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# Bench Life (Work Time) of Moulding and Core Sands with Chemical Binders – a New, Ultrasound Investigation Method

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## Abstract

The obtained results of the investigations of influences of the selected technological factors on the bench life (work time) of moulding and core sands with chemical binders are presented in the hereby paper. The bench life assessment is performed by the new, author's method with the application of the ultrasound technique. This method was patented by the author. The influence of such factors as: matrix (surroundings) temperature, matrix water content, ratio of binding components hardener/binder (h/b) and the reclamation – on the bench life of furan moulding sands was determined. The empirical dependencies (regressions) were determined, which allowed forecasting the bench life ( $B_L$ ) of moulding sands as functions:  $B_L = f(W\%)$ ,  $B_L = f(T)$  for the fresh and after the reclamation sands,  $B_L = f(h/b)$ . These dependencies should be treated as examples of the new method application for investigating the bench life of moulding sands with chemical binders.

**Key words:** Bench life, Ultrasounds, Binding of moulding sands, Investigation methods

## 1. Introduction

Bench life of self-hardening moulding sands is relatively weakly defined technological property. The most often it is defined as a time during which a moulding sand can be still moulded – counted from a moment in which all components - necessary for binding reaction - are introduced into a mixer. However, various criteria are used for the bench life assessment. Once it is 30% of a strength decrease, another one 20% and sometimes sand fluidity measuring is used as a bench life criterion [1, 2]. It is assumed that this is a time period between a sand preparation and making the sample (core, mould) after which the sand strength is not smaller than 70% of the strength obtained by samples directly after the moulding sand preparation.

The longest bench life have moulding sands, in which at an ambient temperature none reactions occur, e.g. classic sands, sands with binders binding by dehydration, moulding sands with binders binding by solidification which occurs at a temperature significantly different than the ambient temperature e.g. coated sands. A long bench life have fast-setting sands since a hardener (usually accelerator) is introduced only to a sand shaped already in a form of a core or a part of a mould. The shortest bench life characterises self-hardening sands, especially moulding sands with highly reactive resins and strong acids (hardeners) [1, 2].

Several technological tests allowing to describe this feature of sands with chemical binders were developed [1, 2]. The binding process starts when components of a binder are in contact, it means in the mixer. In case of the cold-box technology, the long bench life is one of the most important good points. Due to the

fact that the hardening process of the thickened sand occurs only when the core is blown through by a gaseous catalyst, these moulding sands are characterized by a long bench life [1]. A bench life determination, in the technological practice is generally performed for sands of a very short, short and middle bench life. The most often loose self-hardening sands with resins or with water-glass as well as fast-setting sands with synthetic resins are tested.

## 2. Methods of a bench life testing

Methods of testing a bench life of loose slow and fast-setting sands can be listed as follows [1, 2]:

- The modified fluidity  $P_{sz}$  method, it means shattering of the sieved sand on the sieve of the determined mesh and measuring the amount which 'flows' through it,
- Angelov method – intended only for loose self-hardening moulding sands, based on determination height changes of successive samples made, at a constant compacting energy, as time goes by after mixing. The successive samples are lower and lower and the time, after which the height decrease is 30%, is assumed as the bench life,
- The method, in which the apparatus for a determination of moulding properties  $W_k$  is used. As the time goes by a moulding sand loses its binding ability and more sand grains is passing through the rotating sieve,
- The method developed by NPO CNIIT-sand, in which the PRS apparatus measuring changes in cohesion and internal friction as time of sand hardening goes by, is used,
- The method of measuring hardness changes of the surface layer, sometimes by means of an awl, 6 inches long (152.4mm),
- The index FIP – parameter of binding intensity, determination method [3].

## 3. Kinetics of moulding sands hardening

A rate with which a hardening process of a moulding sand with a chemical binder occurs is an important technological parameter. On this rate depends: the sand bench life and time needed for obtaining the strength necessary for performing successive technological operations. The hardening process rate is not constant and, in a similar fashion as in the majority of physical and chemical processes, after an initial period including incubation period, the rate starts increasing. After a certain time it reaches the maximum and then starts decreasing and approaching zero. The kinetics of process rate changes depends on several factors, which influence was determined by means of ultrasound investigations and described in publications of the author [4–7, 11,12]. The most important are the following:

- binding material kind,
- ratio of **hardener/binder (h/b)** components,
- matrix kind (grain composition, moisture content, chemical reaction (pH), etc.),

- matrix temperature,
- conditions of gaseous components exchanging with surroundings,
- ambient temperature (air),
- air humidity,
- time of being under the selected conditions,
- layer position (surface, middle part of a mould) and other.

Out of the listed above factors the **most important** for the kinetics of complex hardening processes are: a moisture content of a matrix used for the sand preparation, its temperature and proportions of the main components of the binding material, it is: hardener/resin. The methodology of the bench life determination with using the new ultrasound method is presented on examples of influence of these factors,

Metoda określania zmiany wytrzymałości wraz z upływem

## 4. Investigations of moulding sands bench life

The whole group of organic binders is sensitive to water presence in a moulding sand [9, 10]. A water presence in a matrix on its grains surfaces decreases adhesive joints between a binder and matrix, lowers their instantaneous strength, slows down a hardening process. Furan resins - including also resins from the Askuran group - belong to binders sensitive to water presence. Figure 1 presents the hardening kinetics of these resins at changing the matrix water content in a range 0.00 – 0.30%  $H_2O$ . Investigations of modulus of elasticity changes of moulding sands during their hardening were performed by the **ultrasound technique**, developed, described and patented by the author (as the AGH patent) [8]. As the moulding sand water content increases the hardening rate decreases and at a matrix moisture content  $W > 0.15\% H_2O$  a binding process is strongly hampered.

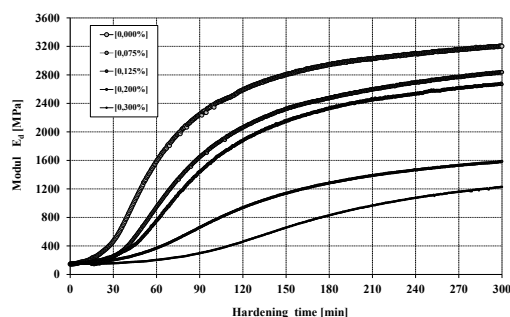


Fig. 1. Influence of a matrix moisture content on the hardening of the moulding sand with furan resin, from the Askuran group,  $T = 20^{\circ}C$

In investigations of the process kinetics, for their mathematical description, the most often the derivative of the measured value changes after a time in which this process occurs – is used. This derivative contains information on the instantaneous process rate, it means on the rate which occurs in the given moment of the process. In ultrasound investigations the derivative of wave velocity changes ( $dc_L/dt$ ) or dynamic modulus of elasticity changes  $E_d$  ( $dE_d/dt$ ), which are calculated from the wave velocity, can be determined. Also the hardening degree

index ( $S_x$ ), which is closely related to the ultrasound wave propagation velocity  $c_L$ , in dimensionless formulation [8], can be utilised. The results of such calculations, in relation to data obtained from measurements (shown in Fig. 1) are presented in Figure 2. Changes rates of the modulus ( $dE_d$ ) were determined as the process time function for each case (a sand moisture content). In each case the phase of increasing the derivative value  $dE_d/dt$ , obtaining maximum and then decreasing of its value are seen. Decreasing of  $dE_d/dt$  value means decreasing the process velocity. From a formal point of view the derivative maximum means the inflection point on the differentiated curve and the end of the period of the increasing velocity of changes as well as the second phase beginning – process slowing down.

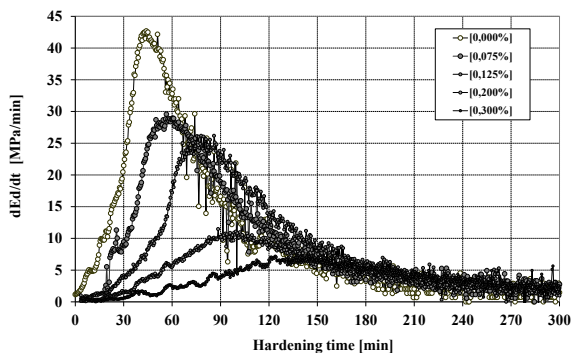


Fig. 2. Influence of the matrix moisture content on changes of instantaneous rates of the hardening process of the moulding sand with furan resin from the Askuran group,  $T = 20^\circ\text{C}$

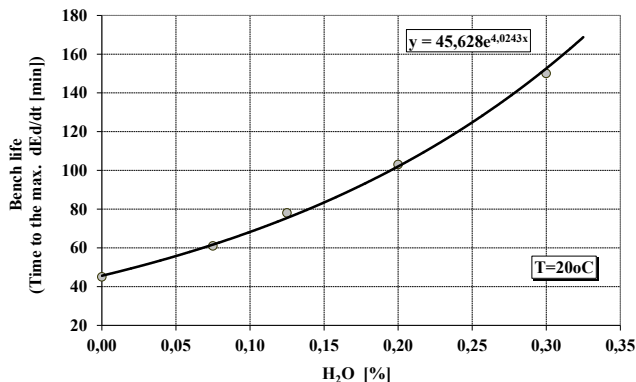


Fig. 3. Influence of the matrix moisture content on a bench life of hardening of a moulding sand with furan resin from the Askuran group,  $T = 20^\circ\text{C}$

For the assessment of the technological suitability of a moulding sand, its suitability for a moulding process, this first period – before obtaining maximum – is the most important. According to the proposition of the author, this period is considered as the period during which the sand is suitable for moulding, it means this is its bench life.

A water presence in a matrix is delaying the moulding sand hardening process, and obtaining elastic features, which are determined by the ultrasound technique. An influence of a sand moisture content on a bench life is graphically presented in Figure

3. Due to technological reasons an excessive prolongation of a hardening time is 'not acceptable', which commonly is called 'sand is not binding'.

Temperatures and the kind of a matrix used for preparation of a moulding sand are successive factors which significantly influence the binding rate and moulding sand hardening. Generally, the sand obtained in the reclamation process is used as the moulding sand matrix. Reclaimed sands have on their surfaces remains of a binder and hardener, which can cause some changes in a binding process. The investigation results of the binding kinetics of moulding sands based on two kinds of the matrix (fresh sand and reclaim) at the application of the same binder – furan resin FR75A – are presented below.

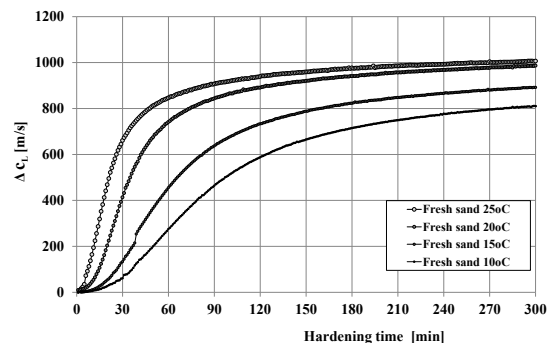


Fig. 4. Temperature influence on the hardening kinetics of the moulding sand with FR75A furan resin and the fresh matrix;  $h/b = 0.50$

The influence of the matrix temperature on the kinetics of hardening of the furan moulding sand based on the fresh sand is shown in Figure 4. Tests were made in the closed sampler at the ratio of binder components:  $h/b = 0.5$ . Investigations were realised at four different temperatures from a range:  $10\text{--}30^\circ\text{C}$ . In case of this FR75A resin (and other resins of an increased content of furfuryl alcohol) the matrix temperature strongly influences the hardening kinetics, that is the bench life too. This is also seen in the recorded data in Figure 4.

In order to be able to compare the results the same tests were performed for the moulding sand with the same binder - FR75A resin, but the matrix reclaimed material was used as the matrix. The results are presented in Figure 5.

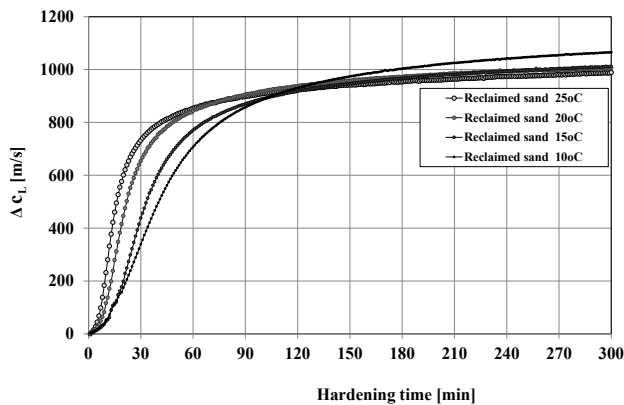


Fig. 5. Temperature influence on the hardening kinetics of the moulding sand with FR75A furan resin and the reclaimed matrix;  $h/b = 0.50$

The comparison of the hardening kinetics indicates that moulding sands with the reclaimed matrix have much shorter bench life and temperature changes from 10 to 25°C, anyhow influencing the process rate, have much smaller influence than in case of moulding sands with the fresh sand (Fig. 4). This process is quite fast both at a lower and higher temperature.

The derivative calculation of the binding rate of the moulding sand with the fresh sand are shown in Figure 6, while with the reclaimed material in Figure 7. Under comparable temperature conditions the hardening rate of the moulding sand with the reclaimed matrix is nearly two-times higher than of the moulding sand with the fresh sand (Fig. 6 and 7).

The temperature is one of the factors, which influence the most intensely chemical reactions rates. It is assumed, that each temperature increase by 10°C accelerates the reaction twice. The data presented in Figure 8 allow to assume that increasing the moulding sand temperature from 10 to 20°C leads to the bench life shortening from 60 to only 25 minutes – in case of the moulding sand with the fresh sand and from 32 to 16 minutes – in case of the moulding sand with the reclaim.

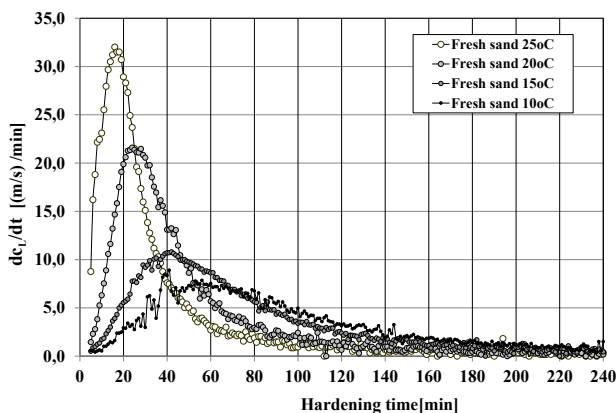


Fig. 6. Temperature influence on the instantaneous hardening rates of the moulding sand with the fresh sand and furan resin (FR75A);  $h/b = 0.50$

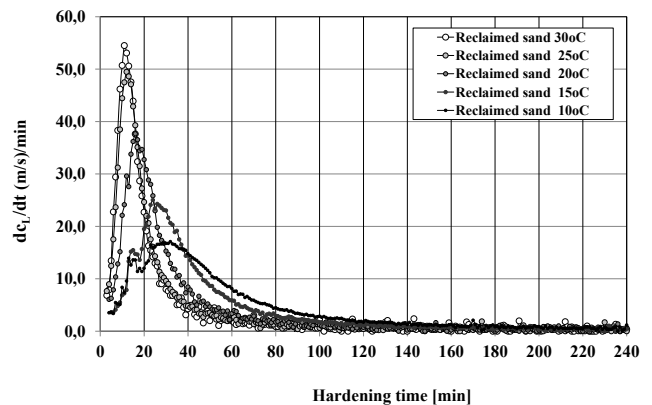


Fig. 7. Temperature influence on the instantaneous hardening rates of the moulding sand with the reclaimed matrix and furan resin (FR75A);  $h/b = 0.50$

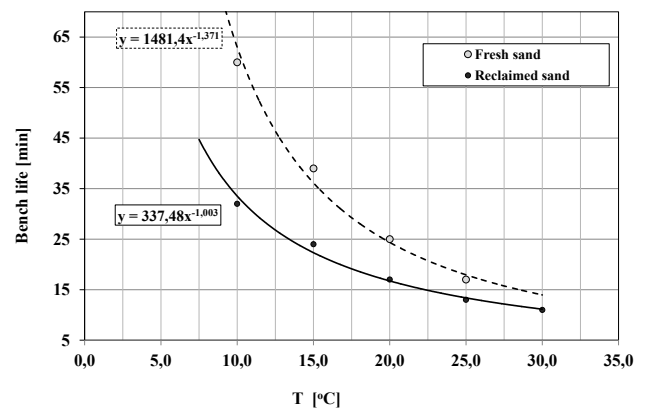


Fig. 8. Temperature influence on the bench life of the moulding sand with furan resin (FR75A) and the fresh and reclaimed matrix;  $h/b = 0.50$

The influence of the temperature on the moulding sand bench life can be described by the regression equation of an exponential character. Knowledge of this equation allows to forecast the moulding sand bench life in the whole temperature changes range.

Another important factor, influencing binding rates of moulding sands with chemical binders is the ratio:  $h/b$ , it means the ratio of the hardener amount to the resin amount. An increase of this ratio value means increasing concentration of the chemical reaction reagent, which - of course - increases the reaction rate (process rate).

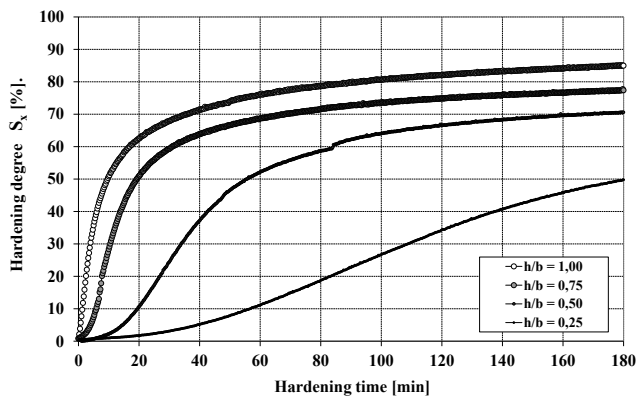


Fig. 9. Influence of the ratio  $h/b$  on the hardening kinetics of the moulding sand with furan resin;  $T = 20^{\circ}\text{C}$

The obtained investigation results of the ratio  $h/b$  on the kinetics of hardening of the moulding sand with furan resin are presented in Figure 9, while on the binding rates in Figure 10. As the ratio  $h/b$  increases the maximal rate also increases, while the time of the first binding period shortens. The influence of this ratio on the first binding period and on the value of the maximum binding rate (maximum:  $dS_v/dt$ ) is presented in Figure 11. The change of  $h/b$  from 0.25 to 1.00 causes shortening of the first period from approximately 100 to a few minutes (3-5). Thus, the bench life of the moulding sand changes.

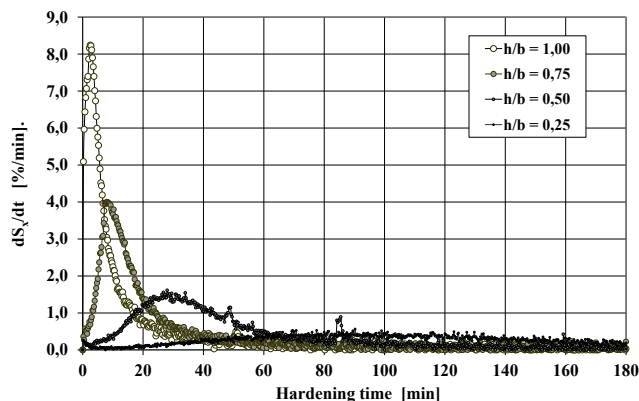


Fig. 10. Influence of the ratio  $h/b$  on the binding rate of the self-hardening moulding sand with furan binder;  $T=20^{\circ}\text{C}$

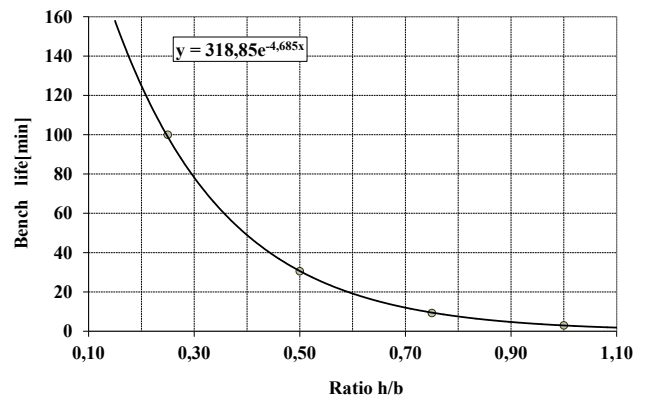


Fig. 11. Influence of the ratio  $h/b$  of the furan moulding sand on its bench life. Process temperature  $T = 20^{\circ}\text{C}$ .

## 5. Conclusions

Investigations of the kinetics of hardening by means of the ultrasound technique allow to monitor the binding process during the whole period and forecasting on this base the moulding sand behaviour in the technological process [11]. Two periods can be singled out in nearly every binding process: the first – when the binding rate increases and the second – when it decreases. Determined, on the grounds of ultrasound investigations, the derivatives of increases of: wave velocity ( $dc_L/dt$ ), dynamic elasticity modulus ( $dE_d/dt$ ), or hardening degree increases ( $dS_v/dt$ ) can be considered the measure of the binding rate. The time of technological suitability of the self-hardening sand (its bench life) is shorter, or - at most - equal to the first period time (before obtaining the binding rate maximum).

Thus, by means of the ultrasound investigations the time duration of the first binding period and the technological suitability of the moulding sand at 'freely' selected temperature conditions, can be accurately determined. In addition, it is possible to describe mathematically – by regression equations – the influence of individual factors such as: matrix temperature, its moisture content and kind, ratio  $h/b$  - on the bench life of the moulding sand. Empirical equations of the bench life, have the most often exponential form (Fig. 3, 8, 10). Such mathematical description of the influence of individual factors provides the possibility of forecasting the moulding sand behaviour (its bench life) without the necessity of performing each time laboratory or industrial tests.

The developed, new, ultrasound method constitutes supplementing of the existing solutions of the bench life assessment. In relation to them it is easier in performing tests, results collecting (computerised measurements) and in explicit interpretation of the obtained results.

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