

# The effect of gas permeability on the pressure of artificial resin-bonded core gases

L Mádi<sup>1</sup> and L Varga<sup>1</sup>

<sup>1</sup> University of Miskolc, Institute of Foundry, Miskolc-Egyetemváros, Hungary

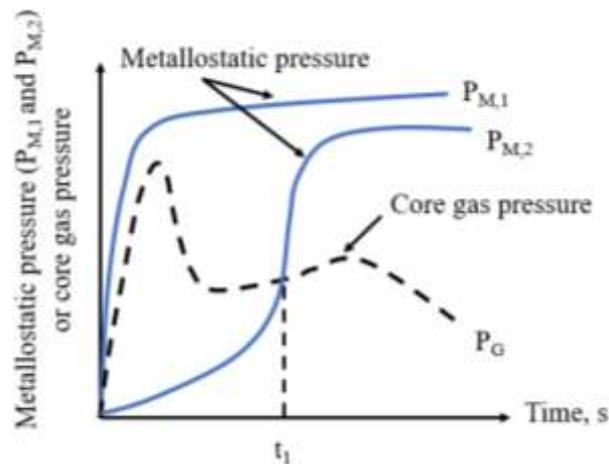
E-mail: ontlaura@uni-miskolc.hu

**Abstract.** In case of the decomposition of foundry artificial resin-bonded moulding materials, the amount and the pressure of the produced gases can have significant effect on the quality of the casting surface during the early phases of the solidification. The produced gases can cause casting defects if the casting skin is not solidified before the gas could pass through. The cores were made out of commercially available multi-element (SH33-34) and sieved SH33 sands with phenol no-bake process, with the same resin content. The gas permeability and gas pressure of the released gases were examined. Furthermore, the changes in the gas pressures of the gases released from various resin quality cores at different casting temperatures were also examined.

## 1. Introduction

In case of the decomposition of foundry artificial resin-bonded moulding materials, the amount and the pressure of the produced gases can have significant effect on the quality of the casting surface during the early phases of the solidification. The produced gases can cause casting defects if the casting skin is not solidified before the gas could pass through. The examination of the gas and its pressure generated from sand cores is a matter of priority. The composition of the produced gases is an important environmental issue, as the regulations are getting stricter. The intense gas release from the core can result in blow holes, while the metal can also penetrate the sand. The relation of the speed of the produced and released gas determined the gas pressure in the core.





**Figure 1.** The pressures influencing the production of blow holes [1]

The metallostatic pressure can be observed in Figure 1. In case of  $P_{M,1}$ , the metallostatic pressure is higher during the solidification than the pressure of the released gases. Thus, products with blowholes are not produced. In case of  $P_{M,2}$ , the core gas pressure is higher than the metallostatic pressure until  $t_1$ , so during this time interval the released gas from the core can enter the melt [1]. In the case of different core recipes, the time course of the gas pressure curves may differ significantly. The aim of the research work is to compare the pressure of gasses developing from various core wit different grain size and quality.

## 2. Objectives

The changes of compactness and gas permeability of the form are reverse in relation to the compaction. Gas permeability is primarily dependent on the granulometry and the geometry of the pore structure during core shooting [2]. There is an interdependence between the pressure of the core gas and gas permeability. Gas permeability test were carried out with two sands on the market, SH33 and SH34, sands with fine and medium fineness that were separated to various fractions under laboratory conditions. Using the same amount of resin,  $\text{Ø}50 \times 50$  mm standard test bars were produced with phenol no-bake process from the sands. The pressures of the gases produced from cores with various gas permeabilities and resin qualities (no-bake, HB-phenol and HB-furan) were examined. The released gases from the different resin quality cores casted at 720 and 1400 °C were also examined

## 3. Experimental

The fire-resistant matrix of the core was washed, separated silica sand from Sajdiková. The effect of gas permeability was examined using silica sand with various grain sizes (SH33-34) and sieved to fractions: 110-220, 220-300  $\mu\text{m}$ . The dominating variable included in this experiment was sand grain size, so sieve analysis was performed. The particle size distributions of the used sands can be seen in Table 1. Based on the particle size distribution diagram it can be concluded that SH33 sand is ternary and SH34 sand is binary. The sand grain sieve analysis implied that there was no issue of grain distribution. This grain distribution together with the grain surface (specific surface) determines the indispensable amount of resin and catalyst. Grain fineness number (GFN) can be determined based on the quantity of sieve residues. To produce high quality sand moulds, good grain size distribution is needed. Grain fineness is defined by the number of mesh-openings per col, in which sand with consistent particle size distribution would pass through. It is basically based on the calculation of weighted mean value. The retained sand is multiplied with the so-called sieve constant and the results are cumulated. This number is divided by the full quantity of the sand used for the analysis [5].

$$GFN = \frac{\sum G_n K_n}{G_n}$$

where,

GFN= number of fineness,

$G_n$ = weight percent of material for each sieve,

$K_n$ = sieve constant for each sieve.

**Table 1.** The granulometric properties of the sands

Granulometric properties	Sand type, mm			
	SH34	SH33	0.11-0.22	0.22-0.3
Average particle size, mm	0.19	0.23	0.19	0.26
Number of fineness	97.73	74.93	105	55
Theoretical specific surface, g/cm <sup>3</sup>	121.74	100.68	126.5	88
Measured specific surface, g/cm <sup>3</sup>	140	105	155	115
Equality ratio, %	34	74	100	100

Three resin qualities were examined during the experiments. The compositions of the mixtures can be seen in Table 2. The effect of the granular structure was examined only in case of phenol no-bake cores. The cores for the resin quality and casting temperature tests were prepared from commercially available SH33 sand.

**Table 2.** The composition of the sand mixtures

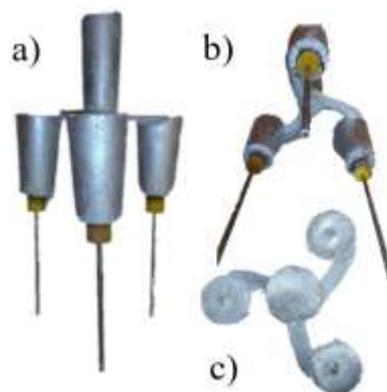
Resin quality	Resin content, wt%	Catalyst content, wt%	Curing temperature, °C	Curing time, min
No-bake	1.2	0.5	no-bake	
HB-phenol	1.5	0.3	220	15
HB-furan	1.33	0.33	200	10

The cores were prepared with constant compacting energy and approximately the same bulk density (1.6 g/cm<sup>3</sup>) under laboratory conditions. The setting time of the no-bake sand mixtures was 3 hours. The geometry of the test bars was Ø28×134.3 mm. The steel pipes used for collecting the produced were (Ø6×300mm) placed 5 mm away from the base of the test bars during core making. The form was prepared using a bentonite mixture containing 8% bentonite and 4% water. The fire-resistant matrix of the form was silica sand. The lower moulding box was Ø330×200 mm and the upper moulding box was Ø330×140 mm. Casting was carried out simultaneously using a tangential access channel in a three-cavity form. Approximately 45 kg bentonite mixture was necessary for each forms which were produced with a Multiserw Morek low speed mixers. The mould cavities were made with cone-shaped wood test bars (Ø70×150mm, draft: 4°). 720 °C foundry aluminium alloy was used for casting. The preparation steps of the waste mould can be observed in Figure 2.



**Figure 2.** The experimental moulding box, a) lower part with the cores, b) tangential access channel without cores and c) with core d) lower and upper moulding box with weight on

The produced gases passed through a silicone tube to a pressure transducer. Three Baumer-type pressure transducers were used for the experiments. A pressure transducer is a front membrane device for low pressure measurement. The device can measure 0-0.1 bar pressure with  $\pm 0,5\%$  accuracy. The output signal is 4-20 mA and the reaction time is  $\leq 0,5$  ms. A HBM QuantumX-MX840B universal 8 channel data acquisition module was used, which is connected to a computer with a HBM Catman software. The sampling rate was 30 Hz. The experimental three-core aluminium casting with the cores and the feeding system can be seen in Figure 3.



**Figure 3.** The three-core aluminium casting with the cores and the feeding system:  
a) cross-sectional view b) bottom view c) top view

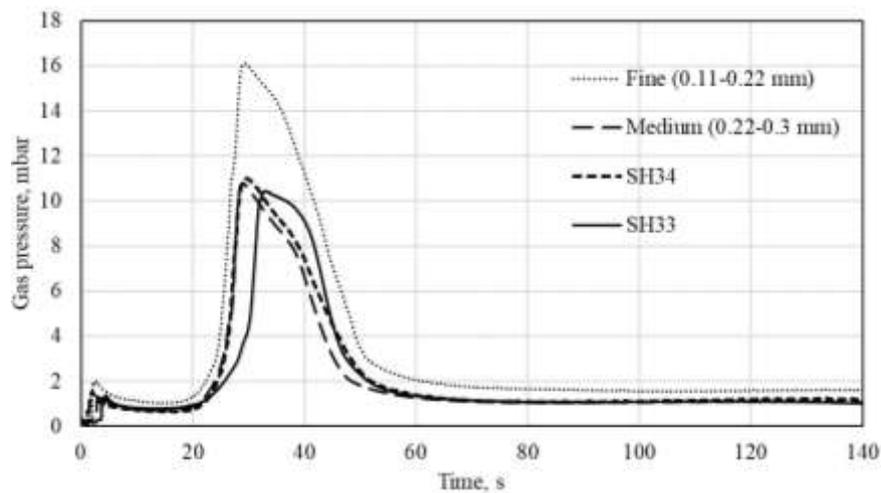
#### 4. The effect of granular structure on the pressure of the released gases

The gas permeability of test bars from the sieved, one-fraction sand and the multiple-fraction sand differ from one another. Significant difference can be observed between the gas permeability of fine and medium sands. The gas permeability of cores made out of medium sand was around 200, and around 100 for fine sand cores. The exact data on gas permeability can be found in Table 3.

**Table 3.** The gas permeability and bulk density of cores with various grain sizes

Sand	$G_k$	$\delta_{average}$ , g/cm <sup>3</sup>
SH33	210	1.6031
SH34	100	1.6104
Medium	180	1.6057
Fine	87	1.5943

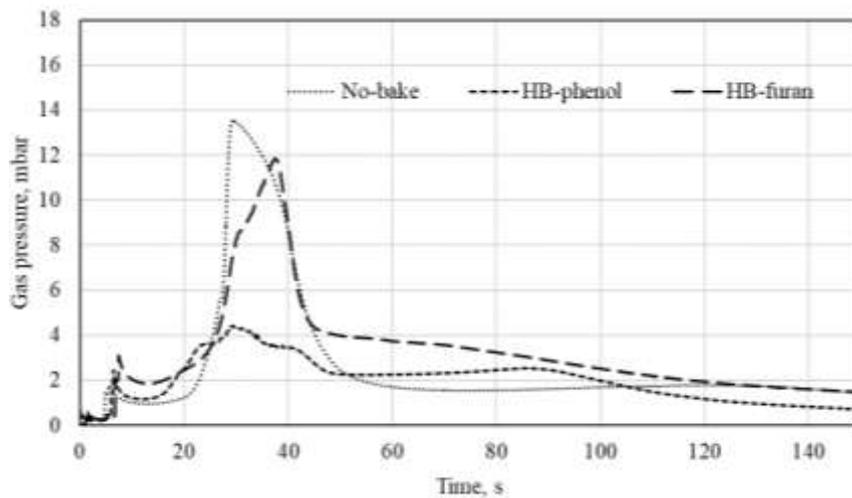
Based on the time course of the curves in Figure 7, two maximums can be observed. The increase in gas pressure is uneven. The first main pressure increase was at 5-10 seconds because the heating up and the expansion of the air trapped in the pores is fast. Furthermore, the amount of gas produced due to the high temperature gradient of the mould wall fills the pores and the gas release is started. More and more moulding mixture is getting heated up and the velocity of gas production is faster. Reaching the maximum pressure value at 30-40 seconds, a steady state is achieved [6, 7].

**Figure 4.** Pressures of the gases produced from cores with various particle sizes

As it can be seen on the diagram, the time dependency of the gas pressure curves of SH34 and the medium sand (0.22-0.3 mm) are almost identical. The gas pressure is higher in cores made from sieved sand due to the low gas discharge. The gas pressure of cores from fine one-fraction sand can reach up to 16 mbar as the gas permeability is very low. The probability of casting defects caused by gas penetration is also increased.

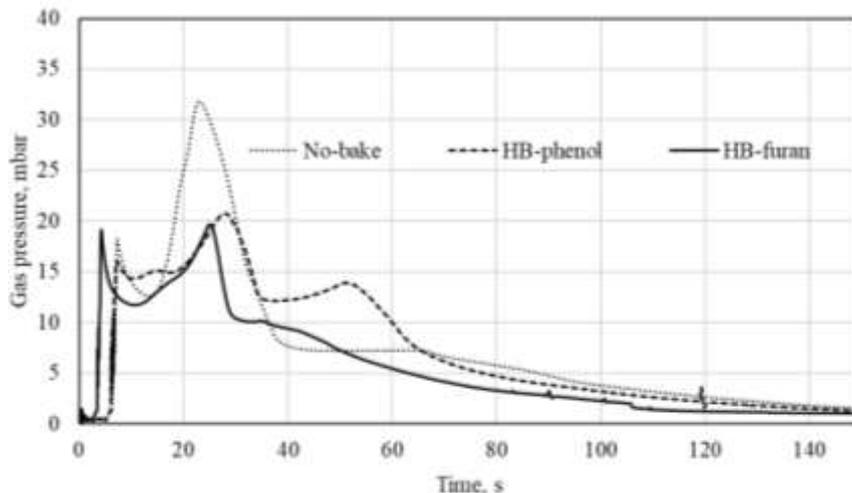
### 5. The effects of resin quality and casting temperature on the pressure of the released core gases

The effects of resin quality and casting temperature on the pressure of the released core gases can be observed in Figures 5 and 6.



**Figure 5.** The effect of resin quality on the pressure of the released gases in case of casting aluminium alloy ( $T_{\text{cast.}} = 720^{\circ}\text{C}$ )

The gas pressure curves are strongly influenced by the resin quality. In case of  $720^{\circ}\text{C}$  casting temperature, the first pressure peak can be observed less than 10 s after casting. The  $p_{\text{max}}$  values vary between 4-14 mbar in case of the different resin qualities. Intermittent resin burning can be observed in the gas pressure curves of the HB-phenol resin cores. Rapid increase in the gas pressure can be observed in the pores of the cores made with no-bake process in 20 s after casting, which increases the possibility of the development of blow-holes.



**Figure 6.** The effect of resin quality on the pressure of the released gases in case of cast iron ( $T_{\text{cast.}} = 1400 \pm 20^{\circ}\text{C}$ )

The maximum gas pressure was 20-32 mbar in case of  $1400^{\circ}\text{C}$  casting temperature. Two similar pressure maximums can be observed in the gas pressure curves of HB-furan resin cores which can be the result of the high moisture content of the binder. The cores made with no-bake process had the highest released gas pressure.

## 6. Summary

Casting defects caused by gas penetration are formed if the maximum gas pressure occurs seconds after casting, before the development of a solid skin.

There is an interdependence between the pressure of the core gas and gas permeability. The gas pressure of the fine-grained cores is higher and developed earlier than in case of medium grained cores. The reason behind is the low gas discharge. The possibility of casting defects due to gas penetration is higher if fine one-fraction sands are used.

The characteristics of the gas pressure curves are significantly influenced by the resin quality. The characteristic curves of the gas pressures of the various resin quality cores casted at different temperatures (720-1400°C) show similar tendencies. In case of 720 °C casting temperature, the first pressure peak can be observed less than 10 s after casting. The  $p_{\max}$  values vary between 4-14 mbar in case of the different resin qualities. The maximum gas pressure was 20-32 mbar in case of 1400 °C casting temperature. Intermittent resin burning can be observed in the gas pressure curves of the HB-phenol resin cores. The gas pressure increases in the first 20 s after casting in case of both casting temperatures (720 and 1400°C), then an intermittent decrease can be observed. The difference in the gas pressures at various casting temperatures can be 15 mbar.

## Acknowledgements

The research was also Supported BY the ÚNKP-17-3 New National Excellence Program of the Ministry of Human Capacities. The authors would like to Mária Ambrus for her linguistic advice.

## References

- [1] L. Winardi, H.E. Littleton, R.D. Griffin J.A. Griffin 2008 Gas from Green Sand Molds and Vapor Transport Zone, *AFS Transactions* p.381-399.
- [2] L. Winardi, H. Littleton, C.E. Bates New 2005 Technique for Measuring Permeability of Cores Made from Various Sand, Binders, Additives and Coating, *American Foundry Society, Paper 395-396., AFS Transactions American Foundry Society, Schausburg, IL USA*
- [3] P.F. Ambidge, P.D.E. Biggins 1984 Environmental Problems Arising From the Use of Chemicals in Molding *Materials Developments for Future Foundry Prosperity* p. 219.
- [4] Mancuso Chemicals Limited, Foundry Products 2005 Technical Data Sheet <http://www.mancusochemicals.com/wp-content/uploads/2018/01/Furan-Binder-Use.pdf>
- [5] Shailee G. Acharya, Jeetendra A. Vadher, Manoj Sheladiya 2016 A furan no-bake binder system analysis for improved casting quality, *Copyright American Foundry Society, DOI 10.1007/s40962-016-0059-x*
- [6] A.Chojecki, J. Mocek 1/2011, 9-14 Gas pressure in sand mould poured with cast iron, *Archives of Foundry Engineering Volume 11, Issue*
- [7] Tóth L. 1997 Gázfejlődés az öntödei formázó és maghomok keverékekben. A bentonitos formázókeverékek aktív bentonit és víztartalmának összefüggése a plaszticitással és a repedési szilárdsággal, *PhD thesis (in Hungarian)*