Selected aspects of the piece production of iron alloy castings in terms of their environmental impact

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Abstract

Problems of environmental protection are nowadays one of the top priorities in a policy programme adopted by the European Community. Reducing the negative impact of the domestic foundry industry on environment should result from complex and long-lasting activities, targeted not only at modernisation of the dust collecting units, but also at searches and implementation of alternative, innovative and more pro-ecology oriented means and techniques of casting manufacture. Reducing to minimum the level of emissions escaping to the environment should be considered at all stages of the casting manufacturing process. In this study, the discussion was restricted to the process of the manufacture of moulds and cores for piece production of the heavy castings. The environmental impact of the technology of making moulds and cores in sands with chemical binders, used most often in piece production of large castings poured from iron alloys, was highlighted. As an alternative technology of mould preparation for the piece production of castings, the ecological and economic aspects of the full mould process were presented.

Keywords: casting of iron alloys, foamed polystyrene patterns, technology of evaporative patterns, piece production of castings, environmental impact

1. Introduction

Joint environmental policy is one of the priorities and the fastest growing area for cooperation among the European Union Member States. Actions regarding the need for harmonisation of respective legislation have already been defined in the Treaty of Maastricht. Therefore, negotiations on the Polish accession to the European Union were, among others, associated with the adjustment of legislation on environmental protection to the requirements operating currently within the Community. Since 2001, specific requirements in this respect have been gradually introduced to the existing laws and regulations or were implemented as new legal regulations. For some of the requirements resulting directly from the EU Council Directives, Poland has already managed to negotiate the transition periods that allow a delay in introduction of the directives to the national legislation system.

The basic requirement for environmental protection related with correct functioning of a foundry shop is to meet the minimum requirements for the application of Best Available Techniques (BAT) specified in reference documents for the foundry industry. In addition to meeting the requirements concerning the emission levels from individual technological
processes, the requirements to meet the minimum criteria for best available techniques include areas such as the rational use of energy utilities, raw materials and water, reclamation (recovery) of waste and recycling of raw materials, application of appropriate techniques for the storage, transport and distribution of materials, reducing the harmful effect on environment of the sources of fugitive emissions [4].

Taking into account the existing and future legal regulations to implement, the basic, in addition to economic and technological, aspect in the choice of a specific foundry manufacturing technique is the size and nature of the environmental impact of this technique. This problem should be considered at all stages of the casting manufacturing process. In this study, the investigations were confined only to the process of mould and core manufacture for heavy castings made in piece production.

2. Typical mould and core manufacturing techniques for heavy castings made in piece production

In the case of the manufacture of large castings poured from iron alloys in piece production, the typical method used most commonly is that of disposable chemically bonded sand moulds. The process of making these moulds is the source of organised and fugitive emission of impurities to the atmospheric air, mainly of dust and gas in the form of organic and inorganic compounds.

Table 1. Environmental impact of mould and core making processes using chemical binders most popular in the piece production of heavy castings [5]

<table>
<thead>
<tr>
<th>Name of technology and binding components</th>
<th>Hardening method</th>
<th>Emissions to atmosphere during sand mixing and hardening</th>
<th>Emissions to atmosphere during mould pouring</th>
</tr>
</thead>
<tbody>
<tr>
<td>Self-setting sands with ester-hardened alkaline resin Phenol-formaldehyde alkaline resins</td>
<td>Ester-hardened</td>
<td>Formaldehyde Ethers Phenol</td>
<td>Solid particles of CO, CO₂, NO₂ Formaldehyde Phenol, cresol and xylenoles Aromatic compounds</td>
</tr>
<tr>
<td>Self-setting sands with urethane binder</td>
<td>Pyridine derivatives</td>
<td>Phenol Formaldehyde</td>
<td>Amine</td>
</tr>
<tr>
<td>Sands with furan resin Resin containing phenol, urea, furfuryl alcohol, formaldehyde</td>
<td>Acid-hardened</td>
<td>Formaldehyde Phenol Furfuryl alcohol Acid vapours</td>
<td>Hydrogen sulphide Solid particles of CO, CO₂, SO₂, NO₂ Phenol, cresol and xylenoles Formaldehyde Aromatic compounds Sulphur dioxide Ammonia Aniline</td>
</tr>
<tr>
<td>Sands with sodium silicate Hydrated sodium silicate</td>
<td>Ester-hardened</td>
<td>Ethers</td>
<td>CO₂, CO₃, Alkanes Acetone Acetic acid Acrolein</td>
</tr>
</tbody>
</table>

The type, volume and character of emissions mainly depend on factors such as the type of moulding/core sand (with organic or inorganic binders), the method by which this sand is prepared (in mixers, mixer-slingers, etc.), the type and technique of application of protective coatings (alcohol- or water-based; applied with brush, by spraying, or by pouring). The factor that determines the harmful impact on the environment of the process of sand preparation and moulding in disposable moulds is the type of binder and hardener used in these sands as well as the type of protective coating applied on moulds. All these materials contain various volatile substances added as a basic compound or as a solvent. The said substances mixed with the sand react with each other, and their excess as well as the volatile reagents escape and form an emission. Considering properties of the moulding materials, the emitted contaminants are mainly dust and volatile organic compounds. Table 1 gives characteristics of the moulding sands used in foundries for the piece production of large iron alloy castings in terms of the type of the emitted pollutants. From data rendered available by the domestic foundries using sand mould technology for the piece production of large castings it follows that foundries collect the waste gas and dust and reduce the level of dust emissions mainly at the stage of sand drying, handling, preparation and reclamation, but the level of pollutants present in the sand remains unchanged. Neither is collected and
reduced the volume of dust formed in the mould pouring process. When moulds are poured with molten metal, due to the effect of high temperature and reducing atmosphere, the chemical sand components are undergoing thermal decomposition and various gaseous chemical compounds are formed. When moulds are left to cool down, these compounds in the form of gases, vapours and fumes are free to escape to the atmosphere. Because of physico-chemical transformations of the sand constituents, the process of mould pouring and cooling is the source of organised and fugitive emissions to the atmosphere of harmful impurities in the form of dust and gas [4,5].

3. Methods to reduce emissions during moulding, pouring and cooling of disposable moulds

Methods used by domestic foundries making castings in piece production to reduce the level of dust and gas emissions include mainly measures such as reducing the content of binder and hardener in the chemically bonded sands, application of two-layer moulds where the backing sand has a reduced amount of binder, control of the mould preparation system (process automation), control of sand temperature and maintaining it at a level of 15-25°C. Preventing emissions in the process of mould and core manufacture can rely upon measures described above but it can also rely on the use of alternative methods of mould and core manufacture where binders and hardeners are needed no longer. One of such technologies is the full mould process (the use of evaporative patterns). In this technology, patterns are made from foamed polystyrene of the density ranging from 16 to 20 g/dm³ or from methyl polymetacrylate of 25 g/dm³ density [5]. In the case of piece production of very heavy castings, patterns are made from the mechanically processed and glued together elements cut out from the plates or blocks of foamed polystyrene material. Moulding uses pure sand without or with a reduced level (respective of the traditional moulding sand technology) of the chemical binding materials [1]. During pattern evaporation, the following chemical compounds are emitted: hydrogen, methane, ethylene, acetylene, propylene, propane, toluene, styrene and other hydrocarbons. Their content varies and depends on mould pouring temperature. When single castings are made from iron alloys and the mould pouring temperature is comprised in the range of 1350 °C – 1550°C, the emissions contain (mass %) up to 70 % carbon, 13 – 15 % styrene, toluene, benzole and 15 – 13 % of other gaseous products. Studies have confirmed that emission rates determined by the mass flow of organic carbon in function of time, counted since the moment of mould pouring with liquid grey iron until approximately 2 hours, are similar in the full mould process and in the sand moulds with furfuryl (furan resin) binder in the sand : casting ratio = 1,9 to 1,0. The emission of total organic carbon is nearly equal in both mould types during the whole cooling time. In the case of moulds hardened with alkaline resin and acid hardener, the cycle of emissions is similar for benzene, ethylbenzene, phenol and furfuryl alcohol, while in the case of full mould process, the maximum level of styrene and toluene emissions occurs in the time of 15 - 30 minutes since the moment of mould pouring. This is due to the initial condensation of particles of these compounds on mould parts of lower temperature. Since full mould process uses no binder, the volume of waste as well as the overall volume of emissions is lower compared to moulds made with the organic binders. At the stage of mould preparation there is only an insignificant emission of silica dust which results from the sand handling, compaction and pouring of molten metal over the pattern. In the case of heavy single castings requiring moulds of high strength, it is recommended to use sands characterised by high rigidity and permeability as well as a relatively low level of gas emissions, such as e.g. sands with sodium silicate-based binders hardened with liquid esters [2,3].

The technology of evaporative polystyrene patterns enables manufacture of both small and medium-size castings made in lot production and large castings made in piece production, characterised by high dimensional accuracy and good quality. It also enables the use of smaller risers and gating systems. The full mould process is particularly suitable for the piece production of intricate castings. Since it is no longer necessary to use patternmaker’s draft and other technological allowances (pattern is not removed from mould before pouring), the cost of further fettling of the casting (machining, time of finishing treatment) is, depending on the casting type, lower by about 10-15% compared to the casting made by a traditional technique of moulding from wooden patterns. In the case of piece production of castings, an important factor reducing the manufacturing cost is lower labour consumption and shorter pattern-making time compared to classical wooden patterns. In numerous cases of castings characterised by intricate shapes, the cost of making pattern assembly from foamed polystyrene is only 30% of the cost of making the same pattern in wood. Savings thus obtained result mainly from the elimination of pattern coring operation and easy processing, shaping and gluing of the foamed polystyrene pattern compared to wooden patterns.

![Fig. 1. Schematic diagram of the foamed polystyrene pattern evaporation process](image)

However, the manufacture of large unit castings from iron alloys using the technology of evaporative polystyrene patterns requires special discipline in both technology regime and production running. This refers mainly to castings where requirements concerning surface quality are high and subjected to technical acceptance with magnetic powder flaw detection system. In such
The main problems which have not been fully solved yet include: methods for compaction of large moulds, choice of the sand and protective coating that would guarantee the necessary mould strength and permeability allowing free escape of gases formed during the evaporation of large foamed polystyrene patterns. A very important aspect requiring further studies is determination of the kinetics of the foamed polystyrene pattern decomposition, combined with gas evolution. The volume of gases collecting above the surface of the flowing metal (Fig. 1) has, together with the sand mould permeability, an important effect on gas pressure inside the mould. The pressure of gas formed as a result of pattern evaporation is higher than the pressure of gas formed in a traditional mould and it obviously must affect the surface of the flowing metal. The increase of gas pressure above the metallostatic pressure of the flowing metal can arrest totally the metal flow and result in the formation of misruns, or blowholes, or shrinkage porosities.

4. Summary

Full mould process was invented over 30 years ago, but its commercial application was rather slow. In spite of numerous problems related with its practical use, during the past 10-15 years, this technology has been definitely gaining popularity, especially in the case of mass production of castings for the automotive industry. This technology can be used in production of very large castings, e.g. parts of machine tools, presses and similar castings poured from iron and steel. By this technology were made castings weighing up to 50 tons and with the wall cross-sections from several to several hundred millimetres [5]. The application of full mould process in the manufacture of prototype castings and large unit pieces poured from iron alloys is the source of considerable savings in manufacturing costs and shortening of lead times. Therefore it seems advisable to continue studies on individual parameters influencing the conditions of the piece production of castings from iron alloys using the evaporative foamed polystyrene patterns.

References

[6] Dokumentacja projektu celowego Nr 6ZR9 2007C/06941 pn. „Opracowanie technologii i unechomologii ekologicznej produkcji ciężkich odlewów ze stopów żelaza z wykorzystaniem modeli zgazowywanych”.

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