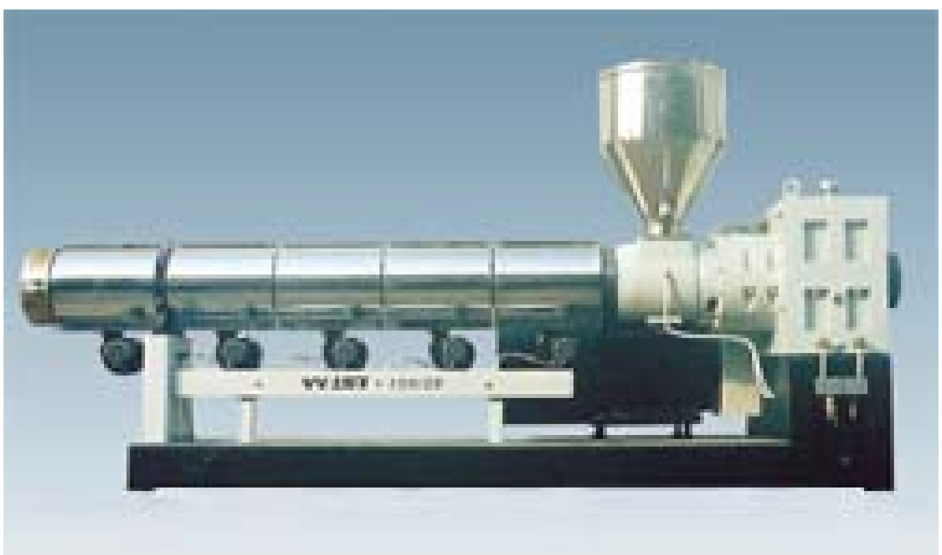

Figure 1.1. Single Screw Extrusion Machine

Generally in extrusion process, raw materials are in the form of thermoplastic pellets, granules, or powder are placed into hopper and fed into the extruder barrel. The barrel is equipped with a screw that blends the pellets and conveys them down the barrel. The internal friction from the mechanical action of the screw, along with heaters around the extruder's barrel, heats the pallets and liquefies them. The screw action also builds up pressure in the barrel. Extrusion produces compressive and shear forces in the stock. No tensile is produced, which makes high deformation possible without tearing the metal. The cavity in which raw material is contained is lined with a wear resistant material. This can withstand the high radial loads that are created when the material is pushed the die (3).

## 1.1 **Objectives**

1) To study and understand the principle of extrusion process
2) To design and fabricate the extrusion machine

## 1.2 **Scope of Project**

This project involves fabrication of extrusion machine. The work stages involve design and fabrication the parts of the extrusion machine. Based on the available design (BASF and Styron model) the machine is developing 1/10 of the actual size. After all parts are completed fabrication, the system is running by using raw material such as plasticine or powder. The extrusion process is done from raw materials until long shape plastic.

# CHAPTER 2

## LITERATURE REVIEW

There is various type of extrusion process in manufacturing technology to form and shape raw materials. Below shows types of extrusion process (4);

a) Cold extrusion

Cold extrusion is the process done at room temperature or slightly elevated temperatures. This process can be used for most materials-subject to designing robust enough tooling that can withstand the stresses created by extrusion. Examples of the metals that can be extruded are lead, tin, aluminum alloys, copper, titanium, molybdenum, vanadium, steel. Examples of parts that are cold extruded are collapsible tubes, aluminum cans, cylinders, gear blanks. The advantages of cold extrusion are:

- No oxidation takes place.
- Good mechanical properties due to severe cold working as long as the temperatures created are below the re-crystallization temperature.
- Good surface finish with the use of proper lubricants.

b) Hot extrusion

Hot extrusion is done at fairly high temperatures, approximately 50 to 75 % of the melting point of the metal. The pressures can range from 35-700 MPa (5076 - 101,525 psi). Due to the high temperatures and pressures and its detrimental effect on the die life as well as other components, good lubrication is necessary. Oil and graphite work at lower temperatures, whereas at higher temperatures glass powder is used.

c) Impact extrusion

Impact Extrusion is commonly used to make collapsible tubes such as toothpaste tubes, cans usually using soft materials such as aluminum, lead, tin. Usually a small shot of solid material is placed in the die and is impacted by a ram, which causes cold flow in the material.

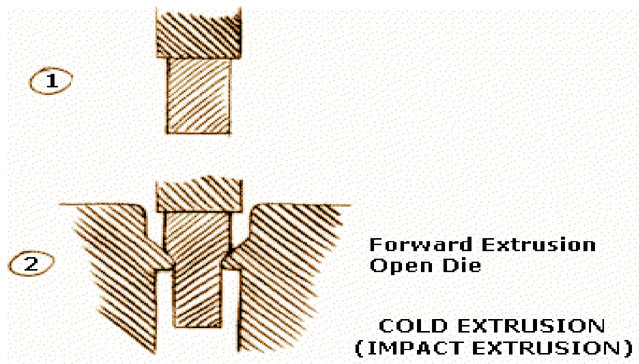


Figure 2.1. Impact Extrusion

d) Hydrostatic extrusion

Hydrostatic extrusion is a form of impact extrusion, uses a fluid hydrostatic pressure instead of a mechanical ram. This is useful for making parts out of materials such as Molybdenum, Tungsten that are relatively hard to extrude using normal extrusion methods.

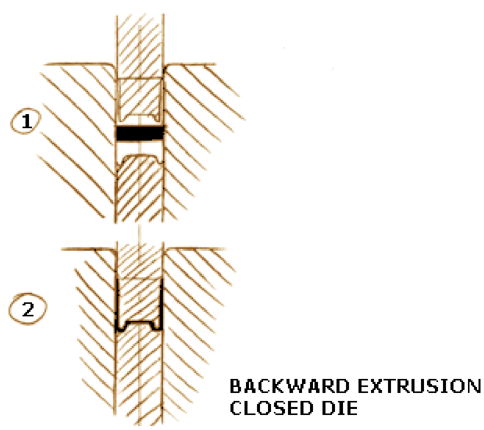


Figure 2.2. Hydrostatic Extrusion

2.1 **Extrusion Machine Design** (1, 5)

The extrusion machine is essentially a machine used to melt the plastic and deliver the melted plastic under pressure to a die. Typically, extrusion begins with granular material, gravity-fed via a hopper to a rotary screw. Extruders are manufactured for horizontal or vertical operation, and are available in many sizes and shapes. Individual product requirements determine the type of extruder needed. Two basic designs are commonly:

- A non-vented barrel with a single-stage screw
- A barrel having one or more vents.

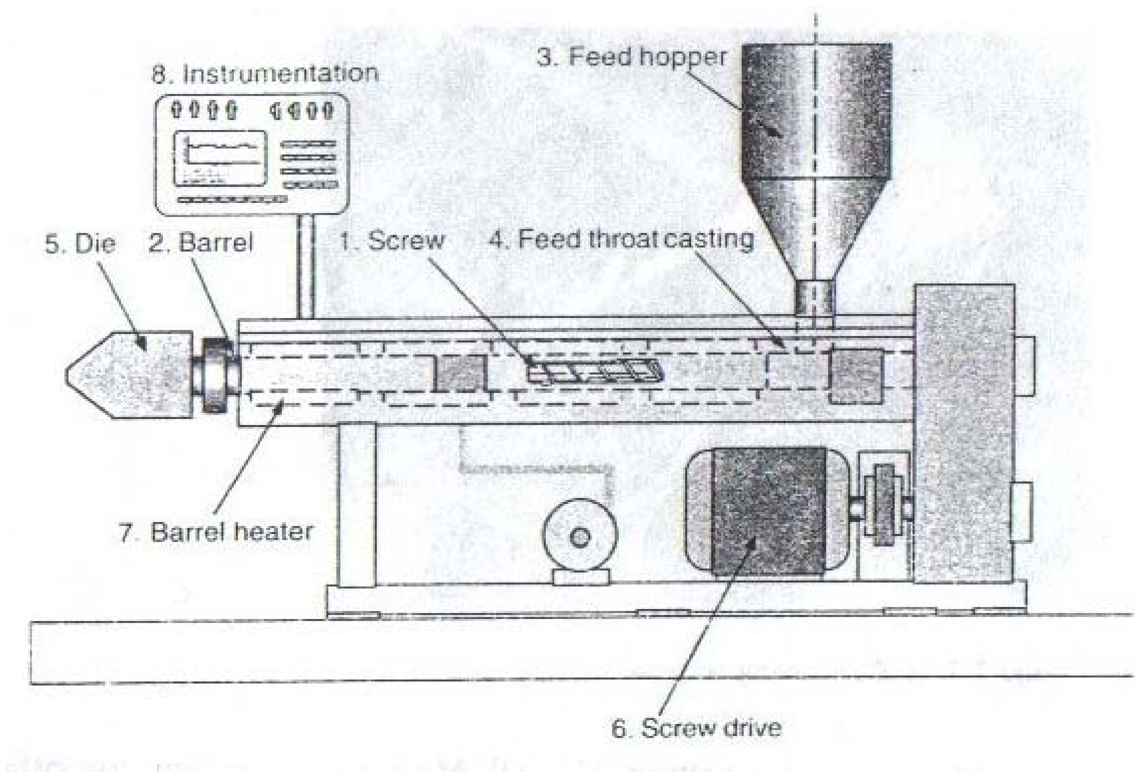


Figure 2.3. Illustration of a non-vented barrel with a single-stage screw

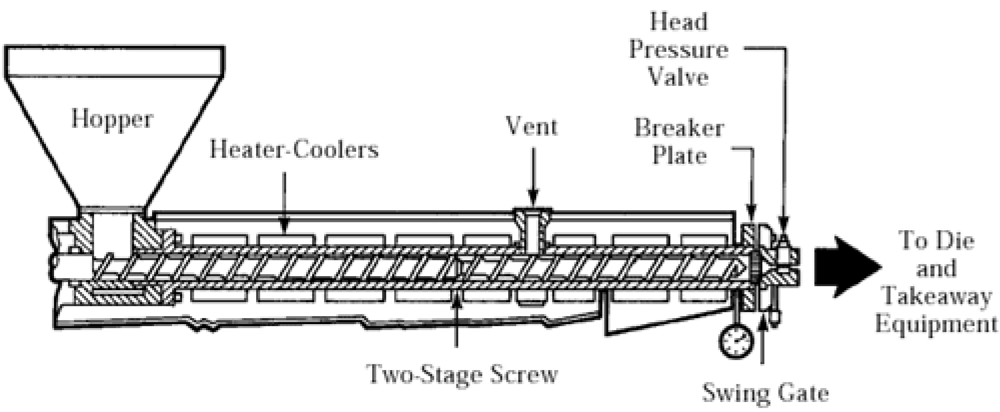


Figure 2.4. Illustration of a vented extruder having a two-stage screw

Vented extrusion allows better release of entrapped volatiles and moisture than does non-vented extrusion leading to better product appearance, uniformity and properties.

## 2.2 **Design Considerations**

### 2.2.1 The extrusion machine screw (1, 6)

Clearance between the barrel and outside - Flight diameter is 0.0508 to 0.1016 mm per side.

a) Single-stage screw

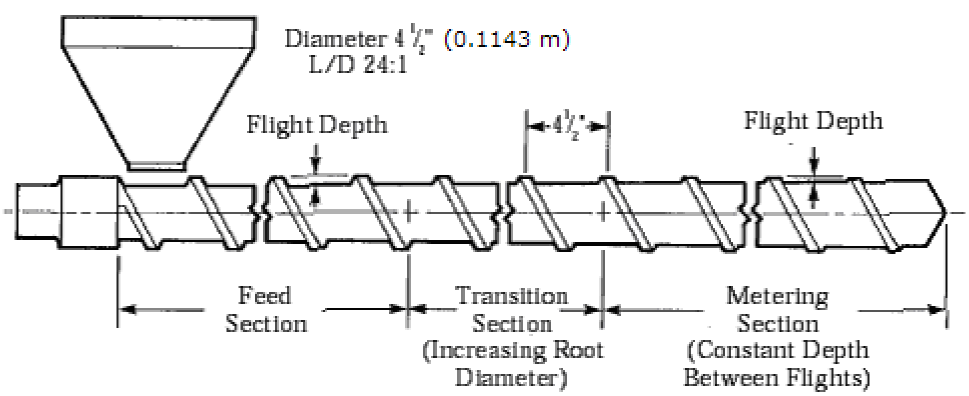


Figure 2.5. Typical Single Stage Screw Design

i. The Feed Section - Flight depths from 12.7 to 19.05 mm for 114.3 mm extruders.

ii. The Transition (Compression) Section – the transition takes place in as much as eight flights. Normally, the transition section is from one-fourth to one-third the entire screw length.

iii. The Metering Section - The range for metering section 114.3 mm extruders is between 3.175 and 5.08 mm in depth, and five to twelve flights in length. On smaller 63.5 mm extruders, flight depth varies between 2.032 and 0.3048 mm, and length runs from five to ten flights.

b) Two-stage screw

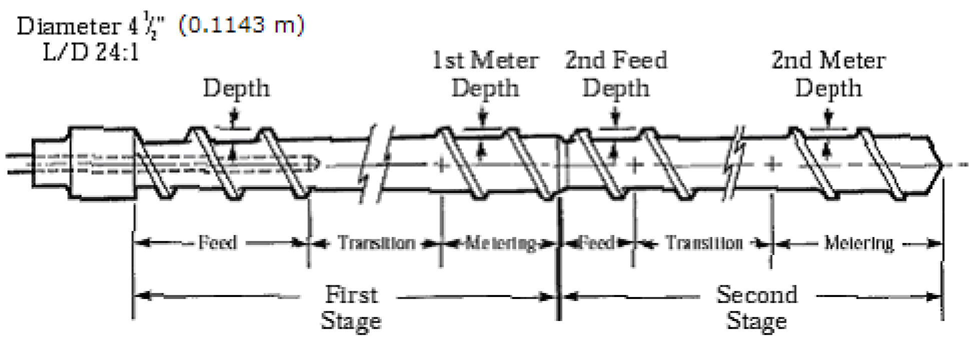


Figure 2.6. Typical Two-Stage Screw Design

The two-stage screws used in vented extruders can be considered as two separate screws in tandem as shown above. The first stage ordinarily comprises about 60 percent of the overall length, or about 17 flights in a 32:1 L/D ratio. The second stage is somewhat shorter, about 15 flights.

Both stages are further subdivided into separate feed, transition (compression) and metering sections of varying length. For 114.3 mm diameter screws, flight depths in the feed sections range between 13.97 and 19.05 mm, with a greater depth in the second stage to provide a decompression zone at the vent. Metering section depths range between 3.81 and 6.35 mm, with a greater depth in the second stage to ensure forward polymer flow and eliminate vent flooding.

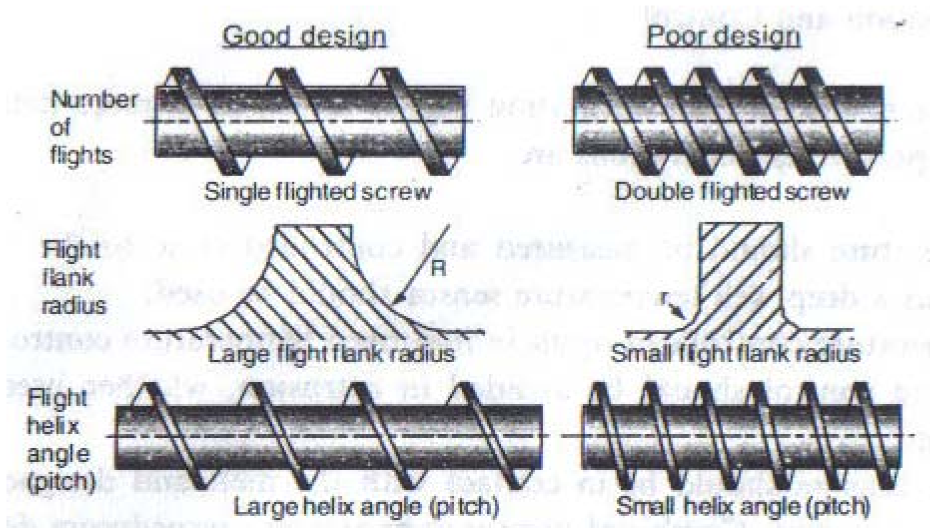


Figure 2.7. Good and Poor Design of Extruder Screw

2.2.2 Extrusion machine barrel (1, 7)

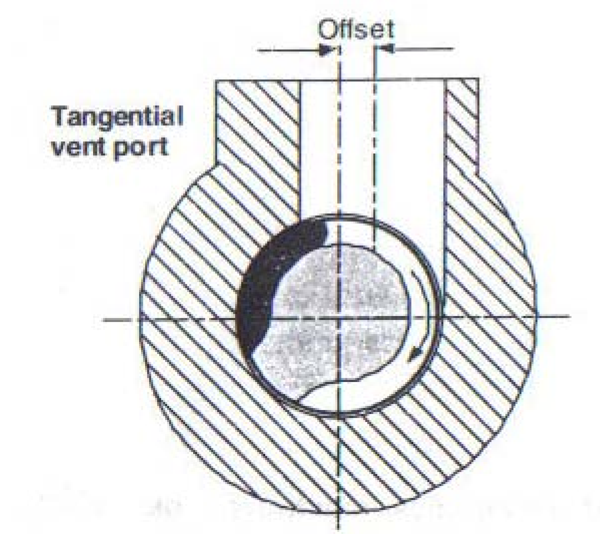


Figure 2.8. Good Design of Vent Port

Extrusion sizes are classified by the inside barrel diameter and overall barrel length. It is common practice to refer to the L/D ratio of the extruder, which is the barrel length to diameter ratio of the extruder. For smaller work, such as monofilament or profile extrusions, 38.1 to 63.5 mm diameter extruders are normally used, whereas for sheet extrusion, 114.3- and 152.4 mm diameter extruders are more common.

2.2.3 Extrusion machine feed hopper (1)

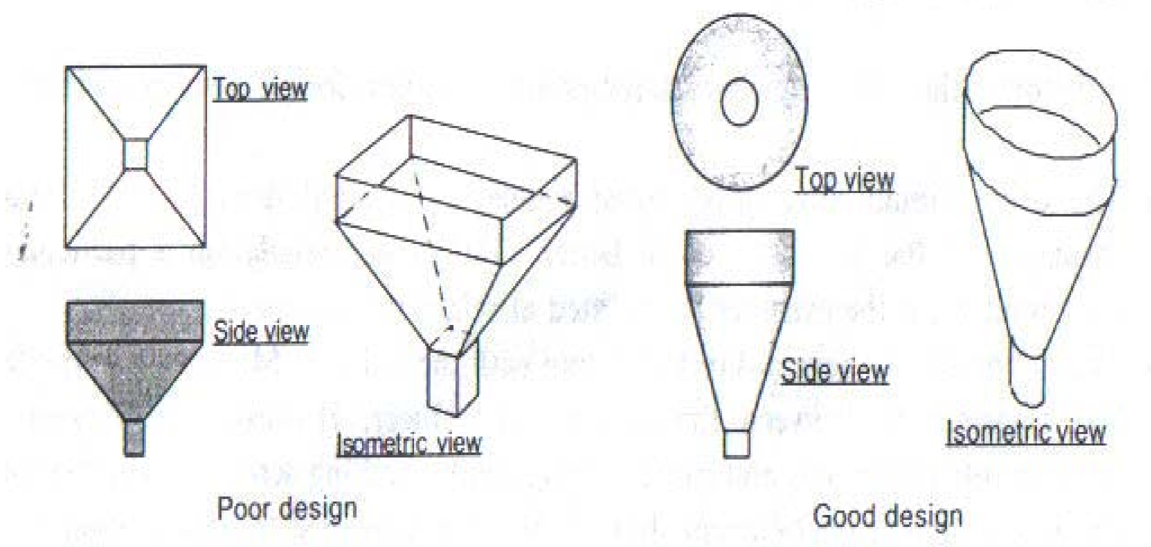


Figure 2.9. Poor and Good Design of Feed Hoppers

Round shape is better than quadrate shape to avoid sharp corners that will interrupt the steady flow. The wall should steep to reduce the chance of bridging and piping

2.2.4 Feed throat casting (1)

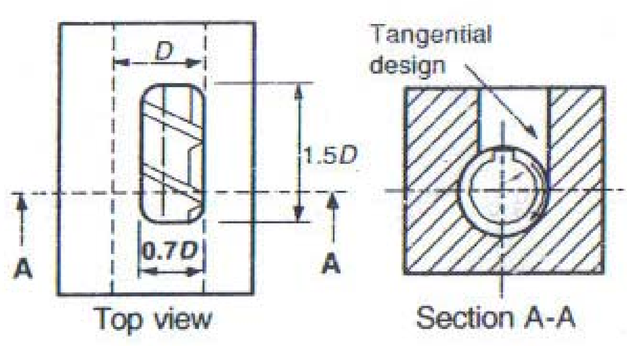


Figure 2.10. Good Design of Feed Opening

### 2.2.5 Die (1, 8)

i. The flow channel geometry should allow streamlined flow without abrupt transitions or dead spots.
ii. The cross-sectional area of the flow channel should reduce gradually from the inlet to outlet to achieve a gradual increase in flow velocity.
iii. The die should be made to be easy to assemble, disassemble and clean
iv. Spider supports should be located as far from the die exit as possible to minimize weld line problems
v. The land length is usually taken about ten times the die gap, although larger and smaller values can also work well
vi. The total flow restriction along each streamline should be the same to achieve uniform exit velocities. The length of the land reduces from the middle to the side to compensate for the longer flow path away from the middle.

## 2.3 **Extrusion Machine Components**

The extrusion machine most commonly used is a single screw extruder. The main components of an extruder are:

### 2.3.1 Extrusion machine screw (1, 6)

Extruder screws work on the principle of rotary motion. A forward motion takes place with the assistance of raised flights having a helical profile. During rotation, plastic material from the hopper section flows vertically into the recess between flights. This material is then forced horizontally forward by friction on the barrel.

The material adheres to the heated barrel walls, and slips on the cool, smooth-surfaced, rotating screw. This way, a continuous flow is assured and the necessary shear for frictional heating and subsequent melting. There is a change in polymer bulk density from approximately 0.7 at the granule stage, to greater than 1.0 at the melt stage.

As screw rotation melts the plastic granules, air entrapped in the process is normally purged back through the hopper. Entrapped air is either removed at the vent on a vented extruder or entrapped in the extrudate.

Because screws take such hard abuse, they are made of rugged alloy steel such as SAE 4140, with Rockwell C hardness of 35 to 40. Screw flights are further toughened by flame treatment to a Rockwell C hardness of 50 or higher, or are protected by application of special hard-facing alloys.

The single-stage and two-stage screw has three separate sections;

a) Feed
b) Transmission (compression)
c) Metering

a) The Feed Section

The feed section is located in the rear cylinder (hopper) zone. Flight depth is at a maximum, allowing material granules to fall directly on the screw. In most designs, the feed section has a constant root diameter throughout its entire length.

b) The Transition (Compression) Section

The transition (compression) section of full-flighted screws is designed to promote both the compression and heating of the plastic granules. This is achieved by a uniformly tapered, increasing root diameter that reduces the available volume between flights, compressing the granules.

As the granules are compressed, air is purged back through the hopper. While the material is being compressed and moved forward, it is also being heated, partly by conduction, but mainly by friction from rotary shear. As it melts, it is also mixed into a homogenous melt. Some screw designs achieve transition within a single flight. A transition section that is too short can promote overheating.

c) The Metering Section

The metering section provides polymer melt stability and helps ensure a uniform delivery rate. Flight depth is at a minimum and is normally constant along the section length. Shallow screws have a short metering length to avoid undue compression and consequent high polymer temperatures. Deep screws have a longer metering length to provide added flow stability.

d) Compression Ratio

Screws are frequently referred to by their compression ratio. This factor is calculated from the relative volumes per flight of one revolution in the feed and metering. In practice, compression ratio is often considered to be the ratio between the relative flight depth in the feed and metering sections.

2.3.2 Extrusion machine barrel (1, 7)

The extrusion machine barrel is a cylinder that houses the screw. It provides the bearing surface where shear is imparted to the plastic granules. The barrel consists of cast or fabricated steel sections and a smooth inner liner, often made of a wear-resistant material. Heating and cooling media are housed around the barrel to keep it at the desired temperatures.

The extrusion machine barrel has to contain the plastic and fit closely around the screw. The following characteristics are important for trouble-free operation:

- The barrel should be straight.
- The barrel should be designed to easily withstand the pressures that occur in the extruder. These can be as high as 70 to 140 MPa (10000 to 20000psi) and even higher in injection molding.
- The barrel linear should be more wear resistant than the screw. The screw is easier to replace and less expensive to rebuild than the barrel.

- The downstream barrel support should be a sliding support, allowing the barrel to expand when heated. A rigid support can cause warping of the barrel with the possibility of severe damage to screw and barrel.
- For improved solids conveying the feed section of the barrel can be grooved. Good cooling capability should be provided at the grooved barrel section to carry away high frictional heat and to prevent melt from accumulating in the grooves. Also, the grooves should taper gradually to zero depth to minimize the chance of material hang-up in the grooves.
- The vent port, if incorporated, should be offset and the tangential to minimize the chance of plastic melt hanging up at the leading edge of the vent port opening. The more conventional symmetrical vent port design tends to give continuous problems with material building up at the bottom of the vent port. The vent port opening can be designed to slant downward to avoid having condensate enter the extruder barrel.

2.3.3 Feed hopper (1)

The feed hopper should be designed to give steady flow of the bulk material from the hopper to the extruder. The hopper should have smooth and gradual transitions and avoid sharp corners. The following characteristics are beneficial for stable flow:

- The walls of the hopper should be steep to reduce the chance of bridging and piping.
- The cross-sectional shape should be circular, not square or rectangular; a circular geometry will minimize stagnation.
- A low friction coating on the side hopper surface reduces hang-up of material
- For difficult bulk materials special features can be used to promote steady flow; examples are vibrating pads and crammer feed.

### 2.3.4 Feed throat casting (1)

The feed throat should be designed to provide smooth flow from the feed hopper to the screw channel. The following characteristics are important;

- The feed throat should have good cooling capability to avoid premature heating of the plastic, which could cause the plastic to stick to the walls, resulting in lower output and unstable flow.
- At the barrel side of the feed throat should be a thermal barrier to minimize heat flow from the barrel to the feed throat housing.
- The axial length of the feed opening should be considerably larger than the screw pitch to avoid flight induced flow instabilities.
- The width of the feed opening should be smaller than the barrel diameter to maintain good forward flow.
- The feed opening should be offset, preferably tangentially, to minimize the intake capability of the screw.

### 2.3.5 Die (1, 8)

Current die design technologies are a result of testing, intensive study, and much practical experience. The early practice of making trial dies from soft metal is no longer necessary for the most common shapes – sheet, film, rod, and tubing.

Parts having more complicated geometries, particularly profiles that require close control over dimension, may require some trial-and-error die design. This is because polymer swell ratios and shrinkage rates cannot always be predicted with accuracy for a given extruder.

Internal die surfaces must have a high finish and good luster. Otherwise, the extruded plastic product may be rough, porous, or have a streaked appearance. Most dies are made of hardened, dimensionally stable steel, suitable for use at 500°F (260° C) and higher temperatures.

Final and exact die dimensions are achieved by sequential machining, grinding, buffing, and/or plating. Extrusion dies have an internal manifold section where material flows sideways for subsequent delivery, and forward for final shaping and exit. Manifolds have various shapes and may be round, tapered, or wedged. The two figures below show these components.

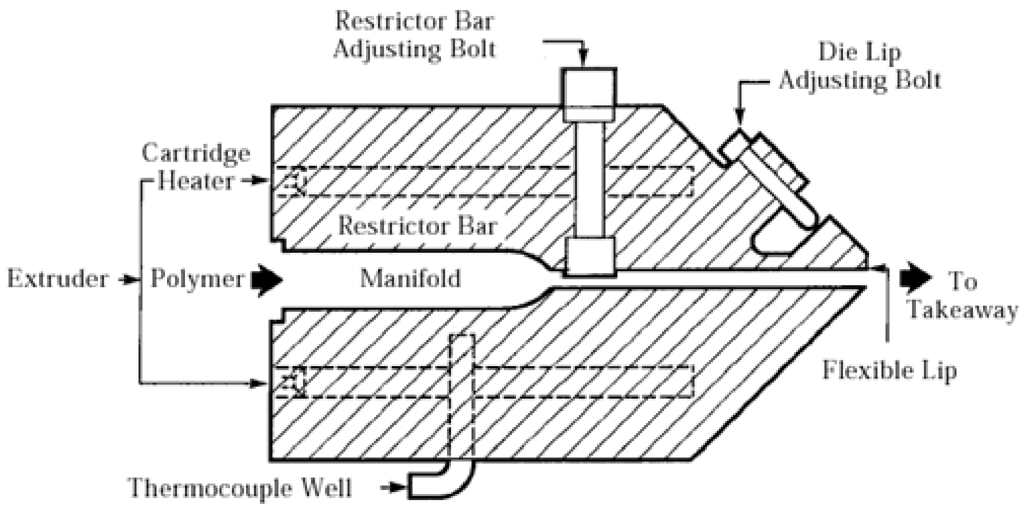


Figure 2.11. Cross-Sectional View of Typical Sheet Die; Flexible Lip Design

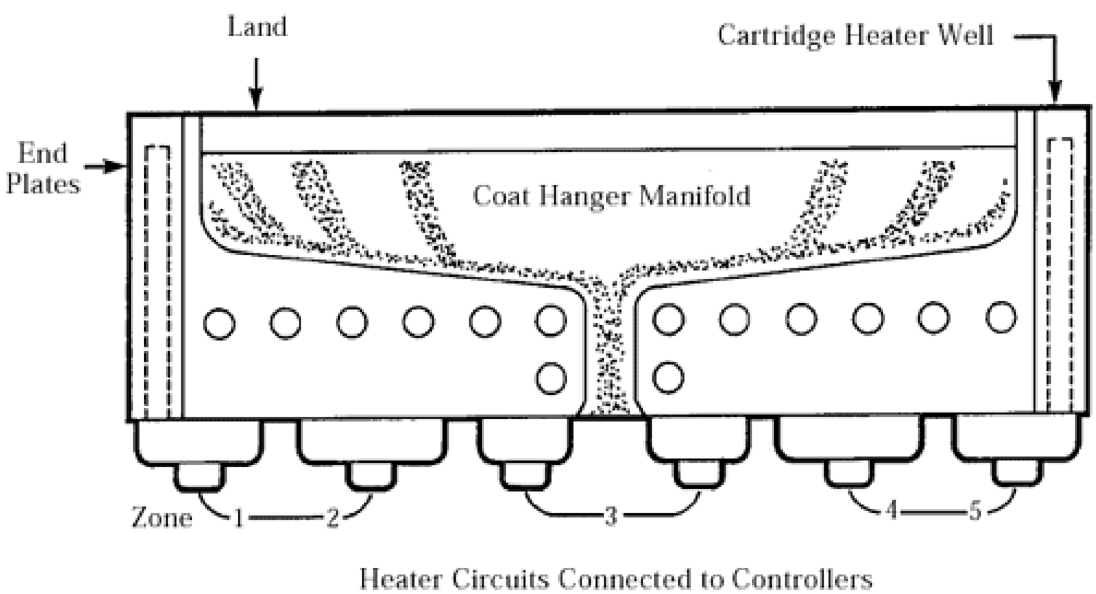


Figure 2.12. Top View of Typical Sheet Die; Coat Hanger Design, Die Open