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Research Regarding the Improvement of the Performance of Rubber Dies

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Abstract—**The paper presents a way to improve the mechanical characteristics of rubber dies, with the purpose of injecting the wax models necessary for the fabrication through investment casting technology. The purpose is to increase the compression strength and the hardness of the die's walls. Three brands of silicone rubber and very short glass fibbers (whiskers) for reinforcement, were used. The results of the experiments and the conclusions are also presented.**

***Index Terms*—Compression, glass fibbers, hardness, rubber**

I. Introduction

FABRICATING the complex pieces through rapid casting under blankness using slightly fusible models is a technology that has optimal results when it comes to the fabrication period, the complexity and the cost price. This technology is especially used for small batches in the case of complex pieces or when launching new prototypes [1]. The procedure includes 5 stages: 1. Fabricating the Master model, 2. Making of the silicone rubber die, 3. The casting or the injection of the models in the dies, 4. Realizing the tree of the wax models and making of the ceramic shape, 5. Casting the metal in a ceramic shape and obtaining the metal pieces.

The wax models (the fusible models) are perfect copies of the piece that is to be obtained. Considering this fact, obtaining the models holds a very important role in this technological process, because these are the ones that determine the dimensional precision and the shape of the piece. The fusible models are made in dies through casting, injection or rapid prototyping technologies. The most used methods are casting and injection, while the rapid prototype technologies are relatively new and rather expensive. The easiest way to obtain fusible models is through casting in the dies. For small batches, silicone rubber dies are used because they bring a wide range of advantages, such as: time saving, the possibility of obtaining complex shapes thanks to various separation fields, a simple technological process and a low cost [2].

Moreover, the dies are elastic, meaning that the models can be extracted easily. However, one disadvantage must be taken into consideration: there is a possibility of incomplete filling – in this case, models with shape defects may be obtained, due precisely to the deformation of the die's walls while the material is introduced. The deformation of the wall can be reduced or even eliminated if an elastic material for the die is used, but this material should also be sufficiently strong, in order to avoid the deformation.

This paper presents the possibilities of improving the silicone rubber dies' properties with the purpose of using them for injection. In order to do so, dies made of silicone rubber reinforced with glass fibber were used [3]. In this way, a high hardness level for the die, as well as high resistance strength are expected to be obtained.

II. Experimental Trials

In order to improve the properties of the silicone rubber dies, the material is reinforced with very short glass fibbers. Experimental data regarding the hardness and the compression resistance are necessary in order to point out the way in which the reinforcement percentage influences the determined characteristics.

A. *The Samples*

The samples were fabricated out of silicone rubber, mixed with very short and discontinuous glass fibbers (whiskers), with the purpose of reinforcement. For samples, 3 types of silicone rubbers from 2 different industrial producers were used, namely: the Essil 291 type, Essil 125 and ZC 825. Each type of silicone rubber has a different hardness, more precisely: Essil 291 has a hardness of 50 IRHD (≈36 Shore A1), Essil 125 has a hardness of 34 IRHD (≈24 Shore A1) and ZC 825 has 31 IRHD (≈21 Shore A1).

The glass fibber has a granulation from 10 to 11.25 and it represents the reinforcement element in the samples. The samples are made of silicone rubber and reinforced with glass fibber in the following proportions: 5, 10, 15 and, respectively, 20% [4]. The dimension of the samples was established according to SR ISO 815-A1:1995, under the form of a circular disk with a diameter of 29.0 ± 0.5mm and a width of 13.0 ± 0.2 mm.

Figure 1 presents the stages that were covered when the samples were fabricated. The homogeneity of the material was realized by mixing the silicone rubber with glass fibber and catalytic agent in the end. After that, the material was degassed by using vacuum at a pressure of -105N/m2 because the silicone rubber has a great affinity for gases and their presence can harm the samples. After the mix was poured in the forming nests, the material was degassed for the second time. The die was introduced in the oven for polymerization, and at the end, the samples were extracted and prepared for the measuring process.

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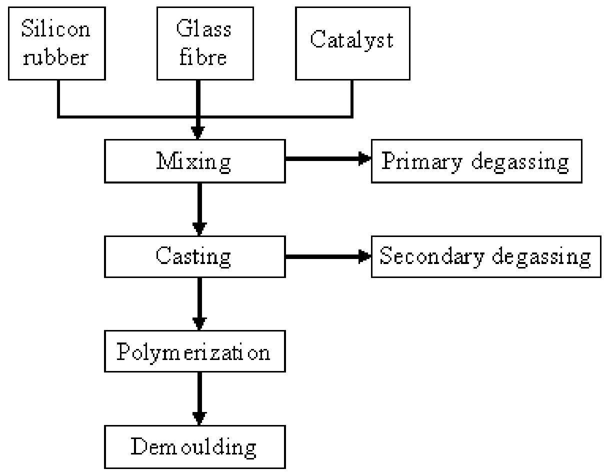

Fig. 1. Samples fabrication scheme

B. Equipment and Determinations

The samples were under 2 types of determinations in order to establish the properties that resulted after using different glass fibber reinforcement percentages for the silicone rubber. In order to determine the resistance under compression, a Zwick/Roel Materials testing machine Z150 with test Control PC and software testXpert II was used. In order to establish the hardness of the material, an IRHD (International Rubber Hard Degree) device was used. The determination of the hardness of the samples was made in international levels of rubber hardness (IRHD-International Rubber Hard Degree) according to SR ISO 7619-2:2010 (Rubber, vulcanized or thermoplastic- Determination of indentation hardness - Part 2: IRHD pocket meter method) and a converting table according to (SR ISO 7619-2:2010)

III. Analysis and Interpretation of the Obtained Data

A. Analysis of Samples' Hardness

The results obtained for each recipe were statistically processed in order to obtain the medium hardness of the rubber.

stats	Essil 291+0%	Essil 291+5%	Essil 291+10%	Essil 291+15%	Essil 291+20%
mean	50.241	54.235	57.284	60.771	66.975
sd	2.774	2.992	2.654	3.765	3.652
cv	0.055	0.055	0.046	0.061	0.054
se(mean)	0.800	0.799	0.736	1.006	1.054

stats	Essil 125+0%	Essil 125+5%	Essil 125+10%	Essil 125+15%
mean	34.178	42.584	47.1	53.412
sd	2.797	1.117	2.329	3.730
cv	0.081	0.026	0.049	0.069
se(mean)	0.747	0.309	0.823	1.318

stats	ZC 825+0%	ZC 825+5%	ZC 825+10%	ZC 825+15%
mean	30.871	33.728	36.314	41.257
sd	0.585	1.062	0.895	1.802
cv	0.018	0.031	0.024	0.043
se(mean)	0.221	0.401	0.338	0.681

Fig. 2. Statistical analyses of the hardness data's

The arithmetic average is very sensitive to extreme values and it is representative only when is calculated out of homogenous values, reason why the extreme values are excluded.

In the tables from figure 2, the results that were obtained after the analysis of the data with the help of the Stata/SE 10 software are presented. Just as the analysis shows, the standard deviation ″sd″ is between 0.58 ÷3.76, meaning an acceptable variation, and the variation coefficient ″cv″ has values between 0.01 ÷ 0.08, representing a weak variation and a good level of homogenization of the obtained values.

The IRHD variation diagram of the rubber according to the percentage of arming material that can be found in its composition can be seen in figure 3.

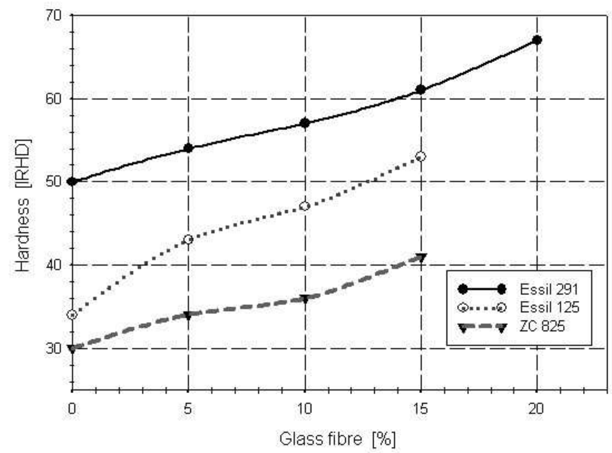

Fig. 3. Variation of hardness according to the glass fibber percentage.

It can be noticed the fact that fabricating the entire batch of samples was possible only for Essil 291. In the case of Essil 125 and ZC 825 there were concentrations of 15% glass fibber - above this level, the sliminess of the silicone rubber that resulted after the reinforcement raises significantly. A high level of sliminess makes the obtained mix unusable in the fabrication of the die process, which is why the experiments have been stopped for these recipes.

Figure 4 presents the histogram of percentile variation of the rubber's hardness, according to the percentage of glass fibber.

If the hardness variation is considered zero at no reinforcement (0% glass fibber) for all the types of tested silicone rubber than it appears that at 5% glass fibber there are the following values for the incremental percentage of the hardness: 8% for Essil 291, 26% for Essil 125 and 13% for ZC 825. At a reinforcement of 15% the values are 22% for Essil 291, 59% for Essil 125 and 37% for ZC 825. As it can be seen, the influence of glass fibber percentage upon hardness is low for ESIL 291, higher for ZC 825 and the highest for ESIL 125,

It can be noticed the fact that the hardness of the rubber varies differently, according to the initial hardness and the physical-chemical properties for the same percent of arming material.

The diagrams show that the hardness of the material increases with the increase of the arming level. For the Essil 291 silicone rubber type, can be noticed an almost linear variation, with a percentile increase between 6% and 12% and in the case of Essil 125, we have again a linear variation, between 12% and 26%. The same linear variation can be seen in the case of the ZC 825 silicone rubber, where a variation between 7% and 17% can be noticed.

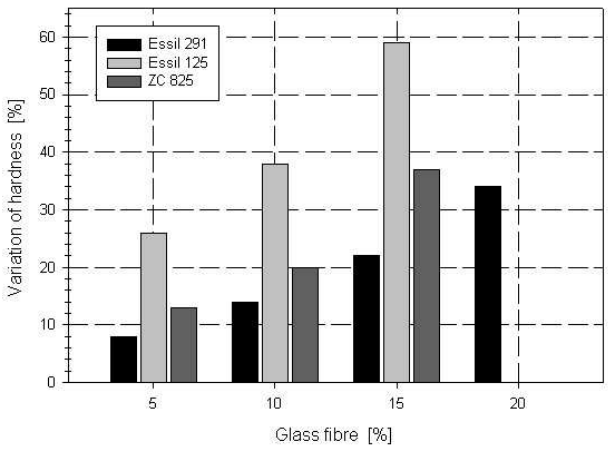

Fig. 4. Variation of the rubber's hardness according to the glass fibber percentage

Another aspect that was explored is the way that samples behave under compression, in the case of shortening them by 50%. In this case, the resistance's variation curves were determined, according to the applied force. The results that were obtained after the compression tests were again statistically processed in order to obtain the average for each one of the sample batches' specific deformation. After the statistic data were processed, it arises that the obtained values are homogeneous and have a high level of representativeness.

Figure 5 shows the variation diagram of the highest force that is necessary in order to shorten by 50% the height of the sample according to the glass fibber percentage that is present in the silicone rubber.

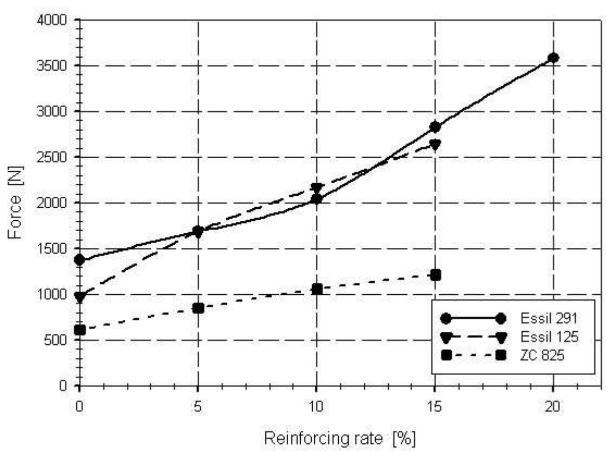

Fig. 5. Maximum force due to reinforcement rate for 50 % compression

It can be seen that the Essil291 silicone rubber considerably improves its strength resistance together with the increase of the glass fibber percentage. Moreover, the Essil 125 silicone rubber presents a much higher raise, increasing its resistance to compression by 121% compared to its initial one, at a glass fibber concentration of just 10%, while Essil 291 reaches 106% at a concentration of 15%. However, Essil 125 cannot be used when fabricating dies with a concentration of over 10% because the sliminess of the mix increases considerably and makes this unusable.

In figure 6 it is presented the variation of the silicone rubber samples' deformation (made of Essil 291) according to the stress applied, in order to have a deformation smaller than 1.5 mm. The stress applied was stopped when specified shortness was reached because technologically, dimensional departures of over 1.5 mm are not generally accepted.

The increase of the necessary force that deforms the samples once the reinforcement material concentration is increased can be noticed. Technologically, this represents a possibility to increase the injection pressure in order to obtain a certain established deformation if the silicone rubber die's properties are improved with the help of the glass fibber.

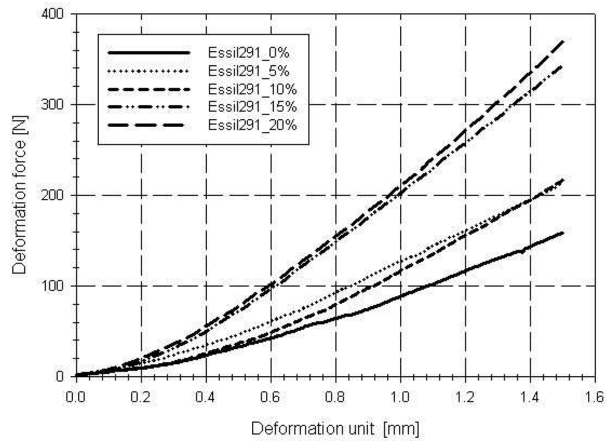

Fig. 6. Specific shortness due to reinforcement rate

IV. Conclusions

As a result of the determinations on each batch of samples and after the interpretation of the results, the following conclusions can be drawn:

--The hardness of the silicone rubber increases once the percentage of glass fibber from its composition increases.

--The hardness that was obtained on each sample batch varies in a non-uniform manner, depending to the type of silicone rubber (due to its mechanical characteristics)

--The silicone rubber dies can be used when fabricating slightly fusible wax models only in the case of gravitational casting under normal pressure or in the case of vacuum casting.

--Including the glass fibbers in the silicone rubber leads to the substantial increase of resistance under compression, that determine smaller deformation.

--Using dies made of silicone rubber reinforced with glass fibber, a much higher injection pressures can be used.

--The increase of the resistance under compression for the same recipe but for a different kind of silicone rubber is different and dependent on the mechanical properties of each type of silicone rubber.

The research revealed also a disadvantage of using silicone rubber reinforced with glass fibber and that is the increase of sliminess. This fact affects the silicone rubber die, because one problem appears: obtaining a die that does not copy the master model perfectly. For simple pieces, we can use high rubber sliminess, but for complex pieces with thin walls or those who have a lot of details that must be reproduced by the die, a reinforcement level of above 20% glass fibber leads to endangering while obtaining the die.

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1) Date of modification: May 25, 2011
2) Brief description of the changes: In the paper information, it was added another sponsor (PCCE "BIOMAPIN) who paid the fee for one of the participants to the conference.