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RAPID TOOLING TECHNOLOGIES FOR RIM MOULDS

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A***bstract:*** *To produce products from integrated polyurethane foam by Reaction Injection Moulding (RIM) beside traditional metal moulds recently often applied tools made by Rapid Tooling (RT). This statement is specially right at production prototypes, first series or in case of limited series. The aim of this paper is to describe a possible and economic engineering material for RIM tools.*

Key words: *PUR, Reaction Injection Moulding (RIM),Rapid Tooling (RT), epoxy resin*

1. Introduction

Rapid Tooling (RT) is the common name of technologies what serve to produce tools for moulding, injection moulding or similar technologies within short period.

The reason of keen interest for RT is as preparing traditional tools by milling and/or by spark machining it too expensive and time consuming process. Beside the mentioned advantages RT admits brand new possibilities as well. Among them a more effective cooling of the mould by foaming cooling passages follow the inner surface geometry of the mould or it allows to manufacture the tool elements using different engineering materials. The only disadvantage of RT moulds is they can not modified later that is during the first it serie proved to be wrong they should be replaced as a complete tool while the traditional moulds can easely be modified in most cases.

2. The RT technologies [1]

The RT technologies can be classified into three groups what are follows: casting-, milling- and laminating processes.

The casting processes can be casting of mass, in closed or open state, or surface castings with cores. The milling technology is a high class method requiring a computer software to operate NC or CNC machine tools resulting precise moulds providing fine surface products. The essence of laminating technology is that the sample will be covered by reinforcing textile layer and soaked in resin then finally cross-linking.

Comparing moulds prepared by RT and traditional technologies one can come to the following statements:

- Required manufacturing period for a metal mould is at about 10-16 weeks while at mould prepared by RT is less than a week.
- The expenses of moulds prepared by RT make 5-10% of traditional metal moulds.
- There are big differences in service life of injection moulds as well, at traditional metal moulds it is normal 1.000.000 pcs, while at RT mould it can be max. 10.000 pcs.
- The RT mould is never be able to keep precise sizes countrary to metal tools.

The steel is the most frequent engineering material of injection moulds. Manufacturing elements from PUR foam using RIM technology both during the mixture injection and at cross-linking the pressure in the tool typically less, than 10 bar, that is the mechanical load on mould is relatively small. But the exothermal reaction generates heat and the complete manufacturing cycle is well longer. That is why epoxy resin mixed with different filling materials can be applied for RIM tools. This way the tool manufacturing is simplier and quicker parallel to it expenses are smaller.

3. The RIM moulds

Moulds form geometric shape and act as reactors should fulfil the following requirements [1]:

- appropriate strength, as pressure foam generation can reach 8-10 bar,
- suitable fixture (fixation?) if the tool,
- possibility of tempering in the range of 40-100 ^{o}C,
- heat resistance up to 150 ^{o}C on its surface,
- precise fit of moving elements,
- suitable to manufacture elements is smaller series (1.000-10.000 pcs),
- good wear resistance,
- size keeping mated with optically analog reproducible form-giving.

Selection the suitable engineering material to mould is essential to fulfil the above requirements. Mould material can be the follows:

- high quality steel; it is advisable to coat surfaces by nickel or by cromium. This type of mould is expensive, time consuming process consequently it is suitable to apply at mass-production only.

- Aluminium casting chemically coated by nickel. This mould is less expensive but still a time consuming process.
- Tools made of epoxy with different filling materials (manufactured by RT technology)

It is the latest mentioned RT technology using different resins casted spread widely for PUR foam moulds. The resins often contain different kinds of filling materials. The role of filling material is partially to improve the different characteristics of the resin, for example filling with metal powder the heat conduction capacity is improved, partially the expenses can be reduced significantly, as prices of filling materials generally far less than resins. The RT technology beside it cheapness and quickness has another advantage too. Namely it makes possible to produce arbitrary shape mould quick and precise enough applying a masterpiece. The usual process to manufacture RIM moulds use as typical engineering material is the Epolam resin and mullite mixture in 1:10 weight ratio. Though the mullite as filling material is relative expensive.

4. The aim of investigation

That is why it was set as aim of our investigation: Is it possible to determine a resin-filling material mixture cheaper to the present used one? Is it possible to replace mullite without reducing pressure carrying capacity or increasing deformation of mould? This problem includes the influences on product quality, the precise shape preserving, the thickness of flash. It seamed to be important to investigate replacing mullite with washed gravel and to determine optimal filling rate for gravel. The state of mould were investigated by Finite Element Method (FEM). To determine by calculation stress and strain states of the mould it is necessary to know the dynamic modulus of the material. As the tools basically are loaded by compression at our investigation the compression modulus were used. It should be mentioned these materials have different modulus for tension and for compression. [3]

Compression material test were carried out in accordance the standard MSZ EN ISO 604:2003. The specimens investigated were prepared with 3 different resins combined with two different filling materials. Further the weight ratios for resin and filling material were selected 1:7; 1:10;1:13. These filling ratios used in the practice.

5. Materials investigated

Resins

- Epolam 2001 epoxy resin, manufactured by Axson company (hardener: Epolam 2001),
- Biresin LS epoxy resin, manufactured by Sika company (hardener: Biresin LS),
- Biresin L84 epoxy resin, manufactured by Sika company (hardener: Biresin L84).

The filling material were:

- Mullite (grain size: 1-3 mm),

  Mullite, is a clay mineral, aluminum silicate ($Al_6Si_2O_{13}$). It is produced artificially during various melting and firing processes, and is used as a refractory.
- Washed gravel (grain size: 0,8-3 mm).

The filling ratios (weight ratios)

1:7 1:10, 1:13.

6. Results of measurements

Results of compression tests are given is **Table 1.** Assuming normal (Gauss) distribution the values in Table 1. gives the average of five measurements and their standard deviation. Results are represented graphically in **Fig. 1.**

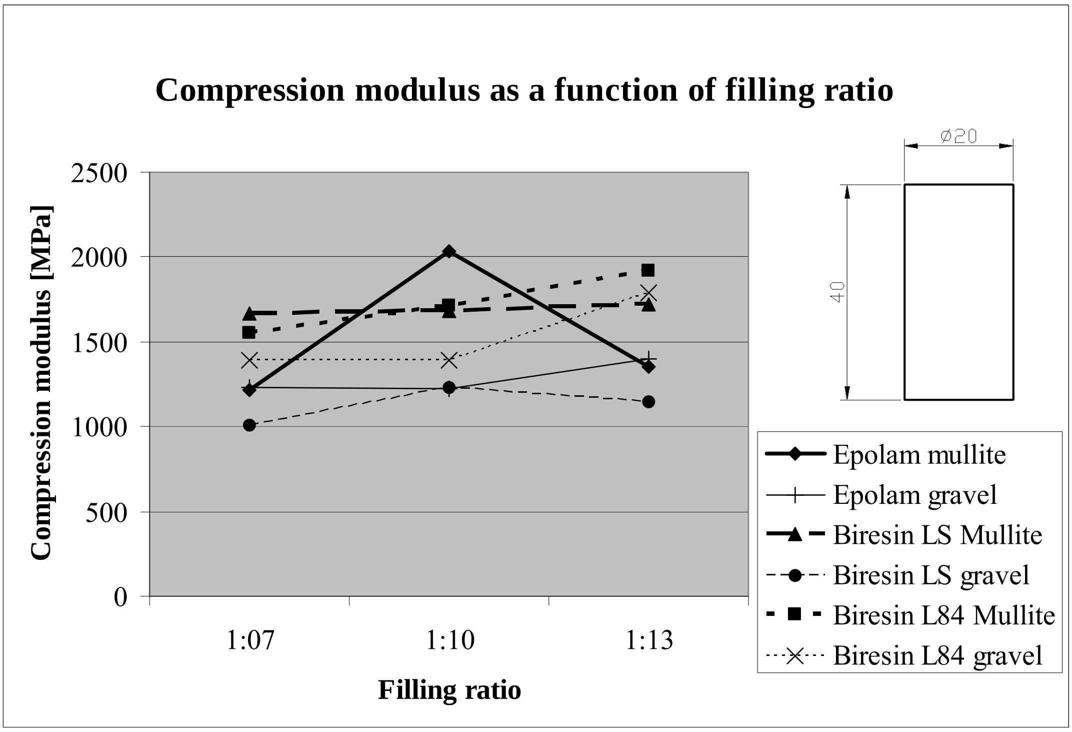

Fig. 1. Compression modulus as a function of filling ratio.

Table 1. Results of measurements. [MPa]

	Mullite			Gravel			Resin
Resin	1:7	1:10	1:13	1:7	1:10	1:13	
Epolam	1217±355	2588±225	1351±310	1229±454	1226±263	1402±318	2200
Biresin LS	1665±182	1685±204	1719±298	1006±312	1234±318	1148±326	2420
Biresin L84	1550±404	1711±486	1915±176	1393±314	1392±299	1788±343	3600

It can be observed that Epolam resin filled 1:10 with mullite and manufactured according the usual technology shows significant higher compression rigidity modules comparing to other variants. It should be mentioned that according to FEM analyses all combinations meet practical requirements the mould have to fulfil.

Parallel to investigations on stress- and strain states of the mould economic analyses have been carried out too. There were calculated prizes of mould materials referring on unit mass. **Table 2.** gives the price of the filling materials and **Table 3.** gives the price of the resins and **Table 4.** gives the prices of materials referring unit mass.

Table 2. Prices of filling materials.

Mterial	Price [HUF/kg]
Mullite	186
Gravel (mixed)	16,3

Table 3. Prices of resins.

Resin	Resin price [HUF/kg]	Hardener (mixing ratio)	Hardener price [HUF/kg]	Resin+hardener together [HUF/kg]
Axson Epolam2001	2550	Epolam 2001 (20%)	5260	3002
Biresin LS	1650	Biresin LS (12%)	3725	1477
Biresin L84	2927	Biresin L84 (24 %)	6640	3646

Table 4. Prices of materials referring unit mass

	Epolam + mullite	Epolam + gravel	Biresin LS + mullite	Biresin LS + gravel	Biresin L84 + Mullite	Biresin L84 + Gravel
1:7	538	389	347	199	618	470
1:10	439	285	302	148	497	343
1:13	383	225	276	118	428	270

It can be observed, that increasing the volume of the filling material the prices of the resin+filling tool materials are decreasing. The degree of decrement is higher by the high price resins. The Biresin LS resin with gravel is far the cheapest from all. According to **Fig. 1.**, the modulus of this material is acceptable, so we think, this is the perfect material for RIM moulds.

7. Conclusions (summary)

Surveying the results of mechanical tests carried out on different materials one can come to conclusion that the effect of filling material far stronger, than that of the resin. It was the mullite what shoved outstanding characteristics out of the tested filling materials. Both the results of FEM investigations and the informations collected from manufacturers and users state that all kind of resin-filling material contributions are satisfactory for manufacturing RIM tools.

Investigating the prices it can be selected the most economic resin-filling material combination where the material price itself is at about one-third of the previously used material making well less manufacturing cost of the mould.

8. Further research

In the future it is planned to investigate new types of resins (polyester-, 3P type resins) parallel to apply further filling materials (metal powder) as well as to carry out additional tests (bending and tensile tests) on the existing materials.

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11. References

[1] DE RIVO, BALÁZS: *Gyorsszerszámgyártási technikák,* Műanyag és Gumi 43(3). 102-106, 2006 március
KémSzám Bt., Budapest, 2004

[2] FARKAS, FERENC: *Poliuretánok*
KémSzám Bt., Budapest, 2004

[3] MAROSFALVI, J - MOLNÁR, L. – GRŐB P. : Analysis of the deformation state at polyurethane integral skin foam moulds, 6th International Multidisciplinary Conference, Baia Mare, 2005