Project 3: Recycling of Foundry Sand through Chemical and Physical Beneficiation
Industrial relevance and appropriateness for the center:

The annual generation of foundry waste (including dust and spent foundry sand) in the United States is believed to range from 9 to 13.6 million metric tons (10 to 15 million tons).[1] Typically, about 1 ton of foundry sand is required for each ton of iron or steel casting produced. There was unanimous agreement at a recent International Sand Reclamation Conference that the effective reuse of foundry sand is one of the highest priority problems confronting the industry.

Project objectives:
The objectives of this research program are to evaluate and develop innovative foundry sand recycling technologies. Recycling technologies may be divided into three general categories: physical beneficiation, hydrometallurgical processing and pyrometallurgical processing. The research team, in conjunction with the industrial members, will characterize the candidate materials and critically evaluate the use of physical and chemical beneficiation on foundry sand. Based upon these results, two aspects will be identified that will serve the basis for a PhD thesis project. Currently, it is thought that one of the topics will be the utilization of a pyrometallurgical approach and the other will be a physical beneficiation approach to foundry sand recycle.

Background:
Foundry sand consists primarily of clean, uniformly sized, high-quality silica sand or lake sand that is bonded to form molds for ferrous (iron and steel) and nonferrous (copper, aluminum, brass) metal castings. Ferrous (iron and steel) industries account for approximately 95 percent of foundry sand used for castings.

The most common casting process used in the foundry industry is the sand cast system. Green sand consists of high-quality silica sand, about 10 percent bentonite clay (as the binder), 2 to 5 percent water and about 5 percent sea coal (a carbonaceous mold additive to improve casting finish. The green sand used in the process constitutes upwards of 90 percent of the molding materials used.[2] In addition to green sand molds, chemically bonded sand cast systems are also used.

A simplified diagram depicting the flow of sand in a typical green sand molding system is presented in Figure 1. [3]

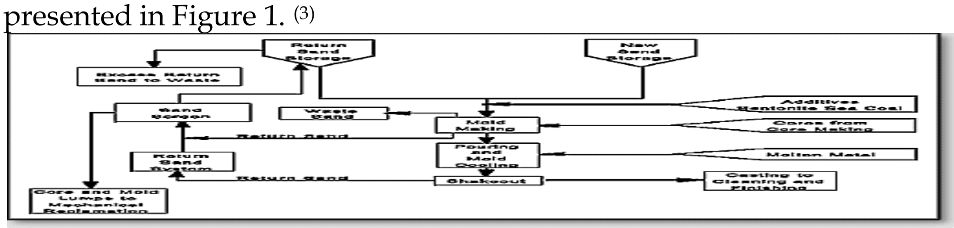

Figure1. Industrial Foundry Sand Material Flows.

Foundry sand, prior to use, is a uniformly graded material. The spent material, however, often contains metal from the casting and oversized mold and core material containing partially degraded binder. Spent foundry sand may also contain some leachable contaminants, including heavy metals and phenols that are absorbed by the sand during the molding process and casting operations. Phenols are formed through high-temperature thermal decomposition and rearrangement of organic binders during the metal pouring process.[4] The presence of heavy metals is of greater concern in nonferrous foundry sands generated from nonferrous foundries.[5] Spent foundry sand from brass or bronze foundries, in particular, may contain high concentrations of cadmium, lead, copper, nickel, and zinc.[3]

Physical Properties

Typical physical properties of spent foundry sand from green sand systems are listed in Table 1. The grain size distribution of spent foundry sand is very uniform, with approximately 85 to 95 percent of the material between 0.6 mm and 0.15 mm (No. 30 and No. 100) sieve sizes. The content of organic impurities (particularly from sea coal binder systems) can vary widely and can be quite high. This may preclude its use in applications where organic impurities could be important (e.g., Portland cement concrete aggregate).[4] The specific gravity of foundry sand has been found to vary from 2.39 to 2.55. In general, foundry sands are dry. A large fraction of clay lumps and friable particles have been reported, which are attributed to the lumps associated with the molded sand, which are easily disintegrated in the test procedure.[3]

Chemical Properties

Spent foundry sand consists primarily of silica sand, coated with a thin film of burnt carbon, residual binder (bentonite, sea coal, resins) and dust. Table 2 lists the chemical composition of a typical sample of spent foundry sand as determined by x-ray fluorescence.

Table 1. Typical physical properties of spent green foundry sand.

Property	**Results**	**Test Method**
Specific Gravity[3]	2.39 - 2.55	ASTM D854
Bulk Relative Density, kg/m^3 (lb/ft^3)[7]	2590 (160)	ASTM C48/AASHTO T84
Absorption, %[1,3,7]	0.45	ASTM C128
Moisture Content, %[3]	0.1 - 10.1	ASTM D2216
Clay Lumps and Friable Particles[1,3]	1 - 44	ASTM C142/AASHTO T112
Coefficient of Permeability (cm/sec)[3]	10^{-3} - 10^{-6}	AASHTO T215/ASTM D2434
Plastic limit/plastic index[7]	Nonplastic	AASHTO T90/ASTM D4318

Table 2. Foundry sand sample chemical oxide composition, %. [1]

Constituent	Value (%)	**Constituent**	Value (%)
SiO_2	87.91	Na_2O	0.19
Al_2O_3	4.70	K_2O	0.25
Fe_2O_3	0.94	TiO_2	0.15
CaO	0.14	P_2O_5	0.00
MgO	0.30	Mn_2O_3	0.02
SO_3	0.09	SrO	0.03

Proposed team (management and staff) with plans to address broadening participation:
This project will be managed by Professors Corby G. Anderson and Patrick R. Taylor. Professor Erik Spiller will participate in the physical beneficiation work. It is expected to fund one graduate student per year. Currently there are two member companies with interests in the topic and it is expected that several others will want to join as a result of funding for this top**ic.**

Proposed deliverables:

- A complete review of all of the technical and patent literature on foundry sand.
- Identification of the most promising avenues to explore based upon the industry needs and participation.
- Detailed experimental investigations of the chosen technical path.
- Identification of implementation strategies with member companies.
- A PhD research thesis and a graduate trained to work in this industry.

Project duration, milestones, and annual proposed deliverables:
The following three year chart outlines the milestones.

Task	**Month 1-3**	**Month 4-6**	**Month 7-9**	**Month 10-12**	**Month 13-15**	**Month 16-18**	**Month 19-21**	**Month 22-24**	**Month 25-27**	**Month 38-30**	**Month 31-33**	**Month 34-36**
1	X											
2		X										
3			X	X								
4				X								
5					X	X						
6							X					
7								X	X	X	X	
8											X	X

Task 1 - Discussions with member companies, complete review of technical and patent literature.
Task 2 - Selection of 2 PhD projects.
Task 3 - Development of experimental systems.
Task 4 - First bi-yearly report and industry review.
Task 5 - Experimental and theoretical work - reports to companies at year end.
Task 6 - Revision of project goals based upon results and industry evaluation
Task 7 - Detailed experimental and theoretical research - reports to companies at mid year.
Task 8 - Final report and defense of PhD thesis.

Determine business or industry need:
Industry needs will be evaluated initially and at each bi-yearly meeting. Two CR3 members have expressed an interest initially in foundry sand recycle and they will provide direction and guidance to assure that the research being performed is of direct interest to their companies.

Describe the available research facilities:
The Kroll Institute for Extractive Metallurgy (KIEM) at CSM has a full complement of characterization, mineral processing, pyrometallurgy, hydrometallurgy and electrometallurgy laboratories and access to all of the other materials processing laboratories available in the Department of Metallurgical and Materials Engineering. These are the;
Mineral Processing Lab: Pyrometallurgy Lab: Hydrometallurgy and Electrometallurgy Labs

Determine time to completion and cost.
The project will be initially planned over three years in order to accommodate a PhD level student to work on this topic. The costs associated with this would be $ 75,000 per year for three years - $ 225,000.

References

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