The kneading and shaping stages in pasta production are done in a machine called an extruder. There are several zones in the extruder which are involved in conveying, compacting, kneading, relaxing, and extruding the pasta dough. Upon entering the extruder, the hydrated semolina mixture first contacts the extrusion screw. The screw is exposed so that the semolina mixture may be dropped directly from the mixer onto the screw as it turns.

The hydrated semolina is conveyed from the screw into the extrusion barrel where it is compacted. There is an increase in pressure from approximately 0 to 2 MPa which helps to transform the hydrated semolina, which is granular in composition, into a compacted dough. During compaction there is also an increase in temperature due to friction between the dough, the screw, and walls of the barrel. The friction is necessary in order to compress the dough as well as move it down the channel. The excess heat is removed by a warm water jacket that engulfs the extrusion barrel, which keeps the temperature of the dough and barrel at approximately 45°C. The ideal temperature for pasta extrusion is between 45 and 50°C, as anything above 50°C will denature the proteins, impeding gluten production and therefore resulting in a soft sticky product. Using a cold water jacket will cool the dough and barrel too much, resulting in undesirable dough viscosity.

The frictional heat can be calculated which, in turn, helps determine how much the system needs to be cooled so the pasta exits the extruder at the desired temperature of 45°C. For example, if the dough enters the extrusion screw at 35°C, and frictional heating causes an additional 33°C rise in dough temperature, the dough will leave the extruder at (35+ 33°C) = 68°C, which means that approximately two thirds of the heat would need to be removed by the water jacket. One variable involved in determining the frictional heat is the specific mechanical energy (SME). The SME is the amount of energy transferred to the pasta product during the extrusion process and is calculated as the mechanical energy (kJ/s) to extrude pasta divided by the pasta production flow rate (kg/s). Elevated dough moisture or temperature can result in decreased dough viscosity and therefore decreased SME. Under normal operating conditions for pasta extrusion the SME is typically 70 KJ/Kg.

To determine the frictional heating of the dough:

first calculate the heat capacity of the dough using the following equation:

$Cp\ (kJ/kg°C) = 1.44 + 2.74X_w$

Where Cp is heat capacity and Xw is moisture content

For example, if the moisture content is 30%:

$Cp = 1.44 + 2.74\ (0.30)$

$= 2.26\ KJ/Kg°C$

The next step is to divide the SME (specific mechanical energy, KJ/Kg) by the Cp value to get the temperature.

If the estimated SME = 75 KJ/Kg:

Frictional heat = (75 KJ/Kg)/ (2.26 KJ/Kg°C) = 33°C

After the dough has been compacted it continues to move along the extrusion screw, where it is kneaded by forward flow and back pressure forces. The gluten molecules in the dough are stretched and aligned with the directional movement of the screw. However, the flow rate of the dough is not uniform as it moves down the extrusion screw, which results in irregular dough development. To increase homogeneity of the dough, a kneading plate is attached to the end of the screw. A kneading plate is stainless steal with small holes and works by splitting the dough into many small strands of dough that remix on the other side of the plate. It aligns the protein matrix and starch granules of the pasta. After the kneading plate comes the extension tube which is used only when extruding long pasta, such as spaghetti . In the extension tube the dough is allowed a brief rest before entering the die. By the time the dough has reached the end of the extension tube it is considered fully developed as it has become translucent and cohesive.

The die is composed of a rectangular support and multiple inserts. The production output is determined by the number of inserts in the die, therefore it must be balanced with the pasta press. Too many could cause the die to weaken and bend under the 10 MPa of pressure, which could decrease the density of the pasta product or cause strands to overlap during extrusion. Too few can cause excessive back pressure which could damage the die and/or the extruder and subsequently reduce production output.

The shape of the opening in the insert determines the shape of the pasta - for spaghetti it is circular. The inserts are also coated with Teflon which helps decrease the coefficient of friction and increase the rate of extrusion. The Teflon also helps yield a pasta product with a smooth surface which decreases its exposed surface area, preventing it from absorbing water to quickly and from soaking up too much pasta sauce when cooked.

Extruder output is described by the following equation:

Extruder output = drag flow - pressure flow - leakage flow.

Drag flow is the forward movement of the dough due to the relative motion between the screw and the barrel. Pressure flow is the backward flow of dough in the screw channel due to a pressure gradient across the screw length. Leakage flow is the backward flow between the flights and the extruder barrel due to a pressure gradient. Further information regarding the details to this equation is beyond the scope of this course.

The long spaghetti stands are deposited on a spreader, which spreads the long strands on sticks and cuts them into a uniform length as the product comes out of the die. There is some trim that results from the uneven flow out of the die. The trim is simply collected and brought back into the mixer through the trim return system. The pasta attached to the sticks is transferred to the dryer.