Due to their high molecular weight and high viscosity, engineering plastics semi-finished and finished products can't be produced with production methods like injection, extrusion etc. which are easily applied to other thermoplastics. The production of engineering plastics components is rather difficult in comparison to such methods and involves special techniques. In general, engineering plastics semi-finished products are produced in simple shapes like rods, plates and tubes and are mechanically machined to their final dimensions and forms. All machining methods (turning, milling, planing, grinding, reaming, drilling, screw cutting, cutting etc.) can be applied to engineering plastics components with standard tools available in universal metal and wood machining workshops. Engineering plastics have similar machining properties to brass, but their tool wearing is relatively higher. Additionally, they are softer, more flexible and pliable and are different than metals.

However, a trained worker can easily machine plastic components in universal workshops with the required precision. Some points must be observed for better results. Polikim applies all machining methods at its in-house workshop. Upon order, all forms are machined out of engineering plastics semi-finished products in required dimensions. Machining that pays little attention to the technical properties of engineering plastics and critical machining rules may cause the efficiency and the operation life of engineering plastics components to decrease. Polikim is ready to provide its customers technical support in selecting the most appropriate semi-finished product, the design and machining techniques for their application.

Special Remarks on Machining

Cooling water

Generally speaking, there is no need for cooling water while machining engineering plastics. At high speeds, the fact that heat formed at the cutting blade of the tool does not dissipate because of low heat conductivity wears out the tools and causes deformation of components due to high thermal expansion coefficient of engineering plastics. For this reason using cooling water is recommended at high speeds. As cooling water, water+water soluble oil compounds (for example boron oil) can be used in 10:1-20:1 ratios.

Dimensions and Tolerances

Normally engineering plastis can be easily machined with ± 0.1mm tolerance. Lower tolerances can be needed in special applications. As engineering plastics are soft and flexible, they adapt themselves automatically to the tolerances in their application environment. Yet despite of this, if lower tolerances are still required, after rough machining, the piece is heat-treated at around 280°C, internal tensions are reduced and then the last operation is applied. This is of course a costly operation. Attention should be paid when measuring the dimensions of machined parts. As a result of expansion property of engineering plastics, it is necessary not to apply pressure on the piece beyond a certain level when taking measurements with precision tools. An inexperienced worker can make an error up to 0.1mm even when measuring with a micrometer. Another point to keep in mind while taking measurements is the environmental temperature. As the thermal expansion coefficient of engineering plastics is very high, temperature variations cause significant differences in measurements. The best solution is taking the measurement at the temperature level which is very close to the final service temperature of the component.

Feed Rates and Cutting Speeds

Generally the size of the component and the degree of cleanliness required of the finished surface determine the feed rate. In turning 1-2.5m/sec cutting speed is ideal to obtain a smooth surface. At these speeds, there is no need for cooling water and generally there must be 0.05-0.25mm/rotation. In lower feeds and rough turnings, high cutting rates are used, but under these circumstances, using cooling water is recommended. Pass depth varies between 0.005-6mm.

		EFALON	KESTAMID	ULPOLEN
SAWING	α ^{0}	20 - 30	20 - 30	20 - 30
	γ ^{0}	5 - 8	2 - 5	2 - 5
	Cutting speed V m/min	300	500	500
	Pitch point t mm	2 - 5	3 - 8	3 - 8
DRILLING	α ^{0}	5 - 16	5 - 15	5 - 15
	γ ^{0}	5- 20	10 - 20	10 - 20
	Φ ^{0}	130	90	90
	Cutting speed V m/min	150 - 150	50 - 150	50 - 150
	Feed rate s mm/rotation	0.1 - 0.3	0.1 - 0.3	0.1 - 0.3
MILLING	α ^{0}	5- 15	10 - 20	10 - 20
	γ ^{0}	5 - 15	5 - 15	5 - 15
	Cutting speed V m/min	250 - 500	250 - 500	250 - 500
TURNING	α ^{0}	10	6 - 10	6 - 10
	γ ^{0}	5 - 8	0 - 5	0 - 5
	χ ^{0}	10	45 - 60	45 - 60
	Cutting speed V m/min	150 - 500	250 - 500	250 - 500
	Feed rate s mm/rotation	0.1 - 0.3	0.1 - 0.5	0.1 - 0.5

Tools

While machining engineering plastics, generally tools of HSS steel are used. In cases where production quantities are high, continuous production is the case, it is useful to use hard material tips. Selection of tools has an important role in controlling the heat created at the cutting blade. While standard tools can be used for better results, profile knives of special shapes can also be used. Using high quality cutting blades is important not only from the point of view of heat dissipation, but also for better tolerances and cleaner final surfaces. A cutting blade that is not regular and is not sharpened, crushes the plastics and prevents machining. For this reason, the cutting blades should absolutely be pointed, sharpened and the sharpening angles should be compatible with the given values. It is not possible to machine engineering plastics components smoothly with dull tools. In order to prevent wear, it is useful to make a small radius on the tip of the chisel. Taking into consideration the physical properties of engineering plastics, components should be firmly installed onto the work bench and centered.

Surface Cleaning

Low coefficient of friction of engineering plastics and their properties to easily adapt to the piece with which they are operating generally leave surface finishing operations unnecessary. In most cases surface cleaning obtained by turning is sufficient. For precision pieces grinding with standard tools can be preferred. In this case 0.4-0.8 µm Ra surface cleanliness can be obtained.

Chips and Burrs

Chips wrap the component around and accumulate on it, pushing it away from the tool, causing divergence in measurements. Besides, they cause insufficient cooling of the piece both in air and water. Burrs are generally created by dull tools at high operation speeds. With the help of a rod or cord, chips should be removed by hand in turners. Preferably turners must be operated at low speeds to prevent chips and burrs.

Mechanical Machining Techniques

Turning

Turning operations can be applied to engineering plastics components in universal workshops. Usually standard tools of HSS steel are used. To obtain a good finishing surface, cutting blades of the tools should absolutely be pointed, sharpened and the sharpening angles should be in line with the values given in figure. Attention must be paid that the tools are completely centered and the component is installed firmly onto the bench. The surface cleanliness obtained at the end of the turning operation is sufficient in most cases. If critical tolerances are not needed, additional surface cleaning operations are unnecessary. Turners must be operated generally at high speeds, with low feed and low pass depths. 1-2.5m/sec cutting speed and 0.05-0.25mm/rotation feed are sufficient to obtain a smooth surface. Automats can be used in cases where production quantities are high and continuous production is necessary. In continuous production, attention must be paid that the cutting blades are sharpened. Instead of HSS steel, hard metal tips should be used.

Cutting

For cutting operations in turners, cutting speed of 1.5-3m/sec and 0.05-0.10mm/rotation feed are sufficient. The angles of the tools should comply with the values given in figure. The surface is obtained by turning and cutting in turners. Engineering plastics components of all dimensions can easily be cut with a saw. Generally thick notched saws should be preferred. Band saws are more appropriate as they are helpful in dissipating the heat. In band saws, a cutting speed of 20-25m/sec and a feed of 5mm/sec, and in circular saws, a cutting speed of 20-35m/sec and a feed of 40mm/sec are recommended. Rods up to 20mm diameter and plates up to 10mm thickness can be cut by a steel knifed guillotine. Components and knives should be firmly installed onto the work bench. With cutting moulds and plaster moulds, engineering plastics can be given forms in presses. Attention must be paid that the moulds are very net shaped so that no burrs are formed.

Drilling

Generally speaking in drilling, standard helical HSS drill tips are used. For deeper holes, drills with smaller helical angles or barrel drills can also be used. The cutting edges of the drill tips should be ground, the chip channels should be deep and glossy. A cutting speed of 0.3-1m/sec and a feed of 0.1-0.2mm/sec are ideal for the drilling operation. The drill tip angle shown in figure depends on the diameter of the hole and the thickness of the wall. For holes with large diameters and thick walls, drills with a tip angle of 115°-130° are appropriate to prevent the expansion of the outer diameter. Sometimes in very thin walls, drills with tip angles of 180° are used to prevent bending. When machining big holes in engineering plastics components, they must first be drilled with a small drill, later on the hole should be enlarged with a bigger drill. When machining a long hole, the tip of the drill should be pulled back a few times. The piece should be left to cool and chips should be removed in the meanwhile. In this way conical holes are prevented.

Grinding

Engineering plastics components do not generally require a very shiny surface due to the fact that they are easily adaptable to the piece with which they work together. In most cases, surface cleanliness obtained by turning is sufficient. For precision pieces when critical tolerances are necessary, all kinds of grinding operations can be applied with a tolerance of ± 0,025 mm. Generally rough up to a diameter of 300mm and thickness of 75mm are recommended. The emery stone speed changes depending on the diameter of the plastic and the quantity. Generally a speed of 2800 rotations/min. is enough. Cooling water should be used at high speeds.

Milling

All kinds of milling operations can be applied to engineering plastics using single bladed tools. The tools must be pointed and well sharpened and work must be done at low feed and low pass depth. 1-2.5m/sec cutting speed and 0.005-0.10mm/rotation feed are appropriate. Due to the natural flexibility of engineering plastics, to prevent deformation during milling, engineering plastics components should be installed firmly onto the work bench. Especially thin walled pieces should be installed onto the work bench, leaving a sufficient opening only for the chisel.

Planing

Engineering plastics can be machined also in planers. To prevent deformation in the planer and variations in dimensions, components must be firmly installed. Cutting blades of the tools should be well pointed and sharpened.

Notching

Standard high speed steel HSS die plates and 3 channelled guides can be used. To decrease friction, 4 channelled guides should be preferred for better results. As in the case of drilling, the hole will have a tendency to narrow down. Therefore it is recommended to work with big guides.

Errors in Mechanical Machining and Causes

ERRORS	CAUSES
TURNING	
Softened Surface of Material	1. Tool is dull 2. Insufficient base angle (Flank surface of chisel abrades piece) 3. Very slow feed 4. Rotation speed is high
Rough surface	1. Very fast feed 2. Wrong tool angles 3. Chisel tip is very sharpened (needs a small radius at the end) 4. Chisel not on axle
Burr at cutting edge	1. Tool is dull 2. No counter bores present on cutting edges
Ruptures, Breaks	1. Too much chisel tip radius 2. Tool not fastened properly onto tool holder 3. Material not fastened well 4. Too much cutting width
CUTTING	
Softened Surface of Material	1.Tool is dull 2.Insufficient base angle (Flank surface of chisel abrades piece) 3.Insufficient cooling water
Rough surface	1. Very fast feed 2. Tool not sharpened regularly 3. Cutting edge not smoothed out
Spiral Lines	1. Burr at tip of the tool 2.Material sticks while drawing back chisel
Concave and convex Surfaces	1. Big chisel tip angle 2. Tool not perpendicular to center 3. Very fast feed 4. Chisel assembled beneath or over axle
Burrs at cutting point	1. Tip angle is not big enough 2. Chisel is dull or its surface not smoothed out 3. Very fast feed
Burrs at external diameter	1. No counter bores present before cutting 2. Tool is dull
DRILLING	
Conical hole	1. Wrongly sharpened drill tip 2. Very fast feed
Burned or melted surface	1. Wrong drill type 2. Wrongly sharpened drill tip 3. Very slow feed 4. Drill is dull
Spiral lines or drill traces on internal diameter	1. Fast feed 2. Not properly centered drill tip 3. Irrationally sharpened drill tip
Big Hole	1. Irrationally sharpened drill tip 2. Very fast feed 3. Big tip angle
Small Hole	1. Drill is dull 2. Tip angle is small
Oval Hole	1. Fast feed 2. Low rotation speed 3. Very fast rotation speed at the beginning 4. Not properly centered drill tip 5. Not properly sharpened drill tip 6. Drill edge is not cutting well, chips are pushing the drill aside
Burrs	1. Drill is dull 2. Cutting speed is very high
Drill becomes dull very quickly	1. Very slow feed 2. High rotation number 3. Insufficient cooling water