



# Influence of Quartz Sand Quality on Bending Strength and Thermal Deformation of Moulding Sands with Synthetic Binders

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## Abstract

Modern techniques of castings production, including moulding sands production, require a strict technological regime and high quality materials. In the case of self-hardening moulding sands with synthetic binders those requirements apply mainly to sand, which adds to more than 98% of the whole moulding sand mixture. The factors that affect the quality of the moulding sands are both chemical ( $\text{SiO}_2$ ,  $\text{Fe}_2\text{O}_3$  and carbonates content) and physical. Among these factors somewhat less attention is paid to the granulometric composition of the sands. As a part of this study, the effect of sand quality on bending strength  $R_g^u$  and thermal deformation of self-hardening moulding sands with furfural and alkyd resin was assessed. Moulding sands with furfural resin are known [1] to be the most susceptible to the sand quality. A negative effect on its properties has, among others, high content of clay binder and so-called subgrains (fraction smaller than 0,1mm), which can lead to neutralization of acidic hardeners (in the case of moulding sands with furfuryl resin) and also increase the specific surface, what forces greater amount of binding agents. The research used 5 different quartz sands originating from different sources and characterized with different grain composition and different clay binder content.

**Keywords:** Innovative foundry technologies and materials, Quartz sand, Self-hardening moulding sands, Synthetic resins, Hot distortion.

## 1. Introduction

There are many technological factors that affect the final quality of the cast. Among them are materials used for the production of moulding sands. Most commonly used material for the production of moulds is quartz sand [2]. During casting production, regardless of applied technology, a continuous control of sands grain distribution is required. The grain composition, their shape and size, both in fresh and reclaimed sands, influences the technological properties of moulding mixtures [3]. As it is described by the authors [1-4], during the selection of right sand

to the applied technology of moulding, it is necessary to pay attention to the physical and chemical properties of the sand. Among the physical properties we can distinguish important parameters i.e. content of clay binder, amount of dust fraction and granulometric composition, including grain size and homogeneity. Whereas to the group of chemical properties are included: content of  $\text{SiO}_2$ ,  $\text{FeO}$ ,  $\text{Fe}_2\text{O}_3$ ,  $\text{Fe}_3\text{O}_4$ ,  $\text{FeS}_2$ ,  $\text{Al}_2\text{O}_3$ ,  $\text{TiO}_2$ ,  $\text{CaO}$ ,  $\text{MgO}$  and carbonates, resistance to high temperatures, calculation losses, etc. In case of moulding sands with binders, it is also necessary to take into account the chemical character of the sand. The acidity (measured by the amount of acid that is needed to change the pH

to a set level) of sands is very important in the moulding technologies based on both acid and alkaline hardeners. Higher amount of admixtures, that are either neutral or alkaline, in the sand increases the acidic hardener usage, which reacts first with alkaline admixtures of the sand [2].

Production of casts with high surface quality and adequate dimensional accuracy requires also the knowledge of high temperature processes occurring in the moulding sands during casting. Those parameters are particularly important in moulding sands used in core production, which recreate the inner surfaces of the cast, any defects in those areas are usually very difficult or impossible to fix. Hardened moulding mixture, due to many factors, such as thermal expansion of sand grains, swelling and expansion of binding materials, thermoplasticity, deforms and due to continuous heating loses its durability [5-7].

In order to evaluate the influence of quartz sands quality on resistance and thermal deformation of moulding mixtures with chosen synthetic binders, bending strength  $R_g^u$  and hot distortion parameter were measured. The research was conducted on sands from five different deposits, using the technology of self-hardening moulding sands with furfuryl and alkyd resin.

## 2. Work methodology

The research was carried in Departments of Moulding Materials, Mould Technology and Cast Non-Ferrous Metals laboratory, on the Faculty of Foundry Engineering of AGH University of Science and Technology in Cracow, Poland.

Moulding sands compositions are listed in table no. 2.

Table 1.

Sands grain composition [8].

Parameter	Symbol [unit]	Sand no.				
		1	2	3	4	5
Clay content	[%]	0,06	0,19	0,44	0,43	0,63
Subgrain content	[%]	0,31	0,86	2,76	0,16	4,97
Grain no. AFS	$L = [-]$	53,51	43,15	46,88	49,02	63,17
Avr. grain diameter	$dL = [mm]$	0,24	0,29	0,27	0,26	0,20
Geometric average	$dg = [mm]$	0,27	0,36	0,32	0,30	0,25
Arithmetic average	$da = [mm]$	0,28	0,39	0,36	0,33	0,28
Harmonic average.	$dh = [mm]$	0,25	0,32	0,29	0,27	0,21
Median	$dM = [mm]$	0,27	0,37	0,31	0,29	0,25
Average grain size	$D50 = [mm]$	0,27	0,37	0,31	0,29	0,25
Main fraction	$F_g = [\%]$	83,09	87,95	76,17	75,73	67,99
Partition coefficient	$S_0 = [ ]$	1,27	1,33	1,35	1,36	1,37
Rate of inclination	$S_k = [ ]$	0,96	0,95	0,92	1,01	0,96
Degree of homogeneity	$GG = [\%]$	72,00	57,00	59,00	58,00	53,00
Surface area	$S_t = [m^2/kg]$	9,10	7,02	7,89	8,27	10,89

Table 2.  
Moulding sands composition.

Moulding sand type	Sand	Binder	Hardener
Self hardening moulding sand with furfural resin	100 mass parts	1,1 mass parts KALTHARZ XA-20	0,5 mass parts 100T3
Self hardening moulding sand with alkyd resin	100 mass parts	1,3 mass parts SL 2002	0,325 mass parts

## 3. Achieved results

Figure 1 shows the results of bending strength tests as a function of hardening time on different sands related to furfural resin. The highest bending strength – in the testing time period – was achieved after 24 hours for moulding sands with sands no. 1 and 2, which contained the lowest amount of binding clay. They also have a low subgrain content, lower than 1%.

It should also be noted that almost all of the examined moulding sands after 2 hours of hardening time achieved a similar level of bending strength as after 24 hours.

Lower bending strength is caused by higher clay and subgrain content, which may neutralize acidic hardeners and increase the surface area of the sand which leads to higher expenditure of resin.

Figure 2 shows moulding sands thermal deformation retrieved using hot distortion parameter.

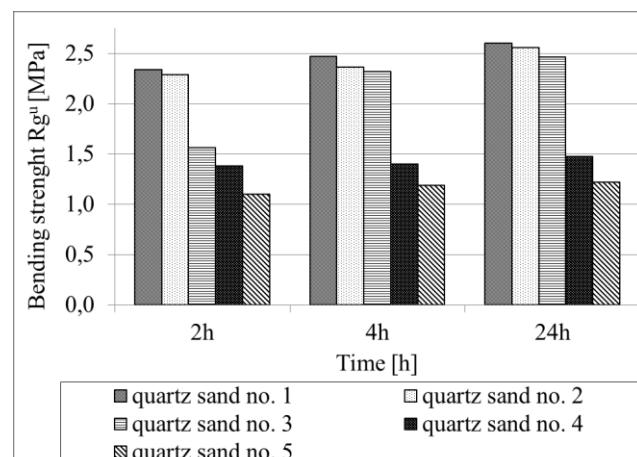


Fig. 1. Influence of quartz sand quality on bending strength  $R_g^u$  in moulding sands with furfural resin

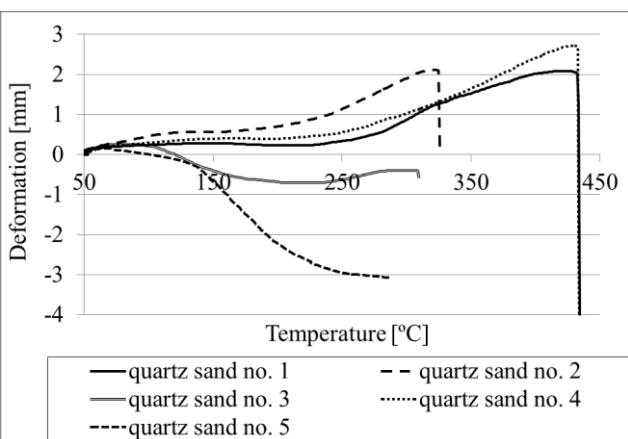


Fig. 2. Influence of quartz sand quality on thermal deformation in moulding sands with furfural resin

The moulding sands 1, 2, 3 have characteristics typical for moulding sands with furfural resins [9 - 11]. They show good resistance to deformation, what is represented on the chart by temperature range in which moulder is destroyed and high degree of strain (read on the chart in mm). They present good deformation resistance and high degree of distortion, which on the chart is represented by the distinctive breakdown of the curve at the end. They represent a higher distortion degree but it proceeds in higher temperatures. A variant chart type can be observed for moulding sands with sands no. 3 and 5, what is visible especially for sand no. 5, there is a correlation between high amount of small fractions, low bending strength and little thermal deformation resistance, based on hot distortion parameter.

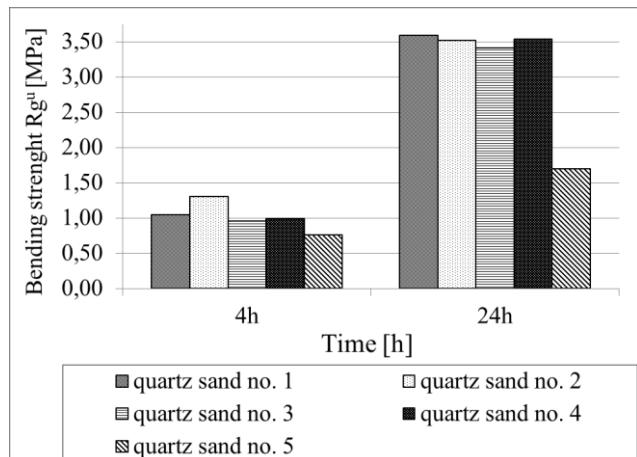


Fig. 3. Influence of quartz sand quality on bending strength  $R_g^u$  in moulding sands with alkyd resin

Figure 3 shows results of bending strength tests on moulding sands with alkyd resin. While using this type of resin we observe slower binding kinetics than in moulding sands with furfuryl based resin. After 24 hours bending strength is higher than for mentioned moulding sands and reaches up to 3.5 MPa. Moulding sands with alkyd resin prove to have lower susceptibility to grain

composition of the sand. Only moulding sands with much higher content of small grain fractions (clay + subgrain) exceeding 5% (sand no. 5) do not surpass the level of 2 MPa in bending strength.

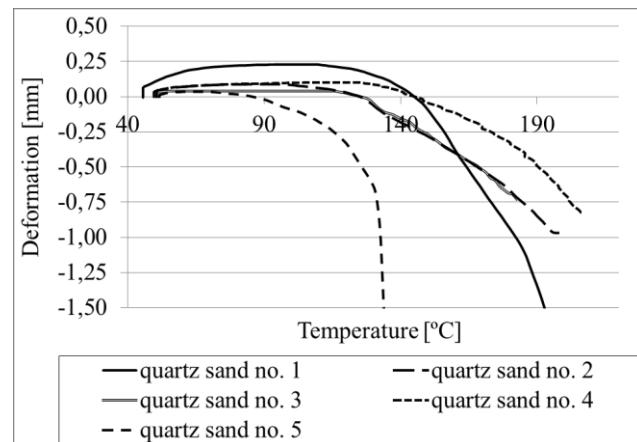


Fig. 4. Influence of quartz sand quality on thermal deformation in moulding sands with alkyd resin

Figure 4 shows thermal deformation of moulding sands with alkyd resin. They have different characteristics than moulding sands with furfuryl resin. Lower deformation and plastification show on the graph as a gentle bend on the curve, which is characteristic for this type of moulding sands. Progress of the deformation is similar for all of the examined moulding sands with alkyd resin. Only for moulding sands with sand no. 5 we observe worse properties than for the remaining four sands. Moulding sand with sand no. 1 shows a higher degree of deformation than the others. The plastification of moulding sands has positive impact on the risk of damaging the moulds and cores during the assembling process.

## 4. Conclusions

On the basis of conducted research and its outcomes we can conclude what follows.

For moulding sands with furfuryl resin the best results were achieved with sands that contained the lowest amount of clay and subgrain. Moulding sands with furfuryl resin show high sensitivity to the amount of the smallest fractions in the sand.

In hot distortion research, the best thermal deformation resistance was achieved for moulding sands with the lowest amount of clay and subgrain. Low thermal deformation resistance appeared in moulding sands with the highest amount of subgrain.

Moulding sands with alkyd resin feature higher bending strength and lower susceptibility to the presence of dust fractions in the sand. Only the moulding sand, where sand no. 5 was used, with clay and subgrain amount higher than 5%, achieved lower bending strength than the rest of the moulding sands, on the level of 2 MPa.

Thermal deformation research, as well as bending strength, show that the amount of small/dust fractions in the sands have smaller influence. Only the sand with more than 5% of small fractions shows worse thermal deformation resistance. The

moulding sand with the lowest amount of clay and subgrain has higher distortion degree reaching 0,25 mm. All of the remaining sands have similar properties.

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