Recent developments in the application of the Polyurethane Cold Box process

FOSECO

Developed over 30 years ago, the Polyurethane Cold Box Process (PUCB) is still the most popular organic cold box technique for the automated production of high volume cores in both ferrous and non-ferrous foundries.

The reason for its popularity is based upon several factors such as high out of box strength, high productivity levels, excellent breakdown properties and cost.

Introduction

FOSECO has recently introduced new technologies with the emphasis on adding value for the customer by improving key areas such as productivity, lower VOC (volatile organic compounds) emissions and by reducing waste.

The following case studies are good examples of these new technologies in action.

Case study 1

PSA Peugeot-Citroën Sept-Fons Site. The development of a new PUCB binder for use on mechanically reclaimed sand based on low VOC solvent technology. Environmental regulations and laws for the protection of the external environment and the internal work place are having a major impact on foundries using chemical binders . Nowadays the foundry industry demands new developments in chemical binders which will offer excellent performance but have little or no detrimental effect on the environment. The present challenge for all major binder suppliers is to develop and supply binder systems that offer lower monomer contents and improved environmental properties such as the use of solvents and other additives that conform to ever more stringent health and safety requirements.

PSA Peugeot-Citroën Sept-Fons site is one such foundry that is driving binder suppliers to take up the challenge.

Type of Casting	Tonnes Produced
Cylinder Blocks	61,163
Brake Discs	44,192
Brake Drums	11,721
Total	**117,076**

Table 1 **Foundry output 2003**

To produce all these castings, the foundry uses a tremendous amount of sand. Due to the stringent legislation appertaining to the dumping of waste sand and the ever increasing costs of new sand, the Sept-Fons site has introduced a dry attrition sand reclamation process.

Mechanical and magnetic treatment of the sand:
The sand coming from the shake out (mix of moulding sand and core sand, burnt or unburnt) is treated:

- Magnetically separate green sand
- Mechanically to eliminate the resin residues

The reclaimed sand is used at 100% in the coreshop.

The challenge for the binder supplier was to develop a system that would give the same strength characteristics as for new sand as well as lowering the emissions of aromatic hydrocarbon solvents, without compromising casting quality.

Using a conventional PUCB resin system based on aromatic solvents, revealed that on reclaimed sand the core strengths were 20% lower than with new sand and in addition the bench life of the mixed sand was much shorter. Obviously a novel approach to the chemistry of the binder system was needed.

	New Sand	Reclaimed Sand
Loss on Ignition	0.15	2.29
Average Grain Size	280	291
Fines Content	0.150	0.25
Dust Content	0.00	0.00

Table 2 **Sand properties (base sand Silfraco LA32)**

	New Sand	Reclaimed Sand
As Gassed	350	310
1 Hour	495	410
24 Hour	550	515
Humidity Resistance	320	260

Table 3 **Strength development comparison**

Values are transverse strength N/cm^2 based on a total binder content of 1.2%. Humidity Resistance = 24hours at 20^oC / 95% Humidity.

	New Sand	Reclaimed Sand
As Gassed	365	325
1 Hour	310	275
2 Hours	280	200
3 Hours	245	150

Table 4 **Bench life properties**

Values are transverse strength N/cm² based on a total binder content of 1.2%.

The simple solution to increase strength on reclaimed sand would be to increase the resin addition, however, there are clear disadvantages associated with this:

- Reduced sand flowability requiring higher blowing pressures
- Higher blow pressures would cause resin wipe off and sticking of the cores
- Higher binder levels would result in poor core breakdown and core shakeout
- Higher binder levels would also increase the risk of casting defects associated with lustrous carbon and gas evolution
- Higher process costs

Clearly an increase in resin content was not a satisfactory solution and as such, alternative solutions would need to be identified.

A new binder was selected based on two novel manufacturing processes. Firstly, a route was identified whereby water could be removed in process more efficiently. This resulted in a significant change to the molecular structure of the resin resulting in a much more reactive resin that enabled higher out of box strengths to be achieved.

The second development route was based on the introduction of new low aromatic solvents. These had a significant impact on the levels of VOC emissions particularly during the casting stage.

	Aromatic Solvent System	Politec* E2000 / E9000
Benzene	13 ppm	3 ppm
Toluene	10 ppm	2 ppm
Xylene	15 ppm	1 ppm

Table 5 **Comparison of VOC emissions during the casting process**

	Aromatic Solvent System	Politec E2000 / E9000
As Gassed	310	350
1 Hour	420	480
24 Hour	550	600
Humidity Resistance	250	350

Table 6 **Strength development comparison: Politec E2000 / E9000 on reclaimed sand**

Values are transverse strength N/cm² based on a total binder content of 1.2 %.

This new development resin system, Politec E2000 / E9000 has now been established at PSA Peugeot-Citroën Sept-Fons Site for use throughout the core shop using reclaimed sand (figure 1). This system has met the technical requirements in terms of strength performance and environmental improvements with additional process benefits such as good bench life, humidity resistance and casting quality being achieved. A further benefit has been a reduction in resin wipe off which in turn reduces box cleaning thus improving productivity.

Figure 1 **Core assembly at PSA Peugeot-Citroën Sept-Fons Site**

Case study 2

TMA: The application of (TMA) Tri-methylamine using new amine generator technology

The choice of amine for use as a trigger in the PUCB process is based upon the following factors; reactivity, odour, cost and the ease at which the amine liquid can be vapourised and injected into a suitable inert carrier gas (usually hot air). This carrier gas penetrates the mould or core mass promoting a reaction between the resin and MDI (Methly Di-Isocyanate) components.

Several amines have been used successfully, however, they all have process limitations, for example TEA (Tri-Ethyl Amine) is not very reactive resulting in higher amine demand, it also has the highest boiling point making it difficult to keep in a vapour form, leading to condensate forming in the gas supply system. DMEA (Di-Methyl Ethyl Amine), is more reactive and has a lower boiling point but has a greater odour and is traditionally more expensive.

FOSECO recently introduced a new amine for use with the PUCB process based on TMA. This amine is significantly more reactive than DMEA resulting in extremely low application rates, which if applied using specifically designed amine generators gives rise to low levels of odour in use.

Furthermore the increase in reactivity and low application rates means that higher productivity gains are achieved by using shorter gassing and purge cycle times, making the overall process costs lower.

TMA exists as a gas at room temperature, compared to other traditional amines, which are liquid. Based on this difference a new approach had to be found in terms of injecting TMA into the carrier gas stream to ensure that process reproducibility could be achieved. Initially a TMA generator was developed which involved heating the TMA gas cylinder above 65°C to achieve a high pressure enabling TMA gas to be drawn off and injected into the carrier gas. Whilst several generators of this type have been built and commissioned successfully in several foundries a number of technical concerns needed to be resolved. The major concern was that as TMA was drawn out of the gas cylinder the pressure dropped. To maintain pressure, and thus ensuring consistent flow application rates, more heat had to be put into the cylinder, this proved difficult especially at low volumes of TMA within the cylinder. In addition, when the TMA was exhausted, a new cylinder had to be heated to the required temperature to achieve working pressure resulting in production down time. A final obvious concern was the health and safety issue concerning the basic principle of heating gas cylinders containing TMA having a low flash point.

Clearly a better design based on the use of "cold" TMA had to be found if the benefits of this new amine technology were to be exploited. Reviewing a combination of existing gas application techniques and looking at new developments in low level metering devices a prototype TMA generator was built with the co-operation of Omega Foundry Machinery Limited.

TMA Generator

TMA is now supplied in a dual port syphon cylinder which when pressurised with a constant nitrogen pressure at ambient temperature enables liquid TMA to be drawn from the cylinder. As the TMA is at a fixed pressure the flow rate from the cylinder remains constant.

The liquid TMA is then atomised at the point of entry into the carrier gas stream using a low level atomiser capable of atomising 1cc of amine per cycle. To achieve this level of accuracy a digital pressure control system prior to the atomiser removes any pressure spikes.

The above process is built into a generator package which supplies the carrier gas at the required temperature, controls gas and purge cycle times through an on board PLC system and allows variations to be made in terms of carrier gas application pressure. As this system allows the use of TMA as received, no down time is necessary when the cylinder is exhausted, bottle change can be made in less than 1 minute. A further benefit can be achieved by using a multiple gas cylinder manifold or bulk TMA supply, in that the operator does not have to handle the amine component resulting in the elimination of a hazard risk.

This new concept generator (figure 2), has undergone field application studies and the results observed show that this process has a lot to offer particularly in terms of improved productivity and the safe handling and application of a very reactive amine.

	TEA	DMIA	DMEA	TMA
Chemical Formula	$(C_2H_5)_3N$	$(CH_3)CHN(CH_3)_2$	$C_2H_5N(CH_3)_2$	$(CH_3)_3N$
Molecular Wt g/mol	101.2	87.1	73.1	59.1
Boiling Point ^{0}C	89	65	35	3
Vapour Pressure mbar (20^{0}C)	69	170	580	2200

DMIA: Di Methyl Iso Propyl Amine

Table 7 **Comparison of Physical Properties of Commercial Amines**

Figure 2 **TMA Amine generator**

	Cope/Drag Assembly	Water Jacket	Inlet Port Core
Machine Cycle Time : DMEA	56 seconds	43 seconds	42 seconds
Machine Cycle Time : TMA	43 seconds	37 seconds	35 seconds
Cores per Hour : DMEA	64	84	86
Cores per Hour : TMA	84	97	103

Table 8 **Comparative productivity rates**

	Cope/Drag Assembly	Water Jacket	Inlet Port Core
Total Binder Content (BOS)	1.3 %	1.4 %	1.1 %
DMEA Addition Rate (BOR)	16.7 %	32.2 %	31.46 %
TMA Addition Rate (BOR)	3.85 %	3.98 %	5.45 %
Cost/Tonne of Sand : DMEA	£ 21.95	£ 26.68	£ 20.85
Cost/Tonne of Sand : TMA	£ 20.42	£ 22.04	£ 17.80
Amine cost saving	6.9%	17.4%	16.6%

Table 9 **Foundry case study: Cost in use comparison, TMA vs. DMEA**

Case study 3

Reclaimed Shell Sand for the production of PUCB cores, the reduction of a waste sand stream.
RSM Castings is a repetition iron foundry producing automotive, hydraulic and general engineering components in grey and SG Iron using the shell mould and core process.

Four years ago, RSM Castings invested in 2 corebelters (figure 3), to enable them to produce PUCB cores so that they could eliminate the sub contract purchase of cores and convert some shell production to PUCB to reduce costs.

Figure 3 **Corebelter**

It soon became apparent, however, that production costs were increasing significantly due to rising costs in respect to new sand purchase and also the ever-increasing cost of sand disposal

With assistance from FOSECO, RSM Castings began a study to investigate the feasibility of using the waste sand stream from its shell moulding process as a replacement for new silica sand in its PUCB process. This PUCB process being based upon a 50 AFS grade new silica sand, bonded with FOSECO Politec XP1000 / XP1080 PUCB binder system in conjunction with TEA amine. RSM Castings produce approximately 250 tonnes of waste stream shell sand per month.

Initial chemical examination of this waste stream showed that the level of binder residue was very low, typically 0.4% due to the low sand to metal ratio associated with the shell process resulting in excellent thermal combustion of the organic component. The main concern, however, was the increase in alkalinity of the sand, caused by oxide residues melting and forming an alkali coating on the sand grain. It is known in the PUCB process that high alkali sands can give technical problems such as low out of box strengths and an increase in amine demand which in turn results in reduced productivity.

Trials were conducted using a pilot dry attrition plant to see if this increase in alkalinity would be detrimental to the process prior to embarking on any capital outlay on new equipment.

Several tonnes of shell sand were processed ready for evaluation on one of the production corebelters. A sample of this sand was tested and the results indicated that the alkalinity was even higher than the initial waste stream sample, this high alkalinity being due to the very high dust content of the sand, the pilot plant had no extraction system at this time. It was decided, however, that this sand would be evaluated on a trial production basis with binder levels being increased to compensate for the increase in AFS and surface area of the sand caused by the high dust content. The resultant cores produced (figure 4), were surprisingly of excellent quality in terms of edge retention and strength, it was also noted that the amine dosing and purge times did not need adjustment.

Figure 4 **Cores (reclaim)**

Castings from these cores were produced with comparable results in surface finish to castings made in new sand and with the added benefit of a reduction in the amount of veining defects .

From these positive results, further quantities of waste stream sand were treated on the pilot plant, with a dust extraction system fitted, and the production exercise repeated with standard binder addition levels. Once again good quality cores and castings were produced (figure 5).

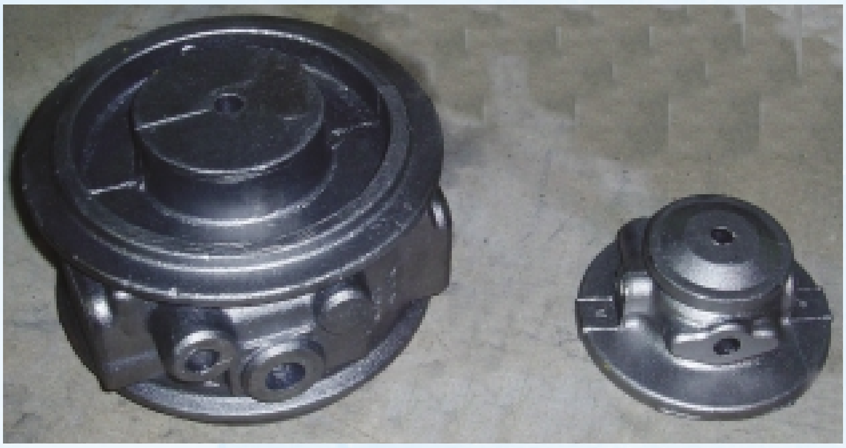

Figure 5 **Castings**

RSM Castings were pleased with the observed results and a commercial study confirmed that the purchase of a 3 tonnes per hour reclamation plant would give a return on investment within 12 months.

Based on this a reclamation plant was purchased and commissioned in September 2003.

RSM Castings are now able to satisfy totally their requirement for PUCB sand from their waste shell stream. Furthermore, RSM Castings supplier of shell sand showed an interest in the waste shell stream and are now successfully recoating 100 tonnes per month with a moulding grade shell resin.

Sample	AFS	Loss On Ignition	pH	Fines%	Dust %
New Silica Sand	50	0.27%	7.40	0.45%	0.01%
Waste Stream Pilot Plant – No Extraction	70	0.68%	8.10	10.96%	1.41%
Waste Stream Production Plant	64	0.32%	7.38	0.88%	0.32%

Table 10 **Sand properties**

Sand	Total Binder	1 Hour	2 Hour	4 Hour	24 Hour
New Silica Sand	1.2 %	290	310	360	375
Waste Stream	1.2 %	220	265	280	295
Waste Stream	1.4 %	285	325	355	39

Strength values: Transverse N/cm^2

Table 11 **Strength development comparison**

	PUCB New Sand	PUCB Waste Stream Sand
New Silica Sand	£ 24.00	-
Sand Disposal	£ 10.00	-
Waste Stream Sand *	-	£ 0.20
Total Binder 1.2 %	£ 17.59	-
Total Binder1.4 %	-	£ 20.31
Total Cost	£ 51 .59	£ 20.51

* Energy cost required to process 1 tonne of waste stream sand .

Table 12 **Commercial comparison**

Conclusion

The above case studies clearly demonstrate that the introduction of new technology to an existing core process can help foundries to improve their process costs, whether it is by improved productivity, the reclamation of sand or indeed by looking at alternative methods for eliminating waste streams. Above all, it is important to continue this process of continuous improvement to ensure that foundries remain competitive and maintain a working environment that meets current and future Health and Safety requirements.

References/acknowledgments

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