COMPUTER OPTIMIZATION OF THE COMPOSITION OF THE CHARGING MATERIALS

BY

DR. E. O. OBADINMA

DEPT. OF MECHANICAL ENGINEERING
UNIVERSITY OF LAGOS
AKOKA, YABA
LAGOS, NIGERIA

ABSTRACT

Computer optimization of the composition of the charge has been undertaken in this paper. On the basis of this optimization, economy of expenses and materials in low supply is attained. The minimum cost of correcting additives and whole charge is also determined

I. INTRODUCTION

The charge or charging materials are all the materials used in the production of a given alloy. For melting purposes, it is always necessary to prepare a charge. The preparation process involves the calculation of the charge, its weighing and its charging into a melting unit. In the melting units the charge will undergo some complex processes like heating and melting, superheating, deoxidation, refining and inoculation. Apart from these processes, physical/physico-chemical processes like the evaporation of the melt and its components, interaction between the liquid melt and the atmosphere of the melting unit (refractories) and those of the crucible take place.

In order to estimate the effects of these processes on the chemical composition of the melted alloy, and in order to maintain the required quality of the technological processes of the melt making, these processes are classified under five stages, depending on the sequence of their completion. These involve the calculation of the charge, its weighing and charging into the melting unit, the melting of the charge, and correction of its composition and additions to the melt. In this case, the effect of processes, like the evaporation, the interaction of the melt with gas atmosphere, with the materials of the furnace and that of the crucible, and the slags and fluxes are considered under what is termed the melting loss.
In each of these stages, there is always certain expenditures which are connected with the usage of charging materials, energy, refractories, refining and innoculating additives.These expenditures determine the cost of the whole stages F. The total cost of preparing an alloy is expressed as:

$$F = F_i + F_{ii} + F_{iii} + F_{iv} + F_v.$$

Where, F_i is the expenditure incurred during the calculation of the charge; F_{ii} is the expenditure on the charge during melting (loss during crushing, washing or cleaning); F_{iii} is the expenditure on energy; F_{iv} is the expenditure on correcting additives; and F_v is the expenditure on refining and innoculating additives.The maximum economy of resources is possible if only the expenditures on each stage become minimal. In this case, the total cost will also be minimal (min F). In each separate stage, the expenditures on the materials are equal to:

$$F_i = C_1X_1 + C_2X_2 + \ldots + C_n X_n = \sum_{j=1}^{n} C_i X_i$$

Where, C_i is the cost of a unit quantity of the charge in absolute or relative units. It is hereby clear that the expenditure on material F_m is equal to the total expenditures on the charge. The expenditures on the materials are spent in the preparation of the initial charge, during the correction of its composition and during the addition of the correcting additives.

$$\text{Therefore, } F_m = \sum_{j=1}^{n} C_jX_j + \sum_{j=1}^{n} C_j X_j^{iv} + \sum_{j=1}^{n} Cj X_j^{v}$$

Where, X_j^i, x_j^{iv}, $x^v{}_j$ are the quantities of j - components of the charge used in 1, iv and v stages of the alloy making processes. The effect of minimization function F_m^{iv} is not always very big. The main effect is obtained in the first stage while solving the problems of the rotational usage of the charging materials. in this case, F_m^i = min. when optimization is to be carried out on the usage of the materials during the correction of the composition of the metal, the fourth stage can be treated as independent and therefore,

$$\text{min. } F_m^{iv} = \text{min.} \sum_{j=1}^{n} C_jX_j^{iv}$$

The possibility of using this type of method in solving this problem has been shown elsewhere. [1]

During the review of literatures, it was found out that optimization has not been carried out for a lot of alloys, hence the need for this paper that pays special consideration to the optimization of the correcting additives. The problem of optimization was solved only for alloyed steel using dynamic programming methods.[2]

Consequently, if the problem of optimization is to economise on expensive components and components in low-supply, then, the optimum will be the charge with the lowest cost, which, at the same time, is within the required specification of the quality of the alloy. Therefore, it is better to adopt calculation methods that will give the optimum variant of solutions for better cost effectiveness.

The problem of this calculation then is to determine the ratio of initial components of the charge that will guarantee the production of an alloy with the required chemical composition, mechanical, technological, and application properties. There are three stages in solving this problem. The first stage is the establishment of the specifications of the chemical composition of the alloy based on the determination of the chemical composition of the alloy. The second stage is the determination of the chemical composition of the alloy for calculation purposes. The third stage is the establishment of the equations for the calculation and their resolutions.

From the review of literatures, there are many methods of solving these equations. [3-4] The methods include: analytical, grapho/analytical, selection, arithmetical and linear programming methods. Optimization method is used when the efficiency function and its limits are given in linear form. This is usually a linear programming problem. [5-6]

Generally, linear programming method determines the variables $X_1, X_2 \ldots X_n$,

which satisfy the minimum requirements of the efficiency function i.e. $F_{min} = \lambda_1 X_1 + \lambda_2 X_2 + \ldots + \lambda_n X_n$

and also satisfy the following limits

$$\sum_{j=1}^{n} a_{ij} X_j = b_i$$

$$x_j \geq 0$$

Where, λ_i, a_{ij}, b_j are known constants.

$i = 1, 2, \ldots, m$

$j = 1, 2, \ldots, n$ and $m < n$

Later, $\sum_{j=1} E_{jic} \cdot X_{jc} \leq E_u^{ic}$ and $\sum_{j=1}^{n} E_{jic} X_{jc} \geq E^L_{ic}$

$X_j = r \leq P$ and $X_j = r \geq q_c$. These equations can be simplifies to:

$$\sum_{j=1}^{n} E_{jic} X_{jc} - X_{k+1} = E^L_{ic} \sum_{j=1}^{n} E_{jic} X_{jc} + X_k = E^U_{ic}$$

Where, $k > n$.

n is the number of the main variable constants, i = 1, 2, ...,m.

Solving of linear equations involves the determination of values of X_j which satisfy the condition of producing an alloy of a specified chemical composition and quality. At the same time, linear equations guarantee the minimum cost of the charge. It is a method of calculation and optimization of the composition of the charge. Graphical, grapho/analytical, and numerical methods are used in solving linear programming problems. [5-7]

ii. COMPUTER OPTIMIZATION

Initial metals/alloys or ferro-alloys, production rejects, additive alloys, secondary alloys or scraps, rejects and additive alloys, and etc., are materials used during melt making.[8] The correcting additives are optimized as follows: The limit on chemical composition is determined.

$$E^L_{im} \leq \sum_{j=1} E_{jic} \cdot X_{jc} \quad E^u_{ic}.$$

Where, n is the number of components to be added to the melt. Usually, the components are added in lump form. In this case,

$$E^L_{ic} \leq \sum_{j=1} E_{jic} \cdot KE_{ij} \cdot X_j + E_{inc} \cdot X_{nc} \leq E^m_{ic}$$

Later, the limit on the maximum capacity of the melting unit and the weight of the liquid melt are established: $q \leq X_{nc} \leq P$.

Where, p is the upper limit, and q is the lower limit.

$$P = Q_c / M_c^n$$

Where, Q_c is the weight of the corrected melt, and M_c^n is the nominal capacity of the melting unit.

If the weight of the melt is not to be increased to a certain given limit, then, p = 1. The lower limit q is expressed as:

$$q = Q_c / M_c^{max}$$

The equation balance on the production of the liquid metal is derived as:

$$\sum_{j=1}^{n} X_{jc} \cdot K_j + X_{nc} = 1.$$

The efficiency function is given as:

$$Fmin = \sum_{j=1}^{n} \lambda_{jc} \cdot X_{jc} + OX_n.$$

This is when the cost of the correcting additives are not considered. If they are considered, then,

where, nc is the cost of the first or initial charge used in obtaining a unit quantity of the corrected melt, /T. In this last variant, F_{min} is equal to the cost of all charging materials used in the different stages of making one tonne of liquid metal.

iii. PRACTICAL APPLICATION OF OPTIMIZATION METHOD

Optimization as a new method has not been undertaken for majority of alloys. It was individually carried out in some industries especially for cupola charge.[9] Optimization sequence of the charge and the technological processes for making aluminum and magnesium alloys is illustrated below. The system involves the calculation of the charging materials, melting, express analysis, calculation of the additives, metal pouring into a mixer, refining, and ingot casting. The aims of the system are:

(1) To calculate the optimum composition of the charge and to correct the composition of the alloy on minimum cost criterion.
(2) To use automatic control in controlling the parameters of the process operations of the melting units and mixers. This will guarantee minimum expenditure on fuel, energy, melting loss, and concentration of gases and inclusions,
(3) To undertake automatic analysis of the express analysis data.
(4) To undertake automatic control of all foundry processes which will optimize the speed of obtaining ingots with a given microstructure.

This system can include calculating and controlling computer complexes: servicing up to 10 foundry melting units. Information on the availability of the charge will come to the charging men who will load this information into the computer.
Also loaded are information on the calculation of the optimum charge. These informations are printed by the computer. The charge is then weighed and charged into the melting units. All the melting units are connected by a single information sensor with the calculating and controlling computer complexes. The operator enters on the calculating computer complex, the working mode and the command to analyse the results of the express analysis which is compared with the results of the specified composition of the alloy and that of the standard composition. If they do not correspond, then, the correcting additives are calculated and charged.
This system controls the metal pouring into the mixer, its servicing mode and the refining of the melt. The computer receives the information of the solidification of the melt in a crystallizer, the temperature of the ingot, the expenditure of the cooling water, and the metal feeding, from the sensor. From the information received, the speed of withdrawing the ingot is then controlled by the computer. The result of the calculation is given by the computer in form of the minimum required composition of each component of the charge X_i that satisfies the condition of minimum cost F_{min}. These values are usually printed by the computer. The unprinted composition of the components of the charge should be assumed to be equal to zero. The computer algorithms producing solutions for basic standard programme can be found in literature.[10]

iv. CONCLUSION

In conclusion, the calculation of the optimum composition of a charge can be evaluated as an independent problem. It is also a part of the problems being solved by the automatic system control of technological processes. The economic effect of this optimization is realized as the cost of the charge is always at the level of = 95% of the departmental cost of the ingots.

All these facts illustrate the necessity of optimizing the composition of the charge with the aim of reducing expenses on expensive materials and those that are in low supply.

NOMENCLATURE

F1	=	The cost of the alloy
Fi	=	The cost of a unit alloy
Ci	=	The cost of a quantity of the change
Xi	=	The quantity of a unit component of the change
E^{L}_{im}	=	The limit on the chemical composition
q	=	The lower limit on the capacity of the melting unit
p	=	The upper limit on the capacity of the melting unit
Qc	=	The weight of the corrected melt
M^{n}_{c}	=	The nominal capacity of the melt unit
nc	=	The cost of the initial charge

F_{min} = The efficiency function\

vi. REFERENCES

1. Belman R., (1960), "Dynamic programming", New York
2. Belman R., et al., (1965), "Applied prob lems of dynamic programming", New York.
3. String A., (1980), "Linear algebria and its application", London
4. Druan M. J., (1966), "Foundry technology", No. 10. pp. 38 - 39
5. Judin D., et al., (1964), "Problems and methods of linear programming, Moscow.
6. Lyashenko H., et al., (1975), Linear and non-linear programming, Kiev.
7. Karpov P., (1975), "Foundry technology". Volgograd
8. Kurdimov A., et al., (1972), "Foundry technology of non-ferrous and rare-alloys", Moscow
9. Melnikov V., et al., (1971), "Journal of the academy of Science", Moscow
10. Medland A. J. (1992), "The computer based design process", New York.