©2006-2018 Asian Research Publishing Network (ARPN). All rights reserved.

AN ASSESSMENT OF THE EFFICIENCY OF UTILIZING COMPLEX MODIFIERS FOR SOFTENING THE LIQUID-GLASS MIXTURES TO IMPROVE IRON AND STEEL CASTING

Falah Mustafa Al- Saraireh
Department of Mechanical Engineering, Mutah University, Mutah, Al-Karak, Jordan
E-Mail: f_saraireh@yahoo.co.uk

ABSTRACT

An experimental investigation has been conducted to propose a complex solution for the problem of softening the foundry molds and cores depending on liquid-glass binders. The proposed solution, employing complex softening modifiers, has been characterized experimentally and showed positive results. To ascertain the effectiveness of combining the constituents that provide softening of the liquid-glass mixture in intervals of low (200-300C^0) and high temperatures (700-800C^0), the obtained results have been checked by various industrial tests. High-quality casting has been achieved which proves the efficiency of this combining.

Keywords: liquid glass, core, mixture, softening, modifier, hydrolytic lignin, bentonite clay, vermiculite, casting.

INTRODUCTION

Utilizing organic binders based on synthetic resin binders is one of the modern casting processes that attract considerable attention nowadays [1], these are: (1.) alpha-set-process: 85% of the production of casting in single sand molds in the conditions of mass production, and (2.) amine-process: 80% of the production of foundry rods [1, 2, 3]. This can be attributed to the fact that they enjoy high processability, thanks to the high technical support, which leads to bringing increased productivity and quality casting.

Nevertheless, using these processes has considerable disadvantages, such as environmental problems where casting facilities are located, poor hygienic and sanitary conditions experienced in the workplace, and the high cost of materials used to provide the said technologies [3, 4, 5]. European Union imposes restrictions on industrial enterprises; accordingly, by 2020, the use of synthetic resins on a phenolic basis will be banned. Taking all these into consideration, finding alternatives has become a must. In this context, a good alternative can be mixtures based on liquid-glass binders.

OBJECTIVES

The objective of this study is to develop effective modifiers (softening additives) that can come over the problems of knocking out casting molds and rods made of mixtures based on liquid-glass binders.

In this paper, the concept of "efficiency" is used to refer to the ability to implement the process of knocking out the mixture without additional costs, in the usual mode of the company i.e. on existing equipment. Moreover, the phrase "to solve comprehensively" indicates the ability to soften in various temperature ranges caused by effect of heat of molten metal on the elements of the casting mold made on a liquid-glass base.

LITERATURE REVIEW

There have been many studies conducted to improve liquid-glass technologies and tackled the problem of knocking-out of mixtures. In fact, this problem results from melting sodium silicates when pouring the metal into the mold. After that, during cooling, sintering of liquid-glass mixture occurs [7, 8].

Numerous studies attempted to explain different methods for softening binder compositions on liquid glass [9, 10, 11, 12]. These methods can be conditionally categorized as organic and inorganic according to the physical nature of the additives placed on. Regarding organic compositions, these are capable to carry any emulsions contain polystyrene; the inorganic is bentonite, kaolin clays, vermiculite, and perlite. The desired results are not always achieved by employing these methods; this is due to the fact that applying these methods does not completely correspond to the nature of the phenomenon i.e. to prevent the consequences of their use. Western companies, recently, have started to produce separate types of liquid-glass binders. Table-1 illustrates the nomenclature of these types [6, 7, 8].

Table-1. Additives used as technical solutions for knocking out liquid-glass mixtures.

Softening additive	Manufacturer
Cordis- Anorgit(fine additive based on clay)	Hüttenes-Albertus ,Germany
Dexil 35 , 50%dextrin + 25% calcium carbonate + 25% iron oxide and manganese dioxide	company Foseco, United Kingdom
Dexil 11 and Dexil 11F – a powdered composition of a solid phenol-formaldehyde resin, an iron oxide and graphite	company Foseco, United Kingdom
Bitumen in a combination of 0.5-0,7% cationic surfactant (polyamine carboxylic acid)	Bulgaria

MATERIALS AND TESTING METHODS

Depending on the residual strength of the samples, the knock-out of the mixture has been estimated

©2006-2018 Asian Research Publishing Network (ARPN). All rights reserved.

quantitatively. The essence of the method can be summarized as follows: standard cylindrical samples aged for 24 hours. After that, they have been divided into two groups where one group has been tested, and the other has been put in a muffle furnace and kept for a whole hour at different temperatures ranged from 200 to 1000°C. Next, they have been cooled together with the furnace in air. Finally, tests to check the strength have been performed. The difference in the changes in the indices has been calculated to determine the residual strength.

Regarding the components, quartz sand with a grain size of 0.2 mm has been used as filler, liquid glass (LG) with a module of 2.5 as a binder. Technical hydrolysis lignin (THL), clay bentonite, and vermiculite have been used as modifying softening additives.

ANALYSIS AND DISCUSSIONS

As has been furnished by the above-mentioned studies, the major drawback of utilizing liquid-glass mixtures in the technological processes of casting production is their unsatisfactory knockout. Utilizing softening modifying agents, containing a blend of materials, has been proposed. What distinguishes this softening agent is that it works in a low -temperature range of (200-300°C).) and a number of its components operate in a high - temperature range of (700-800 °C).

This study revolves around the idea of combining the processes of modifier components destruction with the processes forming the maximum strength of the liquid glass during its polymorphism during heating up the mixture. For low-temperature softening, technical hydrolysis lignin (THL) has been proposed as an initial component. Regarding high-temperature softening mineral additives, clay (bentonite, kaolin) and vermiculite have been proposed.

The maximum in the region of 300°C, corresponds to the thermal destruction of hydrolytic lignin; consequently, it carries out the softening function in this temperature range, whereas the maximum in the region of 800°C corresponds to metamorphism of inorganic components of the modifier clay bentonite, kaolin, and vermiculite, bringing about a similar effect in the high - temperature region.

Liquid glass, by its physical nature, is an aqueous alkaline sodium silicate solution Na_2O (SiO_2) n. It is a heterogeneous system with a complex polymorphic transformation, relying on the concentration of the constituents and temperature [16].

To interrupt and further clarify the polymorphism of mixtures on the liquid-glass binder employed in the experiment, the reliance on the residual strength of various liquid-glass mixtures in a temperature range of 0-1000°C has been investigated.

At this phase, the aim of the study is twofold. Firstly, to identify the residual strength of the maxima for liquid-glass complex utilized in this study. Secondly, to identify the boundary parameters of the impact of the modifier constituents on the strength characteristics of the liquid-glass composition. To achieve this, the standard model compositions listed in Table-2 have been utilized.

Initially, concerning the binder composition, the conducted adaptive series of experiments have come up with the result that the ratio of liquid glass and the softening modifier additives should be one- third of the volume of liquid glass. This has been determined empirically and validated as the initial basis for testing the composition of the desired binder composition on the model compositions of the mixtures.

An examination of the residual strength indicators (σ^0) has been carried out by considering the impact of temperature. The examination has been designed to stimulate the process of exposure of the molten metal on the mold elements, namely: the inner mold cavity and the walls of the core.

Table-2. Compositions based on the liquid glass.

components of the mixture	Model formulations mixtures					
	1	**2**	**3**	**4**	**5**	**6**
Filler quartz sand,%	100	100	100	100	100	100
liquid glass, %	6	6	6	6	6	6
technical hydrolysis lignin, %	-	2	-	-	1	1
Bentonite, %	-	-	2	-	0,5	0,75
Vermiculite, %	-	-	-	2	0,5	0,25

As established by [12], in the range of 200/1000°C, two maxima and two minima have been observed, which is considered a challenge to ensure the knockout out of liquid-glass mixtures.

Literature data [13] and the obtained experimental data (composition No. 1, curve № 1) are in a complete agreement. Accordingly, the temperature of heating up the mixture corresponding to a temperature interval of 400-600 C^0, corresponds to the minimum work of the knockout. When the mixture was heated up to 800 C^0, a maximum has been observed. This corresponds to the formation of a low-melting eutectic in the Na_2O-SiO_2 system. In foundry production, only small rods, with thin-walled elements, are washed by molten metal entirely; consequentially, their temperature can be raised to 800°C and above. On the other hand, the heating process of large rods has its own characteristics: their heating depends on volume and heat spreads in the whole mass of a rod, which results in a lower final heating. Accordingly, only the surface layers of the rod can reach the maximum temperatures.

 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences
©2006-2018 Asian Research Publishing Network (ARPN). All rights reserved.

www.arpnjournals.com

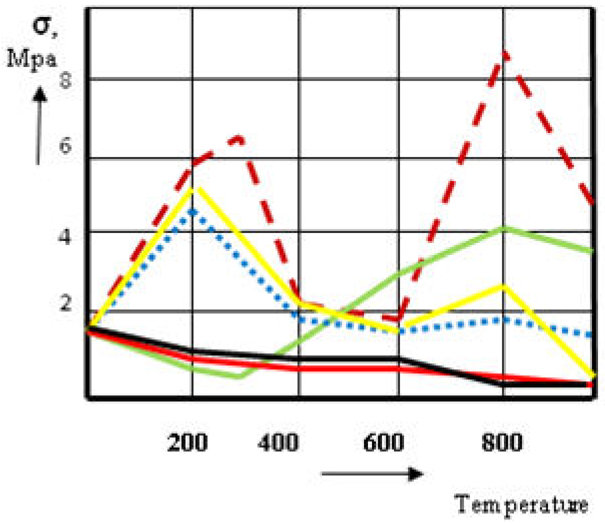

Figure-1. Residual strength of liquid-glass mixtures of various compositions.

№1; №2; №3; №4; №5; №6

Although liquid-glass mixture has a minimum in the temperature range of 400/600C0 (curve № 1), serious deficiencies are encountered through the knockout process. For example, it is a very time and energy consuming process, it works under noisy and high gas operating conditions, and produces dust emissions. Moreover, in respect of thin-walled iron castings, the knockout operation is unsafe due to the cracks. Accordingly, the problem, at this phase of foundry development, has not been completely controlled yet.

As stated in the introduction, this study has been conducted to develop additives in order to come over the problem of the knockout by presenting a satisfactory knockout work level. Thus, it has proposed a modifying additive which is characterized by an acceptable minimum of residual strength in both of a low-temperature range of (200-300C^0) and a high-temperature range of (700-800C^0). For the purposes of this study, the selection of materials is based on preferences i.e. the materials whose action on the liquid-glass base of the binder composition, independently, can come over the problem of softening in a low-temperature range (composition and curve №. 2, in Figure-1), and a high- temperature range (composition and curve №3 and №4, in Figure-1) have been selected and employed in this study.

The idea of softening in this study depends on the fact that thermal distortion processes take place at temperatures ranging from 300-350°C; it produces water vapor, carbon dioxide, and ash. In respect of the process of structure formation in liquid glass, corresponding to the low-temperature maximum, softening is achieved by the products of hydrolytic lignin destructing the emerging structures of liquid glass, which causes a drop in strength to a level of 0.3-0.5 MPa. As a matter of fact, this level can be considered acceptable from the perspective of the "normal knockout" of the mixture [15].

When the heat of the mixture increases, the hydrolytic lignin in liquid glass films burns up. This results in the emergence of fusible eutectic on the surface of the filler, which increases the strength of the composition. An effective solution to this problem may be using the inorganic additives: bentonite clay or vermiculite. By adding them, the desired effect in the high- temperature region (700-800°C) is attained, Figure-1, curves № 3 and № 4. present data on this subject.

It can be said that softening is a polymorphic transformation of materials. For example, swelling phenomenon is a result of phase transformation processes, but more importantly, it is a result of releasing gases, especially, water vapor, due to the release of constitutional moisture at high temperatures. In fact, structure formation of liquid glass and swelling of the mineral components of the mixture leads to weakening as a consequence of the desired result.

A workable remedy for weakening problems in the high-temperature range can be achieved by combining two different types of modifying additives to produce a single substance suitable for practical application. The developed modifier composition consists of lignin, bentonite clay based on sodium and vermiculite, in the percentage of constituents 50:25:25 for iron castings, and 50:40:10 for steel castings respectively. These modifying compositions have been experimentally worked out to produce a formulation taking the form of granules which are made by extruding a mixture containing hydrolytic lignin, bentonite clay, and vermiculite.

The presence of lignin and modifier clay ensures strength at different stages, namely: after preparation, during storage and dosing. As for the presence of vermiculite – fragility, it ensures complete destruction in the stage of mixture preparation. Storing should be in sealed bags or containers to prevent ingress of moisture which results in losing the softening effect of the modifier. Destructing the granules of the modifier, during preparing the mixture, forms granules with a diameter of 1-3 mm distributed eventually throughout the volume of the mixture, they bring about a rauprotting effect, which has been confirmed by the experimental data shown in the curves №5 and №6, Figure-1. The obtained modifier has been tested by producing a casting of "trough", for transport engineering, made of steel 25L, weighs 7 kg. Preparing the mixture has been in accordance with the advised formulation of the developed complex modifier. Then, curing has taken place in two ways, namely: by CO_2, and a drying process in the drying chamber at a temperature of 220°C. Molds shaped in this way has been filled with molten. Next, the casting has been extracted after cooling. Visual inspection revealed that scattered remains emerged by the means of a slight external mechanical influence specifically light rapping on the casting.

This study serves as a base for future studies deal with this problem. It provides an optimal solution to the problems results from decreasing the amount of the binder in the mixture to an acceptable level of 2.5-3.5%. The design of the casting and the alloy used, among others, are

©2006-2018 Asian Research Publishing Network (ARPN). All rights reserved.

key factors in optimizing formulation mixture composition and the modifier composition. The obtained results demonstrate the possibility of carrying out system studies in this area.

CONCLUSIONS

a) An effective complex modifier for molds and core mixtures based on liquid glass has been developed, this modifier softens them to an acceptable level in a wide range of temperature influences (200/300°C and 700/800°C), corresponding to maximum residual strength for liquid glass.

b) The components of the modifier including hydrolytic lignin, bentonite clay on the sodium base and vermiculite, in a percentage of 50:25:25 for cast iron castings, and 50:40:10 for steel castings respectively granted the modifier the disintegrating ability. Thus, alloy type (cast iron or steel) and thermal stress state of the elements of the mold during the formation of the casting, are very important factors. For example, for small and/or thin rods fully washed by liquid cast iron, it is recommended that the components of the modifier be matched to steel casting.

c) Softening modifier complex action influences the properties of the constituents and the mechanisms of physicochemical processes that occur in the mold during the formation of the casting.

d) The idea, implemented in this work, is based on combining the processes of modifier components degradation with processes forming the maximum strength of the liquid glass during its polymorphism during heating up the mixture. Accordingly, the maximum in the region of $300C^0$, corresponds to the thermal destruction of hydrolytic lignin, thus performs the function of softening in this temperature range; maximum in the region of $800C^0$, corresponds to the metamorphism of the inorganic components of the modifier - bentonite clay and vermiculite, having a similar effect in the high- temperature region.

e) To ensure the stability of the modifier softening effect, the modifier shall be pre-prepared to take the form of granules thus becomes easily destructible during preparing the mixture.

f) Pilot tests have been conducted on the proposed softening modifier which has proved its effectiveness: a casting of "trough" of steel 25L, weighing 10kg. for transport, engineering has been conducted. Then, after cooling, the casting has been removed in a conventional knockout grid. Visual inspection revealed that by a light tapping on the casting, the trough, the remains of the core crumbled.

g) Practical applications of the improved version of liquid-glass binders and replacing the hazardous resin binders, especially technology based on the furan process, proved its efficiency in lowering down cost and saving the environment. In other words, this study proved cost and environment effectiveness of this method.

REFERENCES

[1] Modern Casting, January 2014, pp. 23-24.

[2] Modern Casting, December 2012, pp. 25-29.

[3] Galli, P. Polypropylene: a quarter of a century of increasingly successful development. In: Structural Order in Polymers. 1981. pp. 63-92.

[4] Modern Casting, Dec. 2011, pp. 16-19.

[5] Graedel, Thomas E.; Allenby, Braden R. Industrial ecology and sustainable engineering. Prentice Hall, 2010.

[6] Modern Casting, December 2010, pp. 24-27.

[7] Modern Casting, December 2009, p. 17-21.

[8] Modern Casting, December 2008, pp. 24-27.

[9] Shinsky O.I Ecology, technique and economics of foundry production, / Shinsky OI // 3rd International Industrial Investment Forum: investment bulletin Zaporozhye: izd. Chamber of Commerce and Industry, 2012. pp. 34-36.

[10] Gardziella Arno; Pilato Louis A.; Knop Andre. 2013. Phenolic resins: chemistry, applications, standardization, safety and ecology. Springer Science & Business Media.

[11] Frosch Robert A. 199. Industrial ecology: adapting technology for a sustainable world. Environment: Science and Policy for Sustainable Development. 37.10: 17-37.

[12] Goerrissen, Heiner, *et al*. 1988. Molding materials of polyoxymethylene homopolymers and/or copolymers and thermoplastic polyurethane elastomers having improved heat stability, their preparation and their use. U.S. Patent No 4, 780, 498.

©2006-2018 Asian Research Publishing Network (ARPN). All rights reserved.

[13] 1995. Foundations for a Changing World. Evansville, IN. pp. 363-367.

[14] Zhang Yeli; Law Yuet; Chakrabarti Sibu. 2003. Physical properties and compact analysis of commonly used direct compression binders. aaps Pharmscitech. 4. 4: 489-499.

[15] Calzia Kevin J.; Tew Gregory N. 2002. Methacrylate polymers containing metal binding ligands for use in supramolecular materials: Random copolymers containing terpyridines. Macromolecules. 35.16: 6090-6093.