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# The Stand of Horizontal Continuous Casting of Al and its Alloys

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## Abstract

In paper is presented idea of construction and influence of selected parts of stand of horizontal continuous casting on quality of pure Al and AlSi2 alloy ingots. The main parts of the made stand belong to induction furnace, which is also tundish, water cooled continuous casting mould, system of recooling, system of continuous ingot drawing and cutting. Mainly was considered influence of electromagnetic stirrer, which was placed in continuous casting mould on refinement of ingots structure. Effect of structure refinement obtained by influence of electromagnetic stirring was compared with refinement obtained by use of traditional inoculation, which consists in introducing of additives i.e. Ti and B to metal bath. The results of studies show possibility of effective refinement of Al and AlSi2 alloy primary structure, only with use of horizontal electromagnetic field and without necessity of application of inoculants. This method of inoculation is important, because inoculants decrease the degree of purity and electrical conductivity of pure aluminum and moreover are reason of point cracks formation during rolling of ingots.

**Keywords:** Continuous casting, Aluminum, Silicon, Inoculation, Electromagnetic stirring

## 1. Introduction

The technology of continuous casting is applying usually in production of ingots of Fe [1-3], Al [4-6] or Cu [7 and 8] alloys, with high yield and quality. The quality of continuous ingot in comparison with traditional gravity casting with use of ingot mould concerns refinement and uniform of ingot structure, which results from solidification of metal in water cooled continuous casting mould.

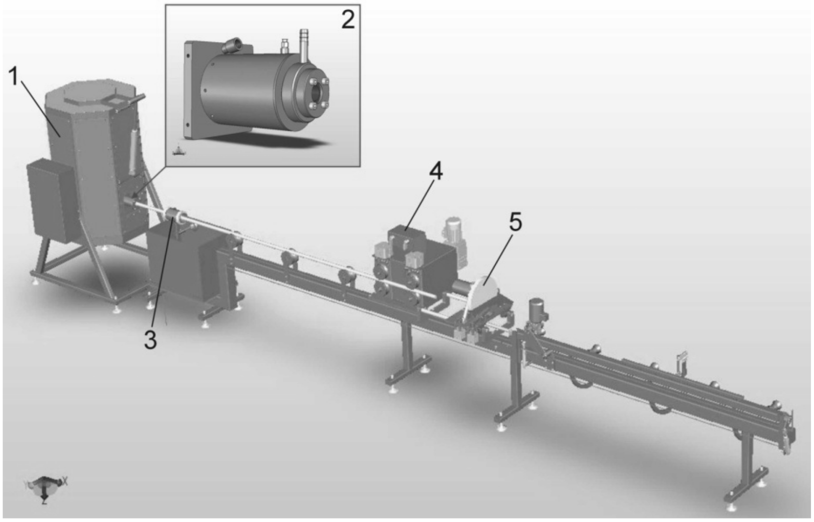
Moreover the refinement of ingot structure can be increases by forced liquid metal movement in time of its solidification results from influence of electromagnetic stirring [1-11]. The forced liquid metal movement guarantees elimination of unfavorable (mainly for plastic deformation of ingot) columnar macrograins from ingot primary structure at simultaneously increase amount of favorable equiaxed macrograins.

Other method of structure refinement is use of traditional inoculation consists in introducing into metal bath of specified substances, called inoculants [12]. Inoculants increase grains density as result of creation of new particles in consequence of braking of grains growth velocity, decrease of surface tension on interphase boundary of liquid – nucleus, decrease of angle of contact between the nucleus and the base and increase of density of bases to heterogeneous nucleation. The effectiveness of this type of inoculation depends significantly on crystallographic match between the base and the nucleus of inoculated metal. Therefore active bases to heterogeneous nucleation for aluminum and particles, which have high melting point i.e. titanium borides, titanium carbides, titanium nitrides, aluminum borides and aluminum titanide [10, 12 and 13].

But this effective method of inoculation in comparison with inoculation with use of electromagnetic field has three faults i.e. inoculants decrease the degree of purity and electrical conductivity of pure aluminum [13] and moreover are reason of point cracks formation during rolling of ingots [14].

Therefore in aim of realization of inoculation with use of electromagnetic field in construction of water cooling continuous casting mould includes the use of the electromagnetic stirrer which will be presented in next part of paper.

a)




b)

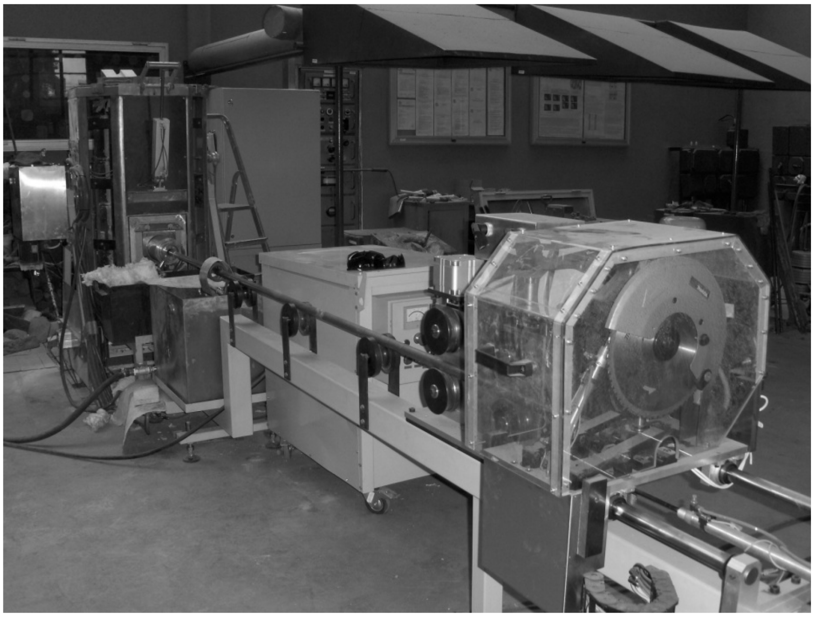


Fig. 1. Scheme (a) and view (b) of stand of horizontal continuous casting: 1 – induction furnace (tundish), 2 – continuous casting mould, 3 – system of recooling, 4 – system of ingot drawing, 5 – system of ingot cutting

## 2. Characteristic of the stand of horizontal continuous casting

On Fig. 1 is presented scheme and view of the stand of horizontal continuous casting, which was constructed in Foundry Department of Silesian University of Technology. The main parts of the made stand belong to induction furnace, which is also tundish with a capacity of up to 60 kg of charge, water cooled continuous casting mould at flow rate from 0,1 to 10 l/min, system of recooling, system of continuous ingot drawing and cutting, which realized method of ingot movement defined by combination of motion to forwards, stop and backwards performed in specified time and velocity from 100 to 500 mm/min set in control system (Fig. 2).

Parameters of ingot drawing such as velocity and time of next stages of movement can be optimized as a result of computer simulation of continuous casting process made in ANSYS FLUENT software (Fig. 3). Important is position of crystallization front inside the continuous casting mould, which in stable conditions of casting should be in about half-length of continuous casting mould. Whereas on Fig. 4 is presented view of example continuous casting process of Al made on described stand.


Fig. 2. View of control panel

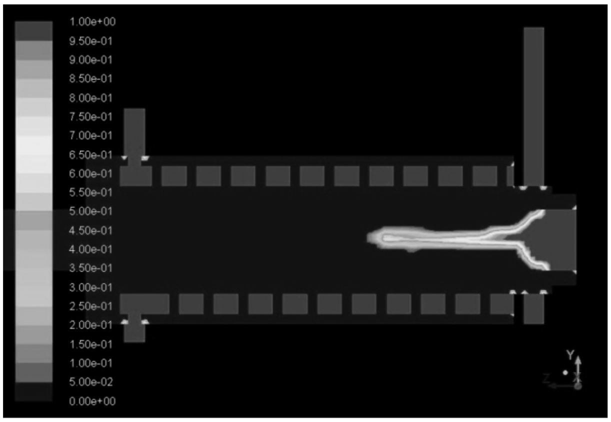



Fig. 3. View of example result of computer simulation made in ANSYS FLUENT concerning quantity of liquid phase of Al in continuous casting mould

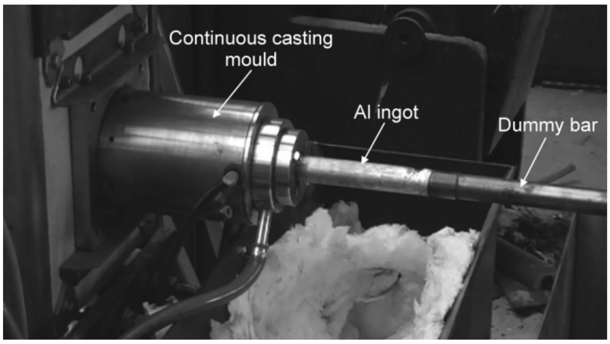



Fig. 4. View of example horizontal continuous casting process

Important element of presented stand, which strongly influences on structure refinement of continuous ingot is electromagnetic stirrer placed in continuous casting mould (Fig. 5), which enables cast of cylindrical ingots with diameter from 20 to 40 mm and high quality of ingot surface (Fig. 6).

a)

b)

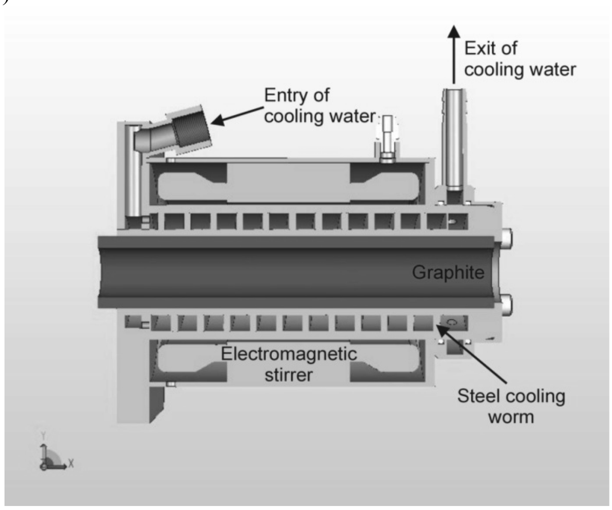
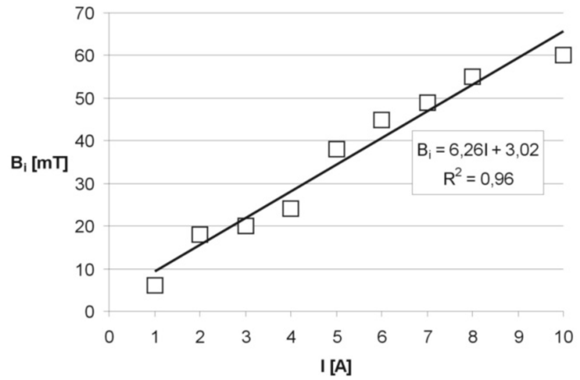



Fig. 5. View (a) and cross-section (b) of water cooled continuous casting mould contains electromagnetic stirrer


Fig. 6. Example view of the continuous ingot of Al alloy

The principle of operation of stirrer based on construction of induction coil, which generated horizontal electromagnetic filed. Efficiency of influence of electromagnetic field on intensity of liquid metal stirring is depending mainly on value of magnetic induction inside the induction coil. As show on Fig. 7a the value of magnetic induction ($B_i$) depends on current intensity (I) supplied to the induction coil. Moreover as show in papers [10 and 11] is a possibility of increasing the force (F), which creates movement of liquid metal and in result of this the velocity of its rotation in mould, also by increasing the frequency (f) of the current supplied to the induction coil (Fig.7b).

a)




b)

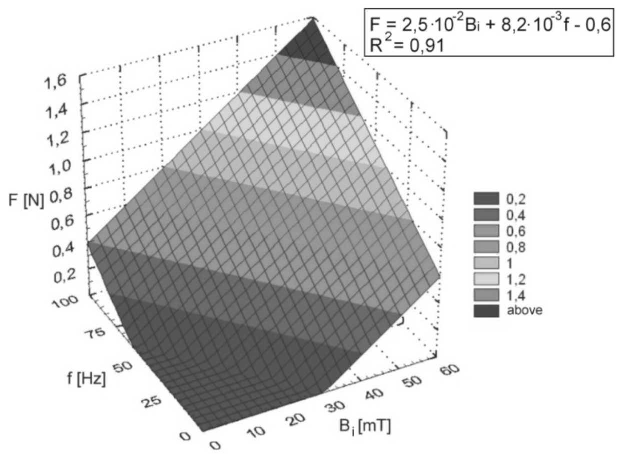
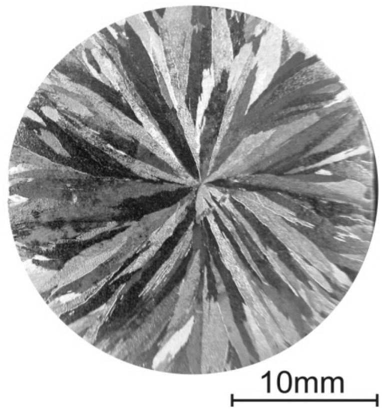


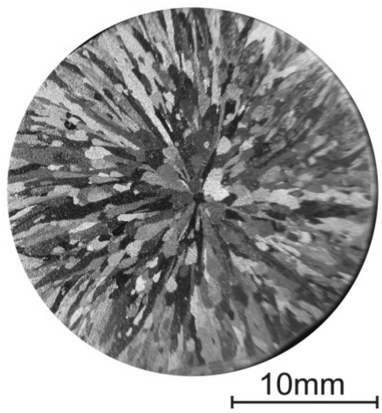

Fig. 7. The influence of the current (I) supplied to the stirrer on magnetic induction ($B_i$) (Fig. a) and common influence of magnetic induction and frequency (f) of the current supplied to the stirrer on force value (F), which creates movement of liquid metal in time of its solidification (Fig. b)

On Fig. 8 and 9 are presented example macrostructures of ingots of pure Al and alloy AlSi2 respectively in initial state, after traditional inoculation with use of Ti and B additives and after inoculation with use of electromagnetic stirring. On the basis of obtained results was affirmed that refinement of primary structure of pure Al and AlSi2 alloy obtained with use of electromagnetic stirring is larger than in initial state and is comparable with obtained with use of traditional inoculation.

a)




b)




c)

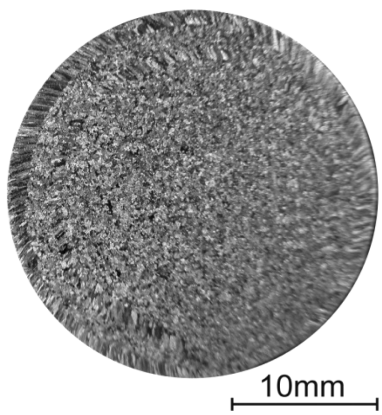



Fig. 8. Macrostructure of pure Al ingots: a – in initial state, b – after inoculation with use of master alloy AlTi5B1 (Ti = 25 ppm, B = 5 ppm) and c – after inoculation with use of electromagnetic stirring ($B_i$ = 60 mT, f = 100 Hz)

a) b) c)

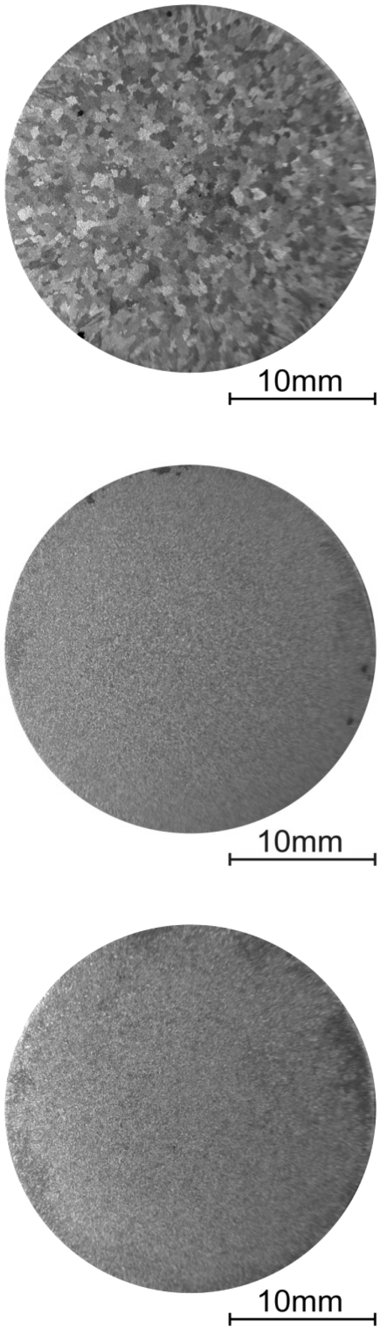



Fig. 9. Macrostructure of AlSi2 alloy ingots: a – in initial state, b – after inoculation with use of master alloy AlTi5B1 (Ti = 0,1%, B = 0,02%) and c – after inoculation with use of electromagnetic stirring ($B_i$ = 60 mT, f = 100 Hz)

## 3. Summary

In conclusion can say, that presented stand to horizontal continuous casting allows to obtain ingots of pure Al and AlSi2 alloy with a high quality represented by large refinement of primary structure. Obtained refinement of primary structure, which is important in point of view of next plastic deformation of continuous ingots, results from influence of horizontal electromagnetic field generated by stirrer (induction coil) supplied by current with frequency larger than power network i.e. 100 Hz on liquid metal in time of its solidification in continuous casting mould. This influence of electromagnetic stirring generates thermal and mechanical erosion of crystallization front, what guarantees refinement of primary structure of pure Al and AlSi2 alloy without necessity of application of inoculants sort Ti and B.

This method of exogenous inoculation is important, because inoculants decrease the degree of purity and electrical conductivity of pure aluminum. Moreover titanium and boron are reason of point cracks formation during rolling of ingots.

## Acknowledgements

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