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Original Research Article

Investigation of the influence of supply parameters on the velocity of molten metal in a metallurgical reactor used for platinum recovery

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ABSTRACT

Exhaust gases which are introduced into the atmosphere contain impurities such as carbon monoxide, unburned hydrocarbons and nitrogen oxide. Auto catalysts enable air pollution from these exhaust gases to be reduced considerably. Typical auto catalytic converters consist of the carrier (ceramic or metallic) and the catalytic system. Platinum group metals (PGM) are responsible for the catalytic function. All spent auto catalysts should be purchased and processed in order to recover the precious metals from them. This article presents the results of coupled analyses of electromagnetic and flow field calculations. The aim of this research was to design a device for extracting precious metals from used auto catalytic converters. Calculations were made to determine the velocity field distribution of a liquid metal, the movement of which was forced by the electromagnetic field. Computational experiments were conducted to obtain the relationships between the metal velocity distribution, the inductor supply and geometrical parameters in order to improve the construction of the presented device. The calculation shows that viscosity and friction has a greater influence on velocity distribution than forces distribution.

1. Introduction

Precious metals are used widely as catalysts in many industrial applications. In the majority of cases, only the use of a noble metal (as these are resistant to corrosion and oxidation in moist air unlike base metals) as a catalyst will ensure a reasonable reaction rate. One of the main applications of such catalysts is in exhaust systems in automobiles. In automotive engines during fuel combustion, compounds harmful to health and the environment are emitted. It happens because the combustion process is accompanied by the formation of inherently toxic compounds: such as carbon monoxide (CO), unburned hydrocarbons (HC) and nitrogen

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oxides (NOx). Catalytic converters reduce this air pollution significantly. Therefore, such compounds must undergo certain transformations to become harmless in the environment. Three-way catalysts (TWC) used in cars serve three important functions: (1) to reduce NOx to free nitrogen, (2) to oxygenate and oxidize (burn) CO and (3) convert HC to carbon dioxide and water [1,2].

The necessary condition for the effective functioning of the catalyst is having a large active area where the carrier has a structure similar to a honeycomb (Fig. 1). The auto catalytic converters used in motor vehicles are constructed from metal or ceramic carriers. The catalytic carrier is wrapped in a fibrous material (to prevent slipping), is enclosed in a stainless steel shell and has the porous structure of the honeycomb (the dense net of square holes). Such a construction increases the active surface which is the contact zone of precious metals with fumes. Platinum metals act as catalysts in the combustion reaction. Usually these are: platinum, rhodium and palladium. Typically, the platinum layer is applied to a ceramic carrier (Al_2O_3 additions of other oxides such as CeO_2) [3].

The content of platinum metals in auto catalytic converters not only depend on the construction and its utilization (an average of about 2 g of platinum), but on the car manufacturer as well. Catalytic converters are devices that should be periodically regenerated, and eventually replaced. Currently, this increasing number of catalysts (coming from exchanges and also from vehicles withdrawn from the market) goes to the landfills. The needs of waste management and high prices of precious metals contained within these wastes, makes the recovery of platinum group metals from used auto catalytic converters potentially profitable [4]. The main problem however, in platinum recovery from catalysts, is its low content within a single catalyst. This paper describes the work and research undertaken in dissolving the platinum group metals from used auto catalytic converters in a metal-collector and flushing out many of these catalysts by using the same metal. These were treated in a hydrometallurgical way in order to obtain pure platinum and other precious metals [5].

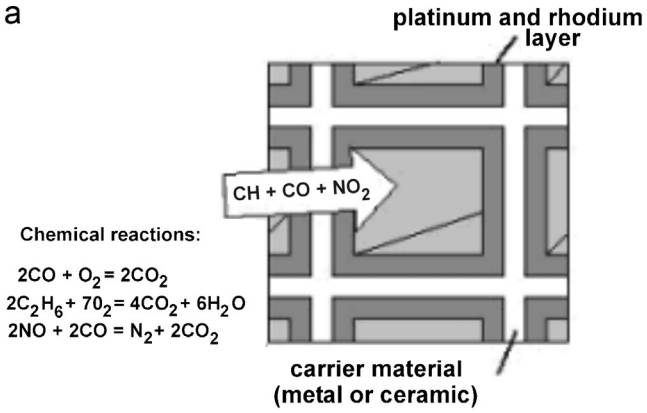

Fig. 1 – The structure of TWC catalyst [3] (a) scheme (b) real view.

In another method, a grinded catalytic converter carrier is melted with the addition of another metal, which is treated as a collector metal [6]. Methods of PGM recovery by collection within another metal are widely applied all over the world. This process allows PGM metals to go to the alloy and the carrier, whereas a slag is separated and becomes a waste. The major advantages of applying a metal collector is to decrease the temperature of the process, and thus a lower cost of PGM metals recovery. The alloy obtained contains a high concentration of platinum and other precious metals which further purification will separate into individual precious metals [5].

Lead has been chosen for the process as it is suitable for a collector metal due to low melting temperature.

In many metallurgical devices, the forced movement (mixing) of the liquid metal is advantageous for the process. This movement enhances and increases the efficiency of the process. This article discusses the issue of flushing used auto catalytic converters into its liquid metal. This is realized by using a magneto-hydro-metallurgical device to force circulation of liquid metal under the influence of electromagnetic fields. The movement of the metal collector speeds up leaching of precious metals. Use of a closed cycle increases the concentration of precious metals in the metal collectors. This paper presents the calculations of the coupled analysis of an electromagnetic field and a flow field. The purpose of these calculations is to determine the relationship between the basic electrical parameters, velocity and flow structure. The effect of power frequency on the flow parameters is also analyzed in the study.

2. Calculation model

To enforce liquid metal movement a rotating magnetic field was used. The model of a device for which calculations were carried out consists of a three-phase inductor (1) placed inside the magnetic core (2) and a channel (5) made of a thin non-magnetic steel filled with a liquid lead (3). The scheme of this device is shown in Fig. 2. The working version of the device is shown in Fig. 3.

An inductor produces a rotating magnetic field which induces eddy currents in a liquid metal interacting with the inductor's electromagnetic field. This interaction generates electromagnetic forces causing metal spin. In a stream produced in this way, used auto catalytic converters (4) are placed in the molten metal and this allows platinum, palladium and rhodium to be flushed from the capillaries. The continuous movement of a metal significantly enhances leaching. The application of the same melt in leaching to a large number of