A POINT OF VIEW ABOUT THE METALLIC MATERIALS DURING THE HUMAN EVOLUTION

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Abstract

In archaeology, the Iron Age is the period when the iron usage and the technological processes of its obtaining were the most important for the society. The Iron Age is the last period from the system of the three ages of classifying the prehistoric societies, preceded by the Bronze Age. The influences on the large areas in Europe were remarkable. Many legends say that responsible for this result were the ancient gods, but it can be also another cause: some people used for the tools and weapons better materials from the first Iron Age, while the inhabitants from other areas used poor quality steel or bronze. It is very important to research the ancient epopees using the 'engineering glasses', to discover the origin of the materials and also the secrets that wrote the history of the world. At the beginning, human believed that everything must remain hidden in the basement, so there were few ones in charge of mines and iron processing. Later, humanity began to understand the iron importance and started to use iron for more and more activities. The present paper limits only to some milestones regarding the evolution of the usage of the new materials, but also to some specific technologies for the epoch.

Keywords: Tools, weapons, iron, history, technology

1. INTRODUCTION

Iron metallurgy had a fast evolution during time, because technical processes were in continuous change, depending on human necessities. At the beginning, humans believed that 'Metals are offering no advantages, so we should not search for them [1]; this is the reason why there were so few the ones which were mining and processing iron. The whole equipment was rudimentary, built in wood, burned clay or in iron and it had specific geometry, seeming like a cavity.

The first evidences of iron usage are from Sumer and Egypt, where there were manufactured different objects of meteoric iron. Only later, in the first Iron Age, Hallstatt, people started to exploit the mineral ores, located in the basement. But along with the discovery and exploitation of the underground deposits, critics and philosophers of the time have launched different assumptions regarding the advantages and disadvantages of these activities, realizing a comparison between the profit obtained from agriculture and mining [1]. For example, Ovidius considered that 'Earth is not hiding and alienating from us what is useful and necessary to humanity, bringing to the light herbage, cereals, fruits and trees; contrary, minerals are buried, so they should not be searched'. Also, Pliny said about iron that it is 'the most abominable fruit of the human inventiveness'. But there are some positive opinions about metals exploitation; therefore, Timocles was considering that 'If iron does not exist, people would have a horrible existence, together with the wild beasts [1].

The present paper is a continuation of the previous researches [2] and it is focused on the study of the ore excavation and iron processing in the Medieval Period, when is starting the wrought iron production and is projected the blast furnace. There is also an improvement of blades and swords and is fabricated the 'wootz steel', known as damask steel, which was of good repute in the entire world. It is an important period in the history of steel obtaining, because it was a time of transition, paved with many advancements, when were also organized the iron obtaining workhouses.

2. WROUGHT IRON PRODUCTION

At the beginning of the Medieval Period, there were no major changes in the iron processing technologies, comparative with the Roman Period. As well, in this epoch, there was not an increase of the iron lump dimensions; contrariwise, after the researches accomplished, it was discovered that most of the lumps had a mass minor than 8kg (this was the maximum mass supposed to be existed in the Roman Age). In Ireland, lumps had a mass between 5.200 g and 5.400 g. In Great Britain, there are evidences that confirm that a lump with the mass of 14kg was manufactured in 1350 A.D. The limits regarding the lump dimensions were imposed by the forge and processing difficulties, not by those appeared on casting. Some collectivities, as Swedish and Slaves, were producing thin bars, with lengths less than 0.32 m, but in most of the countries, big lumps were forged in small pieces, with bar shapes. Furthermore, the furnaces had two main configurations: the bowl furnace, built on horizontally (it was used also in the Roman Age) and the bowl furnace, built on vertically [3]. An example of the last type of furnace was discovered in Bargen (Germany), near Schaffausen (**Figure 1, a**), but it did not resist during time. But it seems that it was a type of medieval furnace, from where the lump was extracted on the superior part, not on the lateral side. This has appeared for the first time in Pyrenees Mountains and, later, it was used in Northern England, in the post - medieval period [4]. The primitive migratory citizenries kept using simple bowl furnaces, although there were improved alternatives, like the Slavonian furnace, discovered in Zelechovice, Czech Republic (**Figure 1, b**).

Another particularity in iron processing in the Medieval Age is the usage of water power; many of the production units are located near to stream. But the minor ones were not using water as energy source, because the water exploitation was needed a high capital, although the necessary air debit was of 300 L / min was not so high and it could be produced using manual implements.

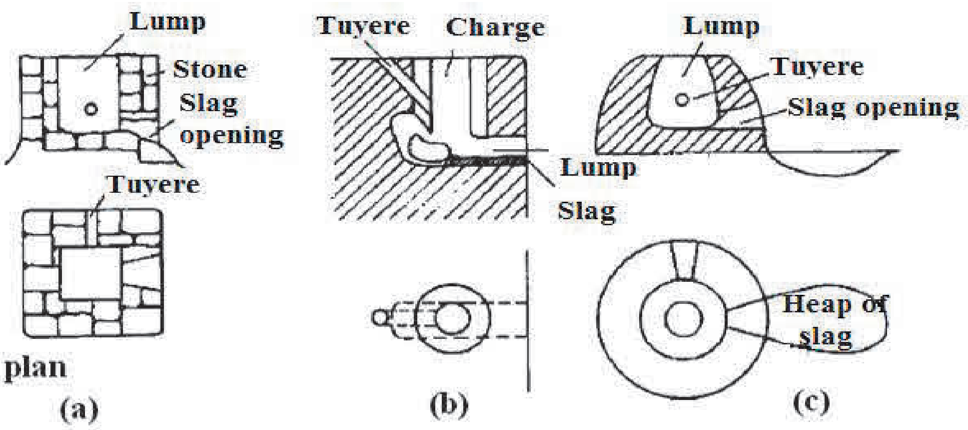


Figure 1 Medieval furnaces, with internal section of 0.3m *(After Crossley, D., Ashhurst, D., 1968, [4])*

a - furnace discovered in Bargen, Germany; b - Slavonian furnace, from Zelechovice, Czech Republic; c - furnace with cupola, discovered in Durham, England

In Europe, only the monastic institutions had enough capital to invest in iron industry, so the evolution, on large scale of this industry, was depending of the ascension of religious institutes.

3. THE BLAST FURNACE EVOLUTION

The advancement and introduction of blast furnace in Europe was one of the most interesting aspects from the history of metallurgy. It is known that the blast furnace was used in China, long before it was used in Europe, but it cannot be supposed that it had an independent Europe origin. Its introduction in Europe occurred when the relations between orient and occident were well established and all that was needed was a cognizance of cast iron helpfulness. Cast iron was produced accidentally for the first time, in the Roman Age and the experimental activities showed that it was possible to produce it in a rabble furnace, with a height of 2m, if it is used a sufficient quantity of coal. The present evidences certifies that Swedish were the first citizenry that used the blast furnace for the first time; this is confirmed by the presence of two sites, Lapphyttan and Vinarhyttan [5], from where there were sampled slag assays, which were analyzed in laboratory; the results (**Table 1**) are showing the carbon content in the iron products in the period 1150-1350 A.D. The minor quantity of lime can be a result of using ash, as main wood. The communion between Swedish and Eastern Europe, through The Volga River, generated the idea that the influences have arrived from China, by the Mongols. There was a keen demand of cast iron in the military department, when the wrought iron was not enough for manufacturing weapons. In the 15th century, the interest was so strong that determined a development of high or low columns of the blast furnace, in order to produce cast iron weapons.

Table 1 Slag samples analyses resulted from blast furnace usage, in Sweden *(After Magnusson, G., [5])*

%	SiO	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	TiO
Vinarhyttan Serning	62.27	10.10	1.34	4.74	1.44	4.12	4.23	2.63	1.86	0.27
Lapphyttan Bjorkenstamm	53.90	6.20	-	3.5	11.80	10	12.10	0.91	0.9	-

The metallurgist observed that some minerals ores were containing a high quantity of flux than others, so they tried to produce a more fluid slag. This would have in their composition a great amount of lime. But in these furnaces, it could be added lime only as powder, not as a cake, because it would be hard to solubilize. The result of these modifications would be the necessity of having a working temperature higher than 1300 ^{0}C, in order to realize that limous slag more fluid.

During time, it was discovered that a possibility of reducing the fuel consumption would be the usage of a higher furnace, to increase the stationary time in intensive reducer conditions [6]. But the cast iron was not used in manufacturing weapons in assault time, being preferred the wrought iron; the explanation could be that the cast iron could not be produced in large quantities, without difficulties, until the 15th century.

4. DAMASCENING AND WELDING PROCESSES

The damascene steel ('wootz steel') had a high content of carbon, which, sometimes, was exceeding the value of 1.6%. If the small steel ingots were worked using a hammer, until they would transform in thin strips, it would be produced a surface decarburization and, when they are welded together on a low temperature, the carbon is not dispersing [7]. In order to diminish the tendency to fracture, there were introduced the damascening and welding processes. Therefore, until the end of the 10th century, it was performed a new technique, where the steel pieces with different percentage of carbon were welded together to obtain an unique piece (for example, a blade for sword), which was then thermal treated (**Figure 2**).

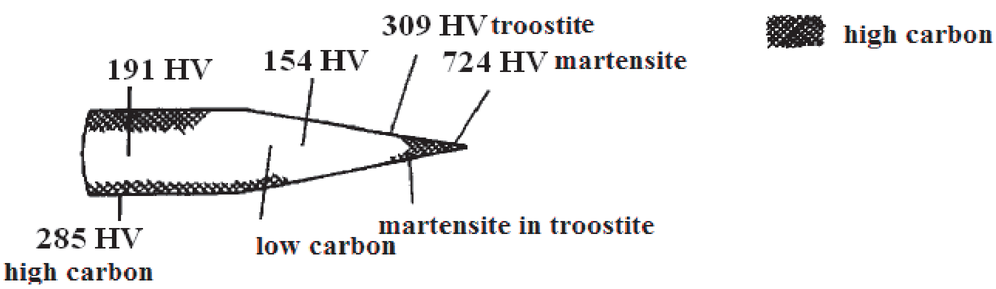


Figure 2 Section in a blade discovered in Japan, dating from 17th century *(After Smith, C. S., 1960, [8])*

It is difficult to establish the chemical composition of the medieval ingots ‘wootz’. Most of the information are obtained from the ingots brought back in Europe by the colonial administrators, in the 19th century. But in this period, there were at least two ‘wootz’ ingots: the first one was realized from wrought iron and wood, which were introduced in a pot, until there was produced an iron ingot, melted in the interior of the pot. The total carbon amount was about 1.6 %, and the ingots had a coarse structure, but homogenous, containing cementite and pearlite.

In the second process, the pots were realized in refractory clay, originating from the granite disintegration, in which was added rice chaff. In the pots, there were not added coal or wood, but it was heated in a furnace bowl. The ingots resulted from the second process were recently examined and it was discovered that the carburization procedure is from the wall of the pot; the carbon content is fluctuating on section, having the maximum value in exterior, of 0.8 % and the center was only ferrite.

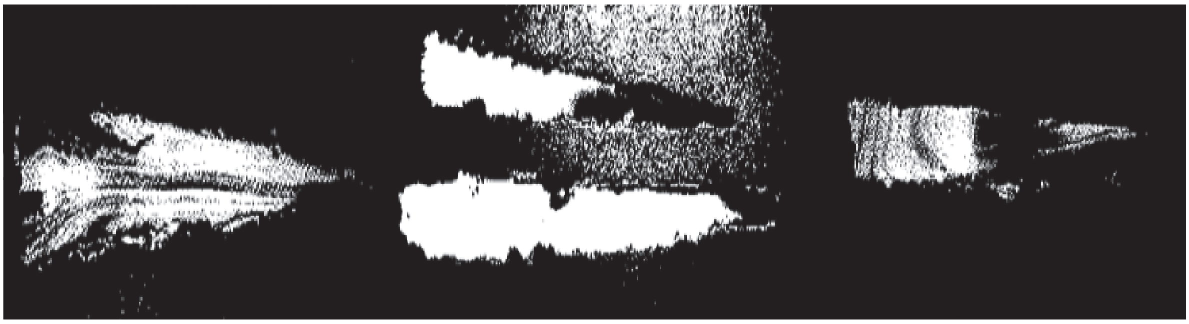
Analyzing these processes, it can be concluded that the damascening and welding (of models) are similar. The obtained methods of the structures, from welding strips of wrought iron, are as follows: welding the decarburized steel strips, welding the carburized wrought iron, combining materials with high and low carbon content or different types of steels or meteoritic iron. It is very important that the working temperature could be conserved on a low value, in order to obtain complete diffusion.

The steel produced in the medieval period is containing high quantities of phosphorus therefore it was an important commerce product, which was important from the areas rich in iron ore. The metallurgists necessitated manufacturing all the working instruments; the gauge instruments were realized in solid steel, which was quenched in water. They were forged, hammered down on a grindstone and then cut, using a hummer with a cutting girth and, on the other side, gab. In order to increase their hardness, they were sprayed with a mixture containing 65 % burned bison horn and 35 % salt. These were heated in fire and then, cooled in water.

To obtain different conditions, which are necessary in the welding heart, for heating on 900 ^{0}C and then, for carburization, a used method was to envelop the ingot in clay or animal leather. The fire would burn the leather until the azoth and carbon compounds; after the carburization, tools were quickly removed from clay layer and cooled in water [9].

5. IRON ARTIFACTS

At the end of the 13th century is appearing for the first time specializations, as the knife producers of art. Knifes were rarely produced from solid steel, because it was too expensive and welding the cutting parts of steel with the posterior part was a complex process, so each ironsmith could have its own technique. Some artifacts from the medieval period were having thin layers, with a high concentration of arsenic (more than 1%). When the iron is heated by a forger, the arsenic content is cumulating in the exterior layers of the iron. In **Figure 3**, there are presented some commune examples used in knife manufacturing. In **Figure 3 - a**, it is presented the used steel as a heart, with a plaque of wrought iron, which can be enfolded on the posterior part, creating sides. **Figure 3 - b** indicates a cutting object, obtained from steel, welded with an iron piece, formed by layers with high and low percentage of carbon, sealed together. The ‘white lines’ are, probably, zones with a high content of arsenic, due to oxidation during the heating process. The claws were steeled as well as the knife blades (**Figure 3 - c**). The thermal treatment of the cutting objects was efficient and the cementation zones had the hardness of 557, 575 and 857HV, which means that they were just as good as the ones used by butchers nowadays.



a. b. c.

Figure 3 Micrographies of the medieval knifes *(After Tylecotte, R. F., 1992, [6])*

6. IRON METALLURGY IN HUNEDOARA, ROMANIA, IN THE MEDIEVAL PERIOD

Valea Cernei, being larger in Hunedoara area, has encouraged the establishing of a settlement which started to process the iron ore, to realize exchanges with grains and other agricultural products. From antiquity, until the medieval period, the iron metallurgy technologies are stable; a major technical improvement is considered the producing of a material considered as scrap in that period - the cast iron. Although the chemistry of iron carburization was unknown for the forger, from practice, he could observe that, if he added more charcoal in the furnace, he could obtain a liquid metal, but if he added less charcoal, he could obtain a lump very good for forging. According with the urbanistic plan *(Urbarium)* [10] from 1681 - 1682, the main smitheries from Hunedoara region are presented in **Figure 4**.

Figure 4 Map of the main smitheries from Hunedoara county *(After Ioan R., 1998, [10])*

(1 - Nădrag; 2. Blast furnace from Govăjdie; 3 - Superior Limpert; 4 - Inferior Limpert 5 - Mower Atelier; 6 - Plosca; 7 - Blast furnace from Toplița; 8 - New Atelier; 9 - Fanci; 10 - Cerna; 11 - Inferior Teliuc; 12 - Perintei; 13 - Hunedoara Bania; 14 - Zlasti Bania; 15 -Inferior Atelier Runc; 16 - Superior Atelier Runc)

In this period, in Valea Caselor was operating a furnace (**Figure 5**), which may be considered an evolved stage in the concept of furnace architecture. It was discovered in 1895, at 3 km from village Ghelari (Hunedoara region), but it is dating from IX-X centuries AD. The furnace discovered in Valea Caselor is very similar, by architecture and construction, with the furnaces for iron ore reduction, using the Catalan procedure, which was frequently used in the French region of the Pyrenees Mountains. The interior profile of the furnace was circular, coated in stone; it was enlarged to the exterior and had the configuration of a square shaft. The charging of the furnace was realized on the upper part; the material layers (iron ore and charcoal) were disposed alternatively and the furnace had bellows, which could be auctioned manual using feet, but the lump was extracted on the superior part.

Figure 5 Restoration of the metallurgical atelier and furnace from Valea Caselor *(Source: Ioan R, 1998, [10])*

7. CONCLUSIONS

Since humanity started to process iron, it was a considerable evolution of the mining and processing technologies. In the Medieval Period, an important aspect was the dissemination of the knowledge and welding techniques in West Europe. It was introduced the blast furnace; the interest became enough strong, so it initiated a development of the blast furnace shaft, to produce cast iron weapons. In order to solve the problem of fragility for steels with a high content of carbon, there were introduced the damascening and welding processes. In Romania and in Central Europe, all the iron processing activities are organized in ateliers; at the beginning of the 16th century, the iron producing ateliers were localized on a stream, because it is the period when the entire Europe is using the water energy.

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