

Development of Manganese Master Alloy for Aluminum Alloys and the Technology of Its Application

Ainur Minnegayanovich Valiev¹, Lenar Rustamovich Kharisov², Dmitry Leonidovich Pankratov³,
Radik Nurgayazovich Gatin⁴

¹PhD in engineering, Associate Professor, Department of Mechanical Engineering, Naberezhnye Chelny Institute, KFU, <http://orcid.org/0000-0002-4758-6315>

²PhD in engineering, Associate Professor, Department of Mechanical Engineering, Naberezhnye Chelny Institute, KFU, ORCID - <https://orcid.org/0000-0003-0434-0718>

³Doctor of Technical Sciences, Professor, Department of Mechanical Engineering, Naberezhnye Chelny Institute, KFU, <http://orcid.org/0000-0001-6628-2280>

⁴Master's Degree Student, Department of Mechanical Engineering, Naberezhnye Chelny Institute, KFU,

Abstract

Currently, aluminum and its alloys are used in many areas of industry and technology. First of all, aluminum and its alloys are used by the aviation and automotive industries. Aluminum is widely used in other industries: mechanical engineering, electrical engineering and instrument making, industrial and civil construction, chemical industry, the production of consumer goods, and food industry. Aluminum firmly took first place among other non-ferrous metals in terms of production scale and economic importance. The latest developments in these and other industries will allow this metal to strengthen its leading position as a key structural material of the 21-st century. The production of quality products from aluminum alloys is impossible without adding alloying elements to the melt. The compositions and technologies for alloying element introduction are very diverse. This work is devoted to the development of a master alloy for aluminum melts with manganese and the technology of its application. To achieve this goal, the following tasks were solved: they performed the analysis of existing master alloys for aluminum melts with manganese and the technology of their application; they developed a highly effective alloy for aluminum with manganese melt; they developed the recommendations for the practical application of the proposed manganese-containing master alloy.

Keywords: manganese ligature, aluminum melt, powdery additive, pelleted additive, foundry.

1. INTRODUCTION

At present, it is of interest to develop a highly efficient master alloy for aluminum melts with manganese and technology for its application. At the first stage, the task was to determine the rational form of the ligature. They considered the variants of powdery and pelleted materials. As is known, aluminum forms a sufficiently strong, chemically dense and thermally resistant Al_2O_3 film. When they introduce any additives into the melt, there is a possibility that the introduced material will be insulated from the contact with the liquid metal by the film

covering it. It seemed effective to introduce various salts with manganese that destroy the continuity of the Al_2O_3 film and prevent the dissolution of manganese. KBF_4 was chosen as such a salt [1-3].

2. METHODS

To carry out experiments, weighed portions were introduced into the 6060 melt under the metal mirror at the temperature of 730 °C, followed by intensive mixing of the melt during the entire control period of assimilation. Weighed portions with manganese were powdery and pelleted mixtures of 50% Mn + 50% KBF_4 . The amount of the added additive was 2% of the melt mass, which could give its increase in the metal by 1% with the complete assimilation of the introduced manganese. The samples for chemical analysis were taken before the introduction of the ligature and after a predetermined exposure with continuous stirring. The manganese content before the introduction of the ligature was taken to be zero for greater visualization of the result.

The resulting dependences are shown on Figure 1 and 2.

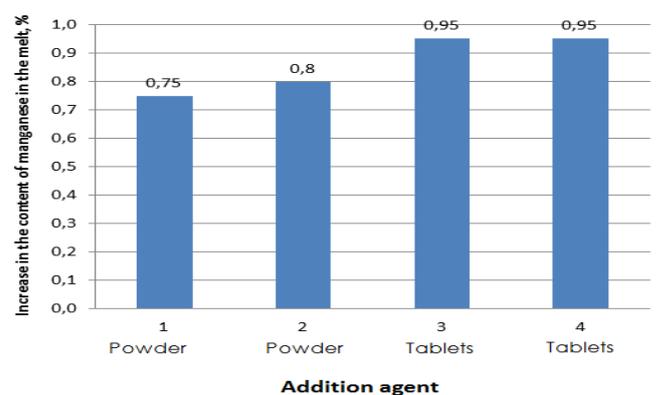


Figure 1: The dependence of the increase in the content of manganese in the melt after fifteen-minute mixing on the dispersion of manganese particles when entering it in the form of a powder and tablet mixture of the composition 50% Mn + 50% KBF_4

1. Powdered additive 50% Mn + 50% KBF₄ with a manganese particle size of 0.1 ... 0.5 mm.
2. Powdered additive 50% Mn + 50% KBF₄ with a manganese particle size of 1.0 ... 3.0 mm.
3. Tableted additive 50% Mn + 50% KBF₄ with a manganese particle size of 0.1 ... 0.5 mm.
4. Tableted additive 50% Mn + 50% KBF₄ with a manganese particle size of 1.0 ... 3.0 mm.

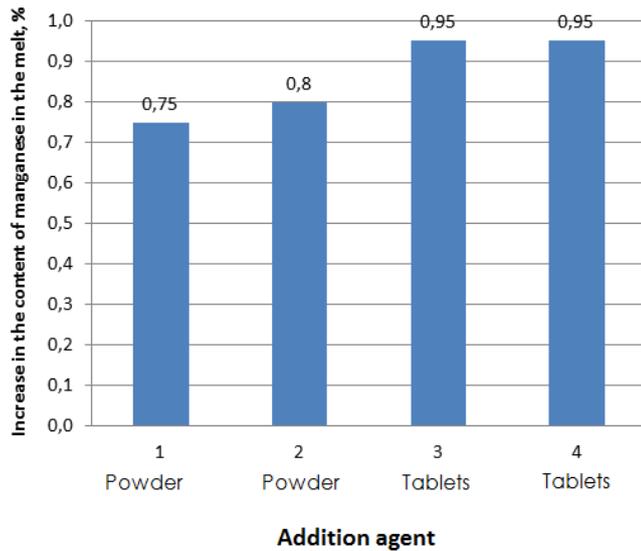


Figure 2: Dependence of the increase in the content of manganese in the melt after thirty-minute mixing on the dispersion of manganese particles when entering it in the form of a powder and tablet mixture of the composition 50% Mn + 50% KBF₄

1. Powdered additive 50% Mn + 50% KBF₄ with a manganese particle size of 0.1 ... 0.5 mm.
2. Powdered additive 50% Mn + 50% KBF₄ with a manganese particle size of 1.0 ... 3.0 mm.
3. Tableted additive 50% Mn + 50% KBF₄ with a manganese particle size of 0.1 ... 0.5 mm.
4. Tableted additive 50% Mn + 50% KBF₄ with a manganese particle size of 1.0 ... 3.0 mm.

3. RESULTS AND DISCUSSION

It can be seen from the results that after intensive fifteen-minute stirring of the melt, the increase of manganese content in the metal is not observed for the used manganese fractions, which indicates its fairly complete assimilation with a specific method of introduction.

It should be noted that the introduction of manganese into the aluminum melt in the form of a powder mixture with KBF₄ provides less assimilation: for 0.1 ... 0.5 mm fraction - 0.75%,

for 1.0 ... 3.0 mm fraction - 0.8%, in comparison with 0.95% increase of manganese melt when it is introduced in the form of tablets containing 50% Mn + 50% KBF₄ with manganese particle sizes of 0.1 ... 0.5 mm and 1.0 ... 3.0 mm.

This result is probably associated with slagging and oxidation of manganese when it is introduced in the form of a powder mixture, since it is practically impossible to introduce the powder mixture effectively under the mirror of the melt, as is the case when they use sinking tablets [4].

The lower assimilation of manganese with a higher dispersion of its particles in the case of a powdery additive use is explained by the fact that the fine fraction is retained by the oxide film and slag phase on the melt surface to a greater extent, which leads to increased slagging and fumes of manganese in comparison with the larger size of manganese particles [5].

To exclude preliminarily the influence of the salt content in the master alloy being developed, they performed similar studies of powder and tableted compositions 90% Mn + 10% KBF₄ with the dispersion of the following manganese particles: 0.1 ... 0.5 mm and 1.0 ... 3.0 mm. The results are shown on Figure 3 and 4.

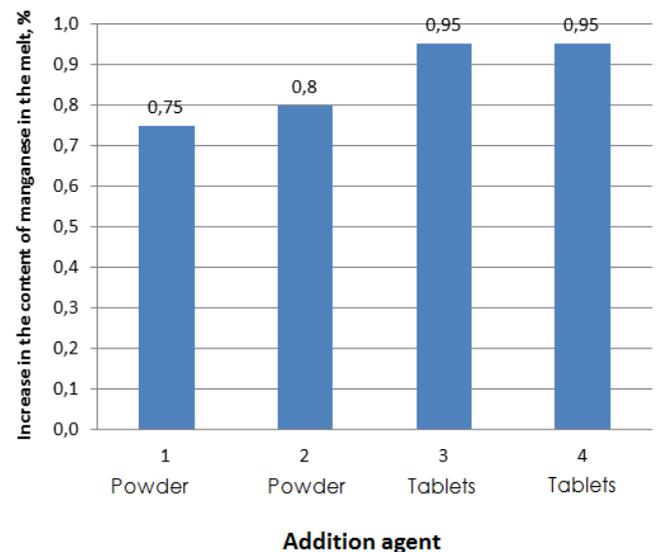


Figure 3: The dependence of the increase in the content of manganese in the melt after fifteen-minute mixing on the dispersion of manganese particles when entering it in the form of a powder and tablet mixture of the composition 90% Mn + 10% KBF₄

1. Powdered additive 90% Mn + 10% KBF₄ with a manganese particle size of 0.1 ... 0.5 mm.
2. Powdered additive 90% Mn + 10% KBF₄ with a manganese particle size of 1.0 ... 3.0 mm.
3. Tableted additive 90% Mn + 10% KBF₄ with a manganese particle size of 0.1 ... 0.5 mm.
4. Tableted additive 90% Mn + 10% KBF₄ with a manganese particle size of 1.0 ... 3.0 mm.

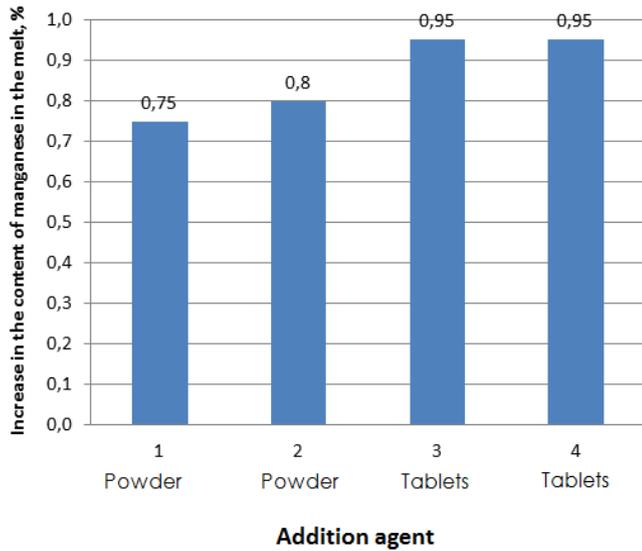


Figure 4: Dependence of the increase in the content of manganese in the melt after thirty-minute mixing on the dispersion of manganese particles when entering it in the form of a powder and tablet mixture of the composition 90% Mn + 10% KBF_4

1. Powdered additive 90% Mn + 10% KBF_4 with a manganese particle size of 0.1 ... 0.5 mm.
2. Powdered additive 90% Mn + 10% KBF_4 with a manganese particle size of 1.0 ... 3.0 mm.
3. Tableted additive 90% Mn + 10% KBF_4 with a manganese particle size of 0.1 ... 0.5 mm.
4. Tableted additive 90% Mn + 10% KBF_4 with a manganese particle size of 1.0 ... 3.0 mm

Obviously, the amount of KBF_4 salt (50% or 10%) for the studied technological conditions (intensive mixing during the entire period of the specified assimilation time) does not affect the result, and the tableted alloying composition is more effective than the powder composition. Thus, further research was aimed at finding a rational composition of the tableted ligature and effective technological parameters of its use.

The next step was the selection of the salt included in the alloying additive. KBF_4 , Na_3AlF_6 , K_2TiF_6 , NaCl , KCl were considered as salts. The amount of salt in the ligature was chosen equal to 50% by weight, which is confirmed by previous studies (Fig. 1, 2).

Tableted materials of the following compositions were studied to search for salt:

1. Pure Mn,
2. 50% Mn + 50% KBF_4 ,
3. 50 Mn + 50% Na_3AlF_6 ,
4. 50% Mn + 50% K_2TiF_6 ,

5. 50% Mn + 50% NaCl ,
6. 50% Mn + 50% KCl .

Tableted ligatures of the indicated compositions were introduced into 6060 melt at the temperature of 730 °C, followed by intensive stirring of the melt during the entire fifteen-minute exposure. The size of manganese particles in all variants was 0.1 ... 0.5 mm. The experimental results are shown on Figure 5.

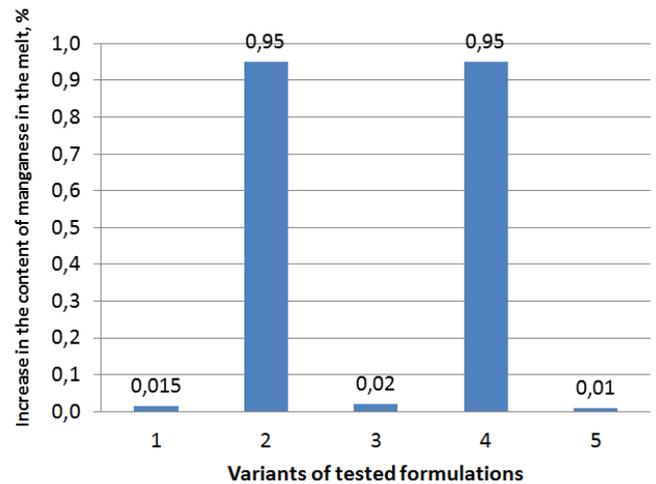


Figure 5: Increase in the content of manganese in the melt when processing it with tableted ligatures of various compositions

1. Pure Mn,
2. 50% Mn + 50% KBF_4 ,
3. 50 Mn + 50% Na_3AlF_6 ,
4. 50% Mn + 50% K_2TiF_6 ,
5. 50% Mn + 50% NaCl ,
6. 50% Mn + 50% KCl .

The results obtained indicate that a salt with a low decomposition temperature must be used as a component of alloying tablets. This material destroys the pellet when heated, and this provides a large surface of "metal manganese - melt" interaction. It should also be noted that the tablets of the compositions 1,3,5,6 did not collapse and continued to lie without visible changes in the furnace bottom.

We choose KBF_4 as a component for the ligature being created, as the cheapest and more accessible material in comparison with K_2TiF_6 .

The next stage of research was the search for the optimal ratio of manganese - the ligature salt. For this, the metal was treated with a tableted master alloy of the following compositions with the following dispersion of the used manganese: 0.1 ... 0.5 mm.

1. 50% Mn + 50% KBF_4 ,

2. 60%Mn + 40%KBF₄,
3. 70%Mn + 30%KBF₄,
4. 80%Mn + 20%KBF₄,
5. 90%Mn + 10%KBF₄,
6. 100%Mn + 0%KBF₄.

To determine the rational composition of the tableted master alloy, we select the technological schedule for ten-minute intensive mixing of the AK5M2 melt at the temperature of 730 °C. The choice of this regulation is due to practical consideration exclusively, which minimizes labor costs during mixing and relatively easy fit into most of the existing technologies of foundries and metallurgical shops.

The results of rational composition of the manganese-containing master alloy determination are shown on Figure 6.

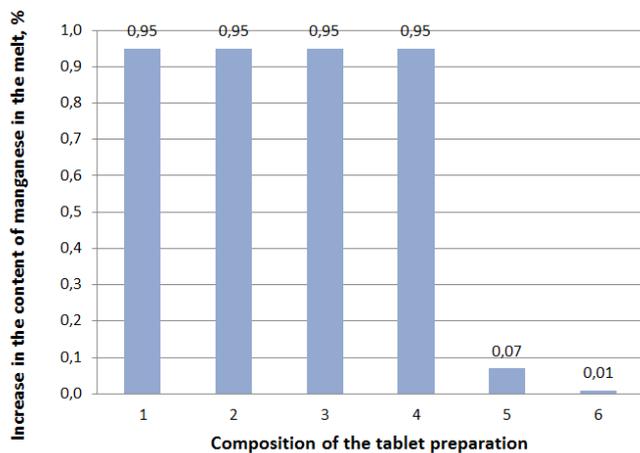


Figure 6: Increase in the content of manganese in the melt after processing manganese containing ligatures of various percentages followed by intensive ten minute mixing

1. 50% Mn + 50% KBF₄,
2. 60%Mn + 40%KBF₄,
3. 70%Mn + 30%KBF₄,
4. 80%Mn + 20%KBF₄,
5. 90%Mn + 10%KBF₄,
6. 100%Mn + 0%KBF₄.

The results obtained indicate that the most rational composition is the composition containing 80% of Mn + 20% of KBF₄. This composition makes it possible to minimize the content of the salt component in a tablet while maintaining a high degree of manganese assimilation (0.95%) with intensive ten-minute stirring of the melt. This composition was used in further research.

The next step was the search for a rational degree of metallic manganese particle dispersion used for the preparation of the

tableted master alloy. It is clear that with fineness increase to a certain level, the time of master alloy mastering will be decreased, however, crushing of metallic manganese is a laborious process and the use of larger fractions of manganese during the manufacture of tableted master alloy will reduce the cost of the latter [6, 7].

To determine the rational size of crushed metallic manganese particles used in the manufacture of tableted master alloy, the time dependence of manganese assimilation was studied with the following sizes of its particles: 0.1 ... 0.5 mm, 0.5 ... 1.0 mm, 1.0 ... 3.0 mm, 3.0 ... 5.0 mm.

The results of manganese particle rational size determination in the tableted master alloy are shown on Figure 7 (the amount of introduced material was determined based on the manganese content increase in the melt by 1%, the composition of the tablets is 80% of Mn + 20% of KBF₄, the time of intensive mixing after the introduction of the master alloy is up to 16 minutes, the alloy AK₅M₂, the melt temperature was 730 °C) [8-10].

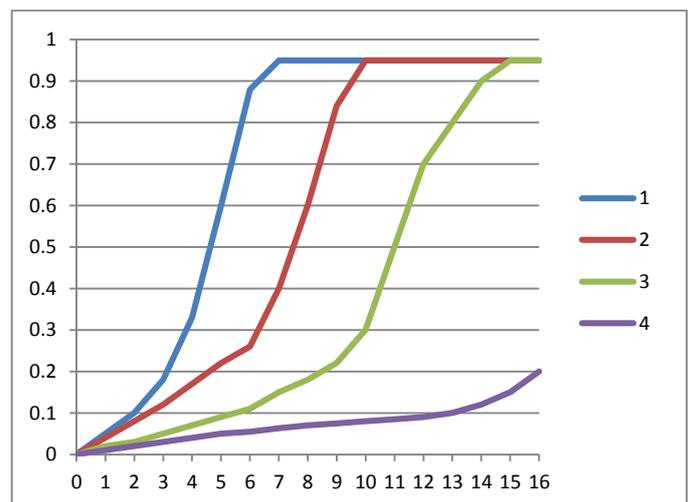


Figure 7: Dependence of the increase in the content of manganese in the melt on the size of the manganese particles in the tableted ligature

1. Particle size: 0,1 ... 0,5 mm
2. Particle size: 0,5 ... 1,0 mm
3. Particle size: 1,0 ... 3,0 mm
4. Particle size: 3,0 ... 5,0 mm

4. CONCLUSIONS

The results obtained allow us to conclude that compliance with the technological regulations (maximum assimilation of manganese with ten-minute stirring) provides alloying tablets with a manganese the particle size of 0.1 ... 0.5 mm and 0.5 ... 1.0 mm. However, it should be taken into account that when the size of manganese particles is 0.5 ... 1.0 mm, the required degree of manganese assimilation (0.95%) is achieved by the

tenth minute of intensive mixing. It is clear that a margin is needed to ensure the guaranteed receipt of the required result in any process and action. In this regard, the choice of crushed manganese use with a particle size of 0.5 ... 1.0 mm seems to be wrong. Thus, it is rational to use the particles of 0.1 ... 0.5 mm when you determine the size of manganese particles in the tableted master alloy for aluminum alloys.

5. SUMMARY

After the studies carried out, a tableted ligature was developed for aluminum melts with manganese and rational parameters of its industrial use technology were determined.

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