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Comparison of Molding Sand Technology Between Alphaset (APNB) and Furan (FNB)

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Abstract

The paper focuses on investigation of properties of two most widely used self-set sand binder systems APNB and FNB across the Globe, for making molds and cores in foundries to produce castings of different sizes involving wide range of metals and alloys, ferrous and nonferrous. This includes study of compression strength values of samples made out of molding sand at different binder addition level using new, mechanically reclaimed (MR) and thermally reclaimed (TR) sand. Strength values studied include dry strength (at room temperature) at specified intervals simulating different stages of mold handling, namely stripping and pre heating, followed by degraded strength after application of thinner based zircon wash by brush, subsequent lighting of, then checking strength both in warm (degraded strength) & cold (recovered strength) conditions. Throughout the cycle of mold movement from stripping to knock out, strength requirements can be divided into two broad classifications, one from stripping to closing (dry strength) and another from pouring to knock out (hot & retained strength). Although the process for checking of dry strength are well documented, no method using simple equipments for checking hot & retained strength are documented in literature. Attempts have been made in this paper to use some simple methods to standardize process for checking high strength properties using ordinary laboratory equipments. Temperature of 450°C has been chosen by trial & error method to study high temperature properties to get consistent & amplified values. Volume of gases generated for both binders in laboratory at 850°C have also been measured. Nature of gases including harmful BTEX and PAH generated on pyrolysis of FNB and APNB bonded sands are already documented in a publication [1]. This exercise has once again been repeated in same laboratory, AGH University, Poland with latest binder formulations in use in two foundries in India.

Keywords: Alphaset, Furan, Foundries, Sand, Hot strength, Residual strength, Gases, Environment

1. Introduction

In 2015, worldwide casting production reached 104.1millions metric tons with contribution from first two producers, China and India are approximately 47.2 million MT and 11.35 MT respectively [2]. In India, approximately 5000 foundries are engaged in manufacturing castings for various sectors like Transportation, Agriculture, Defense, Valves, Pump, Textile, Power etc. engaging 500,000 direct and 15,00,000 indirect work force [3].

Foundry industries can be classified into two broad sectors, green sand foundries and no bake foundries. In green sand foundries molds are made out of green sand (sand, bentonite, dextrin, carbon additive and water) and cores out of resin bonded sand, no bake (self -sets and gas cured) or baking type. Automotive foundries are classic examples of green sand foundries. In no bake foundries both molds and cores are made out of resin bonded sand. Self-set binders in foundry terminology are those where hardening of molds and cores made out of resin bonded sand take place in absence of heat or gas. One of the major applications of self-sets are to make small and medium size repeating molds in Fast Loop Line (FLL) where stripping takes place on roll over and molds produced are flaskless. Classic examples are foundries producing valve body castings and components of pumps. Other

big area is to produce big castings in boxed molds in floor. Examples are castings for wind mill, turbine and big valve body.
Two most common self-sets in use in modern foundries are so called Alphaset (APNB) and Furan (FNB). Incidentally foundry industry is one of the most polluting industries in manufacturing sector. Apart from enhanced quality requirements and faster productivity, modern foundries demand improved workplace environment matching other manufacturing sectors. Whereas, inorganic binders are most environment friendly, formulations available so far can't replace organic self-sets right away. One publication [4] confirms that modified sodium silicate using liquid (esters) hardeners can work as a complete self-set matching properties of organic self-sets including mold collapsibility. Reclaimability (thermo-mechanical process) of used sand is as high as 95%. Workplace environment is obviously of high level.

2. Alphaset (APNB) process

This is two-part system, binders and hardeners. Binders are phenol-formaldehyde resole type of resins in aqueous alkaline (NaOH, KOH) media and hardeners are single or blend of esters of ethylene glycol, glycerol, dibasic acids and also alkene carbonates and lactones.
Hardening (curing) of APNB sand takes place in two stages. In first stage, partial polymerization of resole chains (chain lengthening and partial crosslinking) take place when metal ions (Na+, K+) separating small chains are withdrawn by acids generated during hydrolysis of esters in alkaline media. Strength developed at this stage in molds and cores are sufficient for stripping, handling and closing.

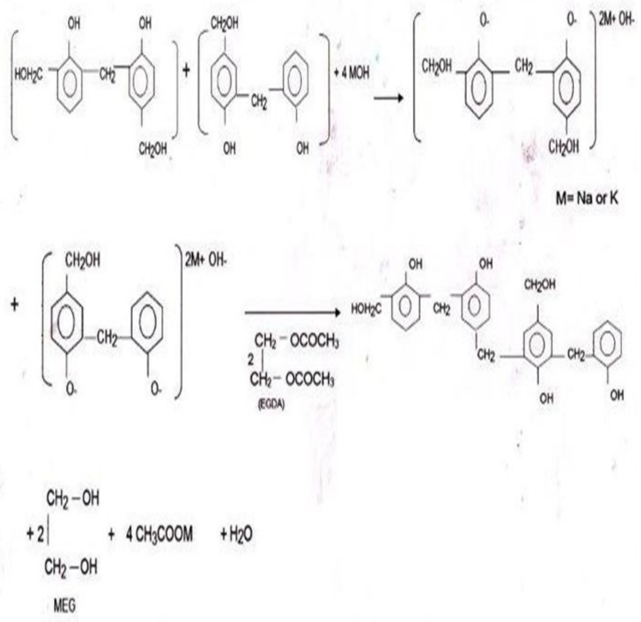


Fig. 1. Probable mechanism for curing of APNB in first stage

Major variables in resin formulations are phenol: formaldehyde mole ratio, total alkalinity, ratio of Na+, K+, non-volatile content, viscosity (extent of reaction) and moisture content. Resins advance on storage as evidenced by rise in viscosity. Advancement is associated with reduction in bench life and drop in strength of mixed sand. Rate of advancement varies directly with storage temperature. Whereas there is no data available in literature relating expiry of binder with change in physical parameters, author feels, individual foundries can correlate expiry with viscosity at a particular temperature say 30°C. In his experience, the value in Indian formulations is 40 secs by Ford cup no 4 (100 cps) at 30°C and it happens in close to 90 days when storage temperature is ≤ 30°C. One more way is to check drop in ultimate strength (24 hours) of mixed sand which can be between 20-30% in comparison with fresh resin.

In foundries, a lot is talked about difference in role of NaOH and KOH in Alphaset formulations. Many believe, KOH is superior to NaOH in terms of lower binder demand to get equivalent strength. Author feels, recipe and process parameters, rather than nature of alkali, dictates binder demand for achieving required dry strength at various stages. Formulating right binder compositions to meet requirements of individual foundries is an art. However, according to a publication [5] sodium based formulations offer better reclaimability by mechanical process and in case of thermal reclamation, it is otherwise. NaOH based formulations offer more viscosity than KOH based formulations with equal nonvolatile content. Most of the formulations contain both in judicious proportions to adjust viscosity of final solution, rate of binder advancement, ease of reclaimability of used sand and of course unit price.

Hardeners (esters) used as curatives differ in rate of hydrolysis to release acids, thus controlling bench life of mixed sand and in turn strip time. Blend of hardeners with varying hydrolysis constant behave almost in arithmetically calculated way, influencing reactivity. Resin-hardener reactivity can be tested by noting down time for gelation on constant stirring of 100 gram resin with 20 gram hardener at a particular temperature. Use of slower hardeners increase bench life of mixed sand but at cost of reduction of bench life: strip time ratio and without much effect on final strength. Storage life of hardeners are well over one year.
Binder demand for Alphaset system varies from 1.2-1.8 % by weight of sand to meet strength requirements at stripping (manual and roll over), handling and closing in case of boxed as well as flaskless molds. It is estimated that compression strength required at strip vary from 2.0 to 7.5 kg/cm² and final dry compression of 18 to 25 kg/cm² to handle all molds, post strip till closing. Hardener demand is between 18-22% by weight of binder. Variation of hardener addition beyond this range don't influence bench life and strength of mixed sand, contrary to FNB.

Reclamation of used sand is done mechanically (MR), thermally (TR) or both. In mechanical process, reclaimability is not more than 70%. Mechanical, followed by thermal increases reclaimability up to 95%. However, in case of thermal reclamation, an additive (0.6-1% by weight of sand) in form of suspension in water is required to be atomized in thermal reclamation chamber (650°C) where reaction of inorganic components of mechanically reclaimed sand and additive bring down its melting temperature and eventually removes with fines. The additive formulation is however very specific and has got huge effect on quality of thermally reclaimed sand. Most important effect is drop in strength of TR sand on storage as reported by some foundries. Alternately, secondary reclamation of Alphaset bonded MR sand gives reuse level of as high as 85% and quality of reclaimed sand produced is excellent with loss on ignition of <1%.

Being free from N and S, this system is suitable for pouring all types of metals including SG iron and steel [6]. However, manufacturers sometimes introduce small amount of urea in the resin formulations particularly for use in CI foundries, as scavenger for formaldehyde, a potential eye irritant. Further, it is well documented [7] that when liquid metal is poured in APNB bonded molds, bonds relax momentarily (thermoplastic deformation) before picking up further strength (secondary curing). This unique behavior compensates for (reversible) expansion of silica sand at 573°C avoiding crack in molds and in turn producing castings free from veining. Post relaxation, strength pick up by molds are good enough to produce near neat shaped castings.

With growing conciseness on ecology & environment, Alphaset is being increasingly chosen as a preferred binder in self-set sector over other organic binders as emission of polycyclic aromatic hydrocarbons (PAH) & derivatives are much smaller in quantities during & post pouring of metals in molds [8]. However, Alphaset resins, although contain very low level of free formaldehyde, evolve formaldehyde, a potential eye irritant during curing with esters. This is also documented in a patent [9].

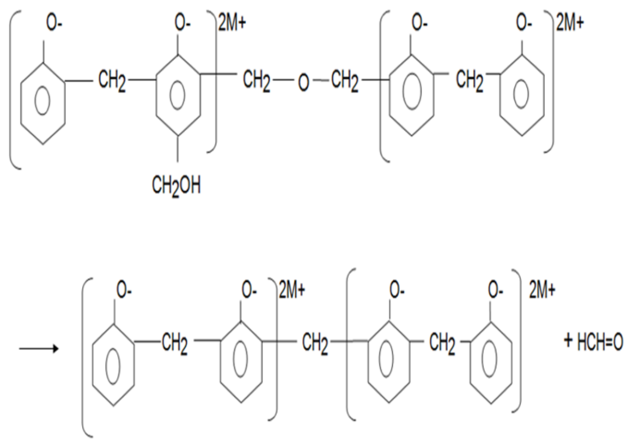


Fig. 2. Probable mechanism for release of formaldehyde during first stage of curing

Detection for formaldehyde in Gas chromatography (GC) of liquid portion of gelled mass after curing with esters conclusively prove generation of formaldehyde during gelation (Fig. 3).

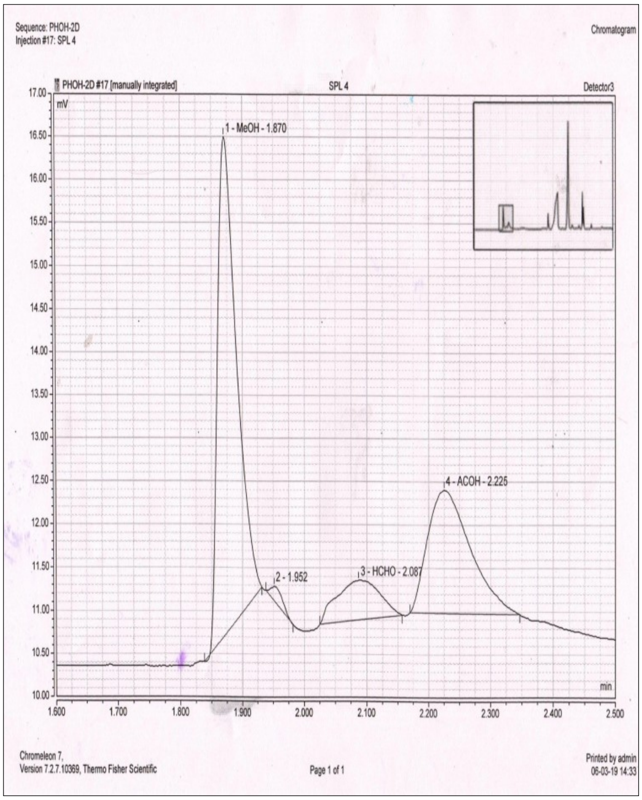


Fig. 3. GC of liquid portion of mass released on gelation of Resin and Hardener 100:20 (W/W)

Instrument make- Thermo Fisher Scientific (Model- TRACE 1110)
Tested at: Forace Polymers (p) ltd., Haridwar, India
Resin (Fortech 300) & Hardener (050) used- Forace Polymers (p) ltd. Haridwar, India

Rate of emission of formaldehyde varies with ambient temperature and type of ester. Higher ambient temperature and faster hardeners aggravate emission rate. Smell of formaldehyde are traceable in pouring area also. Absence of smell of formaldehyde in heat cured gelled mass confirms that formaldehyde released is not in free form in the resin.

3. Furan (FNB) process

Like Alphaset, this is another popular process for making molds and cores by self-set process. Binders are series of resin formulations based on furfuryl alcohol (FA) and formaldehyde (in form of aqueous solution or paraformaldehyde, a solid) in presence of phenol, urea or both. Catalysts are single or blend of organo- inorganic & or inorganic acids.

Hardening of furan bonded sand takes place by reduction in PH with addition of acids. Bench life of mixed sand and strip time of molds are controlled by % catalyst addition with respect to resin and also by changing acids of different potency.

Major variables in FNB formulations are contents of FA, Urea and Phenol. Besides % variation of reactive monomers, variation in process parameters and PH at different stages of reaction offer possibility of synthesizing innumerable formulations having wide range of properties. Stability of Furan resins are better than Alphaset and can vary from 3 months to 12 months depending on formulations, when stored between ≤30°C. Here again, resin advancement is evidenced by increase in viscosity, drop in water tolerance, reduction in bench life and drop in strength of mixed sand.

Original furan formulations used to be based on polymers of Urea, FA and formaldehyde (UF/FA) containing substantial quantity of free FA (up to 70%) with total FA being as high as 90%. With increase in FA price and EU regulation (EC no 1272/2008) [10] of restricting upper limit of free FA to 25% in furan formulations, phenol was introduced as third reactant with formaldehyde providing flexibility in range of formulations. Incidentally hybrid formulations involving three reactants with formaldehyde could offer resins as good as high UF/FA based resins yet keeping free FA in regulated range.

Catalysts for furan formulations are based on aqueous solution of organo-inorganic acids like Para Toluene Sulfonic Acid (PTSA) monohydrate, Xylene Sulphonic Acid (XSA) and inorganic acids like Phosphoric acid. Unlike APNB, in case of FNB, speed of cure can be varied by varying level of catalyst addition which usually ranges from 30-60% by weight of resin. In addition, various catalysts with various dilution ratio increase probability of manipulation of cure speed further. Special care is taken to avoid freezing of concentrated catalysts at low temperature. Storage stability of catalysts are practically unlimited.

Binder demand in FNB formulations are lower than FNB. In MR or blended sand it works very well at addition level as low as 0.8% by weight of sand. In new or TR sand, usually used in mold facing and cores, addition goes up to 1.2% by weight of sand.

Reclaimability of FNB bonded sand is much better than APNB bonded. In mechanical reclamation, it's as high as 90%. Foundries opting for more, reclaim partial quantity of MR sand by thermal process. Quality of thermally reclaimed FNB sand is as good as or better than new sand.

FNB formulations usually contain 0-10% N and 5-15% water. The lower the N and water content, the higher is the grade of binder [11]. In FNB, N comes from urea which is easily dissociated at metal pouring temperature to liberate nascent or atomic N which is more soluble in liquid iron than in solid. Absorption of nitrogen and\ or hydrogen by the molten iron, either individually or jointly, may result in subsurface porosity defects [12]. In general, limit of allowed N contents in resins for steel and SG iron of heavy section thickness is 0-2%, that of CI and SG of low section thickness is 2-5% and that of non- ferrous is without limit. However, N content in molding sand rather than in binder is guiding factor for selectivity of metal to be poured. Recommended upper limit for N in molding sand while pouring CI and SG iron of low section thickness is 0.15% which is 0.10% in case of steel and heavy SG iron castings. In non-ferrous castings increase in N content in resin improves de-coring property. Upper limit being the level till Urea separation in resin.

Sulphur bearing catalysts used as curatives for furan resins decompose through following reactions [13]

$ArSO_3H \dashrightarrow Ar\,OH + SO_2$

During metal pouring, SO_2 shifts to casting surface and react with Mg used to produce SG iron castings as $SO_2+Mg \rightarrow MgS+O_2$, reducing its concentration and eventually flake graphite formation at surface. Depending upon wall thickness and cooling rate, surface degeneration can occur between 0.2 to 1 mm. Bauer [14] suggests limiting value for **S** in molding sand below 0.15% in case of castings up to 25 mm thick and 0.07% up to 75 mm thick. Use of low Sulphur content catalysts, Cao, Mgo and talc based dressings are preventive measures for **S** degeneration in SG iron castings.

Furan systems contain Sulphur which on pyrolysis release SO_2, a potential air pollutant. Aryl Sulfonic acids used for curing may release BTX during and after pouring of liquid metal. FNB with extremely low level of free formaldehyde (not traceable by analytical method) and catalyst compositions with less than 1% free sulfuric acid when used at addition level as low as 0.8:30 can offer working environment as clean as APNB system. A publication [15] says "the Furfuryl alcohol based binder (furan type) was identified to offer the greatest potential for improvement in productivity, casting quality and environmental acceptability". The other two binders in the publication compared are phenolic urethane and ester cured phenolics.

3.1. Pyrolysis Gas Chromatography- Mass Spectrometry (Py/GC/MS): of cured mass of FNB & APNB

Tested at: AGH University of Science and Technology Academic Centre for Materials and Nanotechnology 30-055 Krakow, Kawiory 30, Poland. Test conditions were chosen by Prof. Mariusz Holtzer, Dr. Angelika Kmita & team.

The analysis was carried out in a platinum coil pyroprobe (Pyroprobe 5000, CDS, Analytical Inc.). Approximately 1 mg of the solid sample was centered in a quartz tube and heated to final temperature of 1100°C (both in case of APNB and FNB) using a heating ramp of 10°C/ms. The hold time at the final temperature was 5s. The pyrolysis products were separated on a 30m ×0.25mm × 0.25 µm (film thickness) capillary column (Rxi-5MS, Restek). The inlet was set to a split flow of 30mL/min. The flow rate of the carrier gas (He, 99.9999%) was 1mL/min. A Single Quadrupole (ISQ, Thermo Scientific) MS was used to detect the pyrolytic degradation products. The MS was used in the full scan mode from 30 to 600 atomic mass units (a.m.u.). The transfer line temperature and ion source temperature was 250°C, the electron energy (EI) was equal to 70 eV and emission current was 50 µA. The gas products were identified based on the mass spectral library NIST MS Search 2.0 Libera (Chemm. SW, Version 2.0, Fairfield, CA, USA).

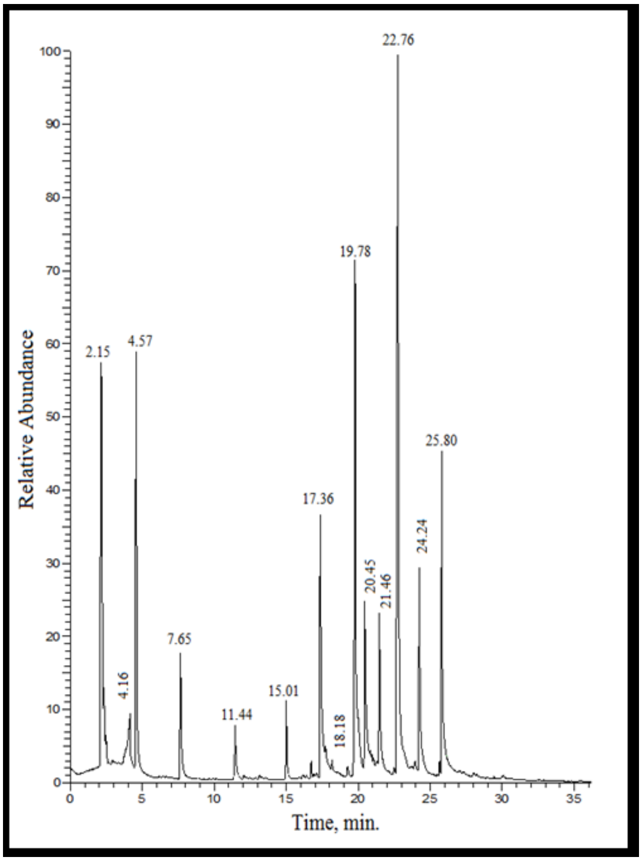
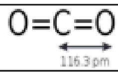
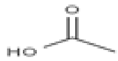
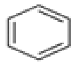
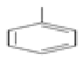
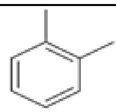
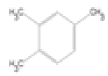
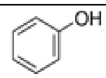
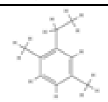
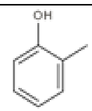
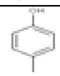
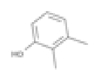
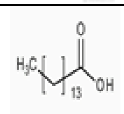
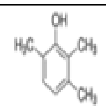
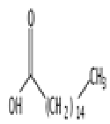


Fig. 4. Py-GC-MS for cured mass of Alphaset with 20% wt. Hardener at 1100°C

Table 1.
Compounds detected and identified by GC-MS released during pyrolysis of Py-GC-MS for cured mass of Alphaset with 20% Hardener at 1100°C

Retention Time (RT)	Name of compound	Structural	CAS No.	Molecular weight
2.15	Carbon dioxide CO_2		124-38-9	44
4.16	Acetic acid $C_2H_4O_2$		64-19-7	60
4.57	Benzene C_6H_6		71-43-2	78
7.65	Toluene C_7H_8		108-88-3	92
11.44	Benzene 1,2 dimethyl o-Xylene C_8H_{10}		95-47-6	106
15.01	Benzene, 1,2,4-trimethyl C_9H_{12}		95-63-6	120
17.36	Phenol C_6H_6O		108-95-2	94
18.18	2 ethyl -1,4-dimethyl benzene $C_{10}H_{14}$		1758-88-9	134
19.78	Phenol, 2-methyl o-Cresol C_7H_8O		108-39-4	108
20.45	p-Cresol C_7H_8O		106-44-5	108
21.46	Phenol, 2,3-dimethyl $C_8H_{10}O$ 2,3 Xylenol		526-75-0	122
22.76	Pentadecanioc acid, dimethyl ester Glutaric acid, dimethyl ester $C_7H_{12}O_4$		1119-40-0	160
24.24	Phenol, 2,3,6 tri methyl $C_9H_{12}O$		2416-94-6	136
25.81	Hexadecanioc acid, dimethyl ester $C_8H_{14}O_2$		627-93-0	174

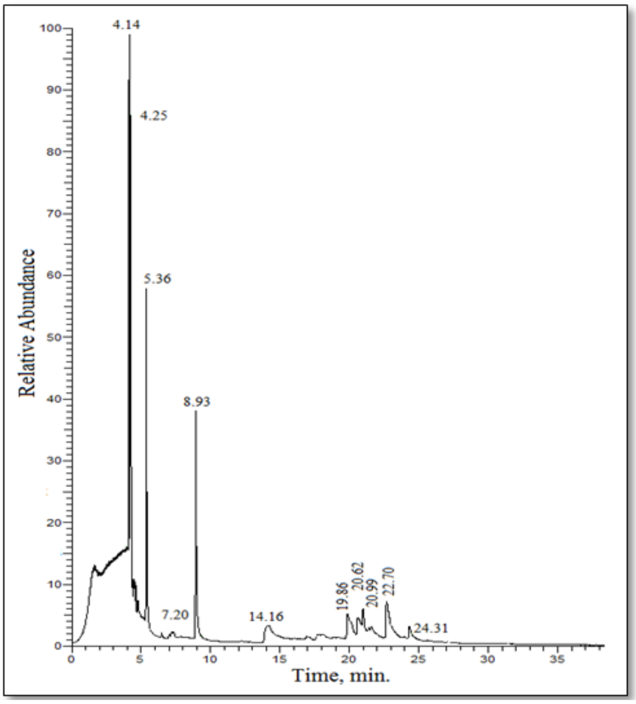
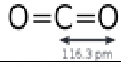
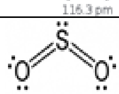
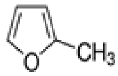
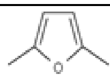
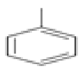
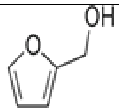
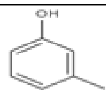
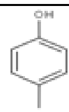
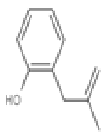
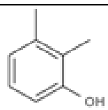
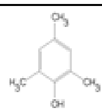


Fig. 5. Py-GC-MS for Cured mass of Furan with 50% Catalyst at 1100°C

Table 2.
Compounds detected and identified by GC/MS released during pyrolysis of Cured mass of Furan with 50% Catalyst at 1100°C.

Retention Time (RT)	Name of compound	Structural	CAS No.	Molecular weight
4.14	Carbon dioxide CO_2		124-38-9	44
4.25	Sulphur dioxide SO_2		7446-09-5	64
5.36	Furan, 2 -methyl C_5H_6O		534-22-5	82
7.20	Furan, 2,5-dimethyl- C6H8O		625-86-5	96
8.93	Toluene C_7H_8		108-88-3	92
14.16	2-Furanmethanl, Furfuryl alcohol, Tetra hydro $C_5H_{10}O_2$		97-99-4	102
19.86	Phenol, 3-methyl m-Cresol C_7H_8O		108-39-4	108
20.62	p-Cresol C_7H_8O		106-44-5	108
20.99	Phenol, 2,-(2-methyl-2-propenyl)-Phenol, o-(2 methyl allyl)- $C_{10}H_{12}O$		20944-88-1	148
22.70	Phenol, 3,4-dimethyl $C_8H_{10}O$ 2,3 Xylenol		95-65-8	122
24.31	Phenol, 2,3,6 Tri-methyl $C_9H_{12}O$		2416-94-6	136

Remarks:

1. Nature of gases released on pyrolysis of cured APNB and FNB as studied by Py-GC-MS mostly tally with those studied by earlier researchers.

2. In practice, pyrolysis of cured binders of molds take place both in oxidative (surface) and inert (subsurface) atmosphere, whereas experiments were carried out in inert atmosphere. Ultimate products of pyrolysis are oxides of elements, most of which are less harmful than BTEX and PAH generated under inert atmosphere

4. Sand tests

4.1. APNB

Source of sand – Bhilai Engginering Corporation, Bhilai, India
Varieties of sand- New, TR & MR
Manufacturer of binder (Fortech 300) & hardener (050) - Forace Polymers (p) ltd., Haridwar, India
Manufacturer of coating (Foarcoat 111, thinner based Zircon coating)- Forace Industries (p) Ltd. Haridwar, India

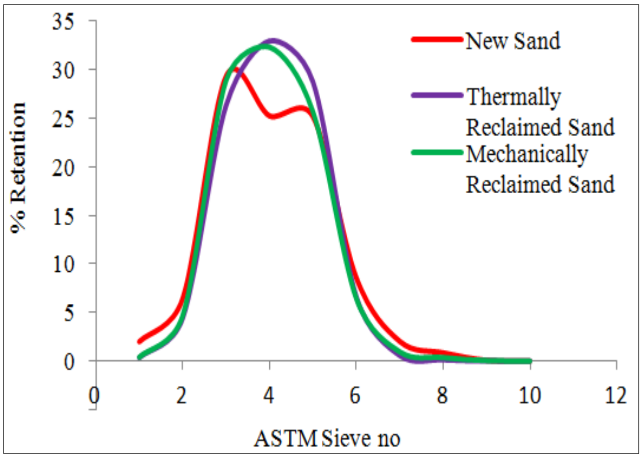


Fig. 6. ASTM sieve no vs % retention

Table 3.
Properties of sand

Parameter	New Sand	Thermally Reclaimed Sand	Mechanically Reclaimed Sand
AFS	42.53	41.69	41.78
LOI (%)	0.786	0.583	2.36
ADV	1.60 ml 0.1 (N) NaOH/100 Gram	24.55 ml 0.1 (N) HCl/100 Gram	22.09 ml 0.1 (N) HCl/100 Gram

Table 4.
Properties of used Resin, Hardener & Coating

Properties	Resin	Hardener	Coating (Zircon Thinner Based)
Viscosity (B-4, 30°C)	24 Sec.	13 Sec.	14 Sec.
Viscosity (Brookfield,30°C)	60 cps	Less than 20 cps	NA
Non-Volatile (%)	47.38	NA	59.63
Sp. Gr. (30°C)	1.190	1.230	NA
Free Formaldehyde (%)	Not traceable	NA	NA
Appearance	Brownish red liquid	Light Brown transparent Liquid	Light Greenish Liquid
PH	12.40	NA	NA
Baume	NA	NA	52
Free Phenol (%)	0.93	NA	NA
Alkalinity as KOH (%)	11.56	NA	NA

Table 5.
Gas value (850°C)

Sand	New Sand		TR Sand		MR Sand	
Recipe	1.6 :20	1.8 :20	1.6 :20	1.8 :20	1.6 :20	1.8 :20
Gas Value (ml/gram)	7.5	9.2	8.0	9.0	9.5	11.0

4.2. Sand test details

Mixer: 3 Kg. capacity
Mixing time: Sand + hardener 2mints, resin 90 sec.
Discharged sand was filled into 50X50 mm gang sample box
Bench life of mixed sand was studied manually.
Strip time was recorded when handful of sand in a tight polythene paper become hard.
It was identified to test samples for compression strength in following stages simulating mold movement

- Dry strength at the time of stripping
- Dry strength at different time intervals up to 24 hours
- Baked strength (dry) after 1 hour & 24 hours
- Strength of molds after application of coating & lighting off: in warm condition (wash degraded strength)
- Above strength after cooling of samples (recovered strength after wash application)
- Hot strength of wash applied, lighted off & cooled samples (hot condition)
- Retained strength (cold condition) of above samples

4.3. Hot & Retained strength

24 hours samples were baked at 135°C, cooled, coated with thinner based coating by brush, lighted off and cooled. These samples were heated in furnace at 450°C for 5 mints, 10 mints & 15 mints. Samples were tested for compression in hot (hot strength) and cold (retained strength) conditions.

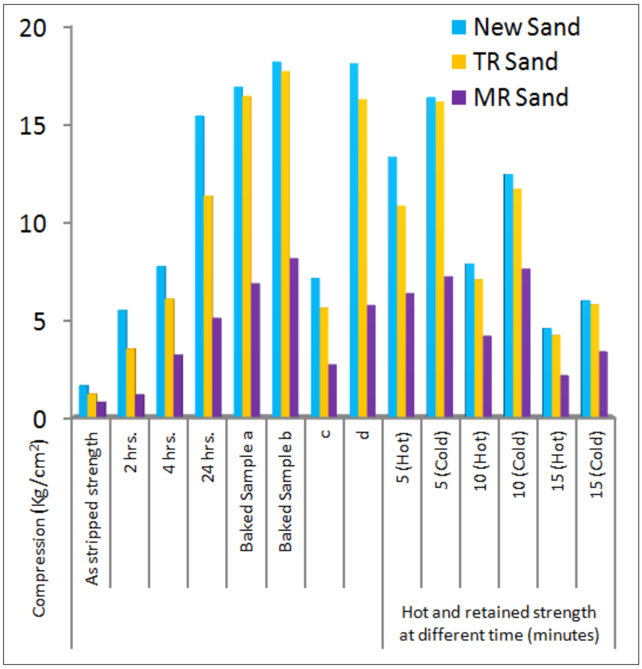


Fig. 7. Recipe: 1.6:20 Medium Fast Hardener RT-20°C, RH-45%

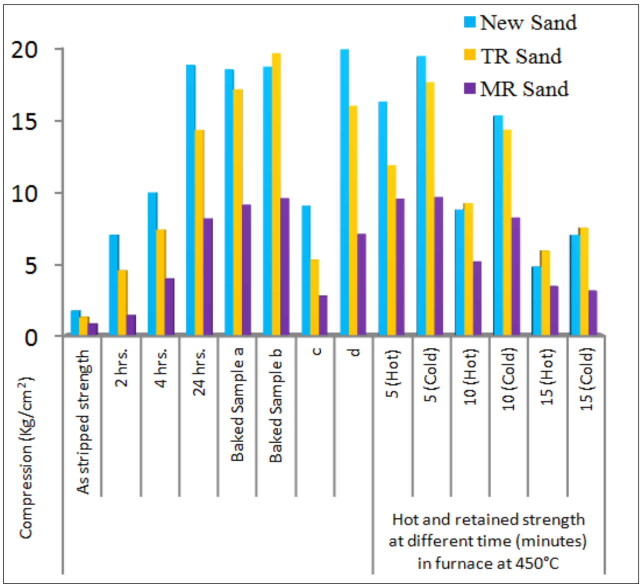


Fig. 8. Recipe: 1.8:20 Medium Fast Hardener RT-20°C, RH-45%

Table 6.
Codes versus strength

a : 1 hr. samples baked @ 135°C for 10', cooled at RT & tested for compression
b : 24 hr. samples baked @ 135°C for 10', cooled at RT & tested for compression
c : Samples **b** dipped in thinner based Zircon wash, lighted off, tested hot for compression
d : Samples **b** dipped in thinner based Zircon wash, lighted off & cooled

5. FNB

Source of sand –Bradken, Coimbatore, India
Varieties of sand- New, TR & MR
Manufacturer of binder (Forfuran 400) & hardener (004) - Forace Polymers (p) ltd., Haridwar**,** India
Manufacturer of coating (Foarcoat 111, thinner based Zircon coating)- Forace Industries (p) Ltd. Haridwar, India

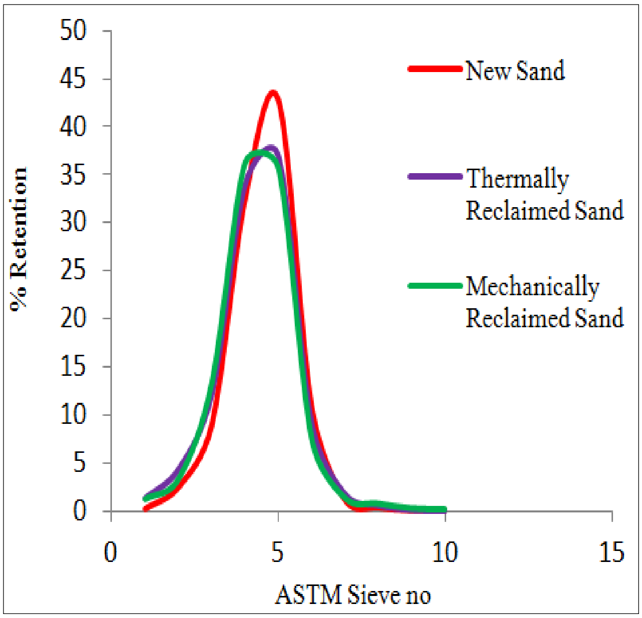


Fig. 9. ASTM sieve no vs % retention

Table 7.
Properties of sand used

ASTM No.	New Sand	Thermally Reclaimed Sand	Mechanically Reclaimed Sand
AFS	47.66	45.69	45.6
LOI (%)	0.484	0.568	2.47
ADV (%)	0.733 ml 0.1 (N) HCL/100 Gram	1.41 ml 0.1 (N) HCL/100 Gram	12.01 ml 0.1 (N) NaOH/100 Gram

Table 8.
Properties of used Resin, Hardener & Coating

Properties	Resin	Hardener	Coating (Zircon Thinner Base)
Viscosity (B-4, 30°C)	14 Sec.	13 Sec.	14 Sec.
Viscosity (Brookfield)	Less than 20 cps	Less than 20 cps	NA
Non-Volatile (%)	31.24	NA	59.63
Sp. Gr. (30°C)	1.130	1.140	NA
Free Formaldehyde (%)	0.121	NA	NA
Appearance	Light Yellowish Liquid	Colorless Liquid	Light Greenish Liquid
PH	7.12	NA	NA
Baume	NA	NA	52
Free Phenol (%)	2.10	NA	NA

Table 9.
Gas value (850°C)

Sand	New Sand		TR Sand		MR Sand	
Recipe	0.8 :50	1.0 :50	0.8 :50	1.0 :50	0.8 :50	1.0 :50
Gas Value (ml/gram)	6.5	7.2	7.5	7.9	8.0	8.7

Details of Sand test and strength requirements at different stages are as in case of APNB

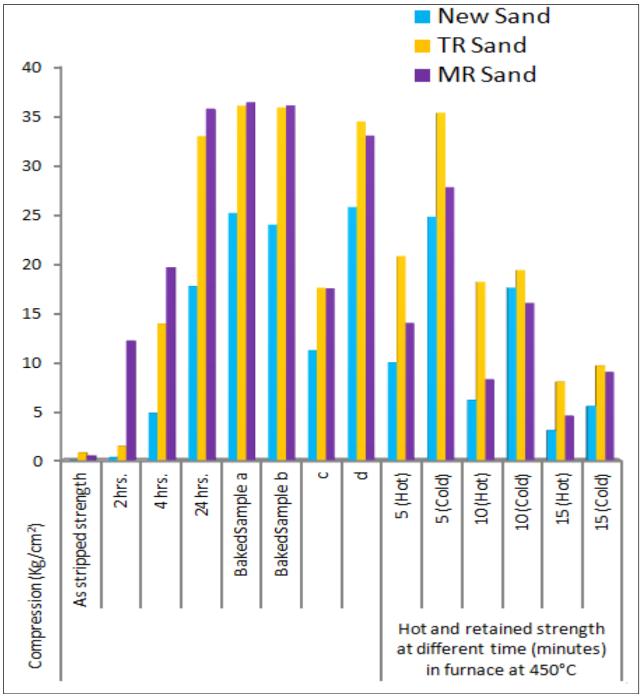


Fig. 10. Recipe: 1.0:50 Medium Fast Catalyst RT-20°C, RH-47%

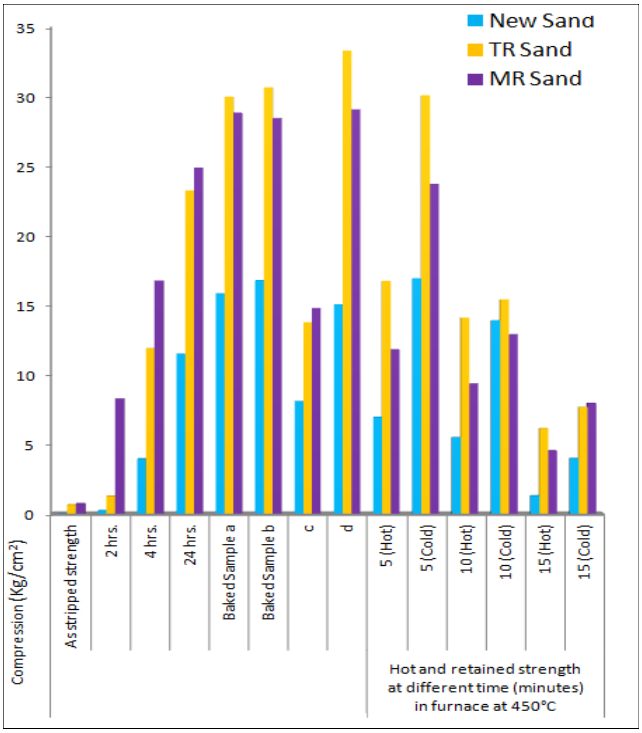


Fig. 11. Recipe: 0.8:50 Medium Fast Catalyst RT-20°C, RH-47%

Remarks

- Baking of molds at any time after stripping enables to achieve final strength both in case of APNB & FNB.
- Strength drops for both APNB & FNB bonded molds after application and lighting off in warm condition while using thinner based coatings (wash degradation) which is almost totally recovered after cooling (recovered strength).
- Binder demand of MR sand in case of FNB is much lower than new/TR sand to get equivalent strength, whereas, in case of APNB it is equal or more.
- Reclaimability of used sand by mechanical process for FNB is as high as 85% whereas same is 70% in case APNB.
- Dry strength properties for FNB are much more than in case of APNB at workable addition level. Rigidity of FNB molds are also much more than that of APNB.
- Flow ability and compactness of FNB sand is much better than that of APNB bonded sand. This facilitates application of FNB bonded sand to produce thin & integrated castings like motor bodies.
- Overall APNB provides a cleaner work place environment than FNB.
- APNB is compatible with all varieties of sand namely silica, olivine, chromite and zircon. FNB is not compatible with olivine sand.
- In case of APNB dry and hot strength at addition level of 1.6 & 1.8% for both new & TR sand are close, whereas same for MR Sand are much lower.
- In case of FNB, both at addition level 0.8 & 1%, dry strength properties of TR sand are equal or better than MR

sand, new sand follows. However, hot strength properties of TR sand are better than new sand, MR comes next.

- Both in case of APNB & FNB, difference between retained strength & hot strength are reduced with increase in soaking time in furnace.
- Difference between dry strength for FNB and APNB are much more than hot & retained strength.

6. Conclusions

- Author feels study of strength of samples made out of mixed sand while tested at high temperature using simple equipments can be a tool to simulate hot strength properties like veining, fusion, hot tear, ease of de coring & likes individual foundries.
- Choice between two binders for green field foundries primarily depend on many factors, main being metal to be cast, compatibility with cheap and available sand and investment capability for mechanical and thermal reclaimer.
- With current stringent regulations for protection of Ecology and Environment, modern binder formulations have gone through changes like reduction in monomer contents, use of hybrid formulations, formulations with lower binder demand, increase in reclaimability of used sand so many.
- Modern Alphaset and Furan formulations are capable of working as clean binder systems at optimum addition level with reclamation, still meeting functional requirements of modern foundries.

Finally, modern formulations of FNB and APNB are capable of meeting most of the requirements of foundries right from BL of mixed sand to ease of de-coring of molds, post pouring and also stringent emission norms of local bodies.

Foundry World will keep on looking for inorganic self-sets which will match functional properties of these two self-sets and offering work place environment like any other manufacturing industry.

One possibility is to use functionally modified silicate with slower liquid hardener like butylene carbonate, which is not available in commercial grade in today’s market.

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- Prof. Holtzer M. and his team of AGH University, Krakow for getting Py-CG-MS done at their facilities
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