Research on uses plant ashes in processing powders for classical moulding of steel

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Abstract. In this work we examine various possibilities of using plant ashes in processing powders for moulding steel, in order to reduce the consumption of steel. Thus, there have been studied plant ashes which can be used to process powders and then some moulding powder compositions have been analysed.

1. Introduction

The shaping of the rough bar blister is determined by a number of factors, which depend both on the process of elaboration of steel, and the process of casting in the cast iron mold regarding: the chemical composition of the steel, the degree of overheating of the steel, the molding rate, the time of solidification of steel to the environment temperature, and the geometry of the cast iron mold.

The research in the field allows us to draw the conclusion that through the use of thermo-insulating materials (anti-blister) both as shrink-head casing and as covering materials for the surface of the steel, the discard, varying on the type of steel, can be reduced with 8-10% for the revert conical ingots, and respective 9-11% for the direct conical ones. In order to get an insulating product capable to fulfill the above mentioned conditions, the following base factors of the blister formation need to be analyzed:

- the size of the volume of contraction which depends firstly on the chemical composition of steel (especially the carbon content) and the solidification temperature;
- the unfolding in time of the solidification, especially the time for the volume of steel from the head of the ingot must be kept liquid, thus it can flow without friction within the empty contraction space, time which should be longer than the time of solidification of the ingot body;
- the heat loss within the ingot head which is the main cause in forming of the blister.

Through actions upon the head of the ingot the heat must be thus directed that the steel from the heaser to solidify later. First a heating of the heaser is induced, and then, after the molding is finished, a slow cooling is due. We are speaking thus about non-stationary heat transmission through convection.[1]

Measurements performed upon the way the heat loss is distributed from the hease (Figure 1) have shown the following repartition [2]:

- 5-8% to the ingot body;
- 24-27% through the anti-blister powder;
- 68% through the storage in the heaser walls and turning to the exterior.
To draw a conclusion, the factors which influence the heat loss through radiation, through the steel glass are:

- the geometry of the ingot cast;
- the mass of the ingot;
- the specific surface of the steel glass;
- the solidification temperature;
- the amount of anti-blister materials used.

In case of large sections of the ingot, with wider solidification range of temperature, the metal volume needed to cover the heat loss is rather big, and it is difficult to reduce the heat loss from the head of the ingot, just by insulation to keep the size of the blister equal to the size of the discard.

In order to do that, we need a further contribution of heat in the head of the ingot, through the means of exothermal mass to work according to the alumina-thermal principle, and which use the oxidation heat of different metals.

For this type of thermal treatment in the hease, we need to observe a certain range of time after the exothermal reaction takes place, depending on the solidification time.

Following an empirical formula, this range should be [3]:

\[ T = 0.0124 \cdot d \]  

(1)

Where \( d \) is the diameter of the heaser in mm.

From the processed data we can draw a prototype model of anti-blister powder. This should meet the following characteristics:

- to have a minimum specific heat;
- to have the lowest possible thermal conductivity factor;
- to have a low volumetric mass and as high as possible thermal insulation;
- the powder layer should have optimal thickness determined by the size of the ingot.

2. Industrial experiments

We presumed the idea of getting a thermo-insulating powder with a reduced volumetric weight in order to have a better insulating performance, and, implicitly to reduce the blister and thus the specific metal consumption. This reduced volumetric weight can be accomplished by using vegetable ashes.[4]

From a chemical point of view the casting powders are part of the area of metallurgic slags, specifically the system (Figure 2).
The top diagram is birds-eye view of the three-dimensional model above. Each sides represents a line blend of the components of the corners, with the corners being 100% of the component and 0% of the others. The entire diagram therefore is similar to a triaxial blend. The white circles mark the lowest-melting point of calcia, alumina and silica.[3] The optimum area for the existence of casting powders in the system is the hachured one in Figure 3.
Except for these basic oxides, SiO\textsubscript{2}, CaO, Al\textsubscript{2}O\textsubscript{3} the casting powders may include MgO, Na\textsubscript{2}O, CaF\textsubscript{2}, MnO, Fe\textsubscript{2}O\textsubscript{3}, C, etc. The presence of these components modify the characteristics derived from the SiO\textsubscript{2}-CaO-Al\textsubscript{2}O\textsubscript{3} system, affecting all the other characteristics of the slag, each in its particular way.

The ashes from different plant can be classified in acid ashes, alkalescent ashes and mixed ashes. The present paper takes into consideration just the acid ashes.

Thus, we have analyzed a number of 11 ashes from different plant which have been obtained through calcination at 600°C in the furnace. The results are given below, in Table 1.

### Table 1. Plant compositions

| Plant          | Ashes          | Chemical analysis, [%] | Volumetric weight, [g/cm\textsuperscript{3}] |
|----------------|----------------|------------------------|---------------------------------------------|
|                |                | SiO\textsubscript{2}  | Al\textsubscript{2}O\textsubscript{3} | Fe\textsubscript{2}O\textsubscript{3} | P\textsubscript{2}O\textsubscript{5} | CaO | MgO | Na\textsubscript{2}O+K\textsubscript{2}O | PC |        |
| Wheat thatch   | 74,84          | 1,89                   | 0,58                         | 2,32                     | 7,27                      | 2,93 | 4,87 | 5,36                              | 0,09 |
| Wheat chaff    | 67,03          | 4,14                   | 4,12                         | 2,03                     | 7,06                      | 1,94 | 7,85 | 5,82                              | 0,12 |
| Barley         | 59,77          | 1,31                   | 0,51                         | 4,32                     | 9,18                      | 2,76 | 17,69 | 4,30                              | 0,10 |
| Oat            | 49,85          | 1,52                   | 0,61                         | 4,92                     | 10,32                     | 2,88 | 25,48 | 4,25                              | 0,13 |
| Rice skin      | 43,29          | 21,98                  | 5,23                         | 2,40                     | 10,62                     | 6,52 | 4,48 | 5,30                              | 0,12 |
| Rice thatch    | 78,71          | 2,58                   | 0,69                         | -                        | 5,12                      | 1,89 | 5,63 | 5,24                              | 0,06 |
| Thatch waste   | 57,64          | 1,79                   | 0,95                         | 3,13                     | 7,56                      | 2,32 | 21,67 | 4,78                              | 0,15 |
| Corn           | 72,68          | 3,91                   | 0,79                         | 2,56                     | 5,03                      | 2,64 | 6,03 | 6,20                              | 0,11 |
| Cane           | 77,48          | 1,00                   | 0,20                         | -                        | 6,98                      | 1,50 | 7,12 | 5,70                              | 0,12 |
| Sedge          | 54,42          | 5,25                   | 1,13                         | 4,14                     | 17,86                     | 3,85 | 6,73 | 6,50                              | 0,10 |
| Fern           | 50,26          | 0,14                   | 0,43                         | -                        | 17,86                     | 9,51 | 16,78 | 4,80                              | 0,10 |

To secure an optimum composition for the thermo-insulating powder, capable to guarantee the chemical and mineralogical composition, but also the minimum volumetric weight possible, thus a higher capacity on thermal insulation, the following ashes have been selected:

- rice thatch ashes;
- wheat thatch ashes.

A number of 8 compositions of thermo-insulating powders have been developed, for which vegetable ashes have been used, and as carbon contribution – the amorphous graphite. The compositions developed are listed in Table 2.

Using the vegetable ashes might give us the following advantages:

- the ashes obtained by calcination at 600°C is a frail powder which does not need grinding to ensure a grinding gauge of 80% under 90 μm;
- the technology of fabrication is simple, because there are but two components within the recipe, thus the errors of dosage are minimized, and the fabrication flow is not impure;
- the amorphous graphite is used in its basic form, not needing other preparations.

### Table 2. Compositions

| Components            | Recipe components, [%] |
|-----------------------|------------------------|
|                       | P1  P2  P3  P4  P5  P6  P7  P8 |
| Rice thatch ashes     | 50   60   70   80   0   0   0   0        |
| Wheat thatch ashes    | 0    0    0    0    50  60   70   80       |
| Amorphous graphite    | 50   40   30   20   50  40   30   20       |
The compositions prepared are characterized from physical, chemical and thermic point of view the results of the analysis being presented in Table 3. The sintering, melting and flow temperatures were established with the high temperatures microscope, and the viscosity was determined theoretically with a soft. The covering thermo steel powder, produced by Stolberg, was considered the standard.[4]

| Analysis             | P1   | P2   | P3   | P4   | P5   | P6   | P7   | P8   | Standard          |
|----------------------|------|------|------|------|------|------|------|------|------------------|
| SiO₂, [%]            | 40.71| 48.31| 55.91| 63.51| 45.98| 53.20| 60.41| 69.20|                  |
| Al₂O₃, [%]           | 1.29 | 1.55 | 1.81 | 2.06 | 0.95 | 1.13 | 1.32 | 1.51 | 1.09             |
| Fe₂O₃, [%]           | 0.35 | 0.41 | 0.48 | 0.55 | 0.29 | 0.35 | 0.41 | 0.46 | -                |
| CaO, [%]             | 2.56 | 3.07 | 3.58 | 4.10 | 3.46 | 4.36 | 5.09 | 5.82 |                  |
| MgO, [%]             | 0.95 | 1.13 | 1.32 | 1.51 | 1.47 | 1.76 | 2.05 | 2.34 | 0.75             |
| Na₂O+ K₂O, [%]       | 2.82 | 3.38 | 3.94 | 4.50 | 2.92 | 3.41 | 3.90 | 0.87 |                  |
| PC, [%]              | 51.27| 42.06| 32.86| 23.65| 51.33| 42.14| 32.94| 23.75| 25.68            |
| CaO/SiO₂             | 0.0628| 0.0635| 0.0640| 0.0645| 0.0629| 0.0635| 0.0956| 0.0963| -                |
| Volumetric weight, g/cm³| 0.33 | 0.27 | 0.22 | 0.16 | 0.34 | 0.29 | 0.24 | 0.19 | 0.48             |
| Granulation, % under 0.06 mm | 82  | 83  | 80  | 82  | 81  | 82  | 83  | 82  | 80               |
| Humidity, %          | 0.83 | 0.86 | 0.83 | 0.85 | 0.82 | 0.82 | 0.82 | 0.85 | 0.86             |

High temperatures microscope analysis

| T₁, [°C] | 1200 | 1230 | 1250 | 1260 | 1200 | 1220 | 1230 | 1250 | >1300             |
| T₂, [°C] | 1260 | 1250 | 1260 | 1280 | 1250 | 1260 | 1290 | 1280 |                  |
| T₃, [°C] | 1300 | 1300 | 1310 | 1290 | 1300 | 1310 | 1310 | 1290 |                  |

Viscosity, Ns/m², Pas (calculated)

| T₁ = Tₓ | 2.2393| 3.1029| 4.5153| 4.8578| 2.0456| 2.9341| 4.2632| 4.1713| 5.4738          |
| T₂ = Tₓ +50 | 1.6304| 2.2911| 3.3891| 3.7046| 1.4302| 2.1206| 3.1041| 3.8246| 4.2165          |
| T₃ = Tₓ +100 | 1.1246| 1.5823| 2.3677| 2.6545| 1.0025| 1.3541| 2.1034| 2.7271| 3.4025          |
| T₄ = Tₓ +150 | 0.7218| 0.9766| 1.4494| 1.7074| 0.6527| 0.8032| 0.6812| 1.8025| 1.9734          |
| T₅ = Tₓ +200 | 0.4220| 0.4739| 0.6341| 0.8634| 0.3836| 0.4153| 0.4821| 0.8733| 0.9887          |
| Superficial tension, [mJ/m²] | 481.172| 516.324| 540.117| 569.192| 478.371| 512.898| 536.112| 565.11 | 574.103         |

3. Results, discussions

Following the analysis of the data from the estimations performed on the prepared compositions there have resulted that:

- indigenous materials were used, materials which are easy to secure, in adequate amounts, at a relatively low cost;
- several compositions of casting powders have been drawn: 4 coverage powders compositions from rice thatch ashes P1 – P4 used for traditional steel casting; 4 coverage powders from wheat thatch ashes P5 – P8 used for traditional steel casting;
- the raw material used has been prepared according the laboratory flows. We can retain the preparation of rice thatch or wheat thatch ashes with additional SiO₂ which gives the product higher qualities;
- the dosing of the components has been made gravimetrically according to the drawn recipes;
- homogenizing the raw is done in electric agate grinding mortar, for 15 minutes, period needed to homogenize the components;
- the physico-chemical characterization of the components is done for the purpose of the best selection of the compositions.

The analysis of the data has given the following results:
the values of the volumetric weights are affected by the volumetric weight of the raw material used and by the percentage of it in the recipe;
- the values of humidity are below 1%;
- the values of the granulation are min. 80% under a sieve of 0.06 mm;
- the values of the chemical composition are affected by the type of raw material used;
- the values of the temperatures of sintering, melting, flowing, are affected by the composition of raw material and its granulation;
- the recipes P4 and P8 have the closest characteristics to the standard powder, so they have been retained for further thorough study.

4. Conclusions
From the analysis of the presented data, we have the following results:
- from the point of view of the chemical composition, the vegetable ashes can be used to produce steel casting powders;
- regarding the chemical composition of the ashes, through their process, we can get powders with acid nature, their composition being determined by the proportion of the components;
- as a result of low volumetric weight, these powders have a high insulating capacity;
- we consider that continuing this research is more than beneficial, and we must have in view more complex recipes in order to secure powders from 3 – 4 sorts of vegetable ashes, focusing on rice and oat ashes, due to their high content of Na₂O şi K₂O with an important significance on the viscosity and superficial tension.

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References
[1] Comsa A 1987 Research on improving the ingots quality by using a new types of lubricating powder, CCPR SA, Brasov, Romania
[2] Comsa A 1988 Research on uses rice straw to manufacture powders and insulation boards, CCPR SA, Brasov, Romania
[3] Solacu S 1968 Physical chemistry of technical silicates, Tehnica Press co., Bucharest, Romania
[4] Teoreanu I, Ciontea N 1985, Refractory products technology, Tehnica Press co., Bucharest, Romania