FINAL REPORT

THE IMPORTANCE OF NICKEL COMPOUNDS: CATALYSTS

Prepared for

European Nickel Institute

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THE WEINBERG GROUP LLC
Le Val Duchesse
360 Boulevard du Souverain, box 5
1160 Brussels, Belgium
e-mail science@weinberggroup.com

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1. INTRODUCTION

Catalysts play a vital role in sustaining the competitiveness of large parts of a modern economy. They are speciality chemicals, produced by a small number of expert companies, many of which are based in the EU. They are carefully formulated to provide uniformity of properties in terms of performance and durability to the customer. In a number of major process industries, most notably oil refining, chemicals processing, and pharmaceuticals, modern catalysts deliver substantial improvements in selectivity, output quality, and process innovation, as well as major reductions in energy consumption, feedstock use, waste and cycle time. In the chemical processing sector, for instance, there are more than 50 major catalytic processes.

Alongside a number of other important metals, nickel technology is widely used in the catalyst industry. Modern nickel-based catalysts must meet the ever-increasing demand for process efficiencies from a number of major industries. Catalyst manufacturers achieve this through a range of different technological solutions, including new materials, new forms of catalyst, and different production processes. Nickel compounds provide a technological pathway for the production of a number of modern nickel-based catalysts.

2. NICKEL AND CATALYSTS

Catalysis is the acceleration of a chemical reaction by means of a 'catalyst' which itself is not consumed by the overall reaction. Catalysts work by providing an alternative mechanism involving a different transition state and lower activation energy. Hence, catalysts can assist reactions that would not run without the presence of a catalyst, or perform them much faster, more specifically, or at lower temperatures. This means that catalysts reduce the amount of energy required to initiate a chemical reaction.

Catalysts are suitable in industrial processes if they are selective, stable and have high activity under the conditions of the process. A catalyst is selective when it increases the yield of the favoured reaction product. In heterogeneous catalysis reactions such as those predominantly used in petroleum refining, a catalyst is highly active if it has the capacity through its large inner surface to adsorb large amounts of reaction gas.

Nickel-based catalysts meet these criteria in a whole range of chemical reactions and are therefore often the preferred choice. Amongst others, nickel-based catalysts find applications in petroleum refining including hydro-treating (e.g., hydro-denitrogenation to reduce NOx and hydro-desulphurisation to reduce SOx), hydro-cracking and hydro-processing as well as steam reforming. In these processes, the active nickel is typically nickel metal that is finely dispersed over porous aluminium or a silica-based carrier resulting in a large catalytically active surface.

The key characteristic of nickel in these catalysts is its ability to adsorb huge quantities of hydrogen thereby greatly increasing the efficiency of the reactions. Additionally, nickel is less costly relative to competing materials of the platinum group.

While the exact chemical processes involved in synthesising the nickel-based catalyst vary by manufacturer and are typically highly confidential, it is well-documented that nickel compounds with varying solubilities such as nickel nitrate, nickel hydroxide, nickel carbonate or nickel acetate are used in the preparation of catalysts for applications in oil refining processes.

Nickel based catalysts are also used in hydrogenation and methane reforming (to produce hydrogen) reactions. In both these cases nickel metal nano-particles are used supported on a thin layer of silica. For the hydrogenation of benzene, the nickel catalyst is derived from nickel acetate precursors. The resulting nickel nano-particle catalyst is more efficient in benzene hydrogenation compared to noble metal-based catalysts because of nickel nano-particle catalysts inherent characteristic for storing large numbers of hydrogen molecules for the chemical reaction. These nickel based catalysts are also more active compared to other catalysts and are used for the hydrogenation of benzene to cyclohexane. Cyclohexane is widely used as a solvent in the chemical industry. It is also used as a raw material for the production of adipic acid and caprolactum, which are then used further for the production of nylon.

Nickel acetate is also the precursor for a nickel-based catalyst used for catalysing the methane reforming process which is highly important for the production of hydrogen. The process involves the decomposition of methane over a nickel based catalyst and produces very pure hydrogen (H_2). By using the nickel based catalyst, it has the important advantage of not producing carbon oxides. Hence, there is no need for separation of gaseous mixtures. Furthermore, the utilization of this nickel acetate derived catalyst saves time and energy by the elimination of the pre-treatment step. In addition, the deactivated catalysts on regeneration with steam produces an additional H_2 and preserves nickel in its metallic form. As a result hydrogen produced from the methane reforming process finds applications in various areas such as in petroleum refineries, the production of ammonia, hydrogenation of fats and oils etc. Also the hydrogen produced can be used in fuel cells.

3. Importance of Nickel Catalyst Technology for the EU

3.1. Economic Impacts

Nickel-based catalyst technology helps underpin the competitiveness of a number of major industries in the EU. These include man-made fibres; fertilizers; food and drink; detergents; and oil refining.

Man-made fibres and auto parts – production of nylon, one of the most important man-made fibres used in the EU, depends on nickel catalyst technology. Adipic acid and caprolactum, two major raw materials used in nylon production, are obtained from cyclohexane which is, in turn, produced from benzene using a nickel-based catalytic process. Production of man-made fibres in the EU generates sales of Euro 12 billion; creates gross value added (GVA) of Euro 3 billion; and supports over 100,000 jobs both directly and elsewhere in the economy. The output of this sector is used in a wide range of applications. Nylon, for example, is used in clothing, carpets, luggage, home furnishings, and auto parts. Throughout the auto parts sector, specialist forms of nylon are used as engineering resins, chiefly for parts moulding applications for body parts and for specialist small parts such as self-lubricating bearings, gears and cams. This reduces the use of heavier, metallic materials, providing car parts makers with opportunities to reduce weight, improve functional performance, and enhance design. EU manufacture of vehicle parts and accessories generates sales of Euro 155 billion, creating GVA of Euro 46 billion and supporting over 900,000 jobs.

Fertilizers and arable farming – most arable farming in modern economies makes extensive use of nitrogen-based fertilisers. Ammonia, the principal form of nitrogen used in fertilizers, is obtained from chemical processes that depend on nickel-based catalyst technology. Despite competition from non-EU sources, over 100,000 jobs (directly and indirectly) depend on the production of fertilisers in the EU which generates sales of more than Euro 14 billion and creates GVA of Euro 3 billion. This is, however, only part of the value chain of the fertiliser industry. The greatest economic impacts are in user industries, principally arable farming. Nitrogen-based fertilisers help the EU's arable farmers to maximise yield and to minimise land use, contributing to the EU's wider goals of food security and rural development.

Food and drink – oils and fats are important ingredients for the EU's food industry. They are used in the production of a wide range of food products, including cooking oils, spreads, ice creams, cakes, biscuits, ready meals, and bread products. Much of the production of oils and fats derived from natural sources, such as palm and vegetable oils, depends on nickel-catalyst technology. Production of food for human consumption is one of the EU's largest industries. Over 5 million jobs depend on it directly, and it generates sales of more than Euro 650 billion and GVA of Euro 190 billion.

Detergents and cleaning – nickel-based catalyst plays a major role in the production of surfactants from petro-chemical and oleo-chemical (natural oils) feedstock. For the detergents industry, surfactants are an essential ingredient, delivering major functional performance benefits and providing a platform for complex product innovations. They are critical for the competitiveness of the detergents industry. Surfactants, for example, enable detergent products to fulfil their primary role of removing dirt. Production and use of detergent products generates significant economic benefits for the EU through a complex value chain. Manufacture of detergents that use surfactants generates sales of over Euro 22 billion, creating GVA of Euro 13 billion, and supporting over 260,000 jobs (including jobs and GVA in producers, suppliers, retailers, and elsewhere in the economy). On top of this, over 3 million people work in the contract cleaning sector which has sales of over Euro 45 billion and creates GVA of Euro 32 billion.

Oil refining – nickel catalyst technology plays a complex and extensive role in underpinning the competitiveness of the EU's oil refining industry. It enables refiners to use a range of feedstock to meet market demand for fuels used in air and road transport efficiently. It helps reduce levels of sulphur in finished products, meeting customer and regulatory requirements for cleaner fuels. Finally, it facilitates greater flexibility of choice of input materials by refiners. Taken together, these benefits help sustain the efficiency of an industry which, in 2006, had sales of Euro 320 billion; supported direct employment of over 110,000 jobs; and generated GVA of Euro 29 billion.

3.2. Other Impacts

Nickel catalyst technology also creates additional benefits for the EU:

Efficiency – products and processes that depend on nickel catalyst technology improve efficiency in a number of major industries. Yield and land use in arable farming depend, to a considerable extent, upon modern nitrogen-based fertilisers. In turn, the high levels of process efficiency achieved by the EU-based fertiliser industry rely on the use of nickel catalyst technology in the production of hydrogen – a critical input for the manufacture of fertiliser. In the oil refining sector, nickel catalyst technology helps oil refiners improve output efficiencies (by increasing the yield of transport fuels), cut input costs (by facilitating use of lower cost feedstock) and restrict growth in energy inputs.

Innovation – surfactants, derived in most cases from production processes that make extensive use of nickel catalyst technology, are one of the building blocks for innovation in the detergent industry. Careful blending of different types of surfactants enables detergent companies to develop products to meet a wide range of different usage conditions. Combined with other ingredients, surfactants also contribute to the development of modern concentrated, biodegradable and low temperature detergents. In the auto parts industry, advanced engineering resins based on a range of materials, including nylon, help manufacturers develop products with new and improved performance characteristics. Moreover, the luggage industry has also used the properties of nylon as a basis for product innovation, developing new shapes and colours, and products to meet new needs, such as protection of laptop computers.

Sustainability – modern nickel catalyst technology has helped to make outputs more energy efficient in a number of major process industries, including fertilizers, oil refining, and detergents. At the same time, products derived from processes that use nickel catalyst technology have also created sustainability benefits for Europeans. Car parts based on engineering resins, rather than metallic materials, reduce weight and fuel consumption. Synthetic lubricants, derived from natural oils through oleochemical processes, reduce environmental impact in applications such as cutting oils or marine engines. Finally, surfactants have helped reduce the environmental impact of detergents.

4. CONCLUSIONS

Nickel catalyst technology plays a major role in sustaining the competitiveness of a number of major EU industries. This generates wealth and jobs for the EU and Europeans. Alongside these benefits, products and processes that make use of nickel catalyst technology create substantial efficiency, innovation, and sustainability gains for Europeans. Development and production of nickel catalyst technology makes use of nickel compounds.