Challenges of New Manufacturing Methods for Refrigeration Compressors

C Thomas¹*, U Hesse¹

¹ Technische Universität Dresden, Bitzer Chair of Refrigeration, Cryogenics and Compressor Technology, 01062 Dresden, Germany
christiane.thomas@tu-dresden.de

1. Necessity for a crucial look into new materials and manufacturing methods
Despite major research and development activities in the field of compressors for both refrigerants and process gases, some aspects have been touched barely. One of these sectors is the question of materials and new manufacturing methods.

For decades it is a common rule to use mainly steel, cast iron or aluminum for the main components in a compressor. The way to aluminum was essential considering the weight reduction for the application in mobile systems. Steps further in this direction can only rarely be found. The main demands on the materials are: good mechanical and thermodynamic properties, low price level and experiences. A change of the materials and manufacturing methods require a closer look. This paper especially considers household and transport applications.

2. Challenges of compressor types
Considering the question of possible new manufacturing methods including new materials, an investigation of the specific challenges is necessary. Within this paper only the positive displacement machines will be evaluated – which does not mean that this discussion is only suitable for this category. Regarding the working principles different demands result for the specific parts of the compressor. Challenges for the compressor industry are the valves, lubrication and leakage, bearings and high forces/momentums. In the case of sealing elements plastic composites are already used. For this paper the focus is on valves and displacers.

3. Material and manufacturing options
In recent years the concept of "3D-printing" or "additive manufacturing" experienced a giant hype in several fields. For industrial applications especially for small plastic pieces additive manufacturing has been established e.g. in the automotive, electronics and medicine sectors. Different additive manufacturing principles are described in the paper that can be useful as a substitute for conventional principles. Their advantages as well as disadvantages and challenges are explained. These methods are Stereolithography (SLA), Fused Filament Fabrication (FFF), Multi-Jet-Modelling (MJM), Layer Laminate Manufacturing (LLM), Bound Metal Deposition (BMD) and Injection Moulding.

4. Analysis of material and manufacturing options
The choice of methods was based on the fact that the most promising principles for the use of metal and plastic based material should be evaluated. In compressor industry the challenges and requirements on the materials are very high. Starting with the strength of the material itself and the possibility to connect...
components of different materials with each other e.g. via a screw connection, is only one point. Other factors are the heat conduction, a known and manageable thermal expansion and the temperature stability – especially in cases where the compression process leads to high compressor outlet temperatures or the friction between sliding components is high which requires a good transport of heat to the surrounding or the cooling channels. Furthermore the new materials have to withstand the gases (and the lubricant) and have to show a good wear behavior.

Figure 1. Young\'s Modulus vs Density and Thermal Expansion vs Thermal Conductivity [1]

Hence, especially the Young\’s Module, the density, the thermal expansion and thermal conductivity are important characteristic values (see Figure 1).

In the case of thinking about reducing the weight and costs of existing compression designs more or less only an adjustment of the existing design is possible. The principle of having a scroll or piston type displacer shall be kept in the first step. Nevertheless it is possible to substitute the material for entire components or to substitute only parts of the material used.

The broad solution considers the complete change of basic manufacturing methods to achieve a lightweight component in a short amount of time which also leads to a reduction of costs.

Especially for the field of household and mobile cooling application fast and cheap manufacturing methods are necessary. FFF, MJM, LML and BDM do seem interesting but not reasonable for these purposes at this stage of development.

The principle of injection moulding seems promising for the manufacturing of poppet/discus or ring plate valves due to the wide range of applicable plastics, the high production speed and the resulting costs. For small-scale compressors it seems also favorable for the manufacturing of displacers. Having a well suited after-treatment even the scroll-sets seem manageable with this technology. The next steps are the identification of temperature stable plastic materials with a high enough strength which is not an easy task. Thinking about an entire substitution of the known materials might lead to an adjustment of the possible operation ranges, which is not favored in the first place.

The most suitable idea is to use the best of both materials: known metals for a good stability and thermal conductivity and lightweight materials for the reduction of mass – especially of moving components to enhance the efficiency of the compressor. These sandwich structures can be applied for different geometries and with varying properties – also more complex geometries like the scroll-sets are possible with e.g. the injection moulding principle.

[1] Granta Design, „teachingresources.grantadesign.com,“ [Online]. Available: http://teachingresources.grantadesign.com/Charts-overview. [Zugriff am 14 Jan 2019].