

The water trompe or the Pyrenees Trompe. Recovery of the functional principle for pumping applications. Approximation by using electromagnetic equations.

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1. Introduction

Archaeological research going hand in hand with engineering research, can offer multiple ideas initially disconnected to be developed together.

In this case, the reconstruction of a pilot model of water trompe from historical references of the “Catalan Forge” or “Catalan method” of obtaining iron directly from iron ore, can drive to study a two-phase fluid using the electromagnetic equations, and improve its behaviour.

The low performances of the device lead to develop an electric device to recover as much energy as possible. Nevertheless, using directly the trompe device, a simple pumping machine can be used as developing technology as well.

Keywords: “Catalan Forge”, “Catalan Method”, water trompe, electromagnetic equations, two-phase flow, air-water flow, hydroelectric integrated machine.

2. The Catalan Forge and the water trompe

The direct method of obtaining iron from ore by means of charcoal is known as Catalan Process of Catalan Forge (“Farga Catalana”). It had a strong implantation in Spanish and French Pyrenees until the development of indirect methods (blast furnace and converters) to the late nineteenth century. [1]

This method involves the warming of the iron ore with charcoal in a low furnace, which receives air from the water trompe or bellows, and the subsequent reduction in iron, without reaching the fusion point as in blast furnaces. Later, forging the spongy mass obtained by hammering, the slag contained in iron ore is expelled until the consolidation and shaping of the block of iron.

The location of the forges in the late Middle Ages, because of the increased demand for iron utensils, was tied to the rivers and minor water courses to provide the driving force necessary to move the hammers, and was walking away from the mine and the bottom of the forest.

The trompe of water, or the trompe of the Pyrenees, is a hydraulic machine in which from a sufficient flow of

water and a drop of between five and twelve meters, a continuous and sustained flow of air is obtained at a sufficient pressure to achieve and be injected into the furnace to feed the combustion of coal.

The trompe is a device for blowing of a robust design: since it do not have moving parts, requires little maintenance and rarely caused the process stop, as opposed to the bellows, which required adjustments and repairs more often. Another advantage of the trompe is the constancy of flow rate, in opposition to their alternative system of bellows. This allowed obtaining a higher and more constant temperature in the furnace, and possibly reducing the time of the operation (about 6 hours).

With regard to the characteristics of the injected air, its temperature and humidity were different in both cases (trompe and bellows). It seems that in the case of the trompe, the air flow could have a lower temperature and a higher humidity, either in the form of vapor or small droplets, possibly facilitating the process of reducing ore to iron, and conferring different properties.

3. Construction of a pilot model of trompe

The objective of the construction of a pilot model of the trompe is to evaluate its possibilities as a simple pumping machine in order to be used as a developing technology.

The reconstruction of the machine from historical and archaeological sources has been done before, but its behaviour hasn't been sufficiently studied

Essentially, the trompe consisted of one or more vertical tubes through which water was channelled by gravity. The water passing through a narrower hole, absorbed the air through holes in the tube, due to the Venturi effect (the more the velocity of the fluid is, the less the pressure become). Bubbles of air were dragged by the water flow until a sealed receptacle called the «wind box», where air was separated from water. Air was sent by adjustable pressure to the furnace nozzle. The trompe became one of the characteristic elements of what became known as the «Catalan method». [1]

The pilot model of trompe was constructed in 2007-2008, at 1:3 scale, by using two electric pumps in order to

recirculate the same water in a closed circuit. The “wind box” was built with an iron cylinder. The waterfall tube was assimilated to a 3 m long iron tube of 6 cm squared shape.

The water flow can be regulated from 0 to 20 l/s, and the air pressure can achieve 0,2 hPa (0,2 atm. aprox.). Energetic performance between hydraulic power and pneumatic power is lower than 15 %, principally because most of energy is carried by water flow and it is lost by the shock of the water against a flat and rigid surface in the “wind box”.

4. Analysis using electromagnetic equations

Thinking that water flow can be assimilated to current, and water pressure, to tension, Kirchhoff laws can be used to study this hydro-pneumatic system. Moreover, in general, electromagnetic equations can be used to analyze the two-phase water-air fluid, and its turbulences and behaviour. Electromagnetic solutions can be used to optimize the system. [5]

In a simpler way, the behaviour of the two-phase air-water fluid can be assimilated to the concept of (hydraulic) impedance, using the idea of density of current.

5. Development of an special electric machine

Knowing that most of energy is lost in the “wind box” by shocking the water against a bench, is plausible in an electric engineering department to try to develop and special electric machine adapted to these contour requirements. This is the objective of our nowadays efforts, in order to achieve a submersible electric machine with the associated hydraulic turbine, developed together.

6. Direct application in the third world

Apart from the electricity generation, the reduced performance hydro-pneumatic system can be useful to provide a simple pumping device as developing technologies. Actually, the process is reversible, ie, from an air flow, some water drop can be overcome. Mixing air bubbles in a vertical duct with water, the two-phase fluid achieve some higher position, always with a reduced performance.

7. Conclusions

The application of electromagnetic equations to this hydro-pneumatic system, called trompe of water or trompe of the Pyrenees, allows to study properly the behaviour of the two-phase water-air fluid circulating in it, and also allows to improve its performances.

Most of the energy of the system is lost in water falling and shocking against a bench, in which case could be replaced by a hydroelectric generator. This circumstance is the excuse to develop a special electric machine in the electrical engineering laboratory of ETSEIB.

The trompe system of blowing can be directly used as a development technology in the third world, and it can be also used as a part of a pumping device in association with another similar device using the same principle in the reverse way.

Supports

The Catalan Society of Technology, a subsidiary of the Institute of Catalan Studies (c. del Carme 47, 08001 Barcelona), now eight years ago provided for that purpose the water pumps used for water recirculation of the pilot model of trompe.

Furthermore, studies are being developed within the framework of the doctoral program of the Department of Electrical Engineering (DEE) of the School of Engineering of Barcelona (ETSEIB) from the Polytechnic University of Catalonia (UPC), and the tutor Dr. Ricard Bosch i Tous, thanks to a pre-doctoral fellowship at the Department of Universities, Research and Information Society of the Generalitat of Catalonia and the European Social Fund.

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