

## MAXIMIZING THE PRODUCTIVITY OF A GAS MELTING FURNACE WITH REGARD TO THE ECOLOGICAL EFFICIENCY OF ITS OPERATION

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### Abstract:

Due to the implementation of environmental regulations and the continual tightening up of the limits for pollutants in combustion systems, we are being forced to pay more attention to this area. A significant source of pollutants originating from the industry is, in particular, the formation of carbon dioxide (CO<sub>2</sub>) and nitrogen oxides (NO<sub>x</sub>) in combustion systems with air intake. The control of pollutant emissions has become a global concern due to the worldwide increase in the use of fossil fuels. Besides the fact that the insufficient combustion process has a significant share of emissions in the environment, it also reduces the overall efficiency and economy of the operation using this energy source. We encounter this problem also in the operation of gas melting furnaces. Therefore, the aim of this paper was to describe the results of experimental measurements of the amount of emissions produced during the gas melting furnace KOV 010/1998 operation, which is in practice predominantly used for the melting of Aluminium alloys. Experimental measurements were performed to design the most appropriate operating mode variant of the melting furnace with regard to maximizing its productivity and at the same time to minimizing the total amount of emissions produced during one melting cycle.

**Key words:** *gas melting furnace, emission, power, efficiency, combustion process*

### INTRODUCTION

A melting furnace can be considered as the primary device used in the Aluminium casting process. First and foremost, it is used for melting and preparing Al alloys with the required mechanical and chemical characteristics that comply with the applicable standard for the respective type of Al alloy. Thermal energy [27] is necessary for melting and preparing the Al alloy in a melting furnace with the required characteristics. This can be obtained by converting electrical energy or a combustion process. Natural gas is a frequently used source of thermal energy obtained by the combustion process [23] in melting furnaces. It is predominantly composed of hydrocarbons, of which the majority is methane. The main products of its combustion are carbon dioxide (CO<sub>2</sub>) and water vapour. Although emissions of nitrogen oxides (NO<sub>x</sub>), sulphur dioxide (SO<sub>2</sub>) and other particles produced by natural gas combustion are several times lower compared to other fossil fuels, they are not negligible [20].

In addition, many producers seek to maximize the performance of their melting furnaces. However, at the same time as maximizing the performance of the melting furnace, the increased production of pollutants that burden the environment is closely linked. These can be reduced in conventional furnaces by means of filters, but in the case of melting furnaces it is very problematic to capture

these pollutants. A certain solution is to maximize the use of thermal energy of a given source while maintaining the same share of pollutants released into the air.

Therefore, the aim of the experimental research was to propose the most suitable variant of its operating mode, based on the results of measurements [14] of pollutant values produced during the operation of the gas melting furnace KOV 010/1998 used mainly for melting Al alloys. The proposal of the appropriate operating mode was based on maximizing the productivity [22] of the gas melting furnace with regard to the smallest total amount of emissions produced during one melting cycle.

### LITERATURE REVIEW

Although the share of pollutants produced in the combustion of natural gas is several times lower compared to other fossil fuels, it is not negligible. The research by Niecke et al. [16, 17] also points to this fact. In the context of the research, they also found out that the actual concentration of pollutants produced during the combustion process is also significantly influenced by the course of combustion itself. These values can increase even several times in the case of insufficient combustion process. Furthermore, a large amount of pollutants is produced [4, 9] in the Al alloy melting process itself [6, 10] and it is very problematical to prevent it. Therefore, it is necessary to

try to reduce at least the pollutant content that is produced during its heating [5]. Pandová deals with the reduction of these pollutants in her research. It seeks to find ways to eliminate these pollutants released into the environment [20]. However, these methods are ineffective in the case of melting furnaces. Brewster also tried to achieve lower emissions in a gas melting furnace. He wanted to achieve this by increasing the proportion of oxygen. He described the results of his experimental research in detail in the work [4]. However, the results of other authors, from which Wang can be mentioned, point to the fact that by injecting oxygen into the melting furnace, the molten metal cools down. This prolongs the melting process [27]. Therefore, one of the most aqueous ways to eliminate the production of pollutants in the gas melting furnace appears to choosing the most suitable variant of the operating mode. Moreover, controlling of the combustion process in a gas melting furnace [7] has several practical meanings. These include, in particular, increasing the overall efficiency of the combustion process [2], increasing the efficiency of a melting furnace operation [1, 19], reducing the pollutants produced, reducing the maintenance costs of a melting furnace technological equipment, increasing the quality and productivity [8, 15, 21] of the production and so on [2, 12].

**MATERIAL AND WORKING METHODS**

**Technical equipment used in the experiment**

The gas melting furnace marked as KOV 010/1998 was considered within the framework of an experiment aimed to maximize [25, 28] the melting furnace productivity with regard to minimizing the total amount of pollutants produced during one melting cycle of the Al alloy. It is a gas melting furnace whose construction consists [3, 13] of steel profiles and sheets [18]. Foundations consist of a supporting frame which is anchored in the basement plate. The melting furnace is mounted on two sliding bearings on one side, while on the other side it is mounted to a hydraulic cylinder. Lifting of the melting furnace is controlled by the hydraulic cylinder [26] during its emptying. The following Fig. 1 shows the melting furnace KOV 010/1998 which was used in the experiment.



Fig. 1 The gas melting furnace KOV 010/1998

Protective sheath of the gas melting furnace, so-called the lining, is made of refractory bricks and ceramic insulation boards. The space of the spout and the exhaust gas opening, as well as the movable door of the melting furnace are protected by refractory concrete. The melting furnace space at the burner place is covered with special refractory material that resists temperatures up to 1600°C. Heating of Al alloy in the melting furnace KOV 010/1998 is realized by means of two gas burners no. 1 and no. 2 with a maximum power of  $2 \times 700$  kW. These are monoblock burners with a built-in fan and an electric motor. The burners have a power control system that includes a programmable automatic flame ionisation fuse.

**The measuring equipment used in the experiment**

The measurement of the pollutant content produced during melting of Al alloys in the gas melting furnace KOV 010/1998 was performed by using the Testo 340 measuring equipment. It is a pollutant measuring instrument, which includes a modular sampling probe and the high-speed printer of recorded results. The following Fig. 2 shows the measuring equipment Testo 340 which has been used in the experiment to measure the pollutant content produced during melting of Al alloys in the gas melting furnace KOV 010/1998.

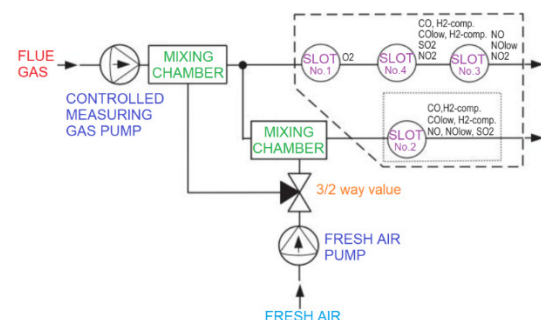


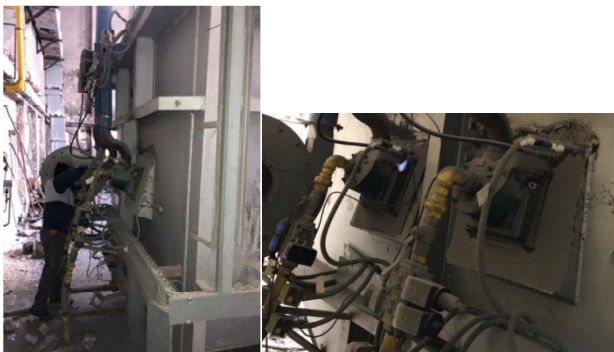
Fig. 2 The gas path of measuring equipment Testo 340  
Source: [29].

**Table 1**  
**Basic technical parameters of the measuring equipment**  
**Testo 340**

Basic dimensions	283 × 103 × 65 mm
Total weight	0.96 kg
Operating temperature	– 5 up to + 45°C
Probe type	K (NiCr-Ni)
Temperature measuring range	– 40 up to + 1200°C
Pressure measuring range	± 200 hPa
Measuring range of chimney losses (resolution)	0 up to 120% (0.1%)
Measuring range of CO (resolution)	0 up to +10000 ppm (1ppm)
Measuring range of NO (resolution)	0 up to +4000 ppm (1ppm)
Measuring range of CO <sub>2</sub> (resolution CO <sub>2</sub> )	0 up to max. CO <sub>2</sub> max (0.01 vol. %)
Measuring range of O <sub>2</sub> (resolution)	0 up to 25 vol.% (0.01 vol.%)

### Experiment conditions

Measurements of pollutants produced during the melting of Al alloy [24] in the gas melting furnace KOV 010/1998 were performed within the experiment. At the same time, the total times  $t_m$  to melt one batch with approximately the same amount of melt of 7900 kg were recorded. There were five separate measurements made during the experiment. Each measurement was performed in different operating mode of the melting furnace [11]. The first operating mode OM\_1 corresponded to the maximum power of both burners. The second operating mode OM\_2 corresponded to the burner no. 1 set to maximum power, with the burner no. 2 set to low power. The third operating mode OM\_3 matched the burner no. 1. to maximum power, burner no. 2 was out of service. The fourth operating mode, OM\_4, corresponded to the minimum power of both burners. The last, fifth operating mode OM\_5, corresponded to burner setting no. 1 to a minimum power, with burner no. 2 being out of service. The following Fig. 3 shows the process of adjusting individual modes of burners no. 1 and no. 2 always before the first Al loading in the gas melting furnace KOV 010/1998.



**Fig. 3** Setting modes of burners no. 1 and no. 2 before the first Al loading in the gas melting furnace KOV 010/1998

The operating parameters of the combustion process were set to achieve the lowest possible levels of pollutants within the individual operating modes OM\_1 to OM\_5 of the melting furnace KOV 010/1998.

### RESULTS OF EXPERIMENTAL MEASUREMENTS OF POLLUTANTS PRODUCED BY THE GAS MELTING FURNACE KOV 010/1998

The measurements of the pollutant content produced during melting of the Al alloy in the gas melting furnace KOV 010/1998 and the time required to melt and heat the Al alloy to a temperature of about 720°C in each operating mode were always performed after the completion of the first loading. The loading was performed in two phases [23] in terms of the Al alloy melting mechanism during the experiment. About 3.55 tons of pure aluminium were loaded in the first phase. After melting, the second phase of loading about 4.35 t of Al, including alloying elements, was carried out at a temperature of about 700°C. The measurement of the pollutant content produced during melting of the Al alloy was performed at the top of the melting furnace at the flue gas outlet. Individual measurements were always completed when the melt temperature reached about 720°C. Fig. 4 shows the course of the measurement of the pollutant content produced during melting of the Al alloy in the gas melting furnace KOV 010/1998 that can be observed by means of a Testo 340 measuring equipment.



**Fig. 4** Measurement of pollutant content produced during melting of Al alloy in the gas melting furnace KOV 010/1998 using Testo 340 measuring equipment

The respective values of the pollutant content, as well as the times  $t_m$  required for melting Al and the attainment of the melting temperature of about 720°C were recorded within the individual operating modes of the melting furnace KOV 010/1998 during melting of the Al alloy. The times required for melting the Al alloy and the experimentally measured pollutant content during the individual operating modes OM\_1 to OM\_5 of the melting furnace KOV 010/1998 are presented in the following Table 2.

**Table 2**  
**Recorded values of pollutant content and times  $t_m$  needed for melting of Al alloy during individual operating modes OM\_1 to OM\_5 of the melting furnace KOV 10/1998**

Operating mode of the melting furnace KOV 010/1998	Melting time $t_m$ (hours)	Power of gas burner		Measured pollutant content			
		No.1	No.2	NOx (%)	CO (%)	CO <sub>2</sub> (%)	TZL (g.m <sup>-3</sup> )
OM_1	10,0	high	high	0.0183	0.0080	10.78	0.0599
OM_2	11,5	high	low	0.0187	0.0083	10.94	0.0674
OM_3	13,0	high	OFF	0.0181	0.0079	10.50	0.0551
OM_4	13,5	low	low	0.0199	0.0093	11.39	0.0774
OM_5	14,0	low	OFF	0.0201	0.0107	11.67	0.0987

The total amount of pollutants produced during the individual operating modes OM\_1 to OM\_5 of the melting furnace KOV 010/1998 was calculated based on the measured values. These values can be seen in the following Table 3.

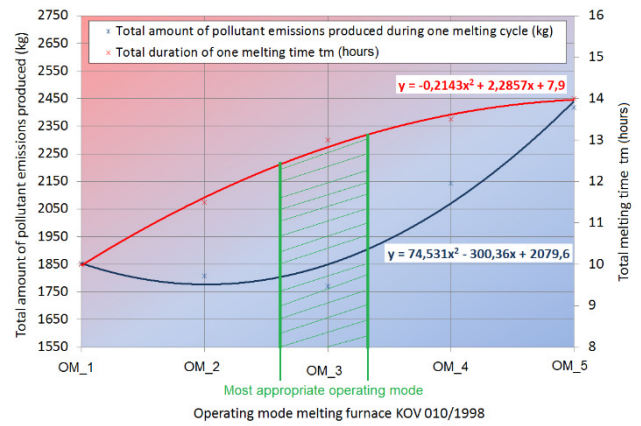
**Table 3**  
**Values of the total amount of pollutants produced during individual operating modes OM\_1 to OM\_5 of the melting furnace KOV 010/1998**

Operating mode of the melting furnace KOV 010/1998	Amount of pollutants produced during one melting cycle					Total (kg)
	NOx (kg)	CO (kg)	CO <sub>2</sub> (kg)	TZL (kg)		
OM_1	3.67	0.99	1846.88	0.06		1851.59
OM_2	3.59	0.99	1802.55	0.06		1807.19
OM_3	3.55	0.96	1767.15	0.05		1771.71
OM_4	4.37	1.27	2138.15	0.08		2143.86
OM_5	4.85	1.60	2410.80	0.11		2417.36

It is possible to observe significant differences from the experimentally measured and calculated data recorded in the Tables 2 and 3. These differences are not only in the total content of pollutants produced during the individual operating modes OM\_1 to OM\_5 of the melting furnace KOV 010/1998, but also in the total times  $t_m$  of the melting time Al and reaching the melt temperature of about 720°C. The graphical dependencies that are presented in the Figure 5 were constructed based on the experimentally measured data given in the Table 2 and empirically determined data given in the Table 3.

They describe the dependence of the total amount of pollutants produced and the total time  $t_m$  needed to melt and heat the Al alloy to a temperature of about 720°C at the individual operating modes OM\_1 to OM\_5 of the melting furnace KOV 010/1998.

From the graphical dependencies shown in Fig. 5 it can be observed that the lowest value of the total time  $t_m$  of melting Al alloy ( $t_m = 10$  hours) was recorded during operation mode OM\_1, while the highest ( $t_m = 14$  hours) during operation mode OM\_5.



**Fig. 5 Dependence of the total amount of pollutants produced and the total time  $t_m$  needed to melt and heat the Al alloy to a temperature of approx. 720°C for individual operating modes OM\_1 to OM\_5 of the melting furnace KOV 010/1998**

The lowest total amount of pollutants (1771.71 kg) was recorded during the operating mode OM\_3, while the highest (2417.36 kg) was recorded during the operating mode OM\_5.

**DISCUSSION**

Experimental research was focused on finding the most suitable variant of the operating mode of the gas melting furnace KOV 010/1998, which is used mainly for melting Al alloys with an orientation to maximize its productivity. Based on the results of experimental measurements, it can be concluded that OM\_1 operating mode can be considered the most suitable variant of the operating mode for the gas melting furnace KOV 010/1998 in terms of its productivity. In this operating mode, one melting cycle lasts only 10 hours.

On the other hand, the operating mode OM\_3, at which the lowest total amount of pollutants was produced, appears to be the most appropriate from the point of view of the production of pollutants during one melting cycle. During one melting cycle in this mode of operation of the melting furnace, 1771.71kg amount of pollutants was produced.

In the operating mode OM\_2, higher melting productivity can be achieved, but at the expense of a slight increase in the production of pollutants. Therefore, during the operation of the melting furnace, with a view to maximizing productivity, while maintaining a favourable balance of pollutants, it is recommended to apply the operating mode OM\_3 resp. OM\_2.

The operating mode OM\_5 can be considered the most improper variant of the operating modes for the gas melting furnace in terms of its productivity and total amount of pollutants produced. This operating mode is in no way recommended to be applied during the operation of the gas melting furnace KOV 010/1998.

## CONCLUSION

As already mentioned in the introduction, the gas melting furnace generally represents the primary equipment used in the casting process. A large amount of pollutants is produced in the Al alloy melting process. They come mainly from the combustion and melting process. We cannot completely eliminate the production of these harmful substances despite the use of modern technological equipment with active reduction of polluting production. The productivity of the melting furnace is another important monitored parameter in the production of Al castings. The technical practice of operating gas melting furnaces is maximization of their productivity with the lowest amount of pollutants produced. These real requirements of the technical practice were also supported by experiments. Based on the results of measurements of pollutant values produced during the operation of the gas melting furnace KOV 010/1998 used mainly for melting Al alloys, their aim was to design the most suitable variant of the operating mode of the given melting furnace. Based on the experimental measurements carried out, the operating mode OM\_1 was recommended as the most suitable variant in terms of the productivity of the gas smelting furnace KOV 010/1998 when Al alloy was melted. On the other hand, the operating mode OM\_3 was recommended to minimize the total amount of pollutants produced during one melting cycle.

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