Novel PEP-SET™ System to Improve Productivity and Reduce Production Costs

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ABSTRACT

A comparison of three Polyurethane No-Bake (PUNB) systems was studied with contrasting properties such as strength, gas evolution and smoke generation, focusing on obtaining the best results with a lower possible price per mixed ton of sand. Results from gas evolution testing provided evidence that a reduction in gas generation up to 9% can be obtained by just changing the ratio from 55/45 to 60/40. A reduction of 6% in gas generation can be seen with a binder reduction of 0.1%. Also, the systems can show equivalent tensile resistances at a lower binder percent. For example, system 1205/2410 at 0.9% binder has comparable tensile resistances with system 1670/2670 with 1.1% of binder. This results in a reduction in cost and gas evolution, even when system 1205/2410 is more expensive when comparing the price per kg.

Keywords: polyurethane no-bake, PUNB, binder, PEP-SET™, tensile, gas evolution, smoke generation, cost reduction

INTRODUCTION

The current demand for high-quality casting products for the automotive, train, construction, hydraulic pumps, electric motor markets, etc. is increasing.[1] At the same time, companies need to decrease production costs. One option to improve the foundry process is optimization of the raw materials, such as binders. One of the most popular resins systems used in foundry is the Phenolic Urethane (PU)[2] system because of the low gas evolution when compared to other resin systems like silicate esters, Furan, shell, etc. and the productivity advantages.[3] The PU system can be separated into Polyurethane Cold Box (PUCB) and Polyurethane No-Bake (PUNB). The focus of this study is the No-Bake process, specifically PUNBs. Since the invention of this system in the 1970s it has been the focus in the study of various properties and applications.[4] For gas evolution, performance was measured at different temperatures bases on different metal melting points[5] and compared with other No-Bake systems.[6]

This study focuses on three PUNB systems. The three systems are under the PEP-SET™ name with different product numbers: system 1670/2670 that has been in the market more than 30 years, 1510/2510 is a system with high performance in gas evolution and tensile strength and system 1205/2410, a new product introduced to satisfy the current production demands at a lower cost per mixed ton of sand.

This work shows the performance of these three system and relation with the cost per ton of sand, looking to decrease gas defects, decreasing the binder level, reducing the gas generation, cost and improving the casting quality and decreasing the scrap.

DESIGN OF EXPERIMENTS

The recipes for the bonded samples are shown in Table 1, all the samples were made using new Wedron 410 sand. The first step was to make the dog bone samples following the AFS 3301-08-S procedure from the "AFS Mold & Core Test Handbook," the tensile strength measurement was also performed under this standard using a Thwing-Albert Model 1265 tensile tester.

Table 1. Binder Systems, Percentages and Ratios

Binder system	Binder percent	Ratios
1205/2410	0.70	55/45 60/40
	0.80	
	0.90	
	1.00	
	1.10	
1510/2510	0.70	55/45 60/40
	0.80	
	0.90	
	1.00	
	1.10	
1670/2670	0.70	55/45 60/40
	0.80	
	0.90	
	1.00	
	1.10	

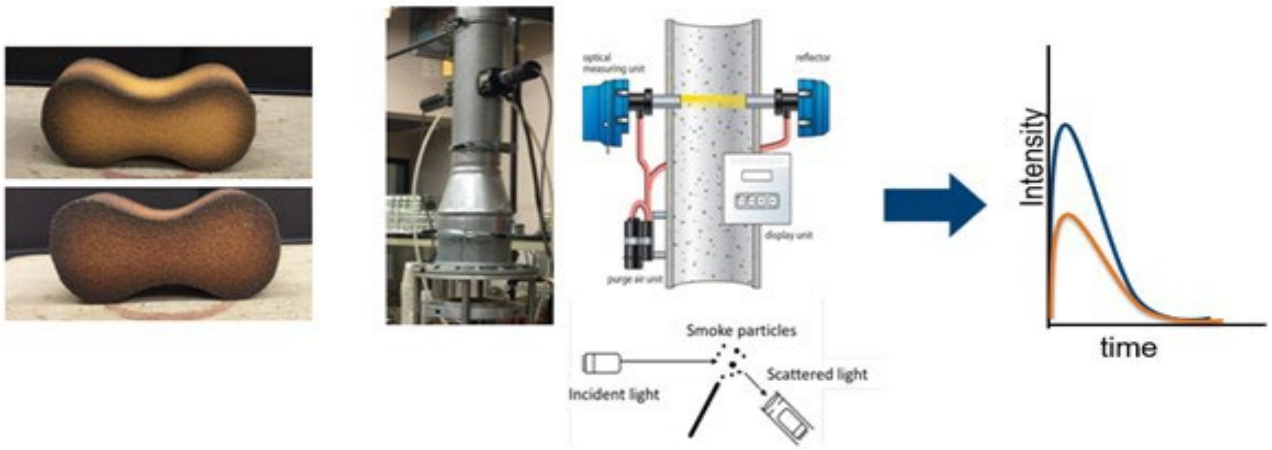

Figure 1. Smoke test dog bone samples and the testing device.

The gas evolution samples were taken from the same dog bones made for the tensile test and aged for 24 hours at 77F (25C) and 50%RH, taking the sand from the center of them. One gram of sand was weighed and then burned at 1400F (760C) measuring all the gas volume generated in 500 sec. The gas evolution test was performed using a Simpson Technologies model PGD-E.

For the smoke test an instrument developed by ASK Chemicals R&D of North America was used.[7] This instrument measures the smoke between a laser emitter and detector after burning the dog bone for one minute at 1292F (700C). The samples are placed in the instrument measuring the gas that cross the lasers paths, sending a signal that will be called "Intensity" measured against time as can be seen in the graphic of Figure 1. The "Intensity" directly correlates to smoke, more "Intensity" means more smoke from the sample.

RESULTS

TENSILE TESTING

Samples for the tensile test were stored in a room at a controlled temperature and humidity for one hour, and then broken, data is presented in Figure 2.

Starting with a ratio of 60/40 the system 1205/2410 and Axiom showed a similar performance in the high binder levels as can be seen in Figure 2, but system 1205/2410 showed a better performance in the lower binder levels. On the other hand, the system 1670/2670 showed lower tensile strength, exposing the performance of a system with old technology. The results of the 55/45 ratio indicated the importance of the system that has been developed. In the case of 1205/2410 tensile strengths with a ratio of 60/40 were better. In comparison the Axiom system demonstrated a marked better tensile strength, reaching better resistance in a short time.

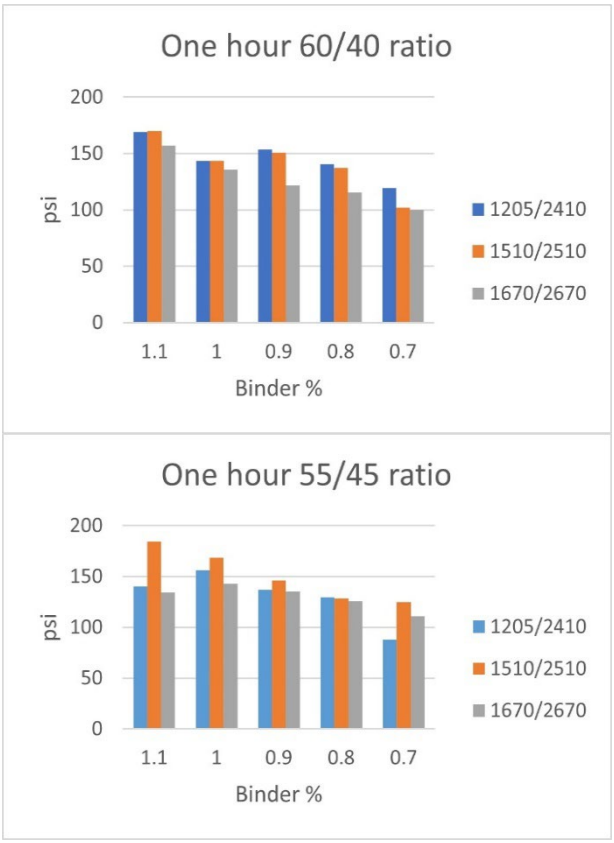

Figure 2. Tensile test results for different systems, binder percentages and ratios.

GAS EVOLUTION

All samples were saved in a controlled temperature and humidity room for 24 hours, then the sand was prepared for the gas evolution test. The results show the difference in the amount of gas generated at two ratios and binder levels. Values were measured up to 1.2 mL/g in all systems with 1.1% of binder, values around 0.8 mL/g were obtained for 0.7% binder level. The data is presented

in Figure 3. Also, the binder ratio directly affects the gas evolution, the 60/40 ratio gave lower values of gas evolution compared against the 55/45 in all systems with the same binder level.

A ratio of 60/40 will always decrease the gas evolution, up to 9% of less gas in binder levels of 1.1% and up to 4% of less gas in low ratios of 0.7% of binder level. Additionally, the tensile results for 1205/2410 had better tensile strengths at a 60/40 ratio. Also, the gas generated can be decreased from 2% to 6%, decreasing the binder percent 0.1%. This gas reduction help decrease the defects caused by gas i.e., bubbles, lustrous carbon, etc.

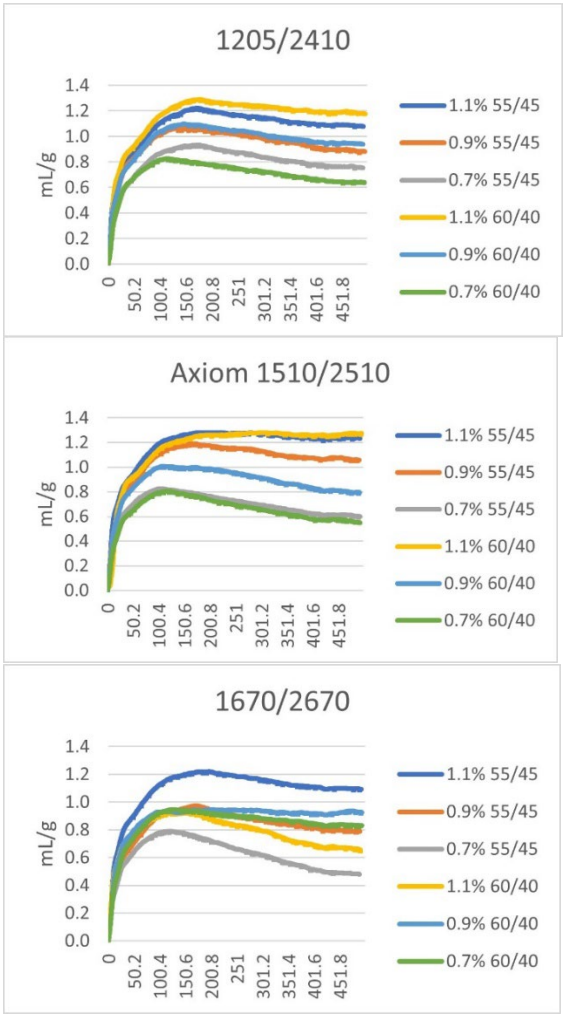

Figure 3. Gas evolution results for each system at different binder levels and ratios.

SMOKE TESTING

The results of smoke can be correlated with the gas generated when molten metal is poured into the mold. In this test, samples were saved for 48 hours at 77F (25C) and 50% RH. The results shown in Figure 4 show a lower smoke generation in the system 1670/2670 with peak values of 0.5 in intensity, followed by the 1205/2410 system with peak values of 0.9 and higher with values up to 1 of intensity, but these results are related with the solvent package of each system. The material used for 1670/2670 system evaporates at a lower temperature, losing these solvents also decreased the mechanical properties and will show a higher odor during the molding process with hot sand in comparison with the other systems. This is one of the reasons the system 1670/2670 shows lower tensile strengths, because of the loss of solvents in the dog-bone, but returning with the gas evolution data, the gas generated by the binder is in the same values as can be seen in Figure 3.

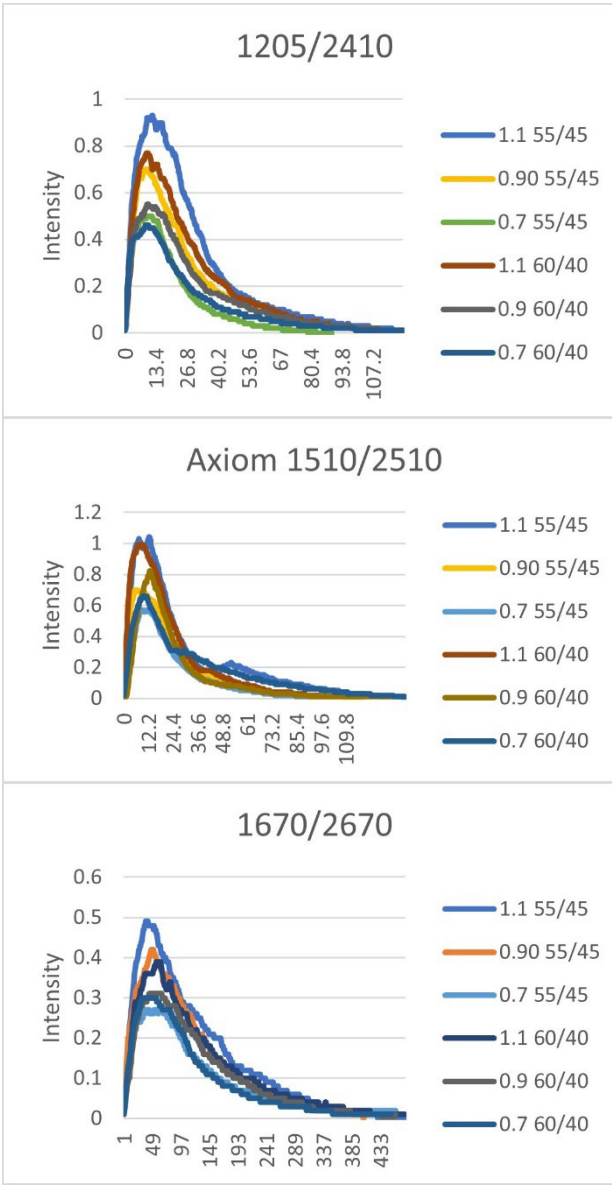

Figure 4. Smoke test results for all systems.

DISCUSSION

The main goal of foundries is to make quality and on time cast products at competitive costs. The newest system 1205/2410 shows similar performance when compared to the previous system 1670/2670 but offers lower cost. So, why should the foundry change to the new system? The answer is the improvement in key values: the cost per mixed ton of sand and not the cost per binder kg. Because the cost per kg can be cheaper and conditions dictate more binder is needed to reach the other key values that are needed (i.e., tensile). The process specifications are based on tensile performance and not on the price of binder kg. So, if a slightly more expensive binder is used at a reduced binder level of 0.1% (or more) or even changing the ratio from 55/45 to 60/40 this can reduce the price per ton of mixed sand, even with a more expensive binder. Additionally, with binder reduction or ratio changes the gas-related defects as seen in the presented data decrease.

For instance, the system 1205/2410 with a binder level of 9.0% with a ratio of 60/40 reach the same tensile of system 1670/2670 with a 1.1% of binder with the same ratio, that means a reduction of 0.2% of binder that means less gas evolution and less defects, even when the system 1205/2410 has a higher price around 5% per binder kg, but with the reduction of binder can save up to 15% of the cost per ton of mixed sand.

CONCLUSIONS

Respecting the supplier product recommendations is important to obtain the best results, as can be seen with the 1205/2410 system that showed better tensile with a 60/40 ratio, because the system was designed to be used at that ratio. Comparing the gas evolution results showed that a change of ratio from 55/45 to 60/40 can decrease the gas evolution values up to 9%. While changing the binder level 1% can modify the gas evolution from 2% to 6%. In the case of smoke results, the solvent package of the different systems can be proved with the smoke results, showing the lowest values with the system 1670/2670 but that solvent package does not develop the highest tensile strength, and the gas evolution results show the same performance.

The system 1205/2410 shows the same results in tensile at 0.9% of binder that the system 1670/2670 at 1.1% of binder but showed less gas evolution values. This affects the appearance of gas defects in the casting process. Comparing the costs of both systems, equivalent tensile strength values can be obtained while saving up to 15% of the cost of mixed sand despite 1205/2410 having around 5% more cost of binder per kg.

REFERENCES

1. “Automotive Market Size, Share, Growth & COVID-19 Impact Analysis, Segmented By Type, Product, Application and By Geography and Forecast 2023 – 2030” (2023).
2. “Phenolic Resins: A Century of Progress,” *Foundry*, Douglas M. Trinowski (2020).
3. “Castings,” The Mould, John Campbell, Elsevier (2003).
4. “Sand Binder Systems,” P.R. Carey and M. Swartzlander, ASK Chemicals.
5. “Measurement of gas evolution from PUNB bonded sand as a function of temperature,” G. Samuels and C. Beckerman, *International Journal of Metalcasting* (2012).
6. “Gas evolution characteristics of three kinds of no-bake resin-bonded sands for foundry in production,” Xue-wen Qian, et al., *China Foundry*, vol. 19, No. 2 (2022).
7. “Smoke chamber for evaluating foundry sand shapes and its method of use,” J. Schneider, US Patent #6377348B1.