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Ecological aspects of the use of lost foam patterns

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Abstract

The paper discusses some aspects of ecology in the use of lost foam patterns for piece production of large castings poured from ferrous alloys under the conditions of Metalodlew SA. Foundry. The technological processes used in the manufacture of castings are related with numerous hazards. Numerous problems requiring prompt solution occur also during the process of foundry mould pouring, to mention only various contaminants, air pollution, noise and other factors harmful to the human health and natural environment. Various technological processes cause strenuous work conditions in foundry shops. Many of the publications that have appeared so far dealing with the problems of environmental protection and hard work conditions in foundries [1, 2, 3, 4, 5, 6, 7, 8, 9] discuss in both general and detailed way problems related with various pollutants, noise and other factors harmful to the human health and natural environment, responsible for hazards faced by foundry workers. Studies carried out by various R&D centres are mainly focussed on the problem of how to reduce the harmful effect of technological processes on the environment through modification of the already existing or development of new ecological and energy-saving materials and technologies.
This paper shows the opportunities and threats resulting from the application of the Lost Foam Process in a foundry, which up to now has been using a more traditional technology.

Keywords: casting, pattern, foamed polystyrene pattern, temperature

1. Introduction

Before the decision is taken to start using the lost foam process for casting manufacture, the type and volume of gas emitted during polystyrene evaporation (pyrolysis) and its effect on the natural environment should be carefully examined.
From own investigations and data given in technical literature [5] it follows that, depending on the temperature of the foamed polystyrene pattern evaporation, changes taking place affect not only the total volume of the emitted gas but also its chemical composition (elements or chemical compounds) and their quantitative content in gas mixture. At lower temperatures, hydrocarbons, such as benzene, toluene, and styrene, are liberated, while at higher temperatures, CO, CO_2, CH_4 and H_2 increase their content. At the same time, an increase of temperature increases the total volume of gas liberated from the evaporating polystyrene pattern. The increasing volume of gas mixture can raise the gas pressure in mould cavity and this, in turn, is the cause of gas inclusions in the melt, first, and in the ready castings, next.

2. Studies of thermal distribution

Studies of thermal distribution [4] were carried out in a furnace within the temperature range of 100÷1200°C under the following conditions:

- without access of air (inert atmosphere);
- with access of air.

First, the products of destruction were absorbed in washers with absorbing solutions, to be analysed next by gas chromatography. Investigations were carried out to determine quantitatively the types of chemical compounds and gases emitted during the pyrolysis of polystyrene.

Tables 1 and 2 show the results of the thermal analysis of polystyrene under the conditions adopted in the investigations, stating also the type of process (with or without the access of air).

Table 1.
The results of thermal analysis without access of air

Constituent	Temperature of measurement	
	1150	1200
Benzene [μg/g]	3363	3063
Toluene [μg/g]	146	122
Xylene [μg/g]	—	—
Styrene [μg/g]	204	188

Table 2.
The results of thermal analysis with access of air

Constituent	Temperature of measurement	
	1150	1200
Benzene [μg/g]	983	977
Toluene [μg/g]	78	62
Styrene [μg/g]	160	140
Carbon monoxide [μg/g]	116800	87688

The investigations carried out have proved that in the case of carbon dioxide atmosphere, the compound emitted in the largest volume was benzene. The content of this gas decreased, but only slightly, with temperature increase from 1150°C to 1200°C. The pyrolitically analysed gases contained also styrene and toluen, although in amounts much smaller, compared with the evolution rate of benzene. Xylene was not detected in gases formed during polystyrene decomposition at any of the applied temperatures.

During thermal decomposition of polystyrene taking place under the access of air, the evolution rate of benzene was lower than in the case of the thermal destruction under carbon dioxide atmosphere. Under these conditions, the evolved gases did not contain any xylene, either. The measured amounts of styrene and toluene were smaller, compared with the content of these compounds in gases evolved during polystyrene decomposition without access of air. In the case of polystyrene destruction with access of air, large amounts of the evolved carbon monoxide were reported.

Figure 1, 2, 3, 4 shows the temperature-related percent content of the main products of polystyrene combustion. Examinations of respective drawing show an interesting effect, which is the amount of gases like benzene and styrene formed at low temperatures (300÷500°C) and of gases like propylene, ethylene and acetylene formed at high temperatures (1000÷1250°C).

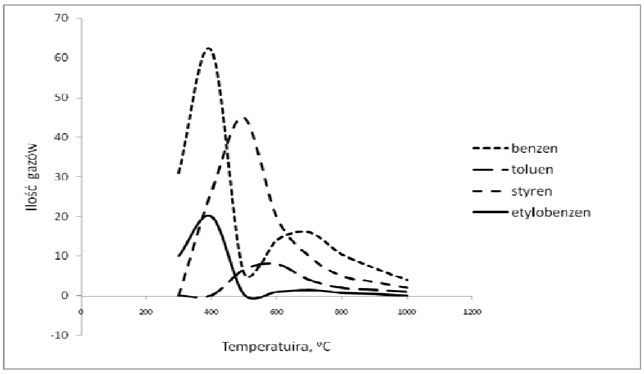

Fig. 1. Gas volume [μg/g] emitted in function of temperature T °C

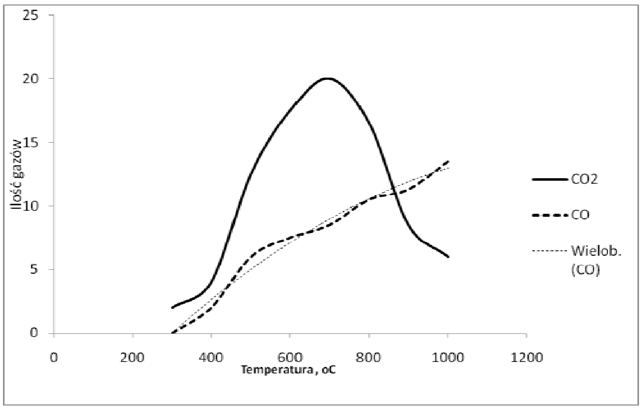

Fig. 2. Gas volume [μg/g] emitted in function of temperature T °C

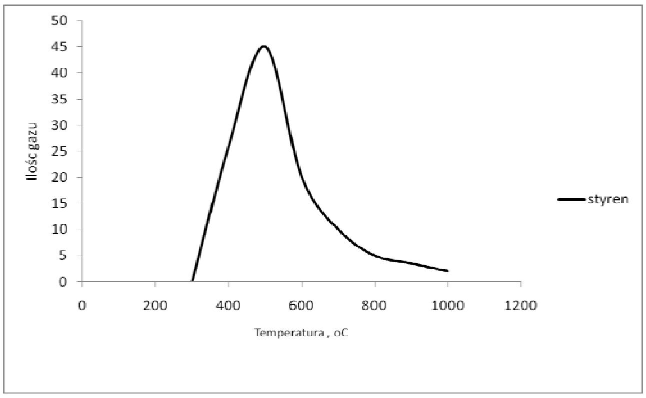

Fig. 3. Styrene volume [μg/g] formed in function of temperature T °C

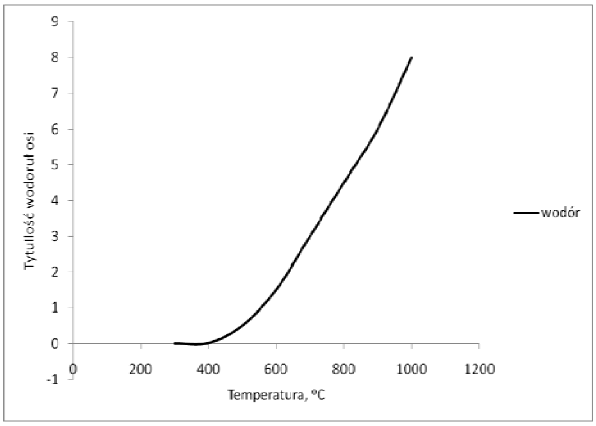

Fig. 4. Hydrogen volume [µg/g] emitted in function of temperature T °C

To eliminate the harmful effect of the substances evolved during the lost foam casting process, it is necessary to ensure in foundry the work conditions complying with the requirements of environmental protection. The conducted studies have aimed at a modification of the chemical composition of polystyrene used in the manufacture of lost foam patterns. The goal is to reduce the volume content of the evolved gas and to eliminate or considerably reduce some gaseous constituents. The next trend in the undertaken studies is related with the development of new materials, capable of satisfying the requirements of physico-chemical, mechanical and technological processes taking place in a foundry mould.

Gas evolution poses more problems when foamed patterns are used in the manufacture of large and heavy castings poured from ferrous alloys. Since patterns are placed in binder-bonded sands, gases formed during pattern destruction should be taken away from mould in a very short time. During this process, the flow of metal depends on a relationship between the pattern destruction parameters and mould properties.

For the sake of comparison, at the foundry of Metalodlew SA., studies were carried out on gas evolution rate from the chemo-setting moulding sands used in the manufacture of large foundry moulds reproduced from foamed polystyrene patterns. Patterns were made from polystyrene of the previously selected physico-chemical and mechanical properties. The adopted scope of studies included the determination of gas volume evolved from mould on pouring it with liquid metal.

Studies also included measurements of the content of carbon monoxide and sulphur dioxide in the atmosphere at the work stand, close at mould and above its level. In parallel, at a test stand in the Foundry Research Institute, the possibility of the occurrence of certain gases in the atmosphere above the mould and in the mould cavity containing the remainders of a polystyrene pattern Tests were carried out with an MSI analyser provided with an electrochemical sensor enabling determination of the gaseous impurities content in the air.

At Metalodlew S.A Foundry, moulds (with foamed polystyrene patterns) were made from sodium silicate-bonded sands hardened with flodur; the sand was prepared in a Bistromix device (self-setting sand of floster type). The investigations conducted on a laboratory stand [1; 2; 3] have proved that sand of this type is the source of the emission of CO, CO_2, H_2, CH_4. On the other hand, no emissions of nitrogen have been observed. A 1g sample of the sand can emit 5 to 6 cm^3 of gas.

The measurements of gas content in the environment, carried out at the stand where castings are poured from iron alloys in the Metalodlew SA.Foundry, included CO and SO_2. The measurements were taken with a probe placed above the mould poured with molten metal and on the mould side. The time of the continuous measurement was 60 minutes. The measurement covered changes in the examined gas content in time. The content of CO and SO_2 was measured at the mould pouring stand, immediately after pouring the moulds of approximately 3500 x 3500 x 2000 mm and 2000 x 2000 x 1500 mm overall dimensions; the measurements were taken at a level above the mould and on the mould side. Immediately after pouring, ,when the emitted gases were afterburning in the air, the average CO content was 146 mg/m^3, the temperature of the emitted gases was 94°C. As soon as the temperature of the solidifying and cooling casting started decreasing and the process of gas afterburning in the air was completed, the content of CO increased. During measurements of CO content in the air it was observed that the emitted gas was not increasing its volume any longer, but the concentration was changing due to the process of gas afterburning completed above the mould level and temperature of the emitted gas dropping down.

When the gas temperature was 36 °C, the need for an extensive air exchange at the mould pouring stand was observed.

No SO_2 was found in the air during the test. Tests carried out by the Foundry Research Institute indicated the presence of CO in the air, but its content did not exceed TLV-STEL and was comprised in the range of 95 to 141 mg/m^3, no presence of SO_2 in the air was traced.

Note

TLV – threshold limit value– the content of CO in the air during work shift should not exceed 30 mg/m^3,

TLV-STEL – threshold limit value – short-term exposure limit– the content of CO in the air during work shift should not exceed 180 mg/m^3 and total gas exposure time should not be longer than 30 minutes.

3. Conclusions

The carried out tests and investigations aimed at the development of guidelines for the manufacture of large castings made in piece production from the lost evaporative patterns. For the execution of this task, properties of materials used in the technology of lost foam patterns were examined. The article presents the results obtained in the first part of the investigations (up to 400°C), during which the gas volume emitted by the examined test pattern material was determined.

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