Bachelor thesis (BT) on Additive Manufacturing (AM) processes

Materials used in AM

The scale of materials usable for purposes of AM is very wide. We can today print plastic objects from different plastics like Nylon, polystyrene and others. Metal objects can be printed, out of common metals such as steel and it’s alloys, titanium, aluminum and so on. Certain technologies make it possible to print even sand parts. Other methods enable building colorful parts. But since there are so many materials, we should be able somehow to categorize them into logical groups. Also, this categorization is related with categorizing different AM technologies themselves. Materials, used in each technology, will be described in detail in related chapters – this is only brief summary of material options

In following lines, some information might be slightly unprecise or misleading. The reason is, that categorization of AM processes and related issues is very sophisticated and there are many slight differences among technologies. Therefore I will try to summarize some main ideas, but detailed description can be found in chapters devoted to specific technologies.

Classification:

State of raw material

Chemical composition and properties – curling / warpage, mech. properties, speed of curing, heat transfer coefficient, thermal expansion coefficient

Curing process

One way of materials categorization is divide them, based on **phase / physical state**. Materials before printing process can be either solid or liquid. Solid materials can be used in forms of powder, wire or thin sheet / folia. Liquid materials so far only photopolymers.

**Solid materials**

Powder materials are usually used for metal printing. Nevertheless, plastics and ceramics powders or sand might be used. Powder material can be processed by partially or fully melting and fusing together, creating a solid part – technologies “powder bed fusion” or “directed energy deposition”. Laser or electron beam can be used to melt the powder. Also, the powder can be glued by a special substance called binder – see “binder jetting” technology.

Wire-form material is always used with “Fused deposition modeling” technology (or rarely used with “directed energy deposition”). Within FDM, probably today the best-know and widespread technology, the plastic wire is partially melted and in controlled manner “spilled”. Due to its viscosity, one can precisely control the deposition process and it’s precision. After solidified again, it forms final object.

Sheet-form materials are used within the “Sheet lamination” technology. It uses thin sheet of metal, paper or basically any material, that can be cut and glued together. Each sheet = layer is cut into the shape

**Liquid materials**

As mentioned, there are substances called photopolymers, used for AM. The principle is having a bath of photopolymer, which is precisely cured by some UV light. Where cured, material undergoes a chemical reaction, creating bonds between separate molecules, thus solidification from liquid state. “Stereolitography” of “Material jetting” commonly use photopolymers. In those chapters, materials will be described more.

We might also want to group materials based on their **chemical composition**. I will not describe fully chemical properties of materials like type of molecule bonds. Still, easily we can distinguish between main groups of materials. One of them are **metals**. Metals are generally materials that are good electricity conductors. This property is related to their other properties. Metals have generally “high” yield strength (hundreds of MPa), very variable thermal expansion coefficient and medium-high melting point (important for heat curing of metals). They are usually also able to undergo some plastic deformation and do not soak water.

Other category is group of **plastic** materials. These materials have much lower yield strength, thus are not suitable for functional stressed parts. They almost do not conduct electricity and have low thermal conductivity coefficient, but higher heat expansion coefficient. Their melting / glass transition point is much lower than metal melting points, so they are easier to cure in this way.

Third category of materials used in AM are **ceramic materials**. Except of one new technology (that will not be discussed in the thesis), curing process is using ceramic powder. Melting point of ceramics is generally slightly higher than commonly used metals, but of course there are exceptions. Ceramics is very hard and strong, yet brittle. This property is often found problematic in AM. Because ceramics show almost no plastic behavior, they crack easily. This makes ceramics hard to process this way, because during printing rapid temperature gradients occur, causing thermal stresses and cracking.

Among other materials can be i.e. **photopolymers**. Even though they are plastic – polymers, I’d like to distinguish between them and other plastic materials, because they differ fundamentally in curing process. Photopolymers are default liquid material, which consists of more types of additives to make curing with UV light easier. So, depending of point of view, they might be considered different material than other plastics used in AM.

Also, mixtures of different materials should be mentioned. Same as we can make metal alloys of specific composition, we are able to incorporate small particles into plastic wires for printing, like bronze of wood. For example - if we have kind of material, consisting of 80% wooden particles and 20% polymer holding wooder particles together, it is among one’s preference to say about which material we are talking about.

Among other ways, we can also divide materials by the **way of** their **processing**. Some materials are processed by **heat**. They are fully / partially melted of heated, and after cooling, material (like in most processes using metal powders) fuses or solidifies together into single physical object. Source of heat are powerful lasers, or in case of conductive materials electron beam can be used instead.

On the other hand, liquid photopolymers are cured by **UV light**. Light of specific wavelength initiates chemical reaction within material, causing creation of new chemical bonds.

Binder jetting is the only technology, which basically **doesn’t process the material at all** – it only binds the material together with special glue, called binder.

What we should realize when thinking about curing materials, are problems we are bringing with the process. Heat processes are related with thermal stresses, expansion / contraction and subsequent curling, warping and cracking. The same issue is related to curing photopolymers, where curling and warping is caused no by heat, but by change of volume of material when changing state of matter. This is unique to binder jetting technology, which doesn’t have to deal with these issues – as will be discussed in dedicated chapter.

It is not always necessary to strictly distinguish between different materials. Instead of having fixed table of categorized materials, we should have complex knowledge of different kinds, their properties, pros and cons.