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IMPROVEMENT OF EFFICIENCY OF CONTAMINANTS CAPTURE IN ENCLOSURE OF AN ELECTRIC ARC FURNACE

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SUMMARY

The paper presents physical model test results concerning improvement of performance of exaust systems of an electric arc furnace for steel melting, 140 Mg volume.

The furnace is equipped with a direct exhaust and additionally, owing to the necessity to limit the emission of noise and pollutants into the hall, with a large enclosure including an exhaust hood, being the second stage of the exhaust.

During the tests special attention was given to proper shape of the capture hood in the enclosure and to proper determination of the amount of exhausted gases required to ensure the good performance.

The range of economical cooperation of the first and the second exhaust stage was determined. The analysis of the enclosure ventilation conditions was made with the use of air pressure distribution within the enclosure.

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INTRODUCTION

Metallurgical process of steel melting in the particular steel melting plant takes place in electric arc furnaces of capacity of 140 Mg consuming 60 MVA of electric power each. The process is carried out with the use of regain method where oxygen is used at the final stage of melting and at the stage of refining. During one melting cycle, the furnace is charged several times. At the same time, the furnace vault is raised and moved aside. Due to the emission of gas and dust contaminants from the furnace the most harmful stages of the melting process are the stages when the charge is actually melting and when the liquid melt is refined with gas oxygen as well as the stages when the furnace is charged. Primary dust emission at the final stage of melting and refining is from 7 kg to 25 kg per 1 Mg of steel. The dust consists mainly of ferrum oxides its particle composition contains mainly of submicrone fractions. Secondary dust emission, when charging and tapping the furnace, is typified by larger particle sizes, from 1 to 20 μm. It must be reduced so as to avoid so-called "visible emission".

In order to limit noise and contaminants emission to the electric steel mill hall, the electric arc furnace was equipped with a direct exhaust of gases, a so-called "fourth opening" being the first exhaust stage. Moreover, it was also placed in a large air-tight enclosure with an air and gas exhaust being the second exhaust stage.

The exploitation of the steel mill revealed some difficulties in the efficient performance of both the exhausts. The improvement of capture effectiveness of exhausted gases consists mainly in settling the pressure distribution and the flow of the exhausted gases within the enclosure of the source, by proper shaping of the enclosure and of its elements.

When working on the improvement of the capture effectiveness of gases and dusts emitted from the arc furnace the aerodynamical processes were simulated by means of physical modelling.

SCOPE AND CONDITIONS OF MODEL TESTS

The enclosure and the contaminants exhaust devices are shown in Figure 1.

The purpose of the tests was to define construction and exploitation parameters of exhaust devices taking into account the actual conditions and limitations in their industrial exploitation.

The measurement stands were constructed in order to:

- choose the shape and the fittings of the exhaust hood inside the enclosure and to determine its aerodynamical characteristics (Figure 1 p.2)
- simulate the performance of the direct exhaust of gases from the furnace (Figure 1 p.1)
- determine the range of economical cooperation of the 1st and 2nd stage exhausts and to analyze the enclosure ventilation conditions.

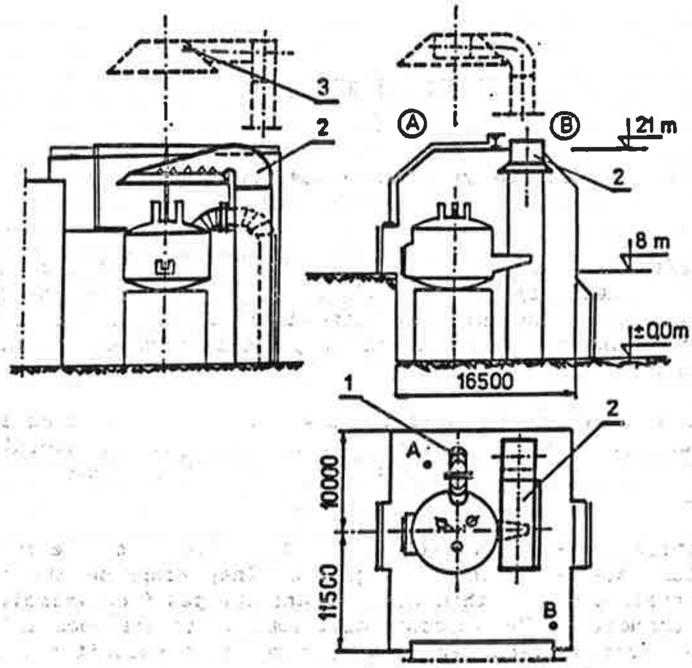


Fig. 1. Furnace location including gas exhausts
1 - direct exhaust
2 - capture hood in the enclosure
3 - canopy capture hood

The assumed scale of the model was 1:20 and the temperature difference scale 1:1.8. The scales of other parameters were determined according to similarity principles [1] for approximate modelling. Technological assumptions necessary for scale model tests were based on the actual conditions in the full-scale industrial building. The model of the furnace was electricly heated. The required air amount was introduced to the model simulating the flue gas flow at the scale. The gases emitted from the furnace were coloured with titanium tetrachloride $TiCl_4$ or with smoke producer.

The tests were begun by simulation of ventilation of the furnace air-tight enclosure under the industrial exploitation conditions. Then the performance of exhaust systems with a modified hood was tested. The amounts of the gases exhausted by the 1st and 2nd exhaust stage were changed while the furnace enclosure was either closed or open. On that way the range of the exploitation parameters that would ensure efficient performance of the enclosure was defined.

In addition, a canopy hood was constructed (Figure 1 p. 3) that would support the exhaust performance at the time of the furnace charging. The canopy hood was placed in the model above the level of the transport travelling cranes.

RESULTS OF THE TESTS

Hood capture inside the enclosure

The tests referred to the shape and the fittings (Figure 1 p. 2) of the hood being the final stage of the exhaust of gases within the air-tight enclosure. All the tested hood variants included the local limitations related to the construction of the air-tight enclosure and to the way of the furnace charging.

Preliminary evaluation of the velocity distribution at the hood inlet was made by visualization of the induction spectrum employing so-called "hot wire method". Figure 2 presents some pictorial records of the visualization.

The quantitative test results, in the form of aerodynamical characteristics, are presented in Figure 3. They comprise the relations between the pressure drop within the hood and the gas flow velocity in the exhaust duct connector. The velocity distribution in the hood inlet plane for particular hood variants are shown as constant velocity lines and a three-dimensional velocity profile.

From the point of view of the performance efficiency, the hood with six profiled equalizing-directing vanes, the triangular cross-section and the wedge-shaped inlet (variant 2E) was the best. Its induction was the evenest among the other tested hoods ($W_{max}/W_{min} = 2$) and it had the relatively good aerodynamical characteristic expressed in the Figure 3. It is worth mentioning that for the hood variant 1, the induction was not even ($W_{max}/W_{min} = 11.34$) and the local resistance factor was $\xi = 7.7$.

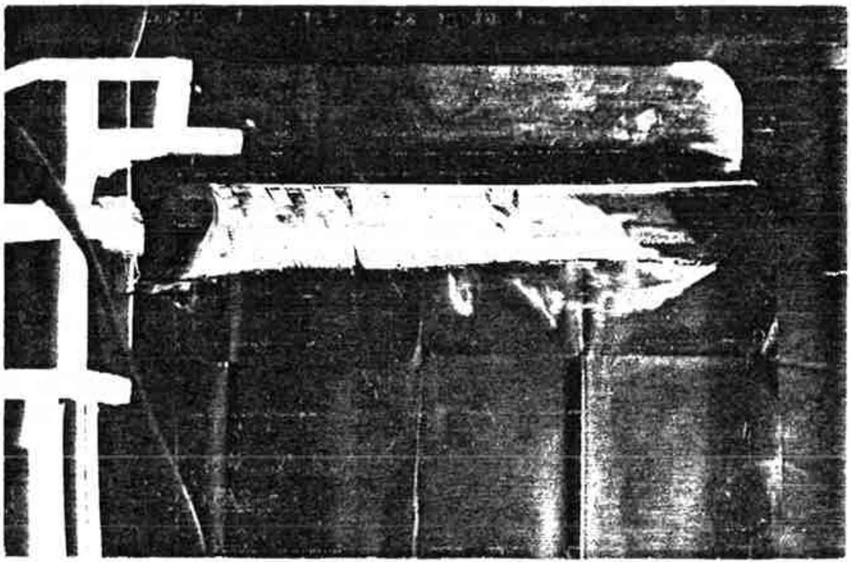


Fig. 2. Visualisation of performance of the capture hood from the enclosure after variant 2E

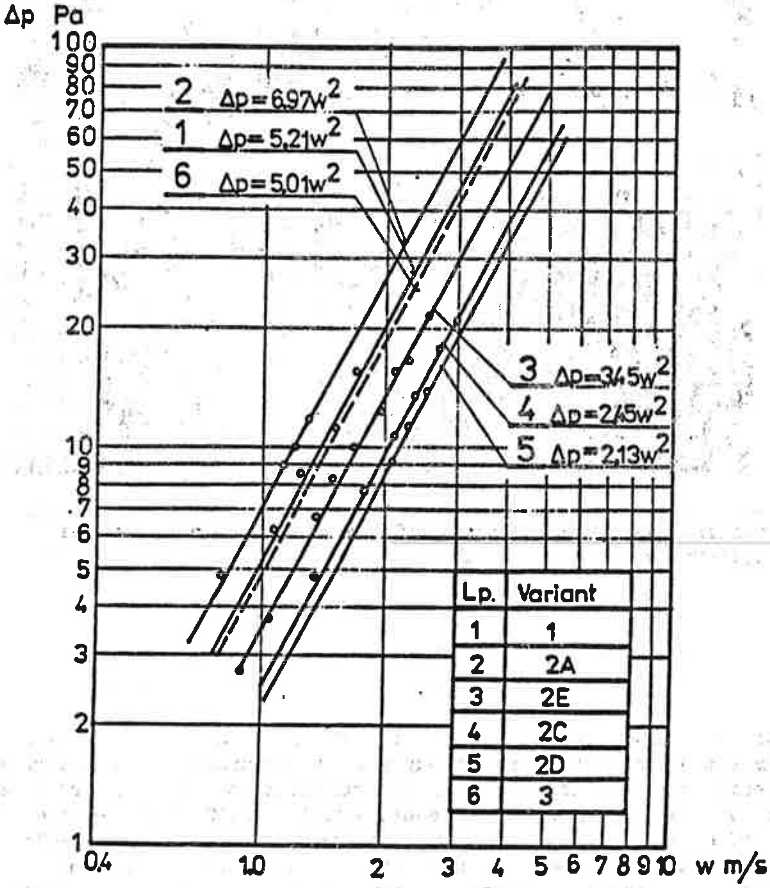
Working parameters of the furnace

When simulating the aerodynamical conditions of the furnace performance the amount of gases to be exhausted through fourth opening in the furnace vault was determined. For the furnace of capacity of 140 Mg at the expected amount of gases from the melt equal 40000 - 45000 m^3/h according to [2] about 160000 m^3/h should be exhausted through the fourth opening. However, it is also worth mentioning that in order to overcome the aeration effect itself, without any gases from the melt, 60000-70000 m^3/h should be exhausted from the furnace through the fourth opening.

In order to verify the literature data, the pressure distributions inside the furnace were measured at different amounts of gases from the melt and exhausted through the fourth opening. The phenomenon of "knocking the gases out of the furnace disappeared when the negative pressure under the vault was 27 Pa. Zero underpressure was acquired when 40000 m^3/h were exhausted through the fourth opening which was the amount stated in the literature for a furnace of the same size.

Cooperation parameters of 1st and 2nd exhaust stage

Lack of effusion of gases out of the enclosure was assumed as the criterion of efficiency of air-tight sealing devices for an arc furnace. The criterion fulfilling requires different amounts of gases exhausted by 1st and 2nd exhaust stage at different tightness conditions of the enclosure.



.*Fig.3. Aerodynamical charakteristic of the tested hood models*

The results acquired during the model tests when the enclosure was closed are shown in Figure 4. They regard the most probable conditions the furnace performance when the amount of gases emitted from the melt is V_k = 40000 m^3/h (under normal conditions).

It appears that at a direct exhaust from the furnace (1st stage) of e.g. 80000 m^3/h, 650000 m^3/h should be exhausted through the 2nd exhaust stage without an efficient hood capture whereas in the case with a hood capture it is enough to exhaust only 450000 m^3/h. When the enclosure is not sealed the output of the exhaust system must be significantly increased e.g. when opening the steeltruck gate one must increase the amount of the exhausted gases from 700000 m^3/h to 1200000 m^3/h.

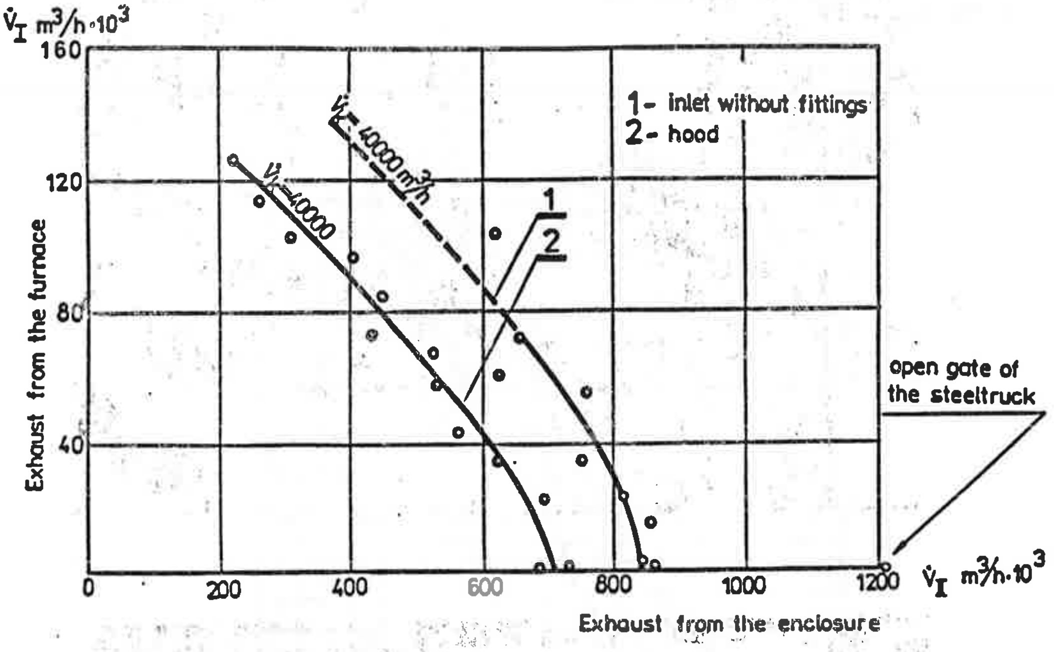


Fig. 4. Required amount of gases exhausted from the enclosure as a function of the amount of the furnace waste gases

The most difficult to overcome is the emission of contaminants at the time when the furnace is being charged while the enclosure is open and the vault is moved aside. The capture of the contaminant emitted during that stage of the process would require the 2nd stage exhaust rate of 1250000 m^3/h. Some examples of the tests visualization for the enclosure with the exhaust hood 2E are shown in Figure 5.

Canopy hood

A trial was made to adapt the canopy hood placed under the steel mill roof (Fig.1 p.3) for the stage of the furnace charging. The canopy hood efficiency was only 40%. Only when the enclosure exhaust capacity was increased to 850000 m^3/h the efficiency of the whole system increased to 80%.

Due to the air motion within the steel mill hall the stream of the contaminants carried out of the enclosure deviated beyond the region of the hood action. It was not capable of effective contaminants capturing.

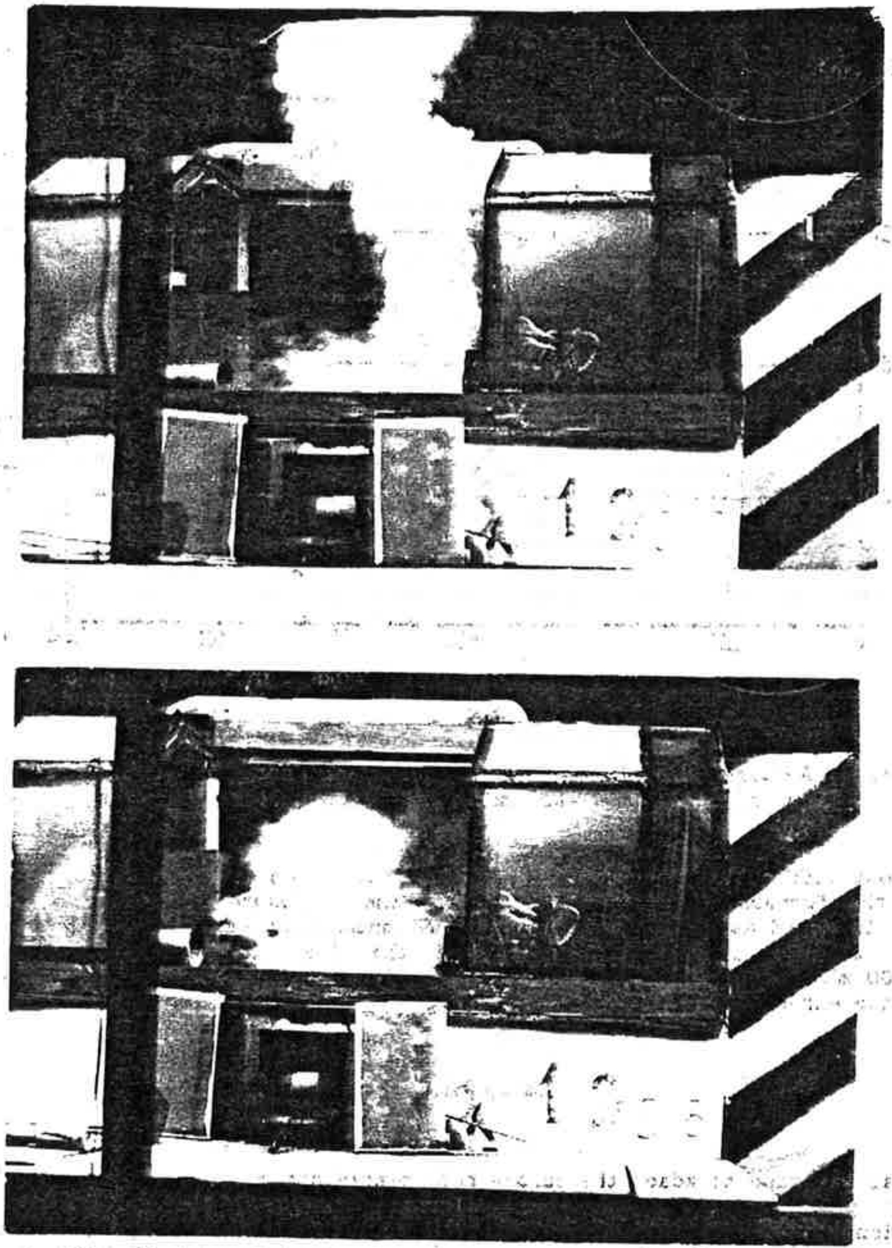


Fig 5. Modelling of the performance enclosure with hood according to the variant 2E while charging the furnace

a. $V_k = 40\ 000\ m^3/h$ b. $V_k = 40\ 000\ m^3/h$

$V_I = 48\ 000\ m^3/h$ $V_I = 48\ 000\ m^3/h$

$V_{II} = 260\ 000\ m^3/h$ $V_{II} = 650\ 000\ m^3/h$

Air motion within the enclosure

Any time when the enclosure is resealed it is necessary to increase significantly the amount of the exhausted gases. Figure 6 shows an exemplary pressure distribution inside the enclosure at different tightening and at determined amounts of gases exhausted directly from the furnace and from the enclosure. The measurements were made in some characteristic regions of the enclosure: in the "hot" region close to the furnace and to the 1st exhaust stage duct (zone A) as well as in the "cool" region at the side of the steeltruck gate (zone B) according to Figure 1.

The observed pressure distributions are the effect of thermal buoyancy forces and the inducing action of the exhaust fans. In result of those actions diagonal upward air flows, through the enclosure to the steeltruck gate occur. When the amounts of gases shown in Figure 4 (curve 2) are exhausted, negative pressure can be observed practically within the whole enclosure (Figure 6, A,B). Only within the zone A at the height above 18.5 m a region of slight overpressure appears as well as a possibility of gases effusion (Figure 6 curves 1 and 2). When the steeltruck gate is open, overpressure occurs already along the whole height of the enclosure in the zone A (curve 3).

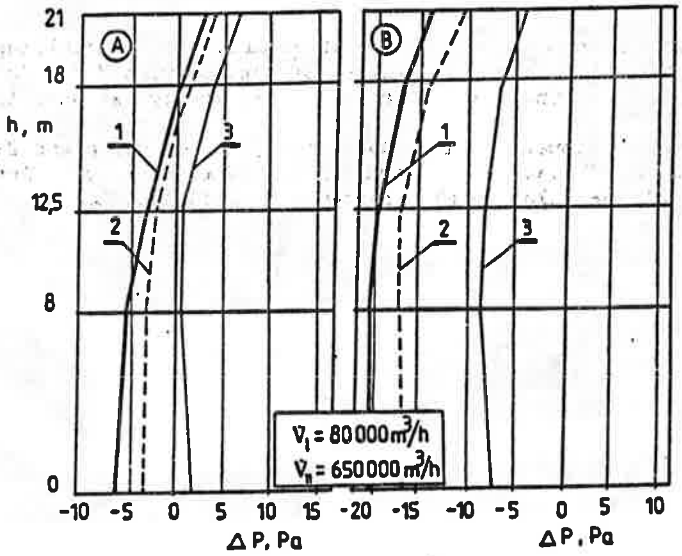


Fig. 6. Pressure distrbution within the enclosure
1 - all gates shut
2 - charging gate open level +8.0 m
3 - steeltruck gate open level ±0.0 m

CONCLUSIONS

Scale model simulation made it possible to analyze aerodynamical aspects of various exploitation conditions of the furnace and of the exhaust system devices with sufficient accuracy. On that basis it was decided not to construct a canopy hood under the steel mill roof since its capture efficiency was low and the investment did not pay. On the other hand, design and exploitation of the existing equipment were modernized taking also into account expected future changes in the technology of steel melting. The suggested solutions proved right. In a difficult case of a large electric arc furnace of the capacity of 140 Mg it was possible to acquire about 95% efficiency of a ventilation exhaust system for fume control.

ACKNOWLEDGMENT

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