10th International Research/Expert Conference
"Trends in the Development of Machinery and Associated Technology"
TMT 2006, Barcelona-Lloret de Mar, Spain, 11-15 September, 2006

# ANALYSIS OF THE SUSTAINABILITY OF A FOUNDRY (SAND CASTING OF NODULAR IRON)

**Irene Buj Corral, Lluís Costa Herrero, Cayetano Sierra Alcolea**
**Department of Mechanical Engineering. Universitat Politècnica de Catalunya (UPC)**
**Spain**

## ABSTRACT

*Casting is one of the most versatile manufacturing processes, given that it allows the manufacturing of complex geometry parts of different dimensions and made of several materials like cast iron, steel, brass or aluminium among others. Usually, casting is analyzed from the standpoint of the particularities of the process as well as from the characteristics of the parts that are obtained. Nevertheless, manufacturing implies the use of resources like materials and energy, with the production of the desired part but also with the generation of wastes and atmospheric emissions. In this work, a study about the necessary requirements for the sustainability of a foundry is presented. Also, the main wastes generated at the different phases of the process are analyzed (used sand, rejected metallic parts, grinding powder, etc.) as well as the way to minimize, reuse or recover those wastes according to the concept of "clean production". It should be noticed that environmental rules are becoming more restrictive and therefore waste management costs are increasing.*

**Keywords:** sand casting, foundry, clean production, waste management.

## 1. INTRODUCTION

Nodular graphite cast iron is a kind of cast iron which contains carbon as small carbon nodules. It is obtained by adding a magnesium alloy (copper-magnesium, nickel-magnesium or silicon-magnesium-caesium) to the molten cast iron. The mechanical properties of nodular iron are very similar to those of iron and it may be subjected to quench [1]. It is used for manufacturing machines with incorporated hardened guides as well as car components: connecting rods, barrels, yokes, exhaust collectors, etc.

The main stages of a nodular iron casting process are as follows: Initially, first smelting of cast iron, cast iron scrap, galvanized steel briquettes from body stampings and iron alloys are smelted in order to adjust the required composition of the metal. Calcareous stone is also added so to convert impurities into slag. If nodular iron is used, a magnesium alloy is necessary. Different kilns are used, like electric induction furnaces or alternatively cupola furnaces fed with coke. In a second stage, a sand mould is obtained by mixing siliceous sand with clay (bentonite), water and coal blacking and compacting the mixture around a model or reproduction of the part. At the same time, cores are manufactured with siliceous sand mixed with an organic compound such as linseed oil or thermoset resins. The cores are usually covered by a painting layer so to reduce surface roughness. The smelted alloy is transported from the furnace with a casting ladle and poured into the moulds, where the cores have been previously placed. Smoke is generated because of combustion of coal and organic additives of the sand, and water also evaporates. An important degradation of the sand takes place because of thermal impact between the metal and the mould. Consequently, some sand grains break and bentonite becomes partially inactivated. Once the mould is full, it advances automatically towards a grating as it gradually cools down. Afterwards, the boxes are opened and sand is removed from the metallic parts by means of a pneumatic or mechanical vibration system. Later on, the tedges and dead heads removed using presses or pneumatic hammers, and the parts are subjected to shot peening in order to clean them. The dust from the shot peening cab containing fine particles of silica and metal is sucked in. At the end, the surface straights of the part are smoothed with portable grinding wheels.

Usually, at this area there is also a suction system with filters that retain metallic particles mixed with abrasives. The parts are inspected by different methods like visual inspection, hitting with a hammer or ultrasound inspection.
The main inputs of material and energy as well as the outputs (products and wastes) of a nodular iron foundry are detailed next:

INPUTS
- New sand to be added to the one of the boxes.
- Clay (bentonite) for agglomerating the sand of the boxes.
- Graphite dust.
- Sand for the cores.
- Resin (for example phenol-formaldehyde) or linseed oil for agglomerating the sand of the cores.
- Catalizer to harden the resin.
- Paint to cover the cores.
- Metals and alloys: galvanized steel briquettes, iron alloys, steel scrap and rejected nodular iron parts, magnesium alloy.
- Energy (electricity, coke or combusting gases, depending on furnace).
- Different fluids: air and water (refrigeration of kilns and cooling down and moistening of mould).

OUTPUTS
- Finished nodular iron parts.
- Smoke from combustion of the organic binder or from casting carbon in the casting stage.
- Particles. The most important are: fine aggregates from degradation of sand, from treatment of used sands or from peening (dry filters) and also sludges from wet suction systems.
- Non reusable earths. The most degraded earths cannot be incorporated to the productive process.
- Metallic wastes. On the one hand some faulty parts are rejected during verification operations. On the other hands, tedges and dead heads become wastes at the end of the process.
- Other solid wastes: slags and refractory material from the walls of the furnaces, grinding dust, remainder of additives and containers with raw material, oil and municipal solid wastes.
- Sanitary water and water from wet filters, suction system of sand preparation and suction towers.

## 2. CLEAN PRODUCTION MEASURES IN A NODULAR IRON FOUNDRY

The United Nations have defined clean production as «the continuated use of products and industrial processes that imply prevention of air, water and soil pollution, the source reduction of wastes and the minimization of risks for human people and the environment». For producteive processes, the clean production results from a combination of conservation of raw materials, water and energy; elimination of toxic raw materials and reduction of the quantity and toxicity of all source emissions and wastes during the productive processes [2]. In order to promote a cleaner production in the industry, the U.S. Environmental Protection Agency introduced a scheme regarding actions to be taken in order to prevent environmental pollution, as detailed at figure 1 [3]:

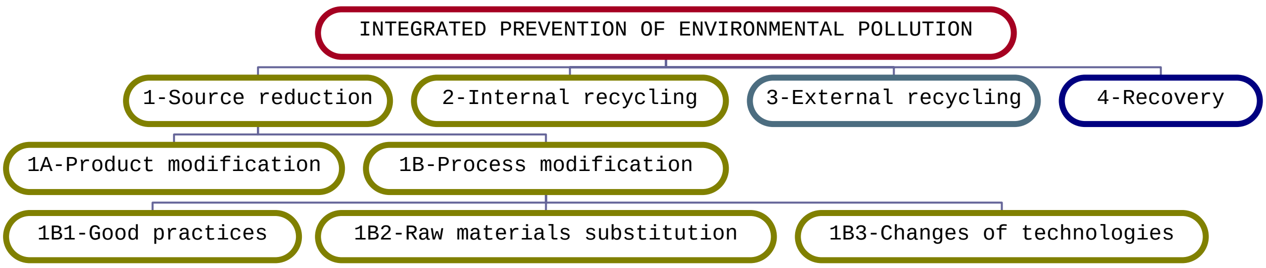


*Figure 1. Scheme of the integrated prevention of environmental pollution*

The main actions that may be taken in order to achive an integrated prevention of environmental pollution of a nodular foundry are listed in the following lines (extended from [4] and [5]):
1A-PRODUCT MODIFICATION

- Design of the moulds with the minimum volume of tedges and dead heads, in order to lose the minimum amount of metal in each part.

1B1-PROCESS MODIFICATION: GOOD PRACTICES.
- Good management of materials in stock so to reduce the amounts of hazardous substances used.
- Checking of the operation and maintenance procedures from reception of raw materials to storing of final product, so that leaking and losses are detected. .

1B2- PROCESS MODIFICATION: MATERIALS SUBSTITUTION.
- Preferably, use of briquettes of galvanized steel from faulty car body stampings so to homogenize the composition of the metal alloy and to allow the external recovery of the fine aggregates.
- Homogeneization of the types of sand as well as the types of binder used for manufacturing the moulds and cores.

1B3- PROCESS MODIFICATION: CHANGES OF TECHNOLOGIES.
- Implementation of an air intake system and dry filter treatment for the furnace emissions.
- Use of a disposal system for the fine aggregates by means of air intake, cyclon separator and hopper which allow the storage in bags and subsequent external recycling.

2- INTERNAL RECYCLING.
- Incorporation of the faulty nodular iron parts, as well as tedges and dead heads to the productive process, by smelting in the furnace. Incorporation of metal particles from shot peening.
- Use of a closed circuit for the sand, which is permanently renewed by additon of new sand and elimination of the fine aggregates by pneumatic removal.

3- EXTERNAL RECYCLING
- Use of the exhausted moulding earths as raw material for the cement industry, brick manufacturing industry, as a base material for roads or as structural material for composting the organic fraction of municipal solid wastes.

4- RECOVERY
- Thermal regeneration of the earths from chemical and core moulding. Some of the systems used are: turbulent layer devices and rotary furnaces. The temperatures range between 700 and 900 ºC.
- Mechanical regeneration of the earths containing clays as a binder. The coverings are separated from the sands by means of friction or hits, flollowed by sifting (air flow in pneumatic facilities for sand-blasting; use of friction drums filled with sand; use of a cleaning machine of centrifugal wheel or a fluidized bed cleaning machine).
- Recovery of the zinc from the fine powder from the fusion furnaces filter system.

## 3. WASTES GENERATED BY A FOUNDRY AND THEIR MANAGEMENT

A nodular iron foundry was studied with an annual production of 20000 tonnes (2004). The amounts of the main raw materials used by the company in one year are detailed at table 1:

*Table 1. Amounts of raw materials consumed by the studied company every year (2004)*

| RAW MATERIAL | ANNUAL AMOUNT (Metric Tonnes) |
|---|---|
| New sand | 4238 |
| Bentonite | 2591 |
| Refractory materials | 177 |
| Iron alloys | 1738 |
| Coal | 1231 |
| Iron scrap | 15829 |

The main solid wastes that were generated by the company the same year and were managed by external companies are shown at table 2:

*Table 2. Amounts of solid wastes generated by the studied company and managed by external companies every year (2004).*

| WASTE | MANAGEMENT | ANNUAL AMOUNT (Metric Tonnes) | COST (Eur/Metric Tonne) |
|---|---|---|---|
| Powder from smelting furnace (containing Zn) | Recovery | 480 | - 48 (income) |
| Used earths | External recycling (cement factory) | 9481 | 8 |
| Used earths | Landfill | 1631 | 47 |
| Paper / Cardboard | External recycling (paper manufacturing) | 23 | 0 |
| Plastic packing | External recycling (packing manufacturing) | 55 | 0 |
| Slag | External recycling (road base material) | 782 | 8 |
| Slag | Landfill | 464 | 47 |
| Wood | External recycling (wood industry) | 93 | 0 |

The total cost of external management of the solid wastes generated by the studied company is 180569 Eur per year, while the income due to the zinc recovery is 23040 Eur per year. Then, the cost for the external management of wastes is 157529 Eur every year (2004).
Regarding atmospheric emissions, at the studied company there are 15 emission focuses with suction and filter systems, and the levels of particles are under limits of regulations. The focuses are: 2 suction systems for chipped edges, 4 suction systems for shot peening, 5 hose filters at the cooling area for moulded parts and 4 induction furnaces.
A total volume of 40000 $m^3$ of water is consumed every year by the company: 25 % corresponds to sanitary water and the remainder is either evaporated during process or used for wet filters, which generate a liquid waste whose concentration of different contaminants remains below the limits.

## 4. REFERENCES


[1] Vivancos, J., Argilés, R.; Pardo, A.; Sierra, A. (1997). Tecnologías de Fabricación. Tomo II. Procesos de fusión y moldeo y de deformación. (Volumen Texto y Volumen Figuras). CPDA - ETSEIB – UPC.

[2] (2001). Cleaner Production - Key Elements, DTIE (Division of Technology, Industry and Economics), UNEP (United Nations Environment Programme). http://www.uneptie.org/pc/cp/understanding_cp/home.htm

[3] U.S. Environmental Protection Agency (1990). EPA/530-SW-90-044. Waste Minimization. Environmental Quality with Economic Benefits.

[4] (1996) Manual de Minimización, Tratamiento y Disposición. Concepto de manejo de residuos peligrosos e industriales para el giro de la fundición. Comisión Ambiental Metropolitana México DF en colaboración con Sociedad Alemana de Cooperación Técnica TÜV ARGE-MEX.

[5] (1998). Libro blanco para la minimización de residuos y emisiones. Arenas de moldeo en fundiciones férreas. Sociedad Pública de Gestión Ambiental, IHOBE, S.A. Departamento de Ordenación del Territorio, Vivienda y Medio Ambiente del Gobierno Vasco.