INNOVATIVE TECHNOLOGICA
METHODICAL RESEARCH JOURNAL
ISSN: 2776-0987 Volume 3, Issue 6, June, 2022

JUSTIFICATION AND CHOICE OF RATIONAL OPERATING CURRENT FREQUENCY IN INDUCTION CRUCIBLE FURNACES

Tursunov Nodirjon Kayumjonovich
Ph.D., Head of the Department of Materials Science and Mechanical Engineering, Tashkent State Transport University, Tashkent, The Republic of Uzbekistan,
E-mail: u_nadir@mail.ru

Alimukhamedov Shavkat Pirmukhamedovich
Dr. Tech. Sciences, Professor of the Department of Materials Science and Mechanical Engineering, Tashkent State Transport University, Tashkent, The Republic of Uzbekistan

Toirov Otabek Toir ugli
Ph.D. Student of the Department of Materials Science and Mechanical Engineering, Tashkent State Transport University, Tashkent, The Republic of Uzbekistan
E-mail: tv574toirov@mail.ru
https://orcid.org/ 0000-0003-4677-1241

Kuchkorov Lochinbek Akhmadjon ugli
Ph.D. Student of the Department of Materials Science and Mechanical Engineering, Tashkent State Transport University, Tashkent, The Republic of Uzbekistan
E-mail: telekommunikatsiya@gmail.com

Urazbaev Talgat Teleubaevich
Senior Lecturer, of the Department of Materials Science and Mechanical Engineering, Tashkent State Transport University, Tashkent, The Republic of Uzbekistan
E-mail: talgat_1988.26@mail.ru

Annotation
The work is devoted to the substantiation and selection of a rational operating frequency of the current in induction crucible furnaces. Criteria are considered when choosing the current frequency of induction furnaces, which provide an

increase in the efficiency of the furnace, an increase in productivity, and a decrease in the cost of electrical equipment. A technique for determining the dependence of the electrical efficiency is given. of the “inductor-metal charge” system on frequency.

Keywords: current speed, metal charge, consumable crucible furnace, electrical equipment, melting.

Introduction

The current frequency for induction crucible furnaces (ICF) is an important operational parameter that determines the technical and economic performance of induction melting. The size of the pieces of charge materials depends on the current frequency [1]. For the operation of induction crucible furnaces, it is necessary to estimate the frequency of the current.

The main criteria for choosing a frequency are the cost-effectiveness of operation and the minimum amount of capital costs. The influence of frequency on the value of capital costs is reflected in the fact that the cost of a frequency converter and a capacitor bank, which are the main components of the cost of an induction installation, depend on the frequency of the current. Since the cost of a frequency converter (by 1 kvar) increases with increasing frequency due to the complexity of electrical equipment, and the cost of 1 kvar of a capacitor bank decreases with increasing frequency, on the contrary, due to a decrease in the required capacity of a capacitor bank, the total cost of the converter and capacitor bank does not remain constant when the frequency changes [2,6].

The capacity of a capacitor bank for an ICF is inversely proportional to the frequency. As the frequency decreases, the capacitance, dimensions and cost of the capacitor bank increase. The cost of a capacitor bank increases more slowly than 1/f, since with decreasing frequency, the reactive power factors change, taking into account the peculiarities of the physical processes of propagation (attenuation and reflection) of cylindrical electromagnetic waves in the inductor and in the metal cylinder. Therefore, the cost of a capacitor bank is the largest part of the cost of electrical equipment.

With increasing frequency, it is possible to increase the price of a unit capacitance of the capacitor (due to the use of a better dielectric), but in general the cost of the frequency converter increases, and it is possible to determine the economically optimal frequency fopt, at which the total cost of electrical equipment will be the

INNOVATIVE TECHNOLOGICA
METHODICAL RESEARCH JOURNAL
ISSN: 2776-0987 Volume 3, Issue 6, June, 2022

lowest. On fig. 1 shows the dependence of the cost of electrical equipment of the ICF on the frequency of the current.

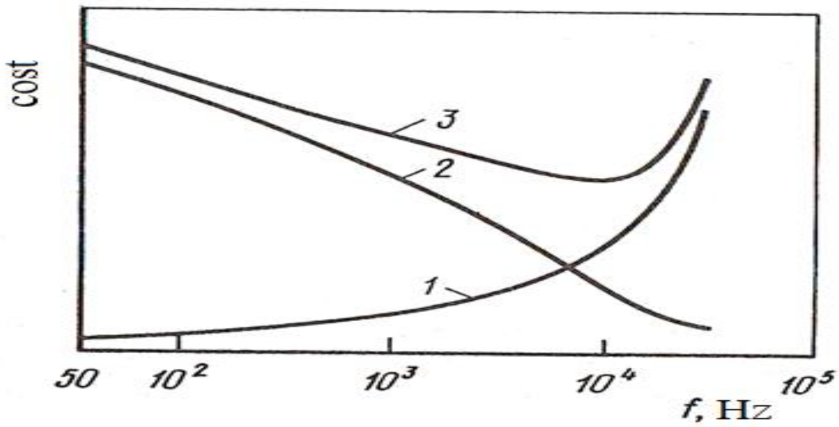

Figure 1 - Dependence of the cost of electrical equipment of ITP on frequency:
1- frequency converter; 2-capacitor battery; 3-total cost

As can be seen from figure 1 with an increase in the frequency of the current, the cost of the current frequency converter increases, the cost of the capacitor bank decreases, and the total cost of the electrical equipment of induction furnaces has an area of optimal values. Therefore, when choosing electrical equipment, it is necessary to use the region of optimal current frequency values.

The values of the minimum f_{min} and critical current frequency f_{kr} are determined for the moment of melting, when the metal charge, consisting of individual pieces, has already lost its magnetic properties (above the Curie point), but has not yet "welded" into a solid cylinder [1-4].

For the operation of the ICF, it is necessary to estimate the frequency of the current. Table 1 shows the optimal sizes of pieces of metal charge depending on the current frequency at temperatures of 300 and 1100 K.

Table 1 - Rational sizes of charge pieces in steelmaking [2]

Frequency, Hz	Optimum size of pieces, cm	
	1100 K	300 K
50	34	32
500	10,7	9,9
2000	5,4	5,0
10000	2,4	2,3
100000	0,8	0,72

As can be seen from Table 1, with increasing current frequency, the size of the pieces decreases. With a preheated mixture, you can increase the size of the pieces.

The choice of operating frequency f_{work} current of induction crucible furnaces is based on the determination of the minimum (necessary) f_{min}, critical f_{kr} and economically optimal frequency f_{ort}.

The operating current frequency f_{work} is selected from the condition:

$$f_{work} > f_{kr}.$$

Критическую частоту $f_{кр}$ в качестве достаточного условия выбора рабочей частоты тока $f_{раб}$ определяют графо-аналитическим методом с учетом зависимости электрического к.п.д. $\eta_{эл.}$ системы “индуктор - металл” от частоты f:

The critical frequency f_{kr} as a sufficient condition for choosing the operating frequency of the current f_{work} is determined by a graph-analytical method, taking into account the dependence of the electrical efficiency. $\eta_{el.}$ of the “inductor - metal” system on the frequency f:

$$\eta_{el} = \frac{1}{1+k_D k_h \sqrt{\frac{\rho_i}{\rho_m} \cdot \frac{k_{i.P}}{k_{m.P} k_z k_{m.p}^2}}} = \chi_\eta(f), \qquad (1)$$

where $k_D = \frac{D_{vt}}{D_m}$ – simplex relative internal (“active”) diameter of the inductor (in relation to the diameter of the metal D_m);

$k_h = \frac{h_i}{h_m}$ – simplex relative height of the inductor (in relation to the height of the metal h_m);

$\rho_i = 2 \cdot 10^{-8}$ Ohm·m - resistivity of a copper water-cooled inductor;

$\rho_m = 140 \cdot 10^{-8}$ Ohm·m - resistivity of liquid steel [6-8];

$k_{i.P}$ и $k_{m.P}$ – active power factors characterizing the conditions of attenuation of a cylindrical electromagnetic wave, respectively, in the inductor and in the molten metal and depending on the respective relative “active” diameters of the inductor $D_{vt}/\delta_{e.i}$;

$k_z = 0{,}9$ –fill factor of the inductor;

$k_{m.p}$ – coefficient characterizing the scattering of the magnetic flux in the given system "inductor - metal" and depending on the ratios of geometric simplices

A study of the dependence of the electrical efficiency was carried out. from the operating frequency on the example of an induction crucible furnace with a capacity of 6 tons (ITP-6) that are in operation at the production of the Foundry and Mechanical Plant. The results of the calculation of the electrical efficiency. systems “inductor - metal charge” according to formula 1 are given in table. 2 and in fig. 3.

Table 2 - Initial data for calculating the electrical efficiency ICF-6

Current frequency f, Hz	10	50	500	1000	67000
Inductor (D_{vt} = 1300 mm)					
Equivalent depth $\delta_{e.i}$,mm	22,4	10	3,2	2,2	0,3
Relative diameter $D_{vt}/\delta_{e.i}$	58,1	130,0	411,1	581,4	4758,8
Metal charge D_{sh} = 280 mm					
Equivalent depth $\delta_{e.d}$,mm	70	31,6	10	7,1	0,9
Relative diameter $D_{sh}/\delta_{e.m}$	4	8,9	28	39,4	311
Coefficient $k_{m.P}$	0,45	0,85	1	1	1
Electrical efficiency $\eta_{эл}$	0,88	0,93	0,94	0,94	0,94

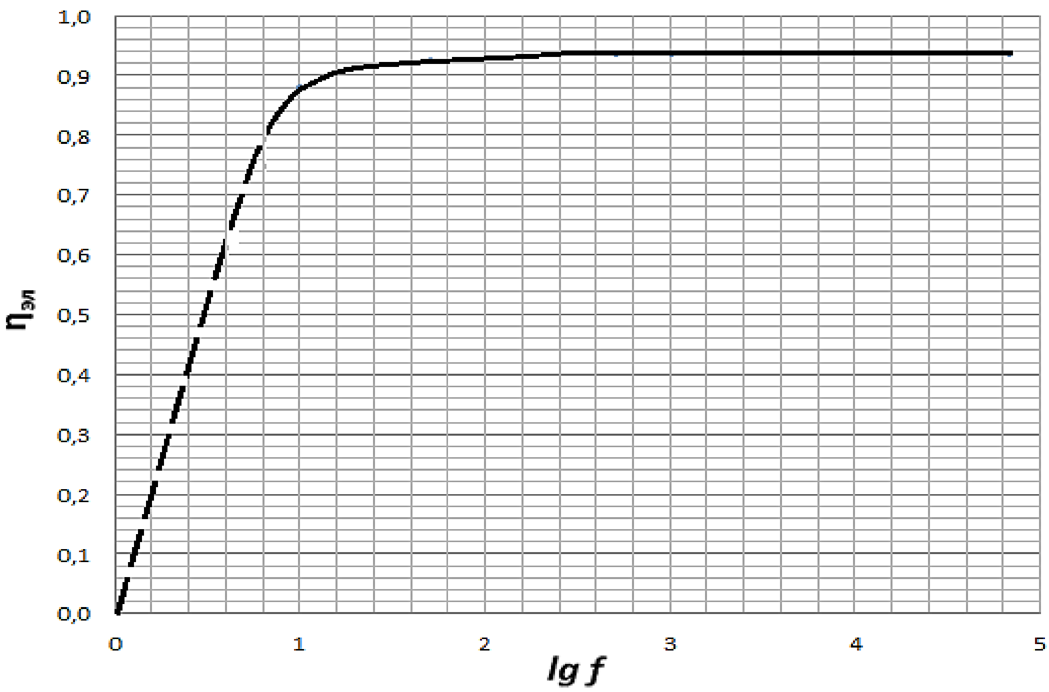

Figure 3 - The dependence of the electrical efficiency. systems "inductor - metal charge" on the frequency of current ICF-6

As can be seen from Fig. 3 for ICF-6, with increasing frequency, the electrical efficiency increases. and at a frequency of 500 Hz reaches its maximum value, i.e. $\lim \eta_{el} = 0{,}94$ Therefore, for ICF-6 it is advisable to choose a current frequency of 500 Hz.

Conclusion

The results of the study on the choice of the current frequency of induction furnaces made it possible to formulate recommendations for increasing the electrical efficiency, rational values of the current frequency, taking into account the performance of the furnace. The dependence of the electrical efficiency is shown. from the operating frequency on the example of ICF-6 in operation.

References

1. Нурметов, Х. И., Турсунов, Н. К., Кенжаев, С. Н., & Рахимов, У. Т. (2021). ПЕРСПЕКТИВНЫЕ МАТЕРИАЛЫ ДЛЯ МЕХАНИЗМОВ АВТОМОБИЛЬНЫХ АГРЕГАТОВ. Scientific progress, 2(2), 1473-1479.
2. Tursunov, N. K., Semin, A. E., & Sanokulov, E. A. (2016). Study of desulfurization process of structural steel using solid slag mixtures and rare earth metals. Chernye metally, 4, 32-7.
3. Турсунов, Н. К., Тоиров, О. Т., Железняков, А. А., & Комиссаров, В. В. (2021). Снижение дефектности крупных литых деталей подвижного состава железнодорожного транспорта за счет выполнения мощных упрочняющих рёбер.
4. Турсунов, Н. К., Санокулов, Э. А., & Семин, А. Е. (2016). Исследование процесса десульфурации конструкционной стали с использованием твердых шлаковых смесей и РЗМ. Черные металлы, (4), 32-37.
5. Tursunov, N. K., Semin, A. E., & Sanokulov, E. A. (2017). Study of dephosphoration and desulphurization processes in the smelting of 20GL steel in the induction crucible furnace with consequent ladle treatment using rare earth metals. Chernye Metally, 1, 33-40.
6. Турсунов, Н. К., Семин, А. Е., & Котельников, Г. И. (2017). Кинетические особенности процесса десульфурации при выплавке стали в индукционной тигельной печи. Черные металлы, (5), 23-29.
7. Турсунов, Н. К., Семин, А. Е., & Санокулов, Э. А. (2017). Исследование процессов дефосфорации и десульфурации при выплавке стали 20ГЛ в индукционной тигельной печи с дальнейшей обработкой в ковше с использованием редкоземельных металлов. Черные металлы, (1), 33-40.
8. Toirov, O. T., Tursunov, N. Q., Nigmatova, D. I., & Qo'chqorov, L. A. (2022). USING OF EXOTHERMIC INSERTS IN THE LARGE STEEL CASTINGS PRODUCTION OF A PARTICULARLY. Web of Scientist: International Scientific Research Journal, 3(1), 250-256.

9. Турсунов, Н. К., & Тоиров, О. Т. (2021). Снижение дефектности рам по трещинам за счёт применения конструкции литниковой системы.
10. Тоиров, О. Т., Турсунов, Н. К., Кучкоров, Л. А., & Рахимов, У. Т. (2021). ИССЛЕДОВАНИЕ ПРИЧИН ОБРАЗОВАНИЯ ТРЕЩИНЫ В ОДНОЙ ИЗ ПОЛОВИН СТЕКЛОФОРМЫ ПОСЛЕ ЕЁ ОКОНЧАТЕЛЬНОГО ИЗГОТОВЛЕНИЯ. Scientific progress, 2(2), 1485-1487.
11. Tursunov, N. K., Semin, A. E., & Sanokulov, E. A. (2017). Research of dephosphorization and desulfurization processes in smelting of 20GL steel in an induction crucible furnace with further processing in a ladle using rare earth metals. Chern. Met., 1, 33-40.
12. Тен, Э. Б., & Тоиров, О. Т. (2021). Оптимизация литниковой системы для отливки. Литейное производство, (10), 17-19.
13. Тен, Э. Б., & Тоиров, О. Т. (2020). Оптимизация литиковой системы для отливки «Рама боковая» с помощью компьютерного моделирования. In Прогрессивные литейные технологии (pp. 57-63).
14. Азимов, Ё. Х., Рахимов, У. Т., Турсунов, Н. К., & Тоиров, О. Т. (2022). Исследование влияние катионов солей на реологический статус геллановой камеди до гелеобразования. Oriental renaissance: Innovative, educational, natural and social sciences, 2(Special Issue 4-2), 1010-1017.
15. Тоиров, О. Т. У., Турсунов, Н. К., & Кучкоров, Л. А. У. (2022). Совершенствование технологии внепечной обработки стали с целью повышения ее механических свойств. Universum: технические науки, (4-2 (97)), 65-68.
16. Riskulov, A. A., Yuldasheva, G. B., Kh, N., & Toirov, O. T. (2022). DERIVATION PROCESSES OF FLUORINE-CONTAINING WEAR INHIBITORS OF METAL-POLYMER SYSTEMS. Web of Scientist: International Scientific Research Journal, 3(5), 1652-1660.
17. Рахимов, У. Т., Турсунов, Н. К., Кучкоров, Л. А., & Кенжаев, С. Н. (2021). ИЗУЧЕНИЕ ВЛИЯНИЯ ЦИНКА Zn НА РАЗМЕР ЗЕРНА И КОРРОЗИОННУЮ СТОЙКОСТЬ СПЛАВОВ СИСТЕМЫ Mg-Nd-Y-Zr. Scientific progress, 2(2), 1488-1490.
18. Нурметов, Х. И., Турсунов, Н. К., Туракулов, М. Р., & Рахимов, У. Т. (2021). УСОВЕРШЕНСТВОВАНИЕ МАТЕРИАЛА КОНСТРУКЦИИ КОРПУСА АВТОМОБИЛЬНОЙ ТОРМОЗНОЙ КАМЕРЫ. Scientific progress, 2(2), 1480-1484.

19. Tursunov, N. K., & Ruzmetov, Y. O. (2018). Theoretical and experimental analysis of the process of defosphoration of steel used for parts of the mobile composition of railway transport. Journal of Tashkent Institute of Railway Engineers, 14(2), 60-68.
20. Тоиров, О. Т., Кучкоров, Л. А., & Валиева, Д. Ш. (2021). ВЛИЯНИЕ РЕЖИМА ТЕРМИЧЕСКОЙ ОБРАБОТКИ НА МИКРОСТРУКТУРУ СТАЛИ ГАДФИЛЬДА. Scientific progress, 2(2), 1202-1205.
21. Турсунов, Н. К., Уразбаев, Т. Т., & Турсунов, Т. М. (2022). Методика расчета комплексного раскисления стали марки 20гл с алюминием и кальцием. Universum: технические науки, (2-2 (95)), 20-25.
22. Toirov, B. T., Jumaev, T. S., & Toirov, O. T. (2021). OBYEKTLARNI TANIB OLISHDA PYTHON DASTURIDAN FOYDALANISHNING AFZALLIKLARI. Scientific progress, 2(7), 165-168.
23. ТУРСУНОВ, Н. (2021). Повышение качества стали за счет применения редкоземельных металлов. ВЯ Негрей, ВМ Овчинников, АА Поддубный, АВ Пигунов, АО Шимановский, 158.
24. Турсунов, Н. К. (2022). Исследование режимов рафинирования стали, используемые для изготовления литых деталей подвижного состава железнодорожного транспорта. Лучший инноватор в области науки, 1(1), 667-673.
25. Riskulov, A. A., Yuldasheva, G. B., & Toirov, O. T. (2022). FEATURES OF FLUOROCOMPOSITES OBTAINING FOR WEARING PARTS OF MACHINE-BUILDING PURPOSE. Web of Scientist: International Scientific Research Journal, 3(5), 1670-1679.