LABORATORY 4

Topic: PRESSING AND INJECTION MOLDING - SAMPLE PREPARATION

/Supervisor: dr hab. inż. Stanisław Frąckowiak

modified by: MSc. Karolina Sobczyk, MSc. Maciej Borowczak/

1. Pressing

Pressing involves placing material in a mold, heating it between the plates of a press to soften it, compressing it under applied pressure, and then solidifying it by cooling. A hydraulic press with a maximum pressure of 10 tons, equipped with heating and cooling plates, was used. Test plates measuring 100 x 100 mm and 1 mm thick were pressed in a metal frame. The pressing temperature and the pre-heating and pressing times were set in advance.

Figure 1. Hydraulic press with heating and cooling plates (LabTech LP20-B).

From the pressed sheets, specimens for strength testing were cut. The samples were obtained using a pneumatic cutter from CEAST (Figure 2). The dimensions of the samples are shown in Figure 3.

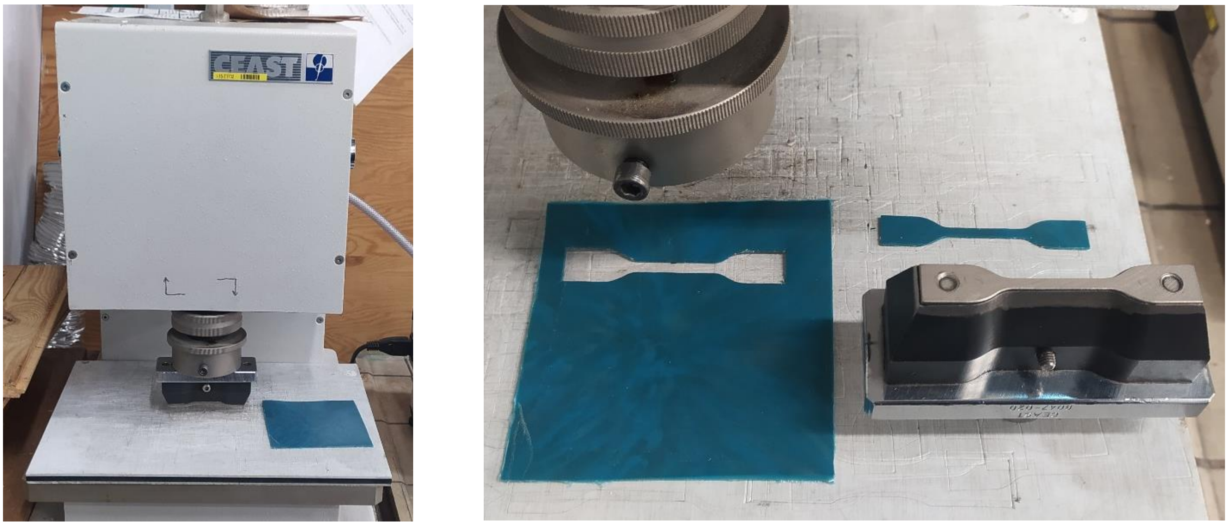

Figure 2. CEAST pneumatic cutter.

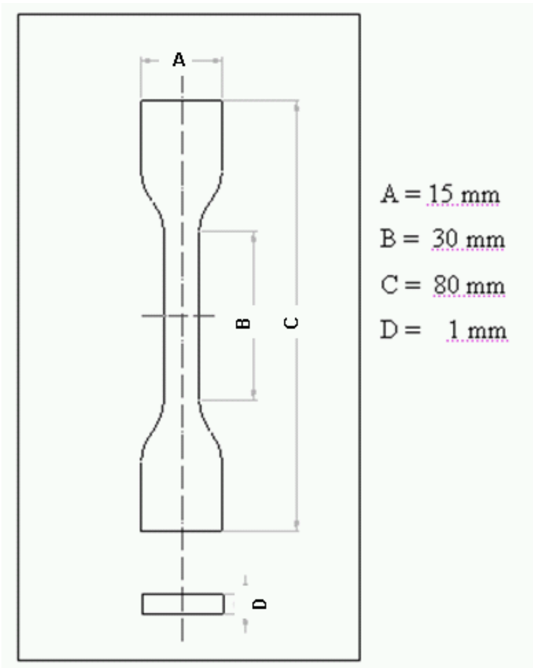

Figure 3. Dimensions of tensile test samples in accordance with ASTM D 0638.

2. Injection molding

Injection molding is a cyclic process where material, usually in the form of granules, is fed into a heated cylinder, plasticized, and then injected through a nozzle into the cavity of a mold. In the mold, the material solidifies under pressure, adopts a specific shape stabilized by cooling, and is then removed as a finished product.

Stages of the injection molding process:

- **plasticizing (feeding and compacting the material with a screw or plunger into the mold),**
- **injection (closing the mold, moving the screw or plunger forward),**
- **ejection (opening the mold, removing the part from the mold).**

This method is used to produce various elements and products from thermoplastic materials such as polyamide, polystyrene, polyethylene, polyvinyl chloride, and others. Injection molding is the most important method for producing molded elements from thermoplastics, ranging from products weighing less than 1 mg to over 10 kg, from micro-parts to transport containers and telephone booths. The cycle times range from a few seconds to several minutes, with minimal post-processing required.

Injection cycle stages:

- **plasticizing the material,**
- **closing the mold,**
- **moving the plasticizing unit to the mold,**
- **injection,**
- **holding pressure,**
- **cooling,**
- **ejecting the part from the mold.**

Injection molding is a cyclic process mainly used for processing thermo- and chemo-setting plastics [1].

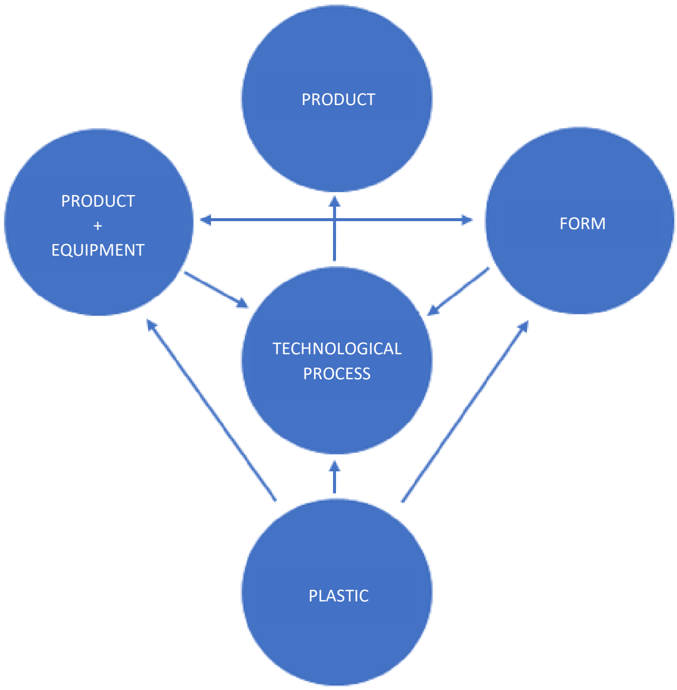

Figure 4. Factors affecting part quality and production efficiency [2].

3. Construction of injection molding machines

Injection molding machines are complex, multifunctional machines used for processing polymer materials. The general structure of all types of machines is similar, consisting of the same functional units, adapted to the specific processing requirements through design or special technological equipment. An injection molding machine consists of three main systems: plasticizing system (plasticizes the material and injects it into the mold), tooling system (consists of the mold and a closing system with three tables), drive and control system. The construction diagram of the screw injection molding machine is shown in Figure 5, while the diagram of the functional units of the injection molding machine is shown in Figure 6.

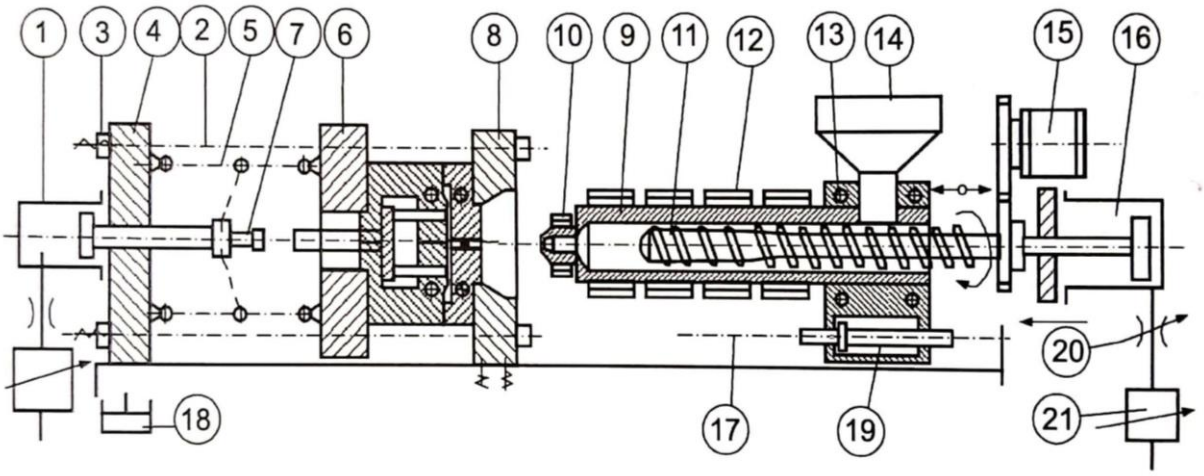

Figure 5. Schematic of a screw injection molding machine with basic components: 1 – drive cylinder for the table, 2 – guiding columns for the table, 3 – height adjustment nuts for the mold, 4 – rear fixed table, 5 – toggle lever system, 6 – moving table, 7 – injection machine buffer, 8 – front fixed table, 9 – injection cylinder, 10 – injection nozzle, 11 – screw, 12 – heaters, 13 – cooling system for the cylinder's feed zone, 14 – feed hopper, 15 – motor for screw rotation, 16 – screw shifting cylinder, 17 – guiding rails for the injection unit, 18 – hydraulic oil tank, 19 – cylinder shifting drive, 20 – throttle, 21 – pressure regulator for the hydraulic system [1].

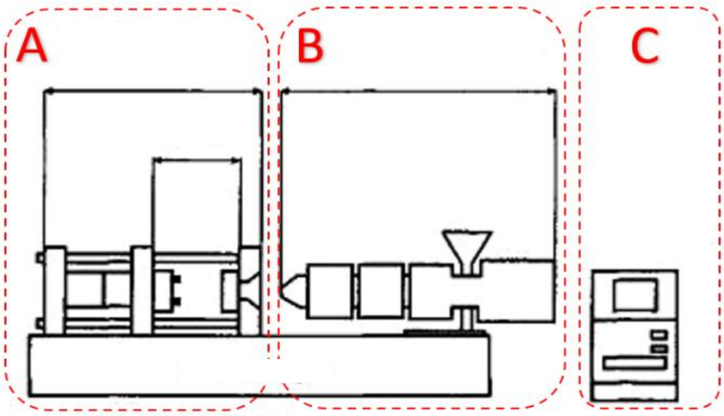

Figure 6. Functional components of an injection molding machine [2]
A - Tooling system, B - Plasticizing system, C - Drive and control system

4. BOY 35A screw injection molding machine

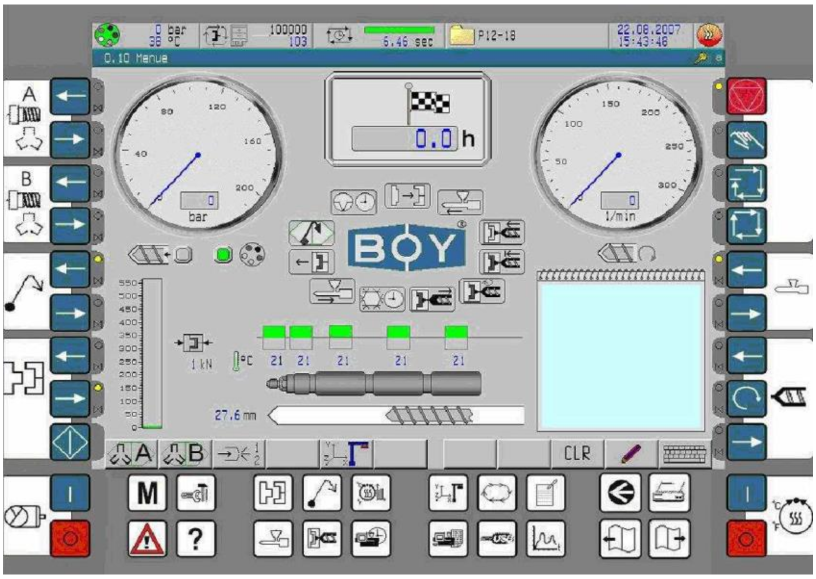

Figure 7. Control panel of the BOY 35A screw injection molding machine

Figure 8. BOY 35A injection molding machine

In the case of a screw-type injection molding machine, the process proceeds as follows: Material in the form of granules (or occasionally powder) is fed to a rotating, heated screw through the feed hopper. The material is moved to the end of the screw and plasticized by the heat from the cylinder and friction. Before the end of the screw, a cushion of plasticized material forms, pushing the screw backward. Once enough material has accumulated, the screw stops rotating and is pushed forward hydraulically, forcing the molten material into the mold. Pressure, typically exceeding 10 MPa, is maintained until the material solidifies, either in the mold cavity or at the gate. The molded part is then ejected from the open mold.

5. PROMA piston-type micro-injection molding machine

Samples for strength testing are prepared using the PROMA laboratory micro-injection molding machine (Figure 9). This pneumatic machine allows the temperature of the cylinder, mold, and injection pressure to be regulated. Piston-type injection molding machines push the material between a thick cylinder and an internal distributor (called a "torpedo"), where it is heated and plasticized. This method led to significant pressure losses, poor mixing and homogenization of the material, inaccurate dosing, and difficulty processing heat-sensitive materials, limiting its use in industrial production. However, it is still used in small laboratory injection molding machines [3].

Figure 9. PROMA Micro-Injection Molding Machine

6. Key terms

- **INJECTION PRESSURE –** depends on the viscosity of the material and the flow path length. The greatest pressure losses occur in the nozzle opening and the gate. The required pressure is set depending on the minimum pressure necessary to completely fill the mold cavity.
- **MATERIAL TEMPERATURE –** increases sharply at the nozzle and gate, which decreases viscosity, aiding cavity filling. However, excessive heat can cause thermal degradation.
- **INJECTION SPEED –** set to maintain a constant flow rate of the material's leading edge within the mold. A rapid injection speed can cause a sharp increase in frictional heat at the gate.
- **INJECTION TIME –** related to injection speed and depends on the plasticizing unit's capacity, part size, and material type. It ranges from a few seconds to several minutes. Efforts are made to minimize cycle time for economic reasons.
- **HOLDING PRESSURE –** continuously replenishes shrinking material. The pressure profile is set accordingly. Amorphous plastics require decreasing pressure to reduce frozen internal stresses, while semi-crystalline plastics, which shrink more, require constant pressure.

- **HOLDING TIME –** should last until the gates solidify. A shorter time or lower pressure can lead to voids. Correct holding time is often controlled by weight: when the part weight stabilizes, further holding is unnecessary.
- **MOLD TEMPERATURE –** regulated by thermostats or industrial water systems. Technical parts require slow cooling and higher mold temperatures, while mass-produced items, such as packaging, require faster cooling for economic reasons. Maintaining a constant mold temperature ensures consistent product quality.
- **PLASTICIZING PRESSURE –** created by restricting the outflow of oil from the cylinder, preventing the screw from retracting too quickly. Incorrect pressure can cause incomplete plasticization or overheating of the material.
- **INJECTION MOLDS –** complex tools not only shape the exterior of a product but also define its internal structure, influencing its durability and performance. Each injection mold consists of technological systems (mold components, gating systems, temperature control systems) and mechanical systems (release and ejection mechanisms, guiding systems, and housing).

7. References:

[1] Wilczyński K., et al.: "Polymer Processing," OWPW, Warsaw, 2018
[2] Wilczyński K., et al.: "Plastics Processing," OWPW, Warsaw, 2000
[3] http://www.tworzywa.pwr.wroc.pl