www.czasopisma.pan.pl PAN www.journals.pan.pl

ARCHIVES
of
FOUNDRY ENGINEERING

DOI: 10.2478/afe-2014-0051

Published quarterly as the organ of the Foundry Commission of the Polish Academy of Sciences

DE GRUYTER OPEN

ISSN (2299-2944)
Volume 14
Issue 3/2014

5 – 10

Optimization of the Brass Melting

S. Biernat[a], A.W. Bydałek[b, c] *
[a] PWSZ Głogów, Piotra Skargi 5, 67-200 Głogów, Poland
[b] AGH University of Science and Technology, Faculty of Non - Ferrous Metals, Mickiewicza 30, 30-059 Kraków, Poland
[c] University of Zielona Góra, Faculty of Mechanical Engineering, Z. Szafrana 2, 65-246 Zielona Góra, Poland
*Corresponding author. E-mail address: adam_bk@poczta.onet.pl

Received 10.04.2014; accepted in revised form 15.05.2014

Abstract

The article describes the optimization of the melting brass. Brasses, as one of the most popular alloys of copper, deserve special attention in the context of the processes of melting, which in turn would provide not only products of better quality, but also reduce the cost of their production or refining. For this purpose, several studies carried out deriatographic (DTA) and thermogravimetric (TG) using derivatograph. The results were confronted with the program SLAG - PROP used to evaluate the physicochemical properties of the coatings extraction. Based on the survey and analysis of the program can identify the most favorable physico - chemical properties, which should be carried out treatments. This allows for slag mixtures referred configurations oxide matrix containing specific stimulators of the reaction. Conducted empirical studies indicate a convergence of the areas proposed by the application. It should also be noted that the program also indicates additional areas in which to carry out these processes would get even better, to optimize the melting process, the results.

Keywords: Computer aided foundry, Optimization, Brass, Melting, Program, SLAG-PROP

1. Introduction

All products made of copper and its alloys, also including brasses [1-7], are widely used in the modern world. Because of its use of the copper part recycled to the total consumption of the metal over the years is a growth. It is largely dictated by economic conditions of obtaining the metal from primary sources relative to the source of the waste. An important element of the whole process is adequate segregation of copper from its other alloys. Particularly significant impact here are such alloys as brass or bronze, which, due to its properties and the extensive use should be subject to a separate melting and refining processes [6-8].

2. Optimization of refining brasses

2.1. The concept of optimization

In order to optimize the melting process brasses, including the best conditions refineries - reducing agents, can be used very widely used method of thermogravimetric analysis (DTA) and differential thermal analysis (TG) as proposed by A.W. Bydałek [7,8]. Using the method described above can be carried out studies aimed at reducing factor EW appointment with an indication of the mass. Comparing the values reported in the table can be used to determine the properties of reducing refiner as weak, strong, or an average of reducing or even oxidation [9-11].

Table 1.
Arrangements for the description of the refineries [7]

No.	Value of EW [kJ/mol]	Value of r [%]	Interpretation
1	<< 0	<< -10	Strong impact of reducing
2	<< 0	-10 < r < -1	Weak impact of reducing
3	≤ 0	-1 ≤ r ≤ 0	No impact of reducing
4	> 0	Of no account	The impact of oxidative

2.2. Results

Based on the findings presented in Chapter 2.1, made a series of studies analyzing the impact of various chemical reagents on the ability to refine the extraction coating on the base of the oxide under conditions of optimal melting process brasses. First, the circuit arrangement has a base consisting of a mixture of oxides: Al_2O_3 (9%), SiO_2 (57%), CaO (22%), Na_2O (8%) and MgO (4%). For the system as a non-metallic inclusions introduced 30% oxides SnO, ZnO and PbO on the relative composition of 1:3:2. The following table shows the results obtained.

Table 2.
Selected results for the refining process modeling brass MO59 - inclusions SnO, ZnO and PbO

No.	Al_2O_3 [%]	CaO [%]	SiO_2 [%]	Na_2O [%]	MgO [%]	Other
1	9	22	57	8	4	40%Al_4C_3, 10%C
2	9	22	57	8	4	40%Al_4C_3, 10%C, 5%(NaCl + NaF_2 as 1:1)
3	9	22	57	8	4	40%Al_4C_3, 10%C, 5%(Na_2CO_3 + NaCl as 3:1)
4	9	22	57	8	4	40%Al_4C_3, 10%C, 5%($Na_2B_4O_7$)

No.	IN [%]	EW [kJ/mol]	r [%]	T [K]
1	30(SnO+ZnO+PbO as 1:3:2)	-1	-5	1410
2	30(SnO+ZnO+PbO as 1:3:2)	-40	-15	1480
3	30(SnO+ZnO+PbO as 1:3:2)	-20	-30	1390
4	30(SnO+ZnO+PbO as 1:3:2)	-20	-40	1320

Analyzing these results it can be seen that the best results were obtained when refiners 4. The energy index EW ratio achieved at the level of -20 kJ / mol, while the mass index r was as high as -40%. A very important effect is the fact that the result was achieved already at a temperature of 1320 K, which is the lowest of the cases previously analyzed.

In the second case it was decided to examine the different mix slag, this time composed of Al_2O_3 (13%), SiO_2 (23%), CaO (52%), B_2O_3 (8%) and MgO (4%). As the non-metallic inclusions were introduced to 20% Cu_2O. The results are shown in the following table.

Table 3.
Selected results of tests for the refining process modeling brass MO59 - inclusion of Cu_2O

No.	Al_2O_3 [%]	CaO [%]	SiO_2 [%]	B_2O_3 [%]	MgO [%]	Other
1	13	52	23	8	4	20%Al
2	13	52	23	8	4	20%Al, 10%C
3	13	52	23	8	4	20%Al, 10%C, 2%(CaF_2 + NaF as 1:1)
4	13	52	23	8	4	20%Mn, 10%C
5	13	52	23	8	4	40%CaC_2, 20%Al
6	13	52	23	8	4	40%CaC_2, 20%Mn

No.	IN [%]	EW [kJ/mol]	r [%]	T [K]
1	20(Cu_2O)	+1	+1	>1273
2	20(Cu_2O)	-35	-10	>1273
3	20(Cu_2O)	-10	-10	>1273
4	20(Cu_2O)	-210	-20	>1273
5	20(Cu_2O)	-370	-50	1200
6	20(Cu_2O)	-140	-15	1210

Also in this case, very good results were obtained to optimize the melting brass. The best value obtained mixture of slag in 5 cases where the calculated energy index EW was at the level of -370 kJ/mol, while the mass index r until -50%. The temperature of the process was carried out as the lowest of the analyzed for this case and amounted to 1200 K.

In the final stage of the study it was decided to examine several different configurations mix Al_2O_3 - SiO_2 - $Na_2B_4O_7$ in conjunction stimulators with different configurations in the form of NaCl and NaF. First, the system was tested on the composition of Al_2O_3 (50%), SiO_2 (10%) and $Na_2B_4O_7$ (40%), adding said stimulators in various combinations. In addition, non-metallic inclusions were used as oxides Cu_2O and ZnO, with a total weight of 30% of the sample, while maintaining a ratio of 1:2. The results are shown in the following table.

Table 4.
Selected results of tests for the refining process modeling brass MO59 - inclusions of Cu 2 O and ZnO

No.	Composition of basic slag [%]			Additional factors - stimulators [%]	
	Al_2O_3	SiO_2	$Na_2B_4O_7$	NaCl	NaF
2	50	10	40	15	-
3	50	10	40	-	10
4	50	10	40	15	10

No.	Other [%]	IN [%] Cu_2O/ZnO as 1:2	EW [kJ/mol]	r [%]	T [K]
2	40	30	-20	-5,0	1480
3	40	30	-25	-5,0	1480
4	40	30	-130	-30	1300

As can be seen, the best refining capacity shows a mixture of the composition of the third. This is achieved here energy index -130 kJ/mol, and the component to 30% by mass. The blend obtained using the above values of the two stimulators in an amount of 25% by weight of the sample while maintaining a 3:2 aspect ratio. It should be noted here that the temperature of the process was now 1300 K, which from an economic point of view is highly desirable.

In the second case the sample was examined merely consisting from $Na_2B_4O_7$ (60%) and SiO_2 (40%) using a similar amount of non-metallic inclusions and a combination of the stimulators. In the conducted study, the results obtained in the following table.

Table 5.
Selected results of tests for the refining process modeling brass MO59 - inclusions of Cu_2O and ZnO

No.	Composition of basic slag [%]			Additional factors - stimulators [%]		Other [%]
	Al_2O_3	$Na_2B_4O_7$	SiO_2	NaCl	NaF	
1	-	60	40	15	-	40
2	-	60	40	-	10	40
3	-	60	40	15	10	40

No.	IN [%] Cu_2O/ZnO as 1:2	EW [kJ/mol]	r [%]	T [K]
1	30	-25	-10	1410
2	30	-35	-20	1380
3	30	-45	-20	1350

It turns out that the same composition as the promoters in the previous study has allowed to obtain the best results. Energy index EW was -45 kJ/mol, while the mass index r = -20%. Here too, the process temperature was the lowest, and it amounted to 1350 K.

Conducting these studies indicated that the most favorable conditions for melting brass overlapped with the best refining abilities slag mixtures. Is this allows, however, draw the thesis of the close and the associated correlation of these two values. A recent study carried out for the composition of Al_2O_3 (50%) and SiO_2 (50%) answers this question by giving a negative answer. The results of a recent study are presented in the following table.

Table 6.
Selected results of tests for the refining process modeling brass MO59 - inclusions of Cu_2O and ZnO

No.	Composition of basic slag [%]			Additional factors - stimulators [%]		Other [%]
	Al_2O_3	SiO_2	$Na_2B_4O_7$	NaCl	NaF	
1	50	50	-	15	-	40
2	50	50	-	-	10	40
3	50	50	-	15	10	40

No.	IN [%] Cu_2O/ZnO as 1:2	EW [kJ/mol]	r [%]	T [K]
1	30	-5,0	-2,0	1380
2	30	-25	-3,0	1430
3	30	-65	-10,0	1480

Also in this case turned out to be the most preferred composition of the pacemaker using the same amount as in the previous examples. The energy index, in this case, was -65 kJ/mol, while the mass index -10. It should be noted that the process temperature in this case was 1480 K, and it was the highest presented during the research. Should therefore apply for the selection of components of slag-forming mixtures, which will minimize the melting temperature, and hence the cost of performed processes.

2.3. Summary of laboratory tests

To summarize the above experiments it can be concluded that the best blend of slag composition to optimize the processes of melting brass sample was determined by the number 5 in the second study. Only this sample received the lowest temperature process at 1200 K and the best properties refiners: energy index EW -370 kJ/mol and the mass index r -50%.

Conducting these studies raises the question. Is obtaining empirical research confirms brass melting process optimization with application SLAG - PROP to assess extraction of physicochemical properties of coatings [11-14].

3. Analysis of program optimization using SLAG - PROP

After the program had to choose a user interesting boundary conditions associated with the exploration areas. Then select the base point stop for refining, melting atmosphere and the search criterion with respect to temperature. Because of the above considerations limit temperature was 1480 K value, this temperature was taken as the maximum, while maintaining the appropriate value changes 1207°C. As the minimum temperature was also adopted minimum temperature taken from empirical research which is 1200 K, and therefore approximately 927°C. After the filtration of a database provided the following results.

Areas that meet your criteria:

Type of slag: Al_2O_3 - CaO - SiO_2

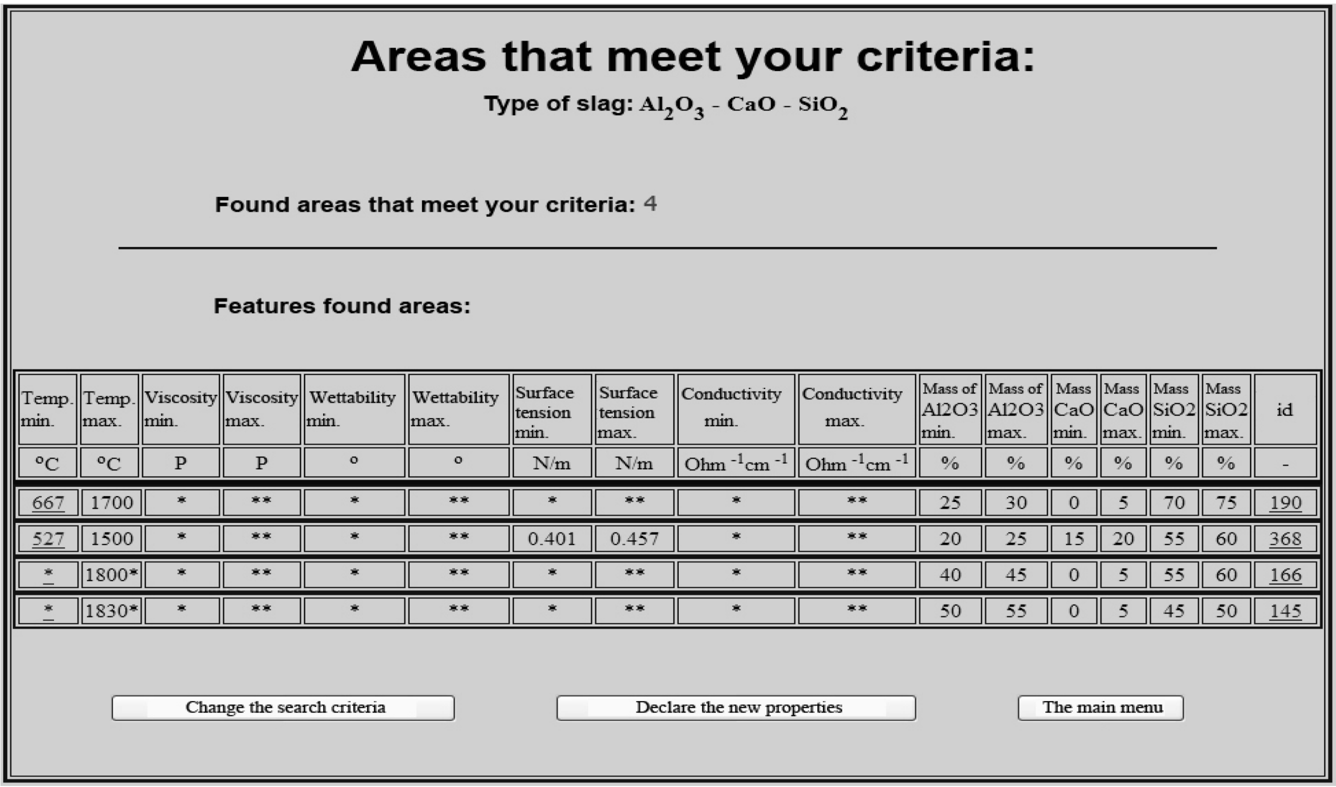
Found areas that meet your criteria: 11

Features found areas:

Temp. min.	Temp. max.	Viscosity min.	Viscosity max.	Wettability min.	Wettability max.	Surface tension min.	Surface tension max.	Conductivity min.	Conductivity max.	Mass of Al2O3 min.	Mass of Al2O3 max.	Mass CaO min.	Mass CaO max.	Mass SiO2 min.	Mass SiO2 max.	id
°C	°C	P	P	°	°	N/m	N/m	$Ohm^{-1}cm^{-1}$	$Ohm^{-1}cm^{-1}$	%	%	%	%	%	%	-
1000	1900	*	**	*	**	*	**	0.0	0.3	10	15	55	60	25	30	307
1107	1800	*	**	*	**	*	**	*	**	45	50	0	5	50	55	156
977	1700	*	**	*	**	0.411	4.809	0.1	0.3	10	15	25	30	60	65	180
1027	2000	*	**	*	**	*	**	*	**	80	85	0	5	15	20	58
*	1800*	*	**	*	**	*	**	*	**	40	45	0	5	55	60	166
*	1830*	*	**	*	**	*	**	*	**	50	55	0	5	45	50	145
1165	1400	*	**	*	**	0.411	4.510	*	**	10	15	20	25	60	65	377
1165	1400*	*	**	*	**	0.401	4.493	*	**	20	25	15	20	60	65	178
1165*	1400	*	**	*	**	0.394	0.449	*	**	15	20	15	20	65	70	186
1165*	1400	*	**	*	**	0.401	4.510	*	**	15	20	15	20	60	65	376
1165*	1400	*	**	*	**	0.401	0.453	*	**	15	20	20	25	60	65	179

Change the search criteria | Declare the new properties | The main menu

Fig. 1. Screenshot for the selection of areas that meet the criteria – I



Areas that meet your criteria:

Type of slag: Al_2O_3 - CaO - SiO_2

Found areas that meet your criteria: 4

Features found areas:

Temp. min.	Temp. max.	Viscosity min.	Viscosity max.	Wettability min.	Wettability max.	Surface tension min.	Surface tension max.	Conductivity min.	Conductivity max.	Mass of Al2O3 min.	Mass of Al2O3 max.	Mass CaO min.	Mass CaO max.	Mass SiO2 min.	Mass SiO2 max.	id
°C	°C	P	P	°	°	N/m	N/m	$Ohm^{-1}cm^{-1}$	$Ohm^{-1}cm^{-1}$	%	%	%	%	%	%	-
667	1700	*	**	*	**	*	**	*	**	25	30	0	5	70	75	190
527	1500	*	**	*	**	0.401	0.457	*	**	20	25	15	20	55	60	368
*	1800*	*	**	*	**	*	**	*	**	40	45	0	5	55	60	166
*	1830*	*	**	*	**	*	**	*	**	50	55	0	5	45	50	145

Change the search criteria | Declare the new properties | The main menu

Fig. 2. Screenshot for the selection of areas that meet the criteria – II

The program offered 11 areas that meet the criteria specified by the user. The optimal temperature for melting brass by application area is marked with an index of 180. Meanwhile, the designated area during the experimental program was on the second place. If the user will look at the area indicated by the description of the program will recognize that the melting temperature of the area, depending on the composition of an additional in the range from 977°C to 1700°C, wherein it appears that at a temperature of 977°C can be obtained energy index EW - 140 KJ/mol and a mass index r = -15%, with the exact composition of Al_2O_3 and slag mix (9%), SiO_2 (57%), CaO (22%), Na_2O (8%), MgO (4%). As can be appreciated, the database program is so broad that it is easy areas with even better conditions, in the context of process optimization melting brass.

Going therefore further illustrated course of the proceedings, changed the search criteria, the program asking if you can get an even better line-ups slag mixtures for optimization of melting brass. As the minimum temperature limit value is entered 419°C, while the maximum value specified at a level that previously described as the maximum, or 927°C. In response, obtained a list of the 4 areas shown in the figure below.

In this case, it is worth noting the area marked number 368 After getting acquainted with his accurate description can receive information that a sample can be melted already at a temperature of 970 K, which is about 697°C, to give the average reduction effects. Energy index EW reaches a value of 12.5 kJ/mol, and the mass index r = -10%, with the exact composition: with the following composition: Al_2O_3 (18%), B_2O_3 (6%), CaO (12%), Na_2O (22%), SiO_2 (42%).

4. Summary

Summing conducted research and analysis on how to optimize the melting process brasses can be seen excellent coincidence with the results presented by the application SLAG - PROP with the results derived from empirical research. It should also be noted that the program can also indicate additional areas worth attention, which optimize these processes meet the criteria posed. Using therefore proposed compositions of blends of slag produced by the program, as well as confirmed experimentally can be largely melting process optimization, and hence significant economic savings.

References

[1] Górny, Z. (1992). *Casting of non-ferrous alloys*. Warszawa: WNT.

[2] Kozana, J., Rzadkosz, St. & Piękoś, M. (2010). Influence of the selected alloy additions on limiting the phase formation in Cu-Zn alloys. *Archives of Foundry Engineering*. 10(1), 221-225.

[3] Kluska-Nawarecka, S., Mrzygłód, B., Durak, J. & Regulski, K. (2010). Analysis of the applicability of domain ontology in copper alloys processing. *Archives of Foundry Engineering*. 10(2), 69-74.

[4] Kondracki, M. & Szajnar, J. (2007). Possibilities for leaded brass replacement with multi-component brass. *Archives of Foundry Engineering*. 7(2), 57-64.

[5] Kaczmar, J.W., Granat, K., Pietrzak, K., Naplocha, K. & Grodzka, E. (2010). Manufacturing and microstructure of MMC based on CuZn38Al2Mn1Fe brass strengthened with δ-alumina fibres. *Archives of Foundry Engineering*. 10(SI1), 411-414.

[6] Bydałek, A.W., Bydałek, A. (2007). *Basics of casting metallurgy in refining processes*. Zielona Góra: University of Zielona Góra.

[7] Bydałek, A.W. (1998). *Slag systems oxygen – carbon in the processes of melting copper and its alloys*. Zielona Góra: University of Zielona Góra.

[8] Bydałek, A.W (2001). Assessing the refining abilities of slags by modelling a real process of metal melting. *Journal of Thermal Analysis and Calorymetry*. 65(2), 591-597.

[9] Kluska-Nawarecka, S., Górny Z., Mrzygłód, B., Wilk-Kołodziejczyk, D. & Regulski, K. (2010). Methods of development fuzzy logic driven decision-support models in copper alloys processing, *Archives of Foundry Engineering*. 10(SI1), 23-28.

[10] Biernat, S. & Bydałek, A.W. (2010). The estimation of quality refining covers. *Archives of Foundry Engineering* 10(SI1), 181-188.

[11] Biernat, S., Bydałek, A.W. & Schlafka, P. (2011). The propriety estimation of the copper alloys refining slag with the stimulators addition use the database. *Archives of Foundry Engineering*. 11(2), 9-12.

[12] Biernat, S., Bydałek, A.W. & Schlafka, P. (2012). Analysis of the possibility of estimation ecological slag propriety with use the DATABase. *Metalurgija-Metallurgy*. 51(1), 59-62.

[13] Biernat, S., Bydałek, A.W. & Schlafka, P. (2013). The analysis of the chloride and fluoride influences one the reducer refinement processes (Carbo–N–Ox) Aluminum Alloys. *Archives of Foundry Engineering*. 13(3), 9-14.

[14] Biernat, S., Bydałek, A., Bydałek, A.W. & Schlafka, P. (2013). Assessment of the possibility of utilising waste materials from the aluminium production in the copper alloys refining processes. *Archives of Foundry Engineering*. 13(4), 15-20.