Chapter 3

Materials for Injection Molds

Because injection molding techniques become widely used to serve the drastic increasing demand for a high quality of plastic products in market. In the aspect of molding materials, it is imperative if the configuration of part is changed or modified, the characteristics of the molding material and the respective selection technique have to be available to meet the requirement for reproducible dimensional accuracy and surface quality. Therefore injection molds have to be made with high precision. In addition, mold materials are expected to provide reliable and repeatable working task under extreme loads during the injection molding process.

There are many several factors determining the selection of materials for cavity and core. They result from economic considerations, nature and shape of molding and its application, and from specific properties of mold materials. In addition, details about the molded part should provide information concerning the plastic material to be employed (e.g. reinforced or unreinforced, strength, strength, chemical and thermal resistance, etc.). These requirements result significantly in the different requirement on its thermal, mechanical, and metallurgical properties. In general, therefore, conflicting between requirements on those properties must be compromised in the selection of materials for injection mold making.

However, as mention in the chapter 1, the scope of this research are identified on only cavity or core of plastics injection mold. Mold operational element, which are mold standards and other types molds for other molding processes are not related in this research. Therefore, materials for mold core will be mentioned in the only scope of materials for plastics injection mold making.

3.1 Steel

Normally, for injection mold manufacturing, steel is the material that guarantees reliably functioning molds with long service lives provided a suitable steel grade from steel manufacturers. Different steels can be treated so as to develop a structure that produces the properties required in use. When the mold maker consider steel as a materials for manufacturing mold, the following properties are expected from steels for injection mold making:

- Characteristics permitting economical machining,
- Capacity for heat treatment without problems,
- Sufficient toughness and strength,
- Ease of polishing,
- Resistance to heat and wear,
- High thermal conductivity,
- Corrosion resistance.

3.1.1 Classification of steels

Because the different steel grades offer the different characteristics and properties of steel required to be used, classification of steels used for injection mold making may help the mold designer and mold maker to select that steel grade which is best suited for a particular job.

According to Menges, et al. [3] and Stoeckhert [9], the steel grades presently offered for producing injection mold cavity can be divided into the following groups:

- case hardening steels,
- through-hardening steels,
- nitriding steels,
- tempered steels
- martensitic Steels
- corrosion-resistant steels,

The more descriptions of these groups of steels are intended to help mold maker in selection of the correct steel.

3.1.2 Case-hardening Steels

Case-hardening are low-carbon steels (C <= 0.3 %) that are given a hard, wear-resistant surface through case hardening process. Case-hardening process or carburizing (treatment temperature approx. 900 to 1000 Celsius), carbon diffuses into the near-surface region of material. The depth of case is the function of temperature and time. After case hardening for a lengthy period of time (several day),a depth of case of approx. 2 mm can be achieved. A hard surface is achieved by quenching the carburized workpiece.

Case-hardening steels best meet the qualifications for mold making. They are not expensive, and thus dominate 80 % of the total steel consumption for mold making. After the necessary heat treatment, case-hardening steels still have a tough core as well as a wear-resistant surface. The high surface hardness on the one hand and modem deoxidation methods on the other offer the best conditions for polishing. Another advantage, if compared with other grades of steels, is the low strength after low-temperature annealing, which facilitates hobbing. This procedure is an economical process suited for small cavities and multi-cavity molds with a large number of equal cavities.

3.1.3 Through-hardening steels

Through-hardening steels are used the hardness/strength and toughness of which can be matched to the particular requirements through heat treating (quenching and tempering). The hardening process consists of preheating, heating to prescribe temperature, quenching with formation of a hard martensitic structure and following normalizing to improve toughness. By selecting the temperature at which tempering takes place, these properties can be optimized. In addition, the desired mechanical properties depend on the quenching medium and the cooling rate.

Through-hardening steels provide excellent dimensional stability when heat-treated. Because of their natural hardening capacity they have high compressive strength and are especially suited for molds with shallow cavities where high peaks may be expected. Thus, the through-hardening steels have proven very well suited for processing of abrasive molding compounds, e.g. those with glass fibers as a filler. They can also be recommended in molds for insert molding (with possible high edge pressure)and, due to good wear resistance and high normalizing temperatures for processing thermosets. Since the introduction of electrical discharge machining (EDM), the use of through-hardening steels has been steadily important.

3.1.4 Nitriding Steels

Nitriding are presently used only in special cases for tool construction, for example, for tools with very thin fins. At the present time nitriding steels are preferred for plasitcizing. Particularly high surface hardness of at least 950 HV are, for instance, attained with aluminum alloys steels. Basically, all steels contain nitriding-forming alloy elements can be nitrided. Such alloying elements are chromium, molybdenum, vanadium and preferably aluminum, which especially favors formation of nitride. These steels absorb nitrogen form the surrounding medium by diffusion into their outer layer.

Nitriding process provides the steels with an specially hard and wear-resistant surface with a Brinell hardness between 600 and 800, depending on steel grade and process. In addition, nitriding steels provide excellent dimensional stability as the result of a chemical change in the surface layer that considerably improves wear resistance and fatigue strengths. However, nitriding steels is not recommended because of the reduction in corrosion resistance. In general nitriding steels are presently used only in the already quenched and tempered condition. The aluminum-alloyed types have a core strength of 950 to 1100N/mm^2.

3.1.5 Tempered steels

Quenching and tempering is a heat treatment used to achieved increased toughness at a certain tensile strength of this group of steel. This causes a reduction in hardness and strength of these steels because tempering steels above 500 °C decomposes the martensite into carbide and alpha iron. The available steels that have treated in this manner are machined in the prehardened state. This is no subsequent hardening of the mold components. By the use of this way, the risk of heat treating cracks and distortion upon hardening is avoided.

Because of the problems with heat treating other steels, quenched and tempered tool steels were originally and preferably employed for constructing medium-sized and large molds. They have the additional advantage that corrections are more easily accomplished if necessary.

3.1.6 Martensitic Steels

Martensitic steels for plastic molds are special steels that were developed as high-strength for aviation and space industry. Martensitic steels combine extreme strength and hardness with the advantage of simple heat treatment. Their structure consists of tough nickel martensite with strength 1100 Mpa. They are suitable for tools with particularly complicated cavities.

If plastics with a high filler content, which causes heavy wear, are processed, it is recommended that martensitic steels be used. This can be combined with the process of precipitation hardening. The steels can be listed in this group with the highest carbide content contain about 50 per cent by volume titanium carbide, which is embedded in a matrix of hardened martensitic steels. The steels concerned are 18 MAR 250 and 18 MAR 300. These special steels are supplied in the solution-annealed condition and have a tensile strength of about 1000 to 1100 N/mm2.

3.1.7 Corrosion-resistant steels

Corrosion-resistant steels owe the special feature to protect molds against such damage caused by aggressive substances in polymeric materials processes. They enable molds for processing chemically corrosive plastics to be manufactured and protected against the corrosion with the use of hard-chrome plating or nickel plating.This special feature to an alloying with chromium, strongly adhering, invisible layers of chromium oxide are formed with oxygen from air or other oxygen media. They protect steel from corrosion.

In addition, the corrosion resistance also depends on the quality of the mold surface exhibits a large area to attack than a smooth, highly polished one. Chrome steels with only, for instance, is corrosion resistant only if the surface is highly polished. However, difficulties occurs with intricate cavities, because a uniform layer thickness can not be attained. In addition, the manufacture of almost seamless plastics parts is impossible because the cavity edges are always slightly rounded off. If the mold is, therefore, subjected to higher bending stresses, the danger exists that the chromium layer electroplated will tear off.

3.2 Nonferrous Metallic Materials

Nonferrous metals best known employed in injection mold manufacturing can be classified into 4 following groups:

- Copper alloys,
- Zinc alloys,
- Aluminum alloys,
- Bismuth-tin alloys.

According to Mohen [3], Stoeckhert [9] , however, high-grade zinc alloys for casting are used in mold making only for prototype molds or molds for small production because of their second-rate mechanical properties. They are more commonly used for blow molding or forming plastics where molds are not under high mechanical loads. Therefore, zinc and its alloy will be skip to be mentioned in this study, which is only cover mold materials used in the real-time practice in injection mold making.

3.2.1 Copper Alloys

The mechanical properties of pure copper are moderate. Thus, it does not serve the demand of extreme features as a mold making materials, even though it is improved by cold rolling or forming. Copper alloys are purposed to do this. The significance of copper alloys as a material for mold making is based on their high thermal conductivity and ductility. According to Menges, et al., beryllium-copper alloy are best known as important materials for mold cavities.

3.2.1.1 Beryllium-Copper Alloys

As the same with other alloys, the mechanical and thermal properties depend on the chemical composition of alloy. With adding beryllium in copper, the mechanical properties and thermal conductivity of copper are improved. However, increasing beryllium may reduce thermal conductivity of materials. Beryllium -copper alloys with more than 1.7 % beryllium are allowed in mold making. With this content, beryllium-copper alloys can be hardened up to 330 to 360 Brinell, which is generally enough for practical purpose. Alloys with a beryllium content higher 1.7 % is very ductile, so has trended to fragility at the edge of work pieces. In contrast, alloys with a beryllium content below 1.7% are only use for functional components such as heat conductors. Table in Appendix summarizes the technical data of some beryllium-copper alloys.

Mold made of beryllium copper are sufficiently corrosion resistant and can be chrome or nickel plated if needed. Presently, electroless nickel plating is normally used to protective coating. In addition, a nickel coating is less prone to cracking than a hard chrome coating. These alloys also offer an advantage if high demands on surface accuracy have to be met.

3.2.2 Aluminum Alloys

Low specific density, easy cutting operations, and high thermal conductivity are the properties which are interesting for injection mold making. This takes particularly true for heat-hardening, high-strength aluminum-zinc-magnesium-copper alloys. The advantage of aluminum molds is that mold weight is less than steel molds due to their specific weights. However, this advantage is not fully mentioned because the individual plates is very thicker than steel plates due to their lower mechanical strength. .

In addition, more advantages result from the good machineability, which,compared to steel, allows a outstanding higher cutting speed. Distortion from machining can not be expected. because aluminum has very little residual stresses due to a special treatment during production. Besides working with cutting tools aluminum can also be shaped with an EDM process. Finally, the good thermal conductivity of aluminum must be mentioned, which causes a uniform and fast heat distribution and dissipation. This facilitates maintaining a correct mold temperature, possibly improves the quality of moldings and results in shorter cycle time. Thus, success of combination of aluminum and steels offers the advantages mentioned above.

3.2.3 Bismuth-Tin Alloys

Bismuth-tin alloy are composition of metals with low melting points (between 40 and 170° C depending on composition). Because of their moderate mechanical properties, bismuth-tin alloys are primarily used for prototype molds in injection molding. More common is their use for blow molds, molds for hot forming. Beside this they are used as a material for special case: as a material for fusible cores.

For this reason, like the case of zinc and its alloys, therefore, Bismuth-tin alloy will be skip to be mentioned in this study , which is only cover mold materials used in the real-time practice in injection mold making. In addition, MATSEL-VPEX will skip to contain the technical data to be used in the consultation.