

## Methodology for appreciation the manufacturing castings from perspective of circular economy

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**Abstract.** This paper presents a methodology for studying the trends toward developing circular economy, comprising the following steps: description the field analyzed statistically and technological, establishing assessment criteria, establishing the event which will be analyzed and its description and evaluation of the event from the perspective of circular economy. The case study was designed to the manufacture castings through the analysis, after the methodology proposed, by the work of the 71-th World Foundry Congress in 2014 from Bilbao. The conclusion of this approach shows us that the manufacture castings through the trends expressed fall in the principles of circular economy. At the level of resources needed for the manufacturing process of castings - specifically immaterial resources, materials and energy, are analyzed at all levels, specific phases, namely: 1. Information analysis specific for the field; 2. Analysis preparation in terms of manufacturing technology and technological infrastructure available; 3. Analysis of manufacturing castings; 4. Analysis of the results of the manufacturing process; 5. Analysis of exploitation and disposal at end of life cycle; 6. Analysis of other phases that contribute to achieving castings; 7. Analysis of the entire process in terms of respecting the environment and sustainable development. The analysis method on a field belonging to the specific requirements of circular economy is made by analyzing a global event. This comprises the following stages: Establish specific criteria for the analyzed domain in relation to the circular economy; Specifying event works falling within the criteria set, which will be analyzed, and justification for selection.

### 1. Considerations and motivations of thematic and methodological approach

Circular economy is considered, in the scientific community, political, economic and administrative, as a model of industrial reconstruction that its principles are taken at our sustainability management systems, in order to ensure operation in the economic and social constraints by setting circuit materials and energy in a technological process. At the same time, variant circular pattern appears as a lever for industrial competitiveness, involving, inter alia, the regulatory capacity for dialogue, communication and development of innovation processes. Despite technological improvements that contribute to a better use of material resources and energy, their consumption and waste generation increased steadily worldwide. Therefore, the circular economy can not be understood outside of this context and is a response to the phenomenon of depletion, wanting, while being an alternative model of development, combining economic growth with a vision needed on term sustainability long. In this way, linear development model is replaced with circular pattern.



Selecting this topic, in the industrial production is justified by the following generalized observations:

- Circular economy is seen as a lever for economic growth by alloying with the ecological and economic ones;
- Circular economy, acting within the perimeter of limited resources, contribute, through specific methods upper and transform them effectively;
- Regulatory framework addresses the circular economy society actors for their success in economic and social activities;
- Quantitative targets specific circular economy, varies according to the targets for recycling and reducing waste disposal;
- Regulatory framework should include the use of material flows macro indicator;
- The existence of public policy instruments that support circular economy, in particular those reported production, purchase and consumption.

Considering the specific manufacture castings to be a major consumer of energy and material resources, it is estimated that the principles of circular economy are required ensuring the development of production in the current cast.

The work presents a method to evaluate the trends towards a circular economy to manufacture castings. In a brief speech, the proposed method has the following steps: description field studied in statistical and technological establish evaluation criteria, setting event which will be analyzed in terms of economy and evaluation of the event from the perspective of circular economy, along with the summary findings of the study on membership trends of circular economy. In the case study analysis that the prospects for production of castings in terms of circular economy, especially global event is the last World Conference of Foundry- 2014 by which the assessment is proposed.

## 2. Description of castings in statistical production and technology

To justify the importance of addressing the production of castings from the perspective of circular economy, are presented in the following, some data on production and consumption dynamics justifying its important material and energy globally. The global production of castings, as one of the 47 - Fourth Report of world production ("47th Census of World Casting Production" - Modern Casting December 2013 - table 1) was in the year 2012 100 834 681 tons, of which 72,438,512 tons of iron castings (weighting 71.83%), 11,299,044 tons of steel castings (11.2% share) and 17,096,125 tons of castings in ferrous alloys (weighting 16.95%).

The analysis phase of the manufacturing process of castings from the point of view of economy circulation is presented in table 1, where they are divided into stages and the stages of the work.

The measures taken are presented in terms of circular economy to the quality in terms of energy and material consumption and minimize negative impacts on the environment and health.

**Table 1.** The analysis phase of the manufacturing process of castings from the point of view of circular economy

Nr.	Phase process	Phase step process	Phase activities
1	1. Analysis of domain-specific information;;	1.1. market analysis	1.1.1. global macroeconomic stability analysis
			1.1.2. analyze developments in raw material costs
			1.1.3. analysis of the evolution of energy costs
			1.1.4. analyze developments beneficiaries of casting pieces
		1.2. analysis of regulations affecting the production of castings	1.2.1. analysis of raw material consumption regulations
			1.2.2. analysis of energy resources management development
			1.2.3. analysis of issues environmental regulations (management of pollutants, water, soil waste, etc)

			1.2.4. analysis of employment regulations and human resource management
			1.2.5. specific spatial regulation analysis and land development
			1.2.6. analysis of fiscal regulations and eco-taxis
			1.2.7. analysis of circuits specific financial regulations
			1.2.8. analysis of financial instruments regulations and policy enforcement
		1.3.analysis of development processes and technological infrastructure	1.3.1. making processes analysis
			1.3.2. Analysis of realization of mould processes
			1.3.3. analysis of the casting process
			1.3.4. analyze the process of cleaning and finishing
			1.3.5. heat treatment process analysis
			1.3.6. process analysis and surface coating paint castings
			1.3.7. analysis and processing activities edging castings
			1.3.8. analysis of the preparation for shipment and delivery
2	Manufacturing preparation .Analysis of point	2.1. constructive concept analysis	2.1.1. constructive database management functionalities required in conjunction with historical typology and technology of casting alloys
			2.1.2. management of traditional instruments establishing constructive forms
			2.1.3. management tools for computer aided design
			2.1.4. global information management on constructive potential coverage of functional needs
		2.2. analysis of technological design	2.2.1. general analysis of casting technology depending on the nature of the alloy, such as technology and construction features of the functionalities required (wall thickness, overall dimensions and differences dimensional to be insured)
			2.2.2 power system analysis and optimization
			2.2.3. solidification by correlation analysis and optimization feeder system, the cooling of constructive typologies designed
			2.2.4. analysis of the cooling process and design optimization from the point of view of stresses which are formed in the casting
			2.2.5. optimization of the technological constructivism alloy composition, the casting characteristics of the shape and conditions of casting
		2.3. technological preparation of production analysis	2.3.1. selection, analysis and optimization of process flow steps
			2.3.2. choice or imposition technological infrastructure needed for the process flow steps
			2.3.3. design and implementation models, forms, devices

			and process flow steps
3	Analysis of manufacturing casting pieces	3.1. direct activities	3.1.1. flow forming mixtures
			3.1.2. development alloys flow
			3.1.3. actual flow casting
			3.1.4. flow finishing of casting pieces
			3.1.5. flow of processing and protection of the casting pieces
			3.1.6. flow exhaust and dust extraction activities
			3.1.7. other streams present in the direct production process
		3.2 indirect activities	3.2.1 flow transport and handling of materials entering into production
			3.2.2. use of equipment and material flow protection
			3.2.3. necessary to ensure the technological process flow utilities
			3.2.4. maintenance flow assurance activities of technological equipment
			3.2.5. flow current activities and general cleaning technology
			3.2.6. flow activities integrated and sustainable waste management and other similar productive household
			3.2.7. other indirect flows
4	Analysis of the results of the manufacturing process	4.1. step analysis useful part process manufacturing – castings delivered to beneficiaries	4.1.1. useful part is delivered directly
			4.1.2. useful part is rectified before being delivered
		4.2. part cash resulting from the manufacturing process	4.2. . the recycled part
			4.2.2. converted the by-product part
			4.2.3. converted from waste part
		5	Analysis of exploitation and disposal at end of life
5.1.2. developing technologies reconditioning of the casting pieces			
5.1.3. development alloys typing parts and castings to ensure interchangeability and linking overall constructive on this criterion			
5.2. recycling of the used pieces	5.2.1. establishment of collection systems based on flow assurance criteria ensuring recycling		
	5.2.2. development of techniques for preparing materials recycling		
	5.2.3. market promotion of recycled materials for competitive production of castings		
5.3. waste management	5.3.1. charging heredity material management		

			5.3.2. application of the principles of extended producer responsibility in relation of casting pieces
			5.3.3. management of historical industrial dumps and landfills specific manufacturing processes of the casting pieces
6	Analysis of other phases contributing to the cast pieces	6.1. analyze production and distribution of the utilities	6.1.1. analysis of water resources
			6.1.2. analysis of energy resources
			6.1.3. analysis of production and distribution of compressed air
			6.1.4. analysis of production and distribution of other utilities
		6.2. analysis of other phases	6.2.1. analysis of maintenance activities
			6.2.2. analysis of transport activities
			6.2.3. analyze storage and insurance activities logistics
			6.2.4. analysis cleaning activities
			6.2.5. the analysis of other types of activities
		7	Analysis of the entire process in terms of respecting the environment and sustainable development
7.1.2. water pollution.			
7.1.3. soil pollution			
7.2. quantification of specific consumption per unit of product materials	7.2.1. new iron		
	7.2.2. old iron		
	7.2.3. recycled material		
	7.2.4. ferroalloys		
	7.2.5. fluxes		
	7.2.6. masonry material		
	7.2.7. sand casting		
	7.2.8. binder		
	7.2.9. timber		
	7.2.10. SDV		
7.3. specific energy consumption per unit of product	7.3.1. electrical energy		
	7.3.2. methane gas		
	7.3.3. recovered energy sources		
	7.3.4. secondary energy sources delivered to other users to be specialized according to the specific technological process		
7.4. other consumption per unit of product			
7.5. waste generated per unit of product	7.4.1. waste generated at the planning stage		
	7.4.2. waste generated during the execution of moulds		
	7.4.3. waste generated during casting		

		7.4.4. waste generated during cleaning and finishing
		7.4.5. waste generated during heat treatment
		7.4.6. waste generated during dyeing and surface coating castings
		7.4.7. waste generated during the edging and processing
		7.4.8. runoff in other technological phases than those specified
	7.6. consumption of recycled material introduced into the production process of the product	7.6.1. recycled materials in the preparation phase
		7.6.2. recycled material in the stage of moulds
		7.6.3. recycled material in the casting stage
		7.6.4. recycled material during cleaning and finishing
	7.7. consumption of recycled material introduced into the production process of the product	7.7.1. recycled materials in the preparation phase
		7.7.2. recycled material in the stage of moulds
		7.7.3. . recycled material in the casting stage
		7.7.4. recycled material during cleaning and finishing
	7.8. the energy recovered into the process product production	7.8.1. recovered energy development phase
		7.8.2. the energy recovered in the stage of moulds
		7.8.3. the energy recovered in the casting stage
		7.8.4. the energy recovered in the process of cleaning and finishing
		7.8.5. energy recovered in the heat treatment step
		7.8.6. energy recovered during dyeing and surface coating castings
		7.8.7. the energy recovered during the edging and machining
		7.8.8. recovered energy other than those specified technological phases

### 3. Criteria for evaluation

In establishing criteria for membership on the circular economy to the analysis made in formulating J.C. Levy on the development of circular economy elements: 1. moderate use of resources as effectively as possible recycled; 2. exploitation of resources important to the upper level of their recyclability; 3. Eco-conception and cleaner production; 4. strict adherence to environmental conditions; 5. The recovery of waste and turn them into resources; 6. The generation of waste treatment without particular problems.

The analysis method on a field belonging to the specific requirements of circular economy is in terms of a global event analysis, based on established criteria. This comprises the following steps:

- Criteria for admission criteria specific to analyze the circular economy;
- Specification of works falling criteria established event, which will be suppose analysis and justification of selection;
- Determination of the total weight of selected works and works in the overall structure of the event;

#### 4. Establishing the event which will be analyzed and description and evaluation of circular economy perspective

Manufacturers castings are represented globally by the World Foundry (The World Foundry Organization) through national structures in 32 states. Since its establishment until now were held 71 world congresses, the last one being carried out in Bilbao. In 2014, this historically and high representative for the case study of the proposed procedure were used Proceedings of the 71st World Congress Foundry.

At the quantitative level, the number of papers presented in the work "71st World Foundry Congress - 2014 - Bilbao", having regard to the program event was 190, grouping them being performed in a total of 10 sections: 1. Cast (Cast iron) with a total of 29 works; 2. Steel (Cast steel) with a total of 8 papers; 3. Ferrous and light alloys (non-ferrous and light alloys) with a total of 31 works; 4. Casting technology, equipment, manufacturing tools, robots and automation (Foundry technologies, EQUIPMENT, manufacturing, tools, robotics and automation) with a total of 30 works; 5. Implementation forms, casting cone and rapid prototyping (Moulding, core making and rapid prototyping) with a total of 22 works; 6. Advanced Engineering: Tools for design, calculation and simulation (Advanced engineering: desing, calculation and simulation tools) with a total of 18 works; 7. Energy (Energy) with a total of 5 works; 8. Environment and Sustainable Development (Enviroment and sustainability) with a number of 11 works; 9. Management, Education and Training (management, education and training) with a total of 6 papers; 10. Young Researchers (Young Researchers) with a total of 6 papers; 11. Paper poster (posters) with a total of 13 works. Reporting the number of participating countries work at the congress is made in table 2 and in table 3 shows the distribution of works on sections of the conference and their share in the criteria set.

**Table 2.** Number of communications relative to countries with Foundry World Congress 2014 – Bilbao

Nr.	Country	Number of works	Share works,%
1.	1 Spain	29	15,34
2.	2 Japan	25	13,22
3.	3 Poland	24	12,69
4.	4 Germany	21	11,11
5.	5 China	14	7,4
6.	6 South Korea	14	7,4
7.	7 SUA	9	4,76
8.	8 India	7	3,7
9.	9 South Africa	5	2,64
10.	10 Norway	3	1,58
11.	11 Turkey	3	1,58
12.	12 Great Britain	3	1,58
13.	13 Belarus	3	
14.	14 France, Romania,	2	1.05x3=3,15
15.	15 Ungary	1	
16.	16 countries		0,53x16=8,46
<b>Total</b>	<b>33</b>	<b>189</b>	<b>100</b>

**Table 3.** Distribution of works on sections of Congress and their share of the total set

Nr.	Section	Number of works	Share works %
1.	S1:Cast iron	26	13,75
2.	Cast steel	8	4,23
3.	Non ferrous and light alloys	31	16,4
4.	Foundry technologies, echipment, manufacturing, tools, robotics and	29	15,34

	automation		
5.	Moulding, core making and rapid prototyping	22	11,64
6.	Advanced engineering: desing, calculation and simulation tools	17	8,99
7.	Energy	5	2,64
8.	Enviroment and sustainability	11	5,82
9.	Management, education and trainig	10	5,29
10.	Young researchers	17	8,99
11.	Posters	13	6,87
<b>Total works</b>		<b>189</b>	<b>100</b>

### 5. Evaluation of the event from the perspective of circular economy

In particular, the expected analysis includes references to the keywords and the theme of the Congress said. Quantifying trends analyzed domain for its framing trend to hire "circular economy" is achieved by superimposing its characteristic elements in the priority areas addressed in the papers presented.

This estimate is based on the work carried out aiming presented in the provisional program of the 71st World Congress of Foundry - Bilbao 2014 - Advanced Sustainable Foundry (1). From this perspective, summarizes some of the characteristics of the congress:

- Keywords (emblem) of the congress: Energy (energy) Environment (environment), market trends and requirements (Market trends and Demands) and innovation (innovation);
- Sections of the Conference presentation to the share of the total work are summarized in table 3. Starting from the analysis of production process of castings made in table 1 is performed, following the methodology presented, reporting and works belonging steps that respond to circular economy. An example of selective analysis is made presented in table 4. In this step goes to the encoded specific measures and selection of articles from the conference corresponding to this analysis. For reasons of space allocated to the presentation of a work within it does not show the entire analysis made at each work.

**Table 4.** Distribution themes work on specific criteria for addressing circular economy

Nr.	Section	NC	NCAEC	PSCAEC	PCAECTL
1.	S1:Cast iron	26	9	34,61	4,76
2.	Cast steel	8	3	37,51	1,58
3.	Non ferrous and light alloys	31	12	38,69	6,34
4.	Foundry technologies, echipment, manufacturing, tools, robotics and automation	29	21	72,41	11,11
5.	Moulding, core making and rapid prototyping	22	13	59,09	6,87
6.	Advanced engineering: desing, calculation and simulation tools	17	15	88,23	7,93
7.	Energy	5	5	100	2,64
8.	Enviroment and sustainability	11	11	100	5,82
9.	Management, education and trainig	10	4	40	2,11
10.	Young researchers	17	11	64,71	5,82
11.	Posters	13	7	53,81	3,71
<b>Total Works</b>		<b>189</b>	<b>111</b>		<b>58,73</b>

Note: NC – Number of works; NCAEC – Number of works on sections addressing to the circular economy ; PSCAEC – - Share the communications section addressing circular economy; PCAECTL – Share communications addressing reported total circular economy works.

Motivation membership trends in the manufacture of castings to the principles of circular economy is made by the following reasoning:

1. Keywords are proof castings production trends orientation to principles of circular economy, in that they are related to reducing energy consumption (energy), the environmental problems

(environment), tracking the actions regulated market to ensure sustainable development ( market trends and requirements) and promoting innovative solutions in all sections of the life cycle of castings, especially in regulating specific material and energy consumption. From the enumeration is done through keyword notes that promotes symbolic but significant market economy principles.

2. The theme of the congress section gives strong arguments to show that they fall circular economy. Some of them are shown in the following:

- **Advanced Engineering** means the development of construction castings and technologies in a virtual space without consul material and energy;
- **Robotics and automation** of manufacturing processes translates into optimizing processes in the material and energy consumption;
- **Environmental protection and sustainable development** creates determinations and conditioning on the development and management processes, in the sense of not affect the state of the environment and natural resources. This translates into castings produced using fewer raw materials, using materials that generate little impact on the environment and human health compared to traditional materials with equivalent functionality through the installation of eco-efficient logistic solutions by using products and processes more flexible, modular, evolutionary and versatile, easier to maintain and repair, with a greater potential for recovery at end of life;
- **Energy remains** an important issue for users of energy-intensive, especially for manufacturing processes castings pursuing solutions to increase energy efficiency complex.
- **Rapid Prototyping** gives opportunities for achieving specific configurations of making parts with low weight and good mechanical performance.

3. The work addresses a problem analyzed directly or indirectly, which can be characterized as part of actions to promote and develop the circular economy on the whole flow generation, the existence and disposal of castings. Without going into details of each job submission, otherwise it would be difficult to achieve at this approach, the overall assessment of the membership of the circular economy is via the data presented in table 4. As shown therein, the share of work addressing, directly or indirectly, the issue of circular economy is about 59%. Reported number of works presented within the framework of the share ranges from 35% to 100% (the Energy and Environment section) Although assessments are loaded with a certain bias, it is considered that concerns research in the production of castings are geared towards promoting circular economy development activities.

The assessment presented is noted that in the circular economy for the production of castings are covered five of the six elements: moderate use and effective as possible recyclable resources, exploitation of resources important to the upper level of recyclability their strict adherence to conditions environment, waste recovery and turn them into resources and waste treatment without generating special problems.

## 6. Conclusions

In a statistical presentation of conclusions regarding the justification trends occurring in the manufacture of castings to the principles of circular economy, the analysis works Foundry World Congress - 2014 - Bilbao are:

Two (energy and environment) of the four (energy, environment, market trends and requirements, innovation) words emblem of the congress aimed at environmental protection and sustainable development, bearing in mind that addresses the major issues mentioned novative processes. This demonstrates that sustainable development is a major concern castings production to the new requirements of industrial processes developments. The third theme (market trends and requirements) demonstrates a reality, studies and research that take into account prevailing market trends domain and its new developments. To study and develop research outside global market trends is an effort that will not materialize in the development and maintenance of market positions.

Of the nine sections of paper conference presentation, three aimed at traditional fields (iron casting, casting light and non-ferrous alloys and steel casting), and six new areas which aims to support the issue of manufacture castings (advanced engineering, environmental protection and sustainable

development, energy, rapid prototyping, management and training). This trend shows the evolution of manufacturing parts is supported at interdisciplinary many vital areas for future development, which may be contained in what is called emblematic "circular economy", developed below. The analysis of individual conference papers found that more than half, directly or indirectly targeting issues they fit into the theme concerns the development of circular economy.

The proposed methodology in the analysis work is found that a significant share of their themes fall into actions to strengthen circular economy development. This is a trend analysis tool for circular economy, proved to be useful in forecasting which are of particular developments in the field.

The case study was the assessment of trends towards a circular economy of production of castings demonstrates that World Foundry Congress - 2014 are in line with development issues analyzed domain. More than this analysis we believe that it provides a methodology by analyzing a field of circular economy development perspective.

## References

- [1] 71-st World Foundry Congress, Bilbao, 2014, Technical Programme, online to: [www.71stwfc.com](http://www.71stwfc.com)>More references.
- [2] Economie circulaire: beneficiar socio-economiques de l'ecoconception et de l'ecologie industrielle, 2012, *ADEME & VOUS, Strategies & etudes*, vol. 33, pp.17.
- [3] J. C. Levy, 2009, L'économie circulaire: l'urgence écologique, Presses de l'École nationale des ponts et chaussées.
- [4] I. Sandu, D. Aparaschivei, V. Vasilache, I. G. Sandu, O. Mircea, 2012 *REV. CHIM. (Bucharest)*, 63, No. 5, pp. 495-500.
- [5] S. O. Jimoh, P.S.A. Irabor, I.U. Abhulimen, S.O. Amiebenormon, 2013 *International Journal of Scientific & Technology Research*, Vol. 2, Issue 1, pp. 257-261.
- [6] K. Das Subodh and Y. Weimin, 2007 *JOM*, pp. 57-63.
- [7] D. P. Kanicki, 2000 *Modern Casting*, 12, pp. 24 - 34.
- [8] N. MARCU, M. SIMINICA, M. CRISTEA, D. DASCALU, 2016, *REV. CHIM. (Bucharest)*, 67, No.3, pp. 589-594.
- [9] W.-Y. Dzan, 2011 *International Journal of Systems Applications, Engineering & Development*, Vol. 5, Issue 4, pp. 529-536.