ARCHIVES
of
FOUNDRY ENGINEERING

Published quarterly as the organ of the Foundry Commission of the Polish Academy of Sciences

ISSN (1897-3310)
Volume 14
Special Issue
2/2014

29 – 32

5/2

# Investment Casting or Forging in the Aspect of Environmental Protection

**R. Haratym [a*], J. Lewiński [a], R. Biernacki [b]**
[a] University of Ecology and Management, Olszewska 12, 00-792 Warszawa, Poland
[b] Warsaw University of Technology, Institute of Manufacturing Technology, Narbutta 85, 02-524 Warszawa, Poland
* Contact: e-mail: r.haratym@wseiz.pl

Received 20.06.2014; accepted for print 12.07.2014

## Abstract

The article compares the energy intensity of ductile iron precision castings manufacturing process with the 0.5% C steel locking mechanism element made with forging die. During the analysis variations of manufacturing processes were taken into account and also additional comparison of energy intensity connected with the machining of the steel blank was made. The influence of the manufacturing processes on the environment was evaluated.

**Keywords:** Investment casting; Forging; Environment protection.

## 1. Introduction

The main problem in the manufacturing of industrial products is the cost of production and optimization of energy consumption during manufacturing. The problem of finishing raw materials used during production of final products is not as dangerous as the possibility of rapid depletion of energy sources [1]. Hence there is a need for a rapid reduction in the energy consumption during the production of products by introducing new technologies with usage of low energy intensity materials.

Taking in to the account the domestic industry it is extremely energy-intensive then other countries [2]. For example, the energy intensity of production in most of Western countries is three times or nearly three times lower than the national; this can be observed in the UK, Norway, Denmark and Germany. Approximately two time lower energy consumption can be seen in Italy, Austria, Sweden, and up to four times less energy consumption is obtained in Switzerland. Such high domestic energy consumption is influenced by inappropriate manufacturing processes, particularly the use of machining, milling. This is the reason, why it is advised to make appropriate selection of manufacturing process [3], which allows saving raw material and energy, for example, favorable processes include: sintering, investment casting or production of plastic products. Then it is possible to achieve products with low production costs, material and energy efficient and high-quality.

## 2. Evaluation of energy consumption in the production of fork locking mechanism made from steel containing an average of 0.5% C

Figure 1 presents the technical drawing of the fork locking mechanism. The basic production technique of this element was hot forging.

Figure 2 presents the opportunity of receiving forged elements which meet given technical requirements. The holes were made for the dimensions of the M12, ∅ 20 H9 and ∅ 8 H8 they will be made with added additional material for further machining.

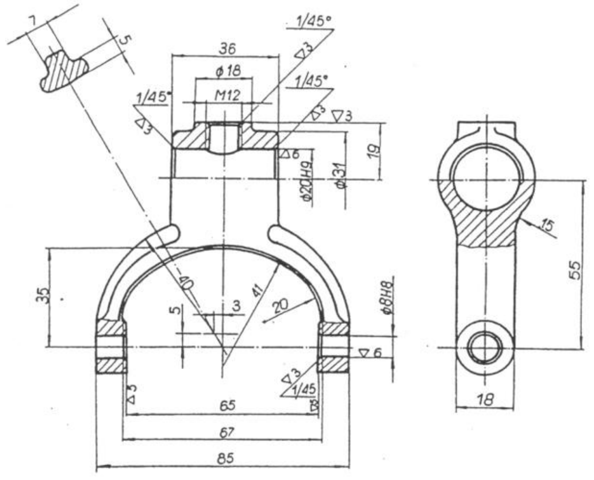
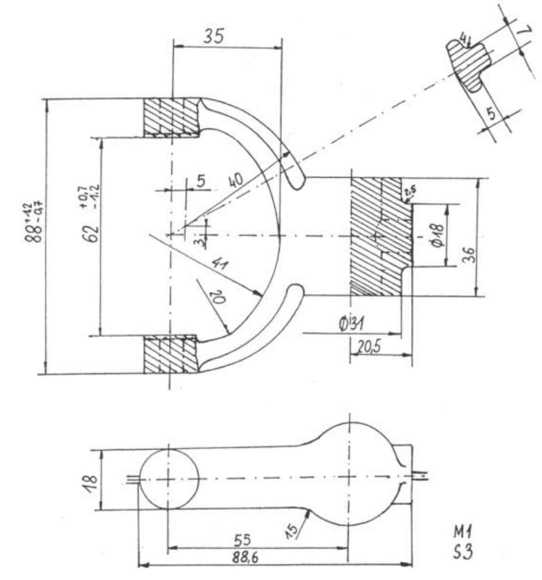



Fig. 1. Fork locking mechanism - technical drawing




| | | |
|---|---|---|
| 12 | Dopuszczalne odchyłki dla wymiarów międzyosiowych | ±0,3 |
| 11 | Dopuszczalne odchyłki dla wymiarów grubości | [illegible] |
| 10 | Dopuszczalne odchyłki dla wym. dług., szer., wysokości | [illegible] |
| 9 | Wymagania specjalne | odbiór wg PN 86/H-94012 |
| 8 | Promienie niezwymiarowane | zewnętrzne 2,0 mm; zaokr. zmiany przekroju 2,5mm |
| 7 | Pochylenia kuźnicze | 6° |
| 6 | Naddatek na wymiar | jednostronny 1,5mm |
| 5 | Wady zewnętrzne | na pow. obr. do 2/3 naddatku, pozostałe w gran. odchyłek |
| 4 | Wady kształtu | dop. przesadzenie 0,4 mm |
| 3 | Pozostałość wypływki | do 0,5mm |
| 2 | Wykończenie powierzchni | śrutować |
| 1 | Obróbka cieplna | normalizować max. 229 HB |

Fig. 2. Fork locking mechanism – forging work piece

Based on previous studies [4], energy consumption of the rough forging is 26 MJ / kg. In case of machining energy consumption would be 10.57 kWh / kg [4].

Weight of raw forgings is 0.4 kg. Mass of material with the necessary machining of holes and dimensions reduced from 88 to 85 and increased from 62 to 65 gives us the decrease of forgings weight by 0.14 kg.

That’s why the energy consumption of the fork locking mechanism production process estimated for the weight of 1 kg (is equal to the sum of a and b) is:

a) 26 MJ / kg forged element,

b) (2,5 x 0,14)x10,57 kW after conversion to MJ (9MJ/1KW) it will be 35 MJ.

It is also necessary to add energy consumption of slot forge furnace during initial material heating process. Energy efficiency of this type of furnace is 0.25 , which gives 2.9 MJ of energy for a single forging.

Thus, the final result of the fork locking mechanism total energy consumption during forging process is 65.8 MJ / kg.

## 3. Energy consumption comparison of fork locking mechanism manufactured by forging, investment casting and machining

Investment casting made from ductile iron will meet all the strength requirements of the fork locking mechanism. According to research carried out at the Department of Foundry, Institute of Materials Science, Warsaw University of Technology, the energy consumption to make the cast is 53 MJ / kg.

An alternative machining process gives:

- The starting material in the flat form 40x90, 0x90, 0 to 1, such element gives a mass of 2.5 kg,
- The material of the fork after finishing in accordance with Figure 1 is 0,40-0,13 = 0.27 kg.

Machining leads to energy intensity (including 50% recycling of chips) 1.11 kg x 10.57 kW / kg = 11.73 kW x 9 = 105.60 MJ MJ (as based on data from the GUS the energy intensity of the production of 1 kWh = 9 MJ [2]).

In addition, taking into account the energy consumption during production of initial flat element 3.2 MJ / kg [5], we obtain the total energy consumption necessary to produce one piece of fork licking mechanism part equal to 108.8 MJ.

Such a comparison allow to realize what a big difference of energy consumption occur during production of fork locking mechanism when different manufacturing processes are used.
Given that a large part of the domestic industry products is often carried out by machining, it’s possible to conclude that this is the cause of a large energy consumption of whole national industry - Figure 3 [2].

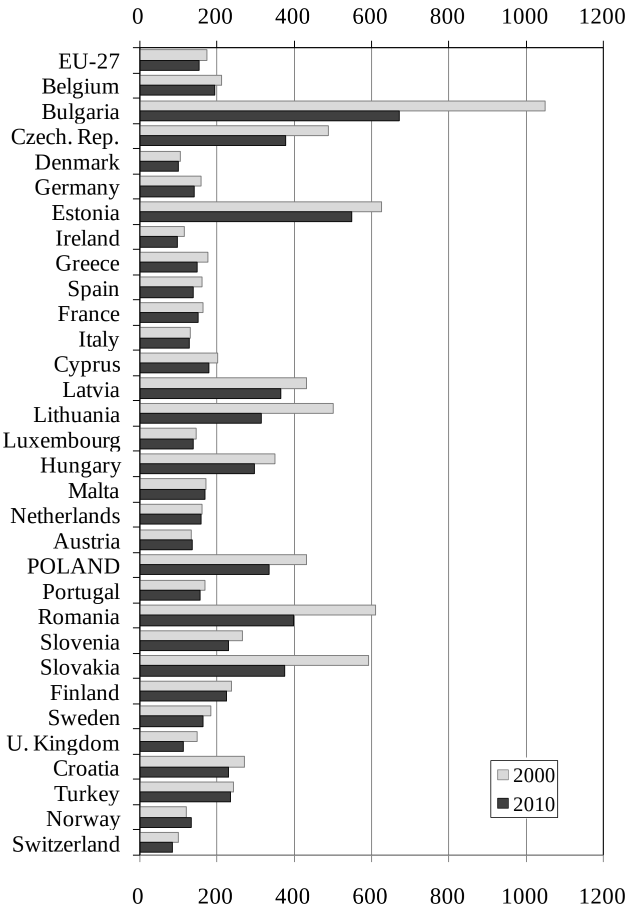



Fig. 3. Energy intensity in kg of oil equivalent per 1000 euro GDP [2]

# 4. Analysis of the manufacturing process of the fork locking mechanism in terms of forging or investment casting

Analyzing those two processes, it is noted that:

a) Energy consumption necessary for the manufacturing of a casted fork (53 MJ / kg) is less than about 20% of the energy consumption of the forging (65.8 MJ / kg) the same part.
b) The cost of producing the casting is lower due to the use of ductile iron material and much lower tooling cost (die is much more expensive than the injection mold used for the production of melted models).

Moreover, the accuracy of the resulting product (cast fork) is higher. Analyzing manufacturing tolerances ΔL of the casting calculated by the dimensional chain shown in Figure 4, where the ceramic mould is made on the basis of $SiO_2$ it is possible to obtain ΔL = 0.8 to 0.9% of $L_{nom}$ ($L_{nom}$ - casting nominal dimension) and compared to the data shown in Figure 2, we have significantly narrowed manufacturing tolerances (casting is more precise).

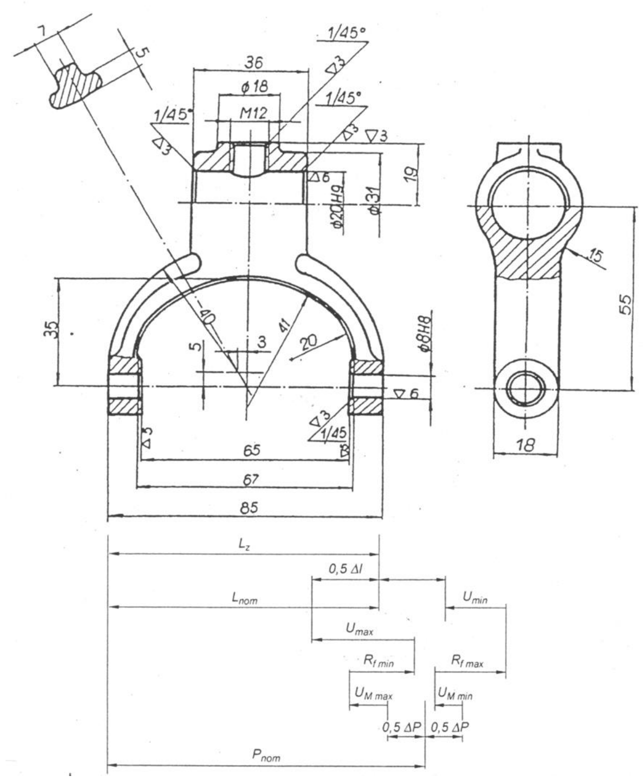



Fig. 4. Example dimension string to calculate ΔL lost wax process models

Natural environment in the production of casting is cleaner due to the fact that carbon based energy production tends to reduce the $SO_2$, $NO_x$ and $CO_2$ emissions. In order to create one KWh emission will be equal to 700 g of $CO_2$, 5.5 g of $SO_2$ and about 4.2 g of $NO_x$ [6].

By reducing electricity consumption this manufacturing process purifies the environment.

In the small scale production of about 10 Mg per year it is possible to reduce $CO_2$ emission by about 42 Mg per year, by switching to casting (instead of forging).

# 5. Conclusions

Production of precision castings from ductile iron instead of forging (from steel which contain 0.5% C) leads to manufacturing cost reduction of high quality products with significantly reduced energy consumption and shows indication towards the wider usage of material saving industrial production.

## References

[1] Ashby, M.F., Jones, D. (1995). *Engineering Materials*. Warsaw: WNT (in Polish).
[2] Environmental Protection. (2013). Warsaw: Central Statistical Office - GUS (in Polish).
[3] Perzyk, M. (1997). *Selection of Manufacturing Process*. Warsaw: WUT Publishing House (in Polish).
[4] Haratym, R., Biernacki, R., Myszka, D. (2008). *Ecological investment casting in ceramic moulds*. Warsaw: WUT Publishing House (in Polish).
[5] Fuel and Energy Economy in the years 2011, 2012. (2013). Warsaw: Central Statistical Office - GUS (in Polish).
[6] Lewandowski, W.M. (2005). *Proecological renewable energy sources.* Warsaw: WNT (in Polish).


# Odlew precyzyjny czy odkuwka matrycowa w aspekcie ochrony środowiska


## Streszczenie

W artykule porównano energochłonność wytwarzania odlewu precyzyjnego wykonanego z żeliwa sferoidalnego z odkuwką matrycową dla widełek mechanizmu blokującego ze staliwa 0,5 % C. Uwzględniono różne warianty procesów wytwarzania oraz porównano je z energochłonnością wyrobu otrzymanego z półfabrykatu hutniczego otrzymanego metodą obróbki skrawaniem. Oceniono wpływ procesów wytwarzania na środowisko.