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Past, Present and Future of FNB Mould System

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Abstract
This review paper is dealing types of binders used in foundry industries. The different binders have advantages and limitations. This paper gives direction on selection of binder system in different metals. This mainly focuses on selection, advantages and limitations in motor body castings. The data was collected from Krislur Castomech Pvt. Ltd., Chitra G.I.D.C., Bhavnagar. The binder system improves productivity of foundry industries by reducing process cycle time. FNB system also produces the net shape product and with good surface finish. This two part no-bake sand mould system is a mixture of sand with furfuryl alcohol as a resin and sulphonic acids as a catalyst. The resin percentage is on the basis of sand and catalyst on the basis of binder percentage.

Keywords: *Furfuryl alcohol, hardener, Furan No-Bake*

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INTRODUCTION
Extremely difficult cast components can be produced with self-set resin systems. It is necessary for production of high quality and accurate dimensional cast products. These castings ultimately assist in production of engineering components of complex shapes.

Because it is fast and self-setting and can be mixed easily and has very good properties of moulding, the Furan No Bake process has enjoyed high popularity for many years and, with more than 80% penetration of market or market cover, rules the area of No-Bake processes.

The significant achievement of the No Bake processes and that of the Furan No Bake process can be seen by steady and regular growth of the production of casting in tonnes by FNB process in foundries of Germany (Figure 1). Furfuryl alcohol (FA) is the major component of all major furan resins, within limited ranges of 60–95%. The reactivity and end hardness of the mould is determined by the range of furfuryl alcohol, i.e. the FA range has a constant effect on the hardening speed and gelation. Furfuryl alcohol has a strong and fast reaction with acids and solidifies in a brittle form like glass.

The FNB resins are also constitute of urea pre-condensate in % range of 3–20. In formulations of resin, the high reactivity of FA is slowed down and also mould disintegration is promoted. The nitrogen content in urea could result in higher defects in casting and gets concentrated in reclaimed sand. The final strength of mould is reduced by a high ratio of urea and also causes consumption of high percentages of acid and resin. Along many different components, real development potential can be predicted for furan resin systems to compete in terms of needs of the foundries.

DEVELOPMENT
In the wish list of essential foundry features of foundry resins, reactivity will always top the list as the most required feature. The ‘reactivity’ concept of FNB resins is the main objective of this development. ‘Reactivity’ is the ability of a substance to undergo a chemical reaction; it shows the qualitative measure of a substance to react.

Chemical reaction necessarily demands reaction partner, as a mixture with the furfuryl alcohol, this is a combination of inorganic or organic acids. Processability time required by sand mixture is the most crucial value regarding overall reactivity for achieving quality mould production.

It is a fact that the final and initial strengths for normal complete solidification develop in a way that correlates to the range of furfuryl alcohol in formulation of resin. This occurs with the application of reclaimed and new sand. The overall reaction and reactivity of resin depends on the amount of resin (Figure 2). The FA ratio thus affects a resin's reactivity as well as the maximal achievable final strength of the furan resin system and determines the possible working time. If we attempt to improve the reactivity of furan resins only by increasing the percentage of the furfuryl alcohol components, reactivity limit is quickly reached. Thus resins with furfuryl alcohol ratio of 95% or above are difficult to use in a safe and reliable manner. Only by using curing agents with low reactivity and sands that are cooled, is a satisfactory mould hardness achieved which is however still quite brittle (Figure 2).

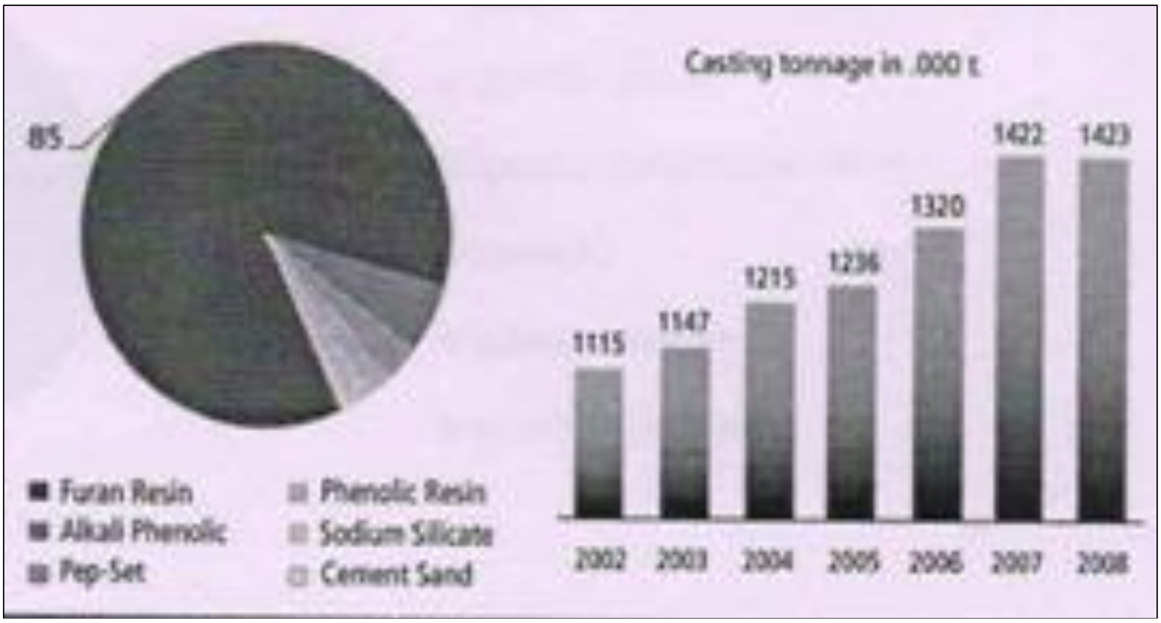

Fig. 1: *Moulding Process and Casting Tonnage Ratios.*

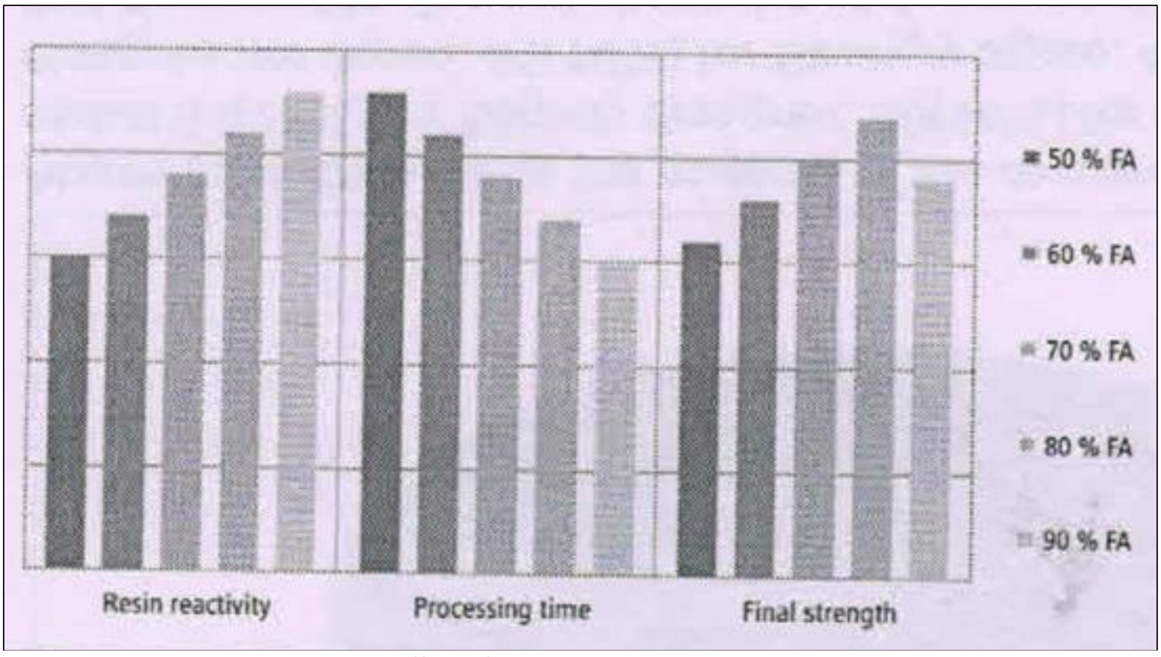

Fig. 2: *Effect of FA Ratio on System Reactivity.*

The solidification of bonded sand chemically takes place through a three-dimensional cross-linking of components of resins. For this aim only, the resins are mixed with inorganic or organic acids. Para-toluene sulphonic acids (PTS) are known to be hardening acids for slow to normal gelation. Phosphoric and sulphuric acids are also applied at low sand temperatures or for rapid hardening [5]. A wide variety of acids and acid blends are available that are applied to ensure completely cured sand (Figure 3). He has investigated on role of sulphur on mould properties and sand and hardener as its source [6, 7]. He have made research on quality of the reclamation sand and casting Surface Structure along with influence of over-cooling the nodular cast iron to the graphite form in the surface layer [[8,9]. Hosadyna have investigated influence of the type of the hardener on the sulphur diffusion of moulding sand to the casting surface [10].

Combination of acid, sand and resin, occurs in a poly-condensate reaction involving monomers of resin to complex macro-molecule structures. Also the process of poly-condensation occurs uniformly; it can be slowed down or fastened up as per requirement. In addition to the criticality of resin reactivity, there are various acids available as partners of reaction for the resin, enabling a speed which is controlled for the overall reaction (Figure 3).

In addition to reactivity of acid and resin, the main theme of this technique was aimed on reduction of emissions by taking acids as a major emissions source. Along with the parameters of metallurgy, the acids which are applied have a considerable effect on the reclaimed sand characteristics. The ratios of sulphur which are varying comes from sulphuric acids, PTS and their compounds give necessary potential for possible reduction of emission. These emissions are absent while using inorganic and phosphoric acid free from sulphur (Figure 4).

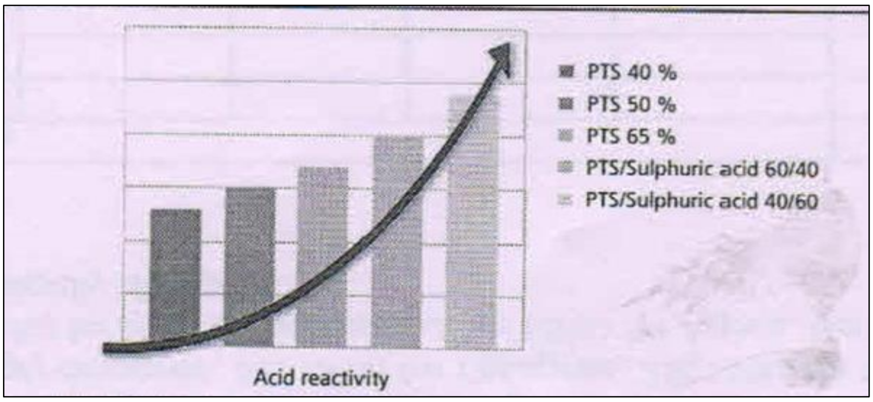

Fig. 3: *Effect of Hardness on System Reactivity.*

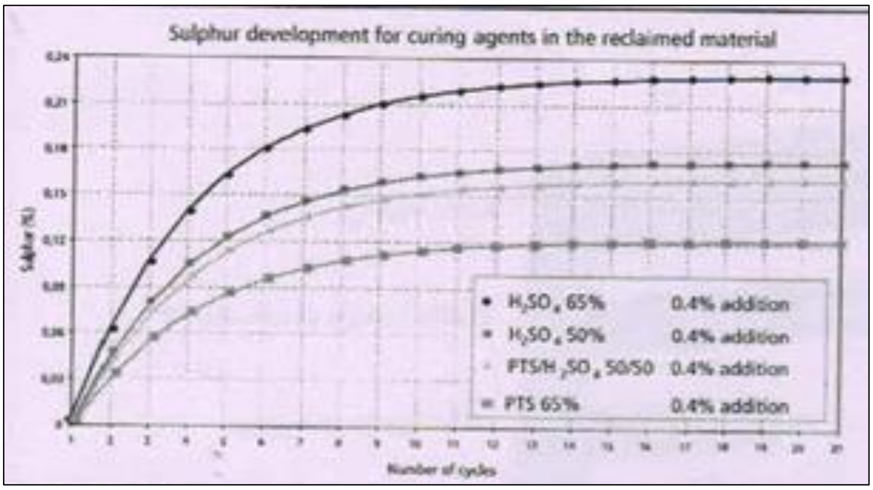

Fig. 4: *Effect of Build-Up of Various Curing Agents in the Reclaimed Sand.*

***Table 1:** Evolution of the Binder.*

Process	Approximate Time of Introduction
Core oil	1950
Shell: liquid and flake	1950
Silicate/carbon dioxide	1952
Airset oils	1953
Phenolic acid-catalysed no-bake	1958
Furan acid catalysed no-bake	1958
Furan hot box	1960
Phenolic hot box	1962
Oil urethane no-bake	1965
Phenolic/urethane/amine cold box	1968
Silicate ester-catalysed no-bake	1970
Phenolic urethane no-bake	1974
Alumina phosphate no-bake	1977
Furan sulphur dioxide	1978
Polyol urethane no-bake	1978
Warm box	1982
Free radical cure sulphur dioxide	1983
Phenolic ester no-bake	1984
Phenolic ester cold box	1985

The reclaimed sand after undergoing some cycles contains sulphur which is obtained from sulphuric acids and PTS which promotes sulphur dioxide emission as a detectable and harmful emission. Fume levels are directly proportional to % addition of acids and sulphur ratio present in it during emptying, cooling, pouring and reclamation of the mould. Table 1 shows the evolution of binders.

Furan No Bake sand moulding is proved to be an efficient process to produce complex castings of medium and low volumes in both nonferrous and ferrous metals. In the no-bake process, sand is mixed with a chemical binder/catalyst system and then moulded around the cope and drag halves of the tooling [1]. Any metal can be cast with Furan No Bake process with a large to small varying weight of components.

A wide range of resin binder processes are currently used, which are classified into the following categories:

- No-bake,
- Heat-cured, and
- Cold box.

In the cold box and no-bake system process, room temperature is required to cure the binder; oven bake processes in the hot box and shell moulding, heat cures are used technically. Process selection and binder type depends on the core numbers or moulds required and size, equipment and production rates [2].

FURAN NO BAKE (FNB) BINDER SYSTEM

FNB binder system comprises of two parts viz. furfuryl alcohol and the acid catalyst, sulphonic acid. There are various other types of no bake resins found in market (above 30 in sum), based on three main chemistries of furfuryl alcohol. All resins have low content of free formaldehyde, zero % UF resins, and are cooked at high scale temperatures, so that they are satisfactorily reactive so that the catalyst will always have a low content almost 1.0% free sulphuric acid product. This proves that FNB binder system is the most user friendly and cleanest system available anywhere on the planet presently, on both pouring and moulding floors.

Application Field

In moulds and cores for steel, aluminium castings or iron alloy; it is most suited for usage with sands which are reclaimed. Exceptional performance for very heavy, thick and large section castings; a varied range of strip and work times are available with appropriate catalyst selection. It possesses a superior through-cure property which makes the FNB resins, a perfect core choice and also operations of making high volumes.

Application Method

It is typically applied at minimum 0.9 to maximum 1.1% on the basis of sand. Percentage level of 0.85% is obtained in foundry industries with good sand control. When applying new or cold sand, level necessary is of 1.2%. One of the following catalysts gives the desired and required hardening:

1. For long and slow bench life conditions.
2. For normal hardening.
3. In winter or for rapid hardening

FNB Product Line

High Scale Modified Resins

These resins are co-reacted with phenol for producing the most cost effective furan resins. 100% 'cooked resin' are often used in large moulding operations and are known for a swift and strong through cure.

Fully Un-modified Resins

These resins are made on a conventional, high amount of furfuryl alcohol content resin and are often used in pit moulding operations; they got replaced by the new developed technology 'hybrid resin'.

Hybrid Resins

It is the most technologically advanced furan resin available in the market. These resins are available for achieving sharp crisp cures. FNB resin is chosen by keeping operating environment and economic factors in mind.

Safety Measures

Resin and catalyst can contact only in the sand presence; absence of sand can cause violent reaction. We should never store our resins in containers that contain catalysts or similar acids and vice versa. Recommendation of rubber gloves to handle sand/catalyst/resin mixture for avoiding natural oils of the skin loss is given.

Shelf Life

Good shelf life for a minimum of 12 months is available if they should not be stored in sunlight.

This paper deals with the application of foundry sand with furfuryl resin and hardeners, produced from sulphonic acids. Under high temperature, the disintegration of the hardener occurs, which produces sulphur compounds getting diffused to molten metal and intensifying in used moulding sand which is available from the process of mechanical/thermal reclaimanation [11,12].

Table 2 comprises comparison of properties of No-Bake binder system [3]; and Table 3 provides technical description of phenolic NB, alkyl phenolic NB and furan NB [4].

Table 2: *No-Bake Binder Systems Properties Comparison.*

Parameter	Process							
	Catalysed with Acid		Ester Cured		Oil Urethane	Phenolic Urethanes	Polyoliso-cyanate	Alumina Phosphate
	Furan	Phenolic	Alkaline/Phenolic	Silicate				
Relative tensile strength	1	0	–1	0	1	0	0	0
Gas evolution rate	–1	0	–1	–1	0	1	1	–1
Thermal plasticity	–1	0	0	1	–1	–1	–1	–1
Easy shakeout	GD	FR	GD	PR	PR	GD	EX	GD
Resistance to humidity	FR	FR	EX	PR	GD	GD	GD	PR
Strip time in minutes[(b)]	3–46	2–46	3–61	5–60	2–182	2–41	3–21	31–61
Optimum (sand) temperature (°C)	27	27	27	24	32	27	27	32
Clay and fines resistance	PR	PR	PR	FR	FR	PR	PR	FR
Flowability	GD	FR	FR	FR	FR	GD	GD	FR
Pouring smoke	0	0	–1	NN	1	0	0	NN
Erosion resistance	EX	EX	EX	GD	FR	GD	PR[(e)]	GD
Metals not recommended	(c)	-	-	-	-	(d)	(e)	-

(a): 1, high; 0, medium; –1, low NN; none; EX, excellent; GD, good; FR, fair; PR, poor.
(b): Rapid times of stripping are required with special mixing equipment.
(c): For steel, use minimized N_2 levels.
(d): Steel requires iron oxide.
(e): Use in supplement with nonferrous metals.

Table 3: *Technical Description of Phenolic NB, Alkyl Phenolic NB and Furan NB [4].*

	Phenolic NB	**Alkyl Phenolic NB**	**Furan NB**
1st part (Binder) Alcohol	Phenolic-water borne	Phenolic-water borne	Furfural based polymers
2nd part (Hardener/Catalyst)	Acid(s) solutions	Organic cured ester(s)	Acid(s) solution
Level of additions in fresh Sand (India)	1.6–2.0: 30–60	1.6–2.0: 20–25	1.0–1.3: 30–60
Binder Viscosity as Processed (B_4, 30ºC, sec)	30–60	20–35	15–25
Minimum Storage life of binder at room Temperature (India) (days)	45	90	180
Presence of Elements			
S	Y	N	Y
N	N	N	May or May not
P	N	N	May or May not
Reclaimability of used sand	Good	Fair	Excellent
Sensitivity to sand properties	Performance is affected by ADV	Not much	Performance is affected by ADV
Bench life control and stripping time of mixed moulds and sands	Fair	Very Good	Excellent
Out of handling and box strength of moulds	Good	Fair	Excellent
Effect of variation of Catalyst/Hardener addition level on curing properties within stipulated range	Appreciable	Not Much	Appreciable
Evolution of gas at workable addition level	High	Low	Least
evolution of BTX at pouring	Mid	Low	Very low
Famous and demanding in India and Middle East	Demanding	Ig	Ig at Fast rate

CONCLUSIONS

Though investigated in late 1950's along with PNB as first synthetic binder systems in world market, Furan No Bake (FNB) took long time to reach Indian Foundries, in fact much later than Alkyd and PNB. Today's modern FNB formulations in India are not only capable of meeting all the requirements of Indian foundry men, both ferrous and non-ferrous, but also competing with international suppliers in Indian market. Further, it can be said that modern FNB in India are not inferior in quality to any of the formulations available in international context. Modern FNB in India is a complete foundry binder compatible with most of sand being used commercially and climatic conditions with up to 95% reclamation.

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