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Original Article

Evaluation of Carbon Footprint of an Engineering Steel for Automotive

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Abstract

In order to quantify the Carbon Footprint (CFP) for an engineering steel from High-Strength Low-Alloy (HSLA) class, forged to obtain an automotive crankshaft, an environmental performance evaluation was made. The results of Life Cycle Inventory (LCI) for steel crankshaft manufactured by conventional and respectively multidirectional flash reduced forging technology have been compared. The analysis results show that the new forging technology is an economical and advantageous alternative to the conventional forging process. It may reduce the greenhouse gases emissions, airborne emissions, waterborne emissions and total waste produced in the life cycle chain of automotive crankshaft. These environmental effects are a consequence of the reduction of material consumption with 3.4 kg/crankshaft and 1.581 kWh/crankshaft energy saving from the reduced weight slug. The significant financial and environmental benefits allow a better positioning in the profile market for a manufacturer of automotive crankshafts.

Keywords: Carbon Footprint, greenhouse gases, Life Cycle Inventory, multidirectional flash reduced forging, engineering steel, crankshaft.

1. Introduction

The aim of the present work is to quantify the environmental impact of the new flash reduced forging technology on SME OMTAS-Turkey that produces automotive two-cylinder-crankshafts.

More specifically, has been evaluated the effect of the flash reduction on the carbon footprint in the multidirectional forging.

This technology is an economical alternative to the conventional forging and it offers several advantages that notably contribute to economic and environmental issues.

These are:

- reduced material consumption,
- reduced energy input (reduced material has to be produced and heated up),
- closer tolerances, improving the material utilization .

Conventional process chain for two-cylinder-crankshaft forging consists of seven steps: it starts with an upsetting operation followed by three preforming operations, a final forming, clipping and calibrating (Fig. 1).

New forging process for flash reduced forging of the two-cylinder-crankshaft consists of two flashless preforming steps followed by a flashless multidirectional forming step and the flash reduced final forming (Fig. 1).

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To achieve an optimal mass distribution the focus was on performing flahless preforming operations. By the use of the new mass distribution the flash is reduced from 54.0 % to 5.7 %.

In this way the metallic material consumption is lowered with 3.4 kg / crankshaft and 1.581 kWh/crankshaft energy saving. As a consequence, in the overall life cycle of metallic material a smaller amount of steel is found and it participation at environmental pollution is reduced.

The evaluation of new forging technology environmental performance was made by quantification of the Carbon Footprint (CFP).

The results of Life Cycle Inventory (LCI) were compared for an engineering steel which can be used to obtain the automotive crankshaft by conventional and flash reduced forging.

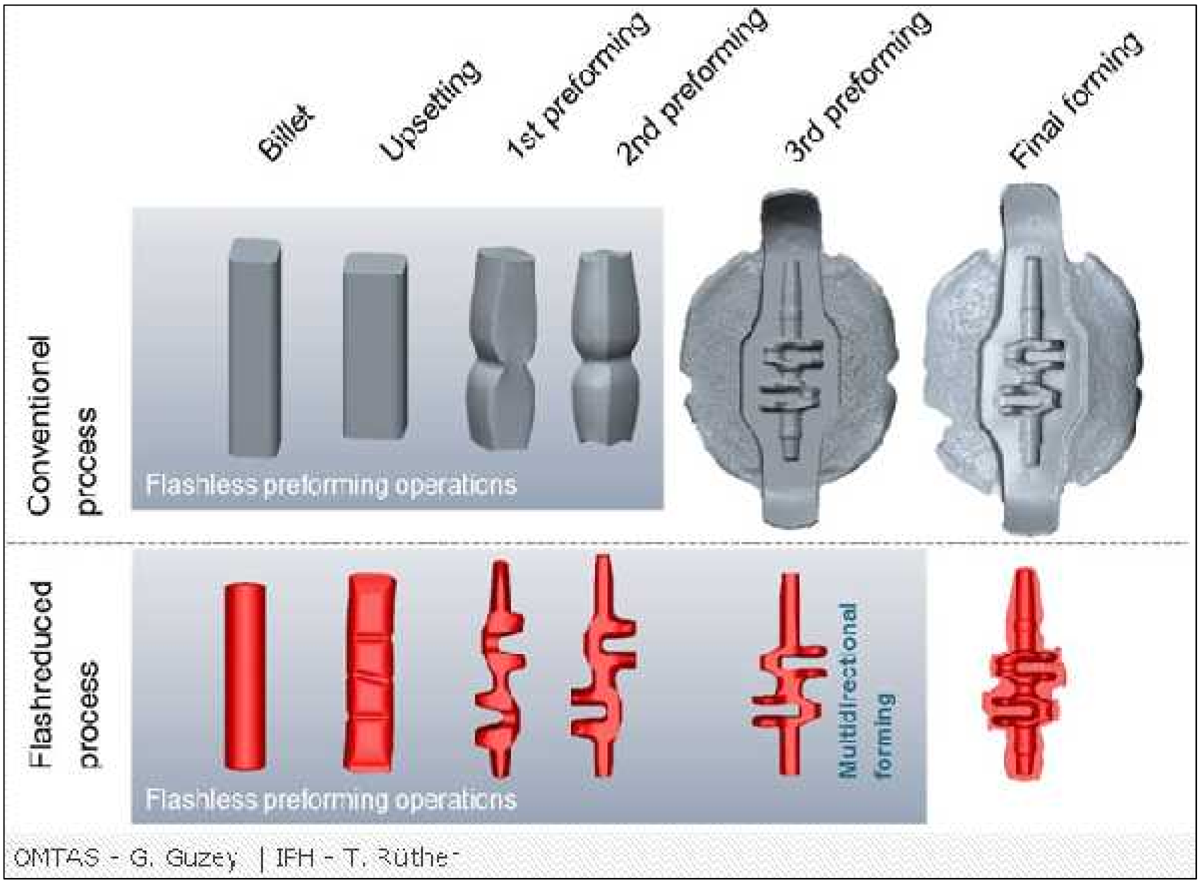

Figure 1. Comparison of conventional and new flash reduced forging sequence of the two-cylinder-crankshaft

2. Material and Method

Our study considers only the contribution of 38MnVS6 microalloyed steel for automotive crankshaft at carbon footprint. This steel belongs to the class of engineering steel for automotive engine, High-Strength Low-Alloy (HSLA) type, for which was determined the LCI data. HSLA steels are strengthened essentially by micro-alloying elements that contribute to fine, ultra-fine or nano carbide precipitation and grain-size refinement.

According to WorldAutoSteel, the automotive group of the World Steel Association (WSA) the engineering steels are fundamentally wrought steels designed for mechanical and related engineering applications, with critical and rigorous levels of properties (e.g. strength, elasticity, ductility, toughness and fatigue resistance, resistance to high or low temperatures, corrosive and other aggressive environments). There is a great variety of engineering steel types and shapes, carefully designed for specific user requirements related to properties, performance and easier fabrication techniques. It is known a wide range of engineering steels, from carbon steels to high alloy and ultra high strength steels.

The LCI data is provided as “cradle-to-gate” method, including 95% end-of-life (EoL) recycling rate. The 95% EoL recycling rate is typical recycling rate for automotive sector and is judged based on WSA experts in Life Cycle Assessment (LCA).

The recycling rate is not recycled content and it refers to the amount of steel recycled at the end of its life. In addition, the data (*cradle to gate* data with end-of-life recycling) doesn't include additional transport like transport to the customers, to the scrap recycling facility or other purposes. Environmental impact assessment of processes by LCA is very complex , difficult and is hampered by the lack of a scientific methodology required to analyze environmental impact categories. The models for impact categories are still under development and involve the use of expensive computer programs [5].

For this reason, a simplified methodology was applied, such as the "LCI analysis", which quantifies the carbon footprint. CFP environmental assessment is to quantify the contribution, the amplitude and significance of potential environmental impacts of a system or product, using the results of the LCI analysis.

To assess the environmental footprint of processes involved in life cycle of crankshaft we used the data provided by courtesy of World Steel Association-WSA, which utilizes its own methodology for Life Cycle Inventory [11].

3. Results and Discussions

An environmental performance evaluation was made by the evaluation of CFP based on LCI of an engineering steel for automotive engine.

The possible environmental savings using flash reduced forging have been described.

Based on the collected data, an environmental footprint evaluation was made in accordance with ISO 14040:2006 and ISO 14044:2006, the leading standards which describe the principles and framework, requirements and guidelines for LCA of products. Also, had been taken into consideration and ISO 14067:2013 requirements and principles, in order to quantify the Carbon Footprint of a product, based on LCA specified in ISO 14040 and ISO 14044. It represents sum of GreenHouse Gas (GHG) emissions of selected relevant processes within the life cycle of a product, expressed as Carbon Dioxide Equivalent ($CO_{2\ eq}$).

During the entire life cycle of a product , there are the following overall sources [6] of GreenHouse Gases (Fig. 2):

- *stationary*: burning of fuels to generate electricity/heat/power in stationary equipment (e.g. furnaces),
- *processes*: emissions generated from manufacturing processes (e.g. breakdown of CaCO3, MgCO3 at steel melting),
- *mobile*: burning of fuels by transportation devices (e.g. cars),
- *occasionally*: emissions that result from intentional/ unintentional releases of greenhouse gases (e.g. leaks from joints, seals, packing, circuit breakers).

There are six Green House Gases as identified under the Kyoto Protocol:

- carbon dioxide (CO_2),
- methane (CH_4),
- nitrous oxide (N_2O),
- hydrofluorocarbons (HFCs),
- perfluorocarbons (PFCs),
- sulphur hexafluoride (SF_6).

These GHGs are targeted because they are the main anthropogenic (i.e., human-emitted) gases. The main goal and the efforts are made to reduce their emissions. The GHGs sources that interest in the present paper are related to the automotive crankshaft steel. The main GHG emission sources [9] associated with iron and steel production are presented in Fig. 3. The consumption of purchased heat, steam and electricity and the on-site transportation of materials are the other GHG emission sources that may contribute significantly to a facility's overall emissions, but these are not represented here. Steel processing does not contributes appreciably.

In our case, the stationary source and processes are the main producers of GHG emissions. These sources act in the production and end-of-life phases of the engineering steel processing for automotive crankshaft.

A cycle inventory analysis of steel for automotive crankshaft was made in the following steps:

- achieving a workflow diagram,
- defining of the analyzed system boundaries,
- collecting and processing of the inventory data,
- interpretation of the results.

Fig. 4 shows the workflow diagram for complex LCA of an automobile by the iconic representation of the subsystems involved in life cycle analysis of the product. This overall workflow intrinsically includes life cycle for automotive crankshaft. In diagram are represented the system inputs (consumption of raw materials, auxiliary and energy) and outputs (emissions in air, water and soil, waste). The level of detail and the assessment methodology for the environmental impact of steel for the automotive industry has taken into account the following aspects:

- the most significant contribution in raw material and energy consumption,
- the relevant impact on the environmental factors.

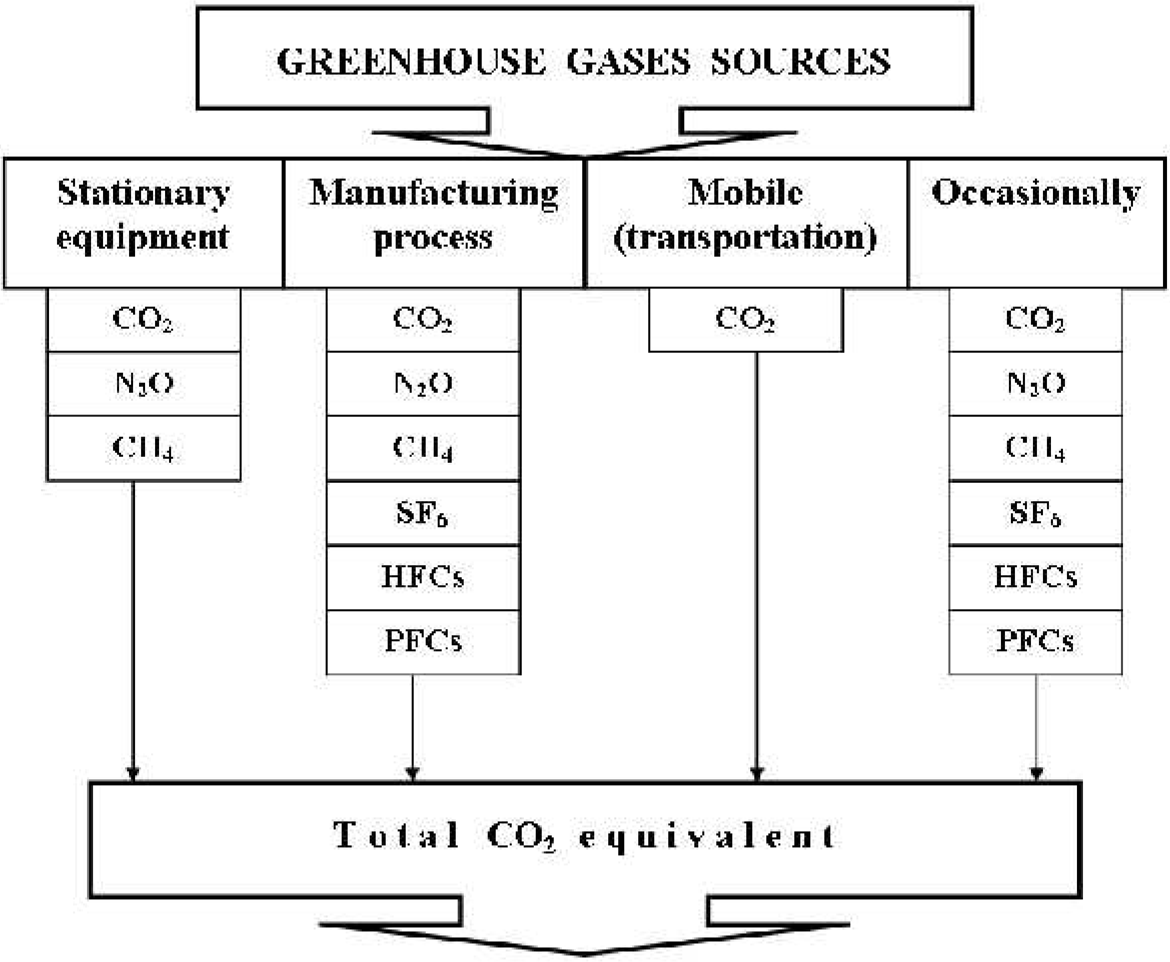

Figure 2. Potential GreenHouse Gases sources during Life Cycle Assesment of a product

The life cycle of automotive crankshaft is included in the life cycle of a car shown in Fig. 4. Considering the previous aspects, it was considered a more limited degree of detail and a partial analysis. This analysis quantifies only the inputs and outputs for the most significant stages of environmental impact that it plays the metallic material, which are the largest consumers of raw materials and energy and the largest sources of pollutant factors.

Having regard to the foregoing considerations the system boundaries were represented in Fig. 5 modified from [3]. The included processes are in black boxes with solid lines and excluded processes are in grey boxes with dashed lines. It is considered only the participation of the subsequent phases in the Life Cycle Inventory analysis of steel crankshaft:

- primary production of steel (melting steel in Basic Oxygen Furnace-BOF with pig iron as raw material produced in Blast Furnace-BF ; melting steel in Electric Arc Furnace-EAF),
- secondary production of steel (melting steel in Electric Arc Furnace-EAF),
- recycling- recovery.

Primary and secondary production and recycling of the metallic products such as the automobile steel is involved in the contamination of air, water and soil, with the different consequences: heavy metal and metal powders pollution, climate changes, ozone depletion, photochemical pollution, acid rain, ecotoxicity and human toxicity, chloro-organics compounds.

The use phase of steel as a car engine crankshafts has a smaller participation and effects on the environment and human health. It coincides with the stages of production and use of the cars (Fig. 4), when the combustion of fuels is the largest environmental impact, which does not matter here. Therefore in the present study was to quantify only the effect from upstream of steelmaking and in downstream of steel recycling.

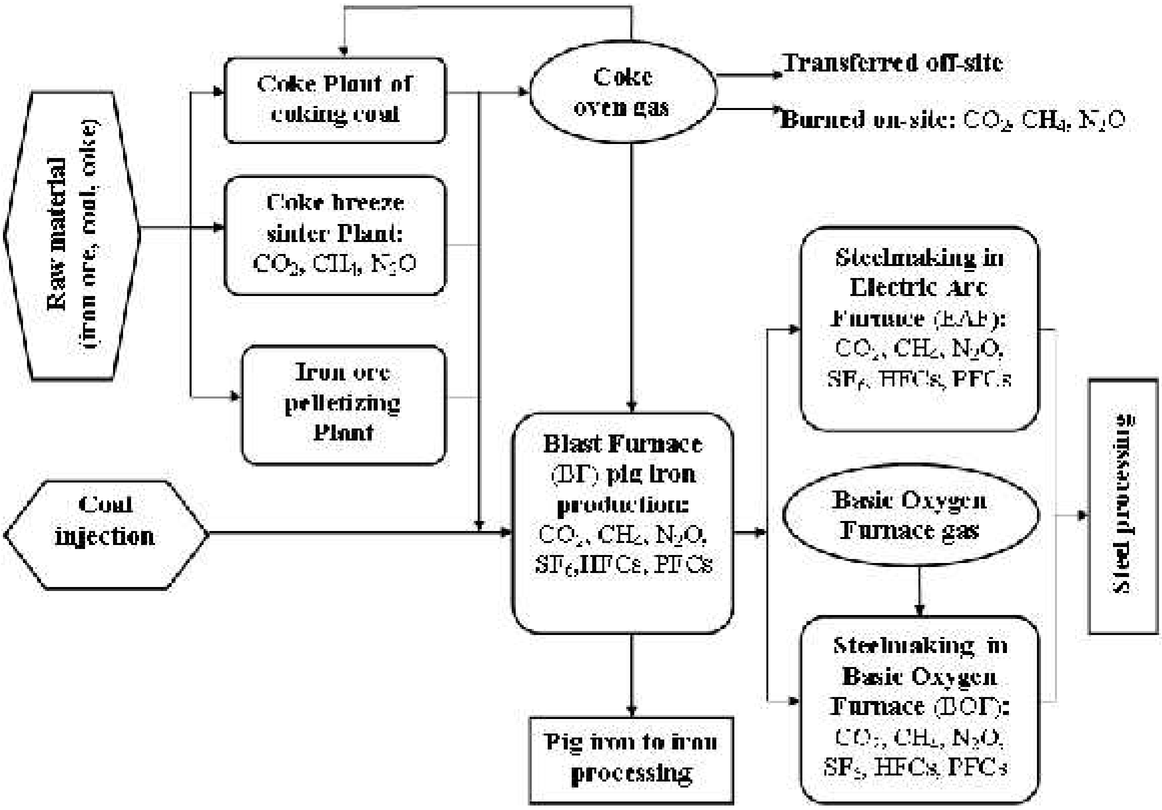

Figure 3. The main GHG emission sources associated with iron and steel production

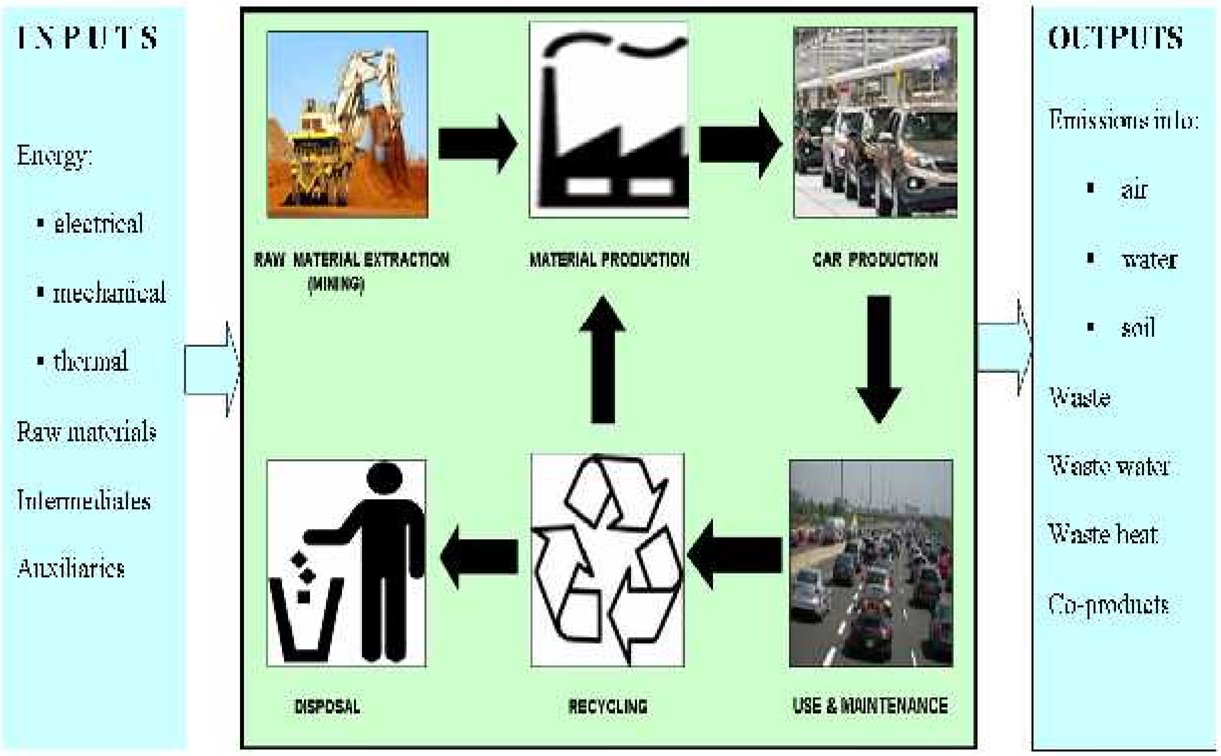

Figure 4. The stages of a car's life cycle

The assesement of the environmental performance of materials can only be performed within the context of their utilisation. The present study is concerned with GreenHouse Gas emissions from automotive materials alone rather than automotive vehicles.

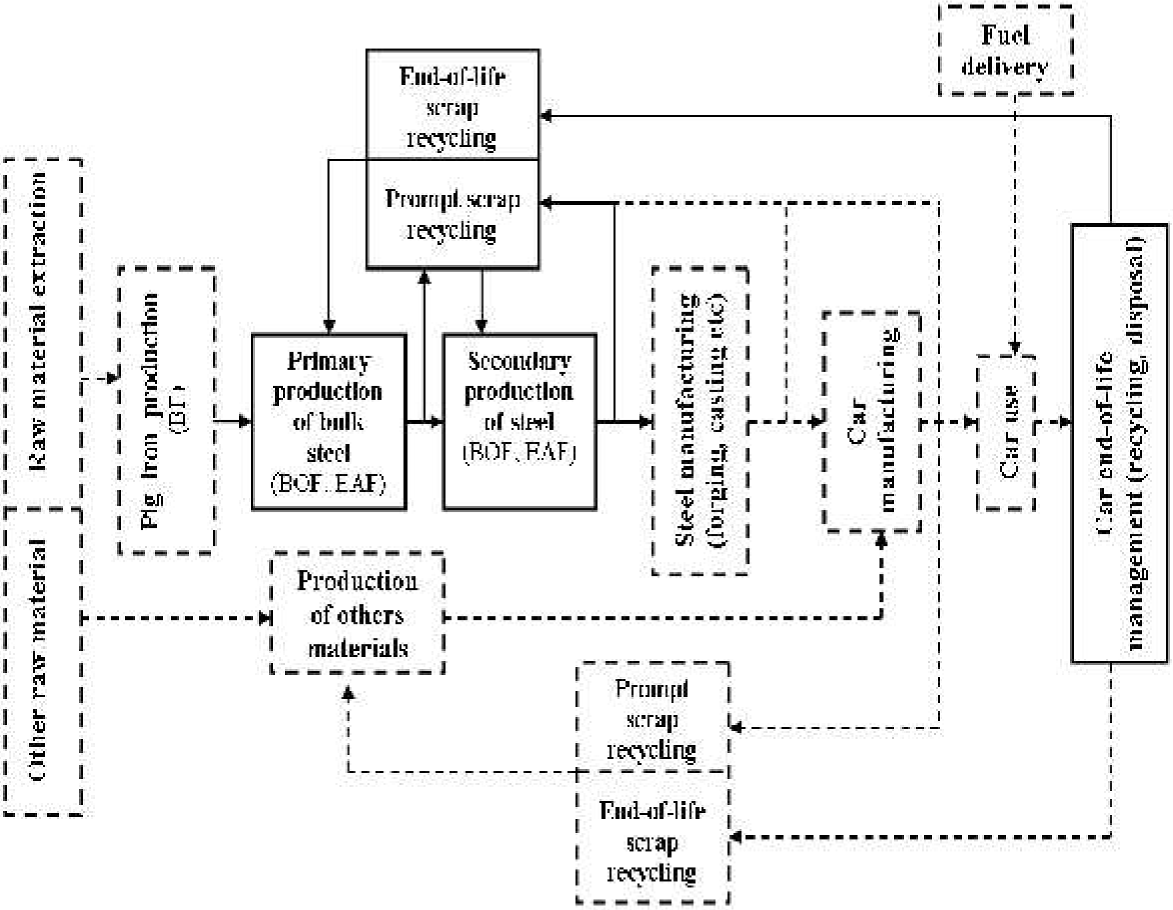

Figure 5. System boundaries in the overall life cycle of steel crankshaft included in the life cycle of a car

Within the framework of LCI for crankshaft had been taken into account the contributions of the following environmental impact categories:

- material consumption,
- consumption of energy (electricity, gas, oil etc),
- air pollution, toxic gases,
- water pollution.

The inventory data were provided by the following sources:

- data collected during the forging tests (Table 1),
- LCI data supplied by courtesy of World Steel Association for 1(one) kg engineering steel for automotive engine (Table 2),
- others.

This Table 2 is supplied for an agreed purpose following consultation with an LCA manager from an worldsteel member organisation. The table shows worldsteel LCI data in simplified form.

In simplifying such a complex subject there is always a risk that information can be misinterpreted. To avoid any such misinterpretation, these data should be viewed as informative data.

The data have been extrapolated to the entire amount of metallic material used to obtain annual production of crankshafts from OMTAS manufacturer and have been obtained the gas, airborne and waterborne emission data of steel (Table 3).

Using the data from this table the CFP data was calculated.

Table 1. Some characteristics of forging crankshaft at OMTAS-Turkey

No.	Characteristics	UM	Current conventional forging process	New flash reduced forging process
1	Production	pc/year	200,000	200,000
2	Net weight of crankshaft	kg	7	7
3	Gross weight of crankshaft	kg	10.8	7.4
4	Flash ratio for crankshaft	%	54	5.7
5	Cycle time	sec/pc	35	35
6	The average heating energy consumption for steel forging	kWh/kg	0.440	0.465
7	The average cost of energy	EUR/kWh	0.08	0.08
8	Steel saving	kg /pc	-	3.4
9	Energy saving	kWh/pc	-	1.581

Because the total CFP cannot be calculated (reasons: the large amount of data required and the fact that carbon dioxide can be produced by natural occurrences), we resorted to a more acceptable practice which was suggested by Wright et. al. [7]. Namely, the carbon footprint is a measure of the total amount of CO_2 and CH_4 emissions of a source (product, system or activity), calculated as Carbon Dioxide Equivalent (CO_2eq) using the relevant 100-year Global Warming Potential (GWP100).

GHGs have a different radiative properties and lifetimes in the atmosphere and as a consequence they have the different warming influences on the environment.

These warming influences may be expressed by CO_2eq emissions**,** which means a common metric based on the radiative forcing of CO_2.

In accordance with [10] CO_2eq emission is the amount of CO_2 emission that would cause the same time-integrated radiative forcing, over a given time horizon, as an emitted amount of a long lived GHG or a mixture of GHGs. Time-integrated represents a specific sampling to collect the pollutants over a specified period of time. For the given time horizon, for each GHG the equivalent CO_2 emission can be calculated by multiplying the GHG emission by its GWP. If a GHG emission source emits more than one greenhouse gas it is obtained by summing the equivalent CO_2 emissions of each gas.

To compute this is used the following formula:

$$\begin{aligned} &CO_2\ Equivalent\ (CO_2eq)\ Emissions = \Sigma(Activity\ data \times Emission\ factor)GHG \times GWP = \\ &= \Sigma(Emission\ of\ GHG) \times GWP \end{aligned} \tag{1}$$

This study uses 100-year GWPs and numerical values (Table 4) consistent with reporting by source [8] under the Intergovernmental Panel on Climate Change - IPCC.

Table 2. Life Cycle Inventory Data for Steel Products (Source: World Steel Association)

Issue	**Major Articles***	**Units**	**Engineering Steel EAF* (5 Sites)**
0	**1**	**2**	**3**
Product: Engineering Steel EAF (EAF= Electric Arc Furnace) **Production and end-of-life phases** are included in the data		**Date of issue:**	Nov. 2005
World average, 1kg		**Date of data:**	1999-2000
Sector: Automotive, Recovery Rate: 95%			
Recovery Rate. The overall Recycling Rate indicates the efficiency with which pre-consumer scrap and post-consumer scrap are collected and recycled. Allocation for End-Of-Life Recycling has been modelled according to the worldsteel-recycling methodology			
Production and end-of-life phases are included in the data. Allocation for End-of-life Recyling has been modelled according to the worldsteel recycling methodology.			

Table 2. Life Cycle Inventory Data for Steel Products (Source: World Steel Association) - continued

0	**1**	**2**	**3**
INPUTS	(r) Coal (in ground)	kg	0.15748849
	(r) Dolomite (CaCO3.MgCO3, in ground)	kg	0.007548567
	(r) Iron (Fe)	kg	0.065485154
	(r) Limestone (CaCO3, in ground)	kg	0.070061781
	(r) Natural Gas (in ground)	kg	0.062259308
	(r) Oil (in ground)	kg	0.079894819
	(r) Zinc (Zn)	kg	0.00247651
	(a)TOTAL Raw material in ground	kg	**0.445214629**
OUTPUTS	**Water Used** (total)	Litre	2.276438392
	(a) Cadmium (Cd)	g	5.2133E-05
	(a) Carbon Dioxide (CO2)	g	784.3286467
	(a) Carbon Monoxide (CO)	g	3.345826781
	(a) Chromium (Total)	g	0.002724634
	(a) Dioxins (unspecified, as Toxic Equivalency TEq)	g	4.1678E-09
	(a) Hydrogen Chloride (HCl)	g	0.060866218
	(a) Hydrogen Sulphide (H2S)	g	0.008675827
	(a) Lead (Pb)	g	0.003523384
	(a) Mercury (Hg)	g	9.9696E-05
	(a) Methane (CH4)	g	1.008004692
	(a) Nitrogen Oxides (NOx as NO2)	g	1.359720341
	(a) Nitrous Oxide (N2O)	g	0.029974387
	(a) Particulates (Total)	g	0.457645511
	(a) Sulphur Oxides (SOx as SO2)	g	2.729604068
	(a) VOC (Volatile Organic Compounds,except CH4)	g	0.095368064
	(a) Zinc (Zn)	g	0.02277238
	(a) TOTAL Airborne emissions	g	**793.4535048**
	(w) Ammonia (NH4+, NH3, as N)	g	0.038341088
	(w) Cadmium (Cd++)	g	7.07684E-06
	(w) Chromium (Total)	g	0.000107899
	(w) COD (Chemical Oxygen Demand)	g	0.021385688
	(w) Iron (Fe++, Fe3+)	g	0.001239978
	(w) Lead (Pb++, Pb4+)	g	0.000297384
	(w) Nickel (Ni++, Ni3+)	g	0.000101234
	(w) Nitrogenous Matter (unspecified, as N)	g	0.094895105
	(w) Phosphorous Matter (unspecified, as P)	g	0.0053217
	(w) Suspended Matter (unspecified)	g	0.1323885
	(w) Zinc (Zn++)	g	0.000710139
	(w) TOTAL Waterborne emissions	g	**0.294795792**
	Non-allocated byproducts	kg	0.057397415
	Waste (total)	kg	0.263750936
	Total waste + byoproducts	kg	**0.321148351**
ENERGY Reminders	E- Feedstock Energy	MJ	0.01290929
	E -Fuel Energy	MJ	13.462915
	E- Non Renewable Energy	MJ	12.75892506
	E- Renewable Energy	MJ	0.701101412
	E- Total Primary Energy	MJ	13.47557605
	E - TOTAL Energy	MJ	**40.41142681**

* (r): Raw material in ground, (a): Airborne emissions, (w): Waterborne emissions

Table 3. GHGs, airborne and waterborne total emissions for total crankshaft production

	Articles	**Units**	**For 1 Kg EAF Steel**	**GHGs***	**GHGs****	**Saving**
0	**1**	**2**	**3**	**4**	**5**	**6 (4- 5)**
INPUTS	**TOTAL Raw material in ground**	kg	0.445214629	961,663.60	658,917.65	**302,745.95**
	Water Used (total)	litre	2.276438392	4,917,106.93	3,369,128.82	1,547,978.11
OUTPUTS	Carbon Dioxide (CO_2)	kg	0.7843286467	1,694,149.87	1,160,891.97	533,257. 90
	Methane (CH_4)	kg	0.001008004692	2177.29	1491.85	685.44
	Nitrous Oxide (N_2O)	kg	0.029974387x10^{-3}	64.74	44.36	20.38
	TOTAL GHGs emissions	kg	0.785366625779	1,696,391.9	1,162,428.18	**533,963.72**
	TOTAL Airborne emissions	kg	0.7934535048	1,713,859. 57	1,174,311. 19	**539,548.38**
	TOTAL Waterborne emissions	kg	0.000294795792	636,758. 91	436,297.77	**200,461.14**
	Non-allocated byproducts	kg	0.057397415	123,978. 41	84,948.17	39,030. 24
	Waste (total)	kg	0.263750936	569,702.02	390,351.38	179,350.64
	Total waste + byoproducts	kg	0.321148351	693,680.44	475,299.56	218,380.88
ENERGY	**E - TOTAL Energy**	***MJ	40.41142681	87,288,681.91	59,808,911.68	**27,479,770.23**

* For total crankshaft production by Conventional forging process (current technology):
200 000 pc/year x 10.8 kg/pc= **2,160,000 kg/year**
** For total crankshaft production by Flash reduced multidirectional forging process (new technology):
200 000 pc/year x 7.4 kg/pc = **1,480,000 kg/year**
*** 1 MJ = 0.2777777777778 kWh

Within the framework of the life cycle of crankshaft, the environmental performance was evaluated by comparing the results of LCI for crankshaft obtained by:

- conventional forging,
- flash reduced multidirectional forging.

Table 4. List of GWPs of the six Kyoto-covered gases

GHGs	**GWP,100 Years** (SAR*)	**GWP,100 Years** (TAR**)
Carbon Dioxide (CO_2)	1	1
Methane (CH_4)	21	23
Nitrous Oxide (N_2O)	310	296
Hydrofluorocarbons (HFCs)	140-12,100	120 – 12,000
Sulfur Hexafluoride (SF_6)	23,900	22,200
Perfluorocarbons (PFCs)	6,500-9,200	5,700 – 11,900

*SAR- IPCC’s Second Assessment Report; **TAR - IPCC’s Third Assessment Report

According to data from Table 2, only the CO_2, CH_4 and N_2O contribute to the carbon footprint -CFP of steel crankshaft.

The first step to determine the carbon footprint consists in calculating of GHG emissions tons, by type of GHG. It can do these calculations in a number of ways, depending on equipment, monitoring practices, and environmental management system. The most common method is the following calculation method [2]**:**

$$\textit{GHG emission} = \textit{Activity data x Emission factor} = \\ \textit{0.001 x (Fuel Usage) x (High heat value) x (Emission factor)} \qquad (2)$$

These values can get from the United States Environmental Agency - EPA's GHG Reporting Program (GHGRP) documentation.

In this work, the data on GHG emissions have been provided by courtesy of World Steel Association, based on the above expression and using its own methodology. These data was requested by an our input questionnaire.

The second step is to determine effectivelly the carbon footprint expressed as CO_2eq by summing the equivalent CO_2 emissions of each gas using the formula (1).

Consequently the total GHG emissions relative to the entire crankshaft production are:

$$CO_2\text{ eq} = (CO_2\text{ emission x GWP of }CO_2) + (CH_4\text{ emission x GWP of }CH_4) + \\ (N_2O\text{ emission x GWP of }N_2O) \qquad (3)$$

Taking into account the results of calculations, the reducing of steel consumption given by the new forging technology has the following environmental effects:

- decreasing of greenhouse gases emissions with aprox. 554 tonne/year Carbon Dioxide Equivalent (CO_2 eq),
- decreasing of CO_2 emissions with aprox. 533 tonne/year,
- reducing of airborne emissions with aprox. 540 tonne/year,
- reducing of waterborne emissions with aprox. 200 tonne/year,
- reducing of total waste with aprox. 180 tonne/year.

Previously the carbon footprint given by melting and end-of-life stages of engineering steel LCA was evaluated.

By another way, it can be disjoined also the environmental footprint given by the multidirectional forging stage of crankshaft steel.

Electricity consumption is often one of the largest sources of emissions for reporting companies, and it is therefore important that the measurement of these emissions is as accurate as possible [1]. GHGs emissions from electricity consumption are calculated by applying an "*emission factor*" to the quantity of consumed electricity. Factors for emissions per kWh "consumed" are useful for LCA of the product taken into account. In the present case, the factors for calculating emissions from electricity consumption are the „*composite electricity / heat emission*" factors published by the International Energy Agency – IEA (Table 5).

Because the partners in this study are in OECD Europe and the crankshaft manufacturer is OMTAS-Turkey had been taken into account only their corresponding data. If the emission factors for Turkey and OECD Europe are in Table 5, then the CO_2 emissions saving due to by the energy saving in forging can be reduced in accordance with Table 6:

- 156.6 tonne/year CO_2, in the case of current OMTAS-Turkey production of 200,000 crankshaft/year, 3.4 kg /crankshaft steel saving and 1.581 kWh/ crankshaft energy saving,
- 6663.0 tonne/year CO_2, in the hypothetical case of new technology introducing to the whole of 15.8 million cars European production [12]**.**

CO_2 emissions saving originated in the steelmaking for crankshaft and end-life recycling of crankshafs is aprox. 533 tonne/year from which can be shared 156.6 tonne/year CO_2 emissions saving due to by the energy saving in multidirectional forging.

As it is known, the most of the CO_2 emissions in steel industry are generated by the iron reduction reaction in blast furnaces (BF) conventional technology. This chemical interaction takes place between carbon and iron ore in the most efficient thermodynamic conditions. However, the reduction of CO_2 emissions is restricted by the technical and technological limitations of the conventional technology.

Table 5. Several composite electricity/ heat factors (2010 Source: IEA)

Country, Zone	**IEA composite electricity/heat factors** ($kgCO_2/kWh$)
Africa	0.6192752
Australia	0.883306
China, People's Republic of	0.7448369
France	0.082717
Germany	**0.441181**
Italy	0.398464
India	0.9682265
Japan	0.436453
Latin America	0.2018896
Middle East	0.6870654
Non-OECD Europe	0.509238
Non-OECD Total	0.5668028
OECD Europe	**0.335223**
OECD North America	0.487216
OECD Pacific	0.498293
Romania	**0.4166456**
Russian Federation	0.3255125
Spain	**0.325878**
Turkey	**0.495279**
United Kingdom	0.486949
United States	0.535031
World	**0.5023264**

Table 6. Reducing in CO_2 emissions due to the energy consumption at crankshaft forging

	Annual steel saving (tonne/year)	**Annual energy saving** (kWh/year)	**Energy consumption for forging** (kWh/kg)	4) **IEA composite electricity/heat factors** ($kgCO_2/kWh$)	**CO_2 saving** (tonne/year)
0	**1**	**2=1x3** (x10^3)	**3**	**4**	**5 = 2x4**
1)**OMTAS-Turkey**	680	316,200	**1)** 0.465	0.495279	**156.6**
2)**OECD Europe**	53,720	19,876,400	**3)** 0.370	0.335223	**6,663.0**

1) Data for 200,000 crankshaft/year; 2) Data for 15.8 million cars European production in 2013, Source: [12]; 3) Data in accordance with The International Iron and Steel Institute (IISI) Report, 2013; 4) Data in accordance with Table 5 (Source: IEA).

For significantly reducing CO_2 emissions in today's steel production a possible solution for the future is the increasing the share of electric processes (e.g. EAF) over 32 % as is currently [4], with cheaper electric from alternative energy sources or from nuclear energy and use direct ore reduction by hydrogen.

Because of relatively high price of hydrogen, in present and in the coming years, the ore reduction by carbon will remain the predominantly process in steel production until will be achieved the hydrogen production from the water as an unlimited resource, at an acceptable price. Also, the significant changes in the steel production technologies are expected in the future, some of these being related to the use of alternative energy sources. There are also the other solutions to reduce of pollutant emissions. In our case a new technological solution for steel processing induces the metallic material decreasing in the chain of steelmaking and consequently the gases, airborne and waterborne emissions decrease.

4. Conclusions

The new multidirectional forging technology of crankshaft reduces the material and energy consumption and might have appreciable economic and environmental effects.

This flash reduced forging is an economical alternative to the conventional forging process, which offers several financial advantages.

The evaluation of carbon footprint based on *Life cycle inventory* of an engineering steel for automotive indicates that the multidirectional forging of crankshaft may significantly reduce the greenhouse gases, airborne and waterborne emissions and total waste.

Both economical and environmental benefits might be achieved, leading to a better positioning in the specific market for crankshaft manufacturer.

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