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Elasticity of Moulding Sands – a Method of Reducing Core Cracking

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Abstract

This paper focuses on mechanical properties of self hardening moulding sands with furfuryl and alkyd binders. Elasticity as a new parameter of moulding sands is investigated. With the use of presented testing equipment, it is possible to determine force kinetics and deformation of moulding sand in real time. The need for this kind of study comes from the modern casting industry. New foundries can be characterized with high intensity of production which is correlated with high level of mechanization and automatization of foundry processes. The increasingly common use of manipulators in production of moulds and cores can lead to generation of new types of flaws, caused by breakage in moulds and cores which could occur during mould assembly. Hence it is required that moulds and cores have high resistance to those kinds of factors, attributing it with the phenomenon of elasticity. The article describes the theoretical basis of this property, presents methods of measuring and continues earlier research.

Keywords: Innovative foundry technologies and materials, Moulding sand, Binder, Elasticity, Cracking

1. Introduction

Both foundry cores and moulds are under constant influence of many mechanical factors connected with technological actions. Removing cores from core boxes, removing the pattern from the mould, core placement, mould assembly, are just examples of situations in which cracks and defects in moulds and cores can occur.

Especially in foundries with high mechanization degree, those actions are executed by machinery. This can lead to cracking of moulds and cores, which can be a source of defects in the foundry. The cause of this is high brittleness of moulding sand mixtures. That is why modern foundries seek moulding sands with higher elasticity. This concerns mainly self hardening core sands with synthetic resins [1].

The parameter of moulding sands elasticity has been investigated by both national and international scientists, but using a different approach [2-4].

Results presented in this article are part of the research focused on the influence of type and quality of the binder, in self hardening moulding sands, on moulding sands elasticity [5-6].

2. Elasticity of moulding sands

During elastic strain of polymer materials straightening of the long tangled macroparticles occurs. Stretched chains in the elastomer do not move between each other, because they are bonded with either chemical of physical nods. Otherwise a permanent plastic deformation could be observed, but it still wouldn't exclude the occurrence of elastic deformation in the material.

The straightening of polymer chains (fig. 1) can be done without any changes in the interatomic distances and covalent angles in the particles. This means the transition does not change the energy in the chemical bonds, because fragments of the particles can rotate around single bonds, like for example coal-coal bond. Straightening of polymer chains during elastic strain leads to entropy reduction in the material (the number of possible conformations decreases, so the entropy decreases). The reduction of entropy results in heat release. After the force, responsible for the elastic strain is removed, the polymer trends to increase its entropy, which is accompanied by absorption of heat. Macroparticles swirl back again and the material comes back to its previous shape.

During the elastic strain and the straightening of polymer chains (fig.1) the kinetic energy of the oscillating particles is emitted in the form of heat. During the elastic reversion, the emitted heat is absorbed and reversed into kinetic energy of oscillating and swirled polymer chains.

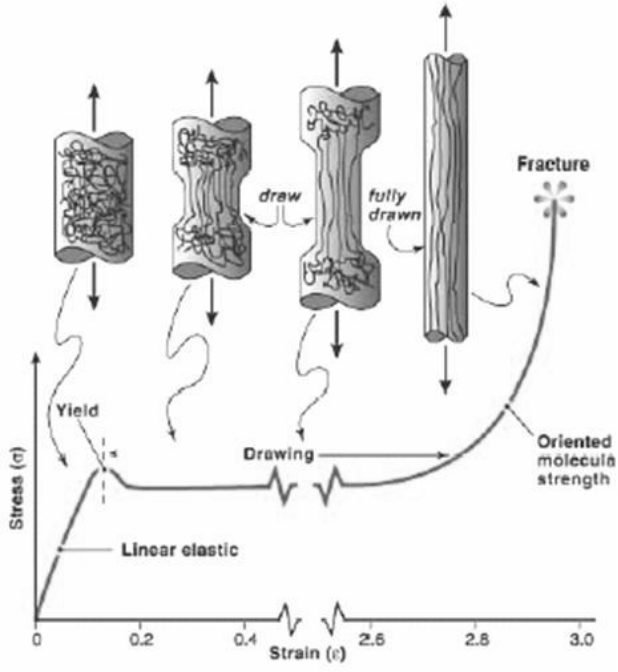

Fig. 1. Stress-strain curve and elongation of polymer chains during deformation [7].

Springiness is often identified with elasticity. But between those two there are slight differences, both the bend as well as in the maximum force. In the case of the usual "elasticity" of materials, the energy causing deformation distorts the interatomic bonds. In the case of materials “springiness”, the energy causing the deformation changes both the length of the atomic bonds as well as/or angles between the bonds. This results in a shift from the minimum energy equilibrium position. The accumulated potential energy of the deformed elastic body has, above all, the nature of electrostatic interactions between atoms. The force driving the return process of the elastic material is correlated with the materials need of achieving minimal atom energy. By taking their equilibrium positions, atoms pass previously taken energy associated with the distortion of the bonds between them. Elastic strains have to be small enough not to cause the destruction of atomic bonds. Larger deformations may cause the destruction of the crystal lattice, permanent deformation and/or irreversible breakage of the material.

Relatively reversible elastic deformation is much larger, by as much as 1000%, than the initial dimensional deformation of the sample material (eg. the products of latex). While the relative size of the elastic deformation, for example in steel is not higher than tenths of a percent.

The time of propagation of the elastic deformation is much larger than the elastic deformation. Whereas the time of return to the previous size in the elastic deformation is very small, ie. several thousand times smaller than a time to return to the previous dimensions of the deformed elastomer.

Perfectly elastic material should always come back to its original state after being stretched without absorption (loss) of mechanical energy, just as the perfectly elastic body. In practice, however, all known elastomers deviate from this ideal, since similarly to the liquids, a portion of energy is absorbed due to occurrence of internal friction. Thus, in the physics of polymers different kinds of mathematical models of the behavior of real elastomer are created. [7]

Finally, the polymeric materials different proportions of both elastic deformation and elastic and plastic (permanent) deformation may be present. The shares of the deformations depend on many parameters, for example strain rate, temperature, deformation range [8-11].

It should be noted that synthetic resins used in the preparation of moulding and core sands when cured can be classified into polymer groups. Hence, attempts to compare the processes in sand molds which are bound by the cured resins and bending strength test of the polymers are undertaken in this article. Since we do not take into account any breakage or elastic deformation of the sand grain itself, we investigate only the bonded resin behavior.

3. Measurement

The research was conducted on a new prototype testing appliance LRu-DMA produced by MULTISERW-Morek company (fig. 2).

Tests were conducted at the Department of Moulding Materials, Mould Technology and Cast Non-Ferrous Metals at Faculty of Foundry Engineering, AGH University of Science and Technology in Krakow.

Presented device consists of two modules:

- DMA – dedicated for measuring thermal distortion – hot distortion parameter,
- D_E – dedicated for elasticity measurement – local bending radius and maximum force detection.

Preliminary tests of elasticity (mechanical deformation) and hot distortion parameter (thermal deformation) were conducted [6]. On their bases presented self hardening moulding sands with synthetic resin binders were used. The test considered two types of resins – alkyd and furfuryl, with complementary hardeners. In

order to determine the effect of bonding agent content and the type of bonding resin on the mentioned parameters different moulding mixtures were tested. Detailed moulding sands compositions can be found in Table 1. For moulding sands marked A100% and F100% resin and hardener quantities were suggested by the resin manufacturer.

Table 1.

Name	Resin	ppw	Hardener	ppw	Sand	ppw
F 100%	Furfuryl resin KALTHARTZ XA-20	1,10	100T3	0,50	quartz sand	100
F 95%		1,05		0,48		100
F 90%		0,99		0,45		100
F 85%		0,94		0,43		100
A 100%	Alkyd resin SL2002	1,00	KL1	0,25		100
A 95%		0,95		0,24		100
A 90%		0,90		0,23		100
A 85%		0,85		0,21		100

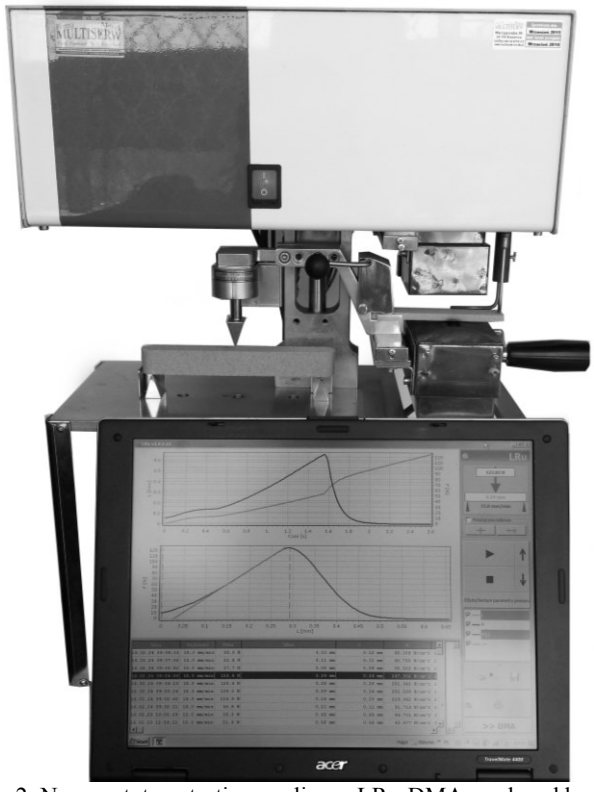

Fig. 2. New prototype testing appliance LRu-DMA produced by MULTISERW-Morek company.

3.1. Mechanical deformation

The D_E-module, dedicated for mechanical deformation measurement, is used for estimation of moulding sands elasticity. It gathers information on the development of force in time with simultaneous registration of the bend extend. This information is necessary for estimating the maximum bending force and maximum bending radius.

The measurement range goes from 0 to 900N. It is possible to regulate the kinetics of force growth by controlling the speed of the indenter. The speed can be set from 0 to 70mm/min with a 1mm step.

Different types of Bending measurements from Rg1 to Rg9 can be selected from a built-in database. It is also possible to enter individual dimensions of the tested sample into the database. The only limitation is the support sparing – there are two available 100 and 150mm [6].

Both bending strength test and elasticity measurements were conducted on standard bending stress samples, 172x22,5x22,5mm, prepared in the same way- by mixing first the sand with the hardener and then with the resin, samples were vibro-compacted. Moulding sand mixtures and their bonding agent contents are listed in table1.

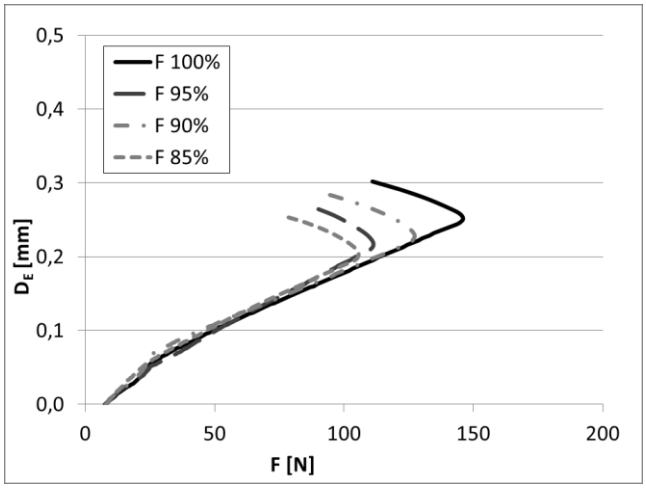

Fig. 3. Elasticity of moulding sand mixtures with different content of furfuryl resin

Presented results are a continuation of preliminary research on elasticity of moulding sands that can be found in previous publication (Elasticity – new criterion of moulding sands quality

assessment) [6]. After conducting numerous tests optimal parameters for moulding sand examination were set.

Conducted tests of elasticity and thermal deformation take different binder content into account. This relates to determining the influence of binder on the parameters of the moulding mixture.

It can be observed that the moulding sands with the original (100%) binder content had the highest deformation rate of 0,27mm (fig.3) and bending strength resistance of 2,92MPa (fig.4). Whereas in the group of moulding sands with lower binder content (from 95 to 85%) both the elasticity and the bending strength appeared to be on a lower level in comparison to the first moulding mixture. The drop rate of bending strength (fig.4) reached 20% and 14% in elasticity (fig.3) in comparison to the highest value for F100%.

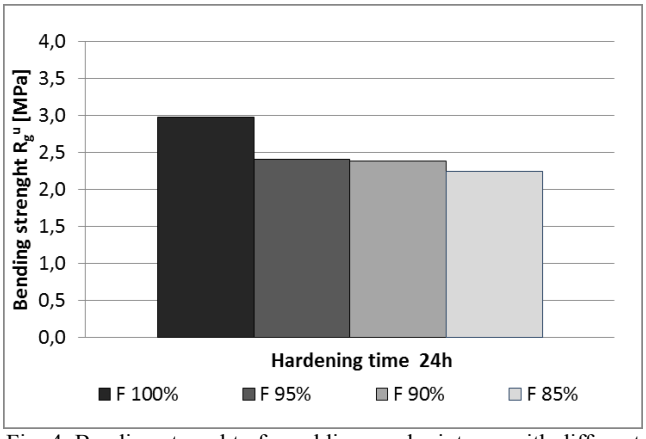

Fig. 4. Bending strenght of moulding sand mixtures with different content of furfuryl resin

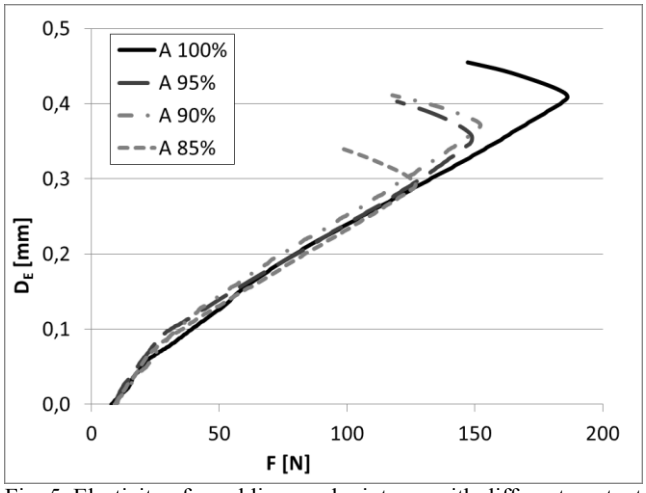

Fig. 5. Elasticity of moulding sand mixtures with different content of alkyd resin

Moving onto the moulding sands with alkyd resin it can be observed that the maximum in both bending strength and elasticity is much higher than in moulding mixtures with furfuryl resin. The difference in elasticity (fig.5) for sands containing the primary amount of binder (100%) amounts to 0,10mm, which is around 26% in comparison to the highest obtained value. It has its reflection in bending strength(fig.6) which is also higher for alkyd moulding sands and reaches 3,68MPa and is 22% higher than for furfuryl moulding mixtures.

Considering moulding sands with alkyd binder on their own it can be noted that moulding mixtures containing 95 and 90% of binder reached similar values in both elasticity 0,38mm (fig.5) and in bending strength 3,00-3,18MPa (fig.6). The gap between the highest value for A100% and the lowest A85% was much more visible than in moulding sands with furfuryl resin and reached 36% for bending strength (fig.6) and 28% for elasticity (fig.5).

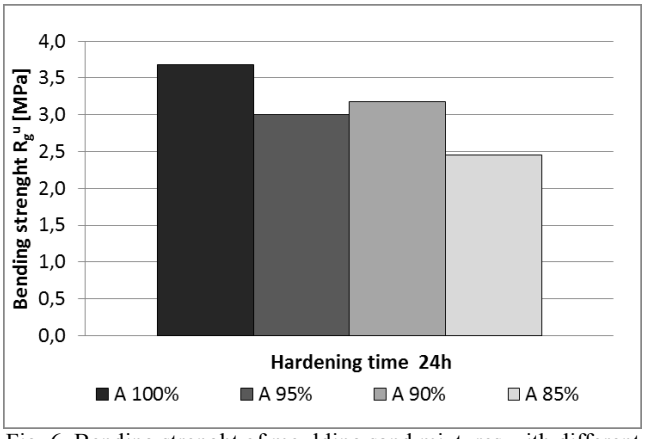

Fig. 6. Bending strenght of moulding sand mixtures with different content of alkyd resin

3.2. Thermal deformation

Thermal deformation module in this appliance is similar to the previous version described in detail in numerous articles.[12-13] However, there are a few changes in comparison to previous models.

Firstly, the top and bottom heating part are independent, and can be heated separately. It is possible to heat both or one of the parts away from the mounted sample and when the heating equipment reaches the desired temperature they can be moved onto the sample. Maximal thermal deformation measured by the device can reach +/-10mm. It is also possible to control either the heating temperature from room temp. to 900°C or the heating power from 0 to 100%.

Tests were conducted for analogical moulding sand mixtures (table 1) as bending strength and elasticity. Although the samples for those tests have different dimensions 114x25,4x6,3 mm, they were prepared the same way as bending strength samples. The deformation axis describes either deformation that occurs towards the heat source (negative values) or in the opposite direction from the heat source (positive values).

During the thermal deformation tests bottom part of the heating equipment was used. It was heated to maximum temperature, which for the device is 900°C, and placed upon the mounted sample. Deformation and temperature of the sample were measured during the tests.

For moulding sands with furfuryl resin binder maximum deformation reached 1,2mm for F100% and the maximum temperature reached almost 450ºC (fig.7). Mixtures containing 95% and 90% of binder gave lower but similar results, reaching 0,87mm and around 400ºC. The lowest deformation but also the lowest temperature resistance was measured for moulding sand F85%, with values of 0,27mm and 250ºC.

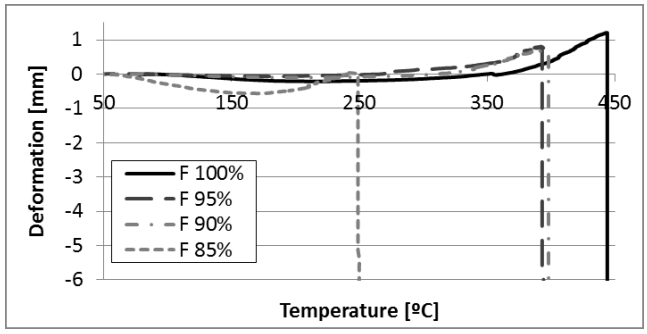

Fig. 7. Hot distortion research of moulding sand mixtures with with different conntent of furfuryl resin

Series with alkyd resin (fig.8) showed a completely different deformation pattern with tendency to deform towards the heat source.

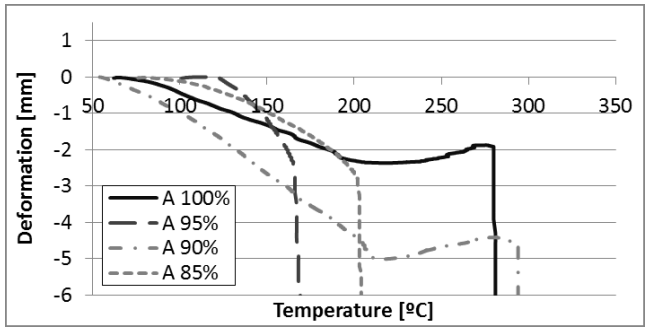

Fig. 8. Hot distortion research of moulding sand mixtures with different content of alkyd resin

It is important to point that the closer the thermal deformation curve is to 0mm the better the moulding sands' resistance to thermal deformation. What is more the temperature is also very important when considering core deformation. It has to be high enough for the core to withstand the pouring process, but low enough so the shake out and cleaning processes won't be affected.

Here the moulding sand A90% containing 90% of binder showed the biggest deformation, which reached 5mm and the destruction temperature was 295ºC. The A100% moulding sand had the breaking point at around 280ºC with maximum of 2,3mm deformation. Both A95% na A85% had the breaking point in 2,4mm and 2,6mm for 160ºC for A95% and 200ºC for A85%.

4. Conclusions

On the bases of presented research and literature study, following conclusions can be drawn:

- Low elasticity of moulding sands can be one of the factors leading to core and mould fracture, especially when manipulators are used,
- The elasticity test can prove to be an important test of moulding sands quality,
- Conducted research proved the usefulness of the new testing appliance.

Is should be emphasized that the studies are still in progress and will be carried out on different moulding sand mixtures with attempts to correlate the new parameter with different properties of moulding sands.

Acknowledgements

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