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Importance Of Recycling Of Precious Metals In Used Automotive Catalytic Converters

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ABSTRACT

Extensive reserves and resources will continue to supply the global demand for precious metals for many decades. Depletion is not the issue - the greenhouse gas emission is. We consume more nonrenewable resources and produce more emissions to acquire the precious metals necessary to produce the catalytic converter that reduces emissions. From the creation of the first modern gasoline powered automobile by Karl Benz in 1886 to the future driverless cars, automobiles remain as one of the greatest inventions of all time. Whether it is a necessity or a luxury, it is most certainly indispensable. Present research article is beneficial for the science and technology researcher as well.

Keywords: catalytic converter, toxic by-products, honeycomb structure, Diesel Particulate Filter

Introduction

In some countries, there are almost as many motor vehicles as there are people. On average, there are 1.88 vehicles per U.S. household [1]. Monaco has the highest number of cars per capita, with 748 cars per 1,000 people [2]. With billions of vehicles running on the roads across the world, it is not only the most widely used mode of transportation but also the number one cause of air pollution. Car exhausts emit toxic gases and hydrocarbons which causes global warming, acid rain, air pollution and adverse effects to human health. According to World Health Organization, ambient air pollution is linked to 4.2 million deaths worldwide, resulting mainly from heart disease, stroke, chronic obstructive pulmonary disease, lung cancer, and acute respiratory infections in children [3].

To prevent air pollution in the USA, Congress passed the Clean Air Act of 1970, which created air-quality standards and required that every new car has to be equipped with a catalytic converter. The first emission norms were introduced in India in 1991 for petrol and 1992 for diesel vehicles. These were followed by making the catalytic converter mandatory for petrol vehicles. Catalytic converters are devices used in the exhaust system of automobiles to convert toxic by-products such as carbon monoxide (CO), nitrogen oxides (NOx) and hydrocarbons (HCs) of fuel into less hazardous substances such as carbon dioxide (CO2), water vapor, and nitrogen gas (NO2). The catalytic converter's honeycomb structure provides the maximum surface area on which oxidation and reduction reactions take place. The honeycomb structure is lined with rare, expensive and precious metals that act as a catalyst.

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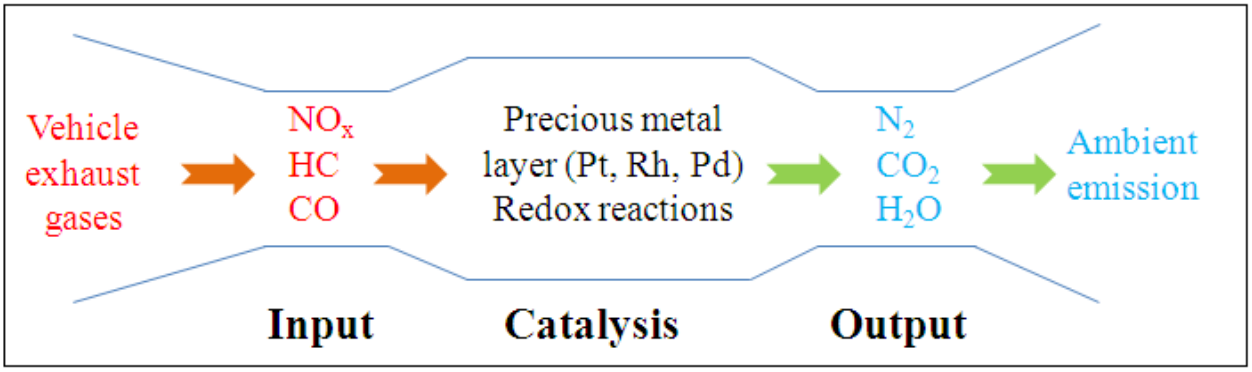
Image Source: howstuffworks

Precious group metals (PGM) are rare, naturally occurring chemical elements that have high economic value and are chemically resistant. Their rarity, luster, and ductile nature sets them apart from regular base metals and allows them to fetch higher prices. The most well-known precious group metals include gold, silver, platinum, and palladium and rhodium. These metals are used in many technologies and products in modern society, especially auto-catalysts. The catalyst used in the converter is mostly a precious metal such as platinum, palladium or rhodium. Platinum is used both as a reduction catalyst and an oxidation catalyst. Rhodium is used as a reduction catalyst, while palladium is used as an oxidation catalyst.

Catalytic Reactions



Due to the role of the catalysts, NO_x can react with the reductant to produce nitrogen gas and water according to the following reactions:

$4NO+4NH_3+O_2 \rightarrow 4N_2+6H_2O$

$2NO_2+4NH_3+O_2 \rightarrow 3N_2+6H_2O$

$NO+NO_2+2NH_3 \rightarrow 2N_2+3H_2O$

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The reactions to oxidize carbon monoxide and unburned hydrocarbon are described by the following reactions:

$2CO+O_2 \rightarrow 2CO_2$

$C_xH_{2x+2}+[(3x+1)/2]O_2 \rightarrow xCO_2+(x+1)H_2O$

Initially, only two types of catalytic converters were used across the automobile industry mainly for gasoline and diesel driven vehicles. With the advancement in technology and stricter emission regulations, the automotive catalytic converter has evolved over the years, becoming more efficient. **Three Way Catalyst (TWC)** oxidizes exhaust gas pollutants (hydrocarbons and carbon monoxide) and converts nitrogen oxides into the harmless components water, nitrogen and carbon dioxide (CO2). Favored for smaller, gasoline vehicles, it has a ceramic substrate with a high palladium and rhodium content.

Chemistry of Particulate Filter

Selective Catalytic Reduction (SCR) has a proven and advanced active emissions control technology system that injects a liquid-reductant agent through a special catalyst into the exhaust stream of a diesel engine. **Lean Nox Trap (LNT)** is used to reduce nitrogen oxide emissions from smaller diesel engines. **Gasoline Particulate Filter (GPF)** has an inline exhaust filter designed to capture soot particulates in direct-injection petrol engines. **Diesel Oxidation Catalyst (DOC)** has an "after treatment" component that is designed to convert carbon monoxide and hydrocarbons into carbon dioxide (CO2) and water, by breaking down pollutants in the exhaust stream in a diesel engine. **Diesel Particulate Filter (DPF)** captures and stores exhaust soot in order to reduce emissions from diesel cars. It contains both platinum and palladium but no rhodium [4].

Although there is a wide variety of possible combinations of PGMs in catalytic converters, the total content of these metals is up to 2000 ppm in the ceramic substrate. Based on the data, the mean mass ratio of the three metals Pt/Pd/Rh is 2.4/5.4/1. This ratio is highly dependent on the commercial price of each metal. However, the Rhodium content in spent ceramic catalytic converters seems to be almost constant at around 296 ppm.

Growing Demand

Demand for PGMs is stronger than it has ever been as emerging economy countries and First World nations improve their emissions standards. Half of world's mined supply of PGMs is sourced from South Africa, one third from Russia and most of the rest from Canada, the USA and Zimbabwe. It is this continuing dominance by just two countries that is often a key factor in the PGMs being assessed as critical metals [5]. Mining operations will not be able to meet the needs of the market, and it will be up to the recycling industry to try to make up the shortfall in supply [6]. Demand for platinum, palladium and rhodium (platinum group metals, or PGMs) coming from recycled catalytic converters has never been stronger. It is estimated that up to 30 percent of

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PGMs will come from the recycling industry by 2021. The United States represents 30% of globally recovered platinum, 50% of palladium and 30% of rhodium from recycled auto catalysts.

It is considerably less expensive to recover precious metals from spent auto catalysts than it is to extract material out of the ground. The average global cost to mine one ounce of platinum from the ground was $932 in 2015 [7]. This is huge considering the average spot price for platinum in 2015 was $1,053 and $988 in 2016, according to Kitco[5]. Catalytic converter buyers that have a good source of buying information can expect to make anywhere from 15 percent to 30 percent profit buying and reselling materials to a converter processor/refiner.

Recycling precious metals takes a lot less time and energy. Effective PGMs recycling from spent automotive catalysts requires a well-tuned recycling chain, consisting of several specialized stages. Catalytic converters are collected from the scrap yards of the car workshops as well as ELV (end of life vehicle) authorized treatment facilities where sorting and dismantling of the converters takes place followed by crushing, milling, homogenization, sampling and assaying.

The final stage consists of PGMs recovery and refining. PGMs recovery from spent automotive catalysts is dominated by big integrated smelters-refineries such as Umicore and Johnson Matthey in Europe, MultimetcoInc and Techemet in USA and Nippon PGM Co in Japan. Hydro- and pyrometallurgical processes are applied for recovery of PGMs from spent automotive catalysts.[8]

Conclusion

Technological advancement in automobile industry and the enormous amount of used cars makes it necessary to control the waste being generated. Given the critical mega-trends of rising global population and consumption, and the need to address climate change, PGM metal recovery from used auto catalytic converters is an important step towards natural resources and energy conservation.

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