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# PROTECTING MELTED ZINC-ALUMINIUM BASED FOUNDRY ALLOYS AGAINST HYDROGEN PICK-UP

# OCHRONA PRZETAPIANYCH ODLEWNICZYCH STOPÓW CYNK-ALUMINIUM PRZED POCHŁANIANIEM WODORU

The paper is devoted to examinations of the refining efficiency of fluxes and refiners applied during melting of zinc and zinc-aluminium alloys. The content of gases, mainly hydrogen, in the alloys not protected during the charge melting and in the ones protected with the fluxes and/or refined is discussed. The performed examinations show that using the protecting fluxes and melt-refining before pouring leads to significant improvement of ductility in Zn and binary Zn-Al alloys as well as significant increase of the material clearness confirmed by increased density. Furthermore, the metallurgical yields are also increased.

*Keywords*: zinc, Zn-Al alloys, hydrogen pick-up, fluxing, refining, strength properties, yield

Praca poświęcona jest badaniom rafinacyjnej skuteczności żużli ochronnych i rafinatorów stosowanych w technologii przetapiania cynku oraz stopów cynk-aluminium. Wykonane badania wykazały, iż Zn i stopy podwójne Zn-Al przetapiane pod żużlami ochronnymi oraz przerafinowane przed odlaniem do formy wykazują zwiększoną plastyczność i zwiększoną czystość, potwierdzoną podwyższoną gęstością masy. Dodatkowo, wzrastają uzyski metalurgiczne.

## 1. Introduction

The zinc-aluminium based alloys are now widely used in foundry engineering as casting material as well as protective coatings on steel or cast-iron casting and construction profiles. It is well known that alloys properties strongly depend on material clearness and casting structure. The casting structure of the Zn-Al alloys can be controlled by grain refinement [1-6], while the material clearness can be improved by melt protection and/or melt degassing before casting [7-15]. It is well known that Zn-Al alloys are prone to gases pick-up during their melting. It is also well known that hydrogen is the main gas which is responsible for inner bubles in non-ferrous alloys, also the zinc-aluminium ones – Fig. 1. The source of hydrogen can be melted charge or furnace atmosphere. That is why special attention should be paid to charge protection by a protective flux during melting. Furthermore, the liquid alloy, especially melted from home scrap, should be refined before pouring.

Fig. 1. Gas pores visible in Al-20 Zn alloy

## 2. Materials and experimental

During the experiments the following materials were used (all compositions are given in [mass %]):

- Zn cathodes (Zn) and Polish coating alloy Zn-0.2 Al (ZPA)
- Zn-Al alloys: Zn-4 Al (Z40); Zn-4Al-1Cu (Z41); Zn-(27-30)Al-(3.5-5)Cu-2Mn (Z284)
- Fluxes: KCl-LiCl-NaCl; KCl-LiCl-$CaCl_2$; $ZnCl_2$-KCl-NaCl-$NH_4$Cl
- Refiners: RU1 and Zincrex

The metal charges were melted in a resistant electric furnace, in graphite crucible of about 2 litres capacity. The Zn-Al alloys were melted from metallurgical pig sows (ps) and also from home scrap (s; scr). During melting no protective atmosphere was used. In one series the charges were melted without protective fluxes and refining before pouring, while in the other the charge was protected with different amount of a flux (0.5-2 mass % in relation to the charge mass) and additionally refined with RU1 [8-9] or Zincrex refiner after pouring. The examined metals and alloys were poured into sand moulds where they solidified with low intensity of heat accumulation; this gives good conditions to hydrogen liberating from solution

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and building gas pores. The effectiveness of the protective activity of the mentioned fluxes and refiners was examined by measurements of ultimate tensile strength (UTS) of the cast samples, their ductility measured by elongation (A5), mass density (d) evaluated from a hydrostatic weight method, gas number (GN) given by Formula 1 as well as the metallurgical yield (Yield).

$$GN = \frac{Density_{sample}}{Density_{theoretical}} \times 100, \% \quad (1)$$

### 3. Results and discussion

The influence of the fluxes on relative change of the UTS, elongation A5, density and metallurgical yield, calculated in relation to melting without fluxes, is shown in Fig. 2, while

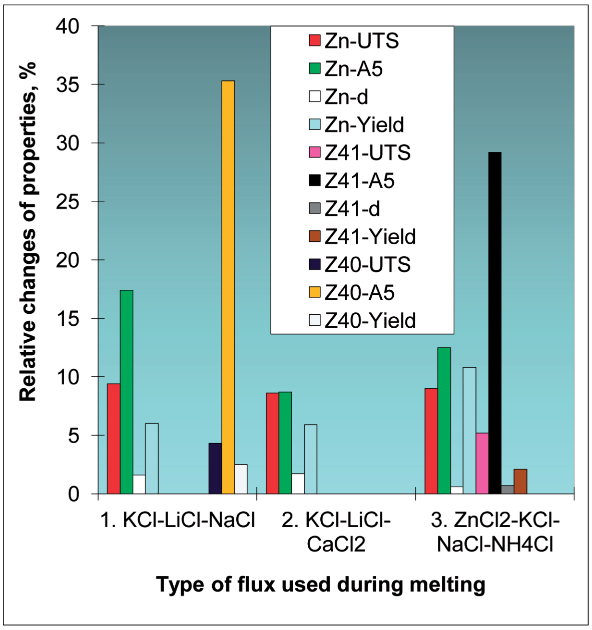


Fig. 2. The influence of fluxes used in amount of 1 mas % in relation to charge on examined properties

Fig. 3 summarizes only the influence of fluxes on absolute changes of the metallurgical yield. From Figs 2 and 3 it can be seen that using the fluxes allows obtaining all the measured properties increased. This proves that the fluxes protect melted alloys against detrimental gases pick-up and metal oxidation, and additionally purify the melt from various inclusions.

Figs 4 and 5 show the effect of the refining process performed before casting by using different amounts of the solid refiners RU1 and Zincrex. Again, it can be seen that implementation of the refining process increases the gas number GN, that is – density of the refined alloys becomes closer to the theoretical density, which means in turn, the refined melt is free of gas pores and various inclusions. Furthermore, it is well known that alloy ductility, measured for instance by elongation, strongly depends on the melt purity. From Fig. 5 it appears that elongation increases by 40-80% after using 0.1 mass% of the refiners RU1 or Zincrex. However, it can be also seen that the refining is more effective in case of the impure home-scrap charge, while in case of pig-sows it is not (see Fig. 4 – series Z40(ps)-GN).

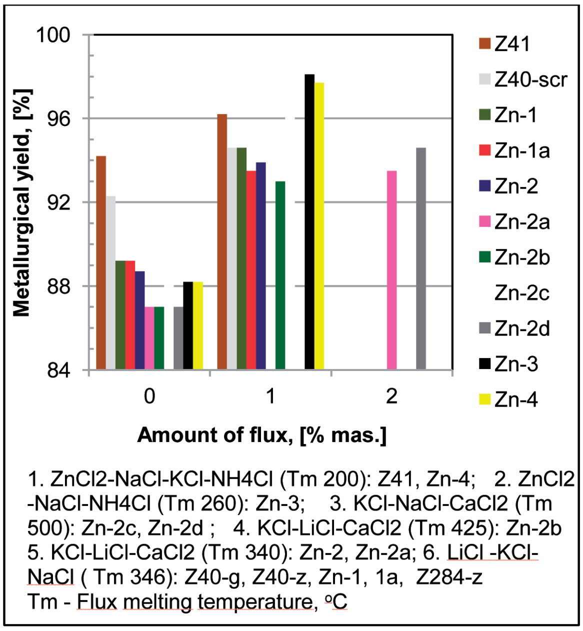


Fig. 3. The influence of fluxes used in amount of 1 and 2 mas % in relation to charge on metallurgical yield of examined alloys

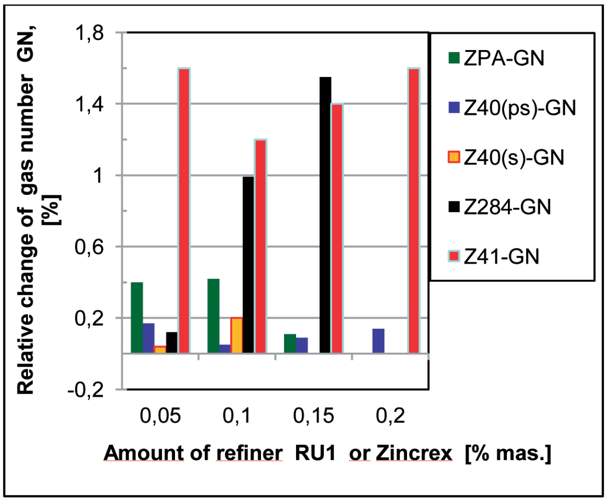


Fig. 4. The influence of different amounts of refiners on relative change of examined alloys gas number GN

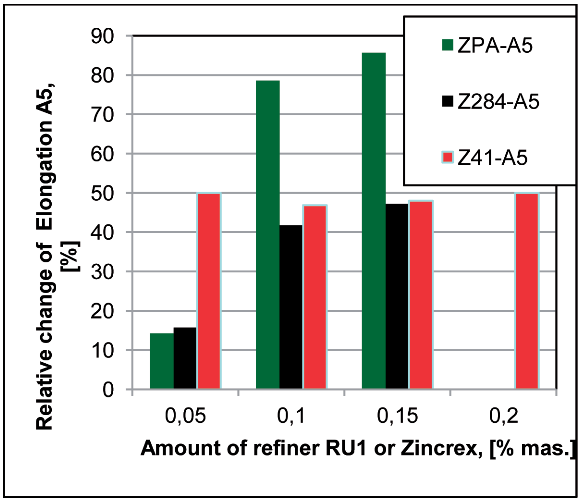


Fig. 5. The influence of different amounts of refiners on relative change of examined alloys elongation A5

## 4. Conclusions

The use of fluxes and RU1 or Zincrex refiners allows for elimination of impurities of the metal bath caused by non-metallic inclusions and gases, mainly hydrogen, in result of which the examined Zn and Zn-Al alloys obtain the increase of tensile strength on average by 10% and elongation by 50% in relation to the properties of alloys without refining. Improved alloys clearness is especially visible in the alloys melted from home scrap of low purity.

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REFERENCES

[1] W. Krajewski, The Effect of Ti Addition on Properties of Selected Zn-Al Alloys, Physica Status Solidi A – Applied Research **147**, 389-399 (1995).
[2] W. Krajewski, Phases of Heterogeneous Nucleation in the ZnAl25 Alloy Modified by Zn-Ti and Al-Ti Master Alloys, Zeitschrift fur Metallkunde **87**, 645-651 (1996).
[3] W.K. Krajewski, Determination of Al Site Preference in $L1_2$ $TiZn_3$ – base Trialuminides, Materials Science Forum **508**, 615-620 (2006).
[4] W.K. Krajewski, A.L. Greer, EBSD Study of ZnAl25 Alloy Inoculated with ZnTi4 Master Alloy, Materials Science Forum **508**, 281-286 (2006).
[5] K. Haberl, W.K. Krajewski, P. Schumacher, Microstructural Features of the Grain-refined Sand Cast AlZn20 Alloy, Archives of Metallurgy and Materials **55**, 837-841 (2010).
[6] T. Wróbel, J. Szajnar, Modification of Pure Al and AlSi2 Alloy Primary Structure with use of Electromagnetic Stirring Method, Archives of Metallurgy and Materials **58**, 955-958 (2013).
[7] J. Campbell, Castings, Butterworth-Heinemann, 1997.
[8] W.K. Krajewski, Efficacy of New Agents for Melt-refining and Grain-refining of Zn and ZnAl-base Alloys, Metallurgy and Foundry Engineering **21**, 233-237 (1995).
[9] W.K. Krajewski, The Alloys of Zinc with Aluminium. Types, properties, usage, AKAPIT, Krakow 2013, (in Polish).
[10] W.A. Keczin, E.J. Lublinskij, Zinc Alloys, Mietallurgija, Moskwa 1986 (in Russian).
[11] S. Rzadkosz, C. Adamski, Synthetic Fluxes for Zinc Alloys, Foundry Review – Przegląd Odlewnictwa, 12, 341-343 (1996) (in Polish).
[12] J. Campbell, R.A. Harding, IRC in Materials, EAA – European Aluminium Association, 1994.
[13] K.M. MacKay, Hydrogen Compounds of Metallic Elements, John Wiley & Sons, Incorporated, 1973.
[14] S. Rzadkosz, W. Krok, Technological and Ecological Problems of Melting and Refining Zinc Alloys, Proceedings of the II International Conference Modern Foundry Technologies – Environmental Protection, Krakow, 55-59, (1997) (in Polish).
[15] R.J. Barnhurst, Zinc and Zinc Alloys, ASM Handbook, Volume 2, Properties and Selection, Nonferrous Alloys and Special-Purpose Materials, ASM International, 527-542 (1990).

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