Expanding Opportunities for Precision Sand Casting

Recent advances in coldbox tool design have shown potential improvements for precision sand cast cores and molds. With these advances, high volume metalcasting facilities can be more capital and labor efficient.

Precision sand casting (PSC) is a molding technique used to produce dimensionally accurate castings with thin sections through the use of chemical binders and dimensionally accurate and durable pattern equipment.

PSC mainly has been applied to the casting of light alloy automotive components. The chemically-bonded sand molds and cores used in PSC usually incorporate phenolic urethane nobake (PUNB) binders due to the excellent mold rigidity and dimensional stability imparted by this binder system. More recently, such molding has advanced in volume output by utilizing vapor curing techniques and mainly phenolic urethane coldbox (PUCB) binders cured with vaporized tertiary amines. The use of these vapor-cured binders gives even better rigidity and precision and allows more rapid mold production.

In high-volume green sand casting facilities, amine-cured PUCB bonded sands have largely remained a means of core production, whereas in light alloy casting facilities, the application of these binders, using PSC techniques, has been adopted as an alternative to the more traditional molding techniques of green sand and semi-permanent molding (SPM).

The application of PSC holds opportunities for both light alloy and ferrous casting facilities for the production of medium- to high-volume components.

**Capital Costs**

There are three basic incarnations of PSC (Fig. 1):
- the core assembly where individual mold and core components are made on a number of core machines and then assembled into complete mold-core packages;
- conventional molds blown on larger core machines, cored and assembled with complete or partial automation;
- stack molding where vertical or horizontal stacks are made using PSC molds blown with form on both sides.

No metalcasting facility is likely to use PSC unless it offers good cost or technical advantages over conventional molding methods. The global casting industry has invested heavily in green sand molding (ferrous) and SPM (non-ferrous) as the dominant techniques for high-volume cored castings. However, in an increasing number of cases, PSC has been used for:
- reduced capital costs in the case of a new installation or product;
- lower operational costs for either a new or existing process or product;
- a lower environmental impact or lower environmental costs.

A look at PSC capital costs gives a picture of how it stacks up against green sand molding and SPM.

In the case of green sand molding, the

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**Fig. 1.** There are three basic precision sand casting molding techniques (from l to r), core assembly, conventional cope and drag and stack molding.
key is often the sand casting plant adequacy. A new molding line plus a new sand plant can ramp up costs such that PSC can reduce capital costs to one-third of green sand. Additionally, PSC relies on multi-unit operation for high capacity, so it is possible to install just enough units to do the job and add more when needed.

However, PSC includes additional pattern costs because multiple production cells each require pattern equipment. One of green sand’s advantages is its relatively low pattern costs. But compared to SPM, PSC requires more PUCB core machine capacity, which is less expensive than automated dies or carousels. Capital costs for a PSC system also includes the cost of automating the mold assembly and indexing to a cast station, which is provided with a green sand or SPM arrangement.

In the case of SPM, where there already is a need to make cores for many casting types, the question of PSC’s benefit is, how much extra PUCB-bonded production capacity would be required versus metal dies, and how would the costs compare?

The cylinder head in Fig. 2 could have been produced via SPM, but was cast via PSC. Two more core machines were required to produce the cylinder head using PSC, but the cost in services, such as sand supply, resin supplies and amine supply, did not result in much cost, as they were already at the facility. The purchase of two core machines removed the need to spend large amounts of capital on SPM machines. In the case of a 15,000/yr. casting requirement, the capital cost saving was estimated to be in excess of $2 million.

Operational Costs

Green sand molding and SPM likely still will have lower material and labor costs than PSC. However, the use of PSC can provide lower energy, environmental and maintenance costs.

When producing castings in green sand with PUCB cores, the core binder decomposes and releases the core sand into the green sand system. In some cases, it may be possible to prevent some of the core sand from getting into the green sand, but this is difficult and often not done at all. The core sand dilutes the green sand system, requiring more clay and organic additive. In addition, perfectly good green sand must be removed from the system and sent to a landfill for disposal. The greater the amount of core sand, the greater the cost.

Further, maintenance costs for a green sand operation can exceed 10% of capital per year. A PSC operation can cost as little as one-third that of a green sand operation in capital terms.

The operating cost comparison of PSC over SPM should account for both the extra costs of the additional PUCB sand mix versus SPM refurbishment and heating costs. The extra mixed sand used in the cylinder head PSC operation would cost $1.30 per casting. This compares with reported mold refurbishment costs of $1.00 per casting and a heating cost of $0.10 per casting. This puts SPM at a $0.20 advantage over PSC. However, if improved yield possibilities are included, PSC would provide an additional $0.35 per casting capital cost savings and $0.18 per casting yield savings.

Environmental Costs

Because the PSC sand mixture requires only a mixing action to distribute low viscosity liquid in the sand, its energy costs associated with sand preparation are lower than green sand preparation, which requires intensive mulling of the sand in order to develop the clay-water bond. The total energy difference between green sand and PSC is 2.25kWh/MT, but when sand-to-metal ratios are factored in (between 4:1 and 10:1 for green sand and between 0.5:1 and 3:1 for PSC), PSC sand preparation energy needs are five times less than green sand.

The biggest potential environmental difference in PSC and SPM is thermal decomposition fume from the PUCB bonded sand. Because PSC uses more bonded sand, it would be expected that this would produce a bigger problem than SPM, but the PSC mold encases the fume for a longer period of time and only minimal extraction is required in order to prevent operators in the casting area. The mold then can be positioned in a reasonably enclosed transfer system where very little extraction volume is needed in order to prevent exposure.

In some facilities, the PSC molds pass quickly to a thermal sand recovery system in an enclosed, combined, heat treatment and sand removal oven operating at around 932F (500C). The resin binder is removed by this method and the
emissions are reduced to low levels by post incineration. This energy-efficient arrangement provides considerably reduced extract volumes, the ability to incinerate all fume sources at a relatively low cost, and high levels of thermal sand recovery.

**Other Costs**

Capital, operational and environmental costs are the most important in defining what castings will best benefit from PSC, but there are other factors that can have a significant impact on this decision, such as:

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Fig. 3. This chart shows a comparison of greensand and PSC costs with variable combined sand costs (purchase plus disposal). According to the data in this figure, greensand costs increase as core sand input increases.
• where the PSC technique provides a technical benefit that can save on downstream costs. The improved dimensional control of PSC compared to vertically cast green sand eliminates disc thickness differences and provides for a smaller machine allowance.
• the ability to coat an assembled mold half rather than coating cores or a core subassembly. This can eliminate flash in some areas and reduce fettling times substantially.
• the ability to permit a modular system of related castings with only minor (and low-cost) core machine tooling modifications.

Making the Choice

When deciding whether to use green sand molding or PSC, casting benefits and cost savings of either method must first be identified. The next stage would be to consider if it is getting close to the time when investment in a green sand machine and/or sand plant is essential and whether PSC could be a more cost effective option.

Second, the level of sand input and whether PSC could give a cost saving on this basis should be considered. The comparison of green sand and PSC costs in Fig. 3 show that green sand costs are sensitive to the core sand input level and to the combined cost of sand purchase and disposal.

In the example used, it has been assumed that all of the core sand results in a comparable disposal of green sand, as will mainly be the case. The PSC examples assume 95% sand reuse with 95% mechanically reclaimed, 15% of the sand thermally treated and 5% of the sand as virgin makeup sand. This equates to an 80/15/5 blend.

Mold costs are not sensitive to the core sand input and the combined sand cost has only a minor impact on the molding cost. The sand-to-metal ratio is the most influential material cost factor for PSC with a 1:1 ratio providing comparative costs to green sand at core sand inputs as low as 30% where sand costs are high.

Deciding between SPM and PSC can be a more complex decision than for PSC vs. green sand because the same opportunity for a large material cost savings does not exist. The factors to consider include:

• the reduced capital cost of the PSC option per casting over the life of the job;
• the reduced maintenance cost of PSC, particularly the elimination of SPM mold cleaning and refurbishment;
• the increased material cost of the PSC option per casting;
• the improved ease and reduced cost of controlling casting emissions from PSC compared to SPM.

PSC also provides the opportunity to use electro-magnetic pumping techniques to fill the casting and the opportunity to feed metal without the use of feederheads. This technique results in high yields and reduced sand-to-metal ratios. MC

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