PASSENGER
FOR SUSTAINABLE AND EFFICIENT RE-FREE MAGNETS

Pilot Action for Securing a Sustainable European Next Generation of Efficient RE-free magnets

PROJECT COORDINATOR
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Strategic Intelligence Bulletins aim to enrich strategic and managerial decisions and to engage stakeholders based on partners networks.

Figure 1. Manganese as chemical element © CANVA

Mn → MANGANESE

Manganese is a transition metal, belonging to the d-block of the periodic table. with an atomic number of 25 (Fig. 1). It was discovered in 1774 by Johan Gottieb Gahn, a Swedish chemist and mineralogist.

It is amongst the most abundant elements on the Earth's crust, occurring naturally in various minerals and with pyrolusite (MnO2) as the main manganese ore.

For its characteristics it is identified as a ferrous metal: it is hard, brittle, has a silvery colour and is paramagnetic. A surface layer of oxide is formed when in contact with air or water, thus passivating the material. Manganese reacts easily with strong acids, as does the abundant and naturally occurring oxide MnO2. Many inorganic salts of manganese are known, including potassium permanganate (KMnO4), a widely-used oxidizing agent.

APPLICATIONS

The main use of manganese in modern industry is primarily in the production of steel, where it is used in the form of ferromanganese and silicomanganese alloys, and metallic manganese[1]. Mixtures of chromium-manganese, tungsten-manganese, and silicon-manganese are also used. There is currently no effective alternative substitute for manganese in steel production. Another industrially relevant Mn-based alloy is copper-manganese, due to its dielectric properties and mechanical damping capacity.

Other industrial applications of Mn compounds include catalysis, the manufacture of pressure gauges and fireworks. Particularly relevant is the use of manganese oxide in the production of batteries, namely as the cathode in lithium-ion batteries.

Some types of manganese salts have applications for medical use, for example, potassium permanganate (KMnO4). In the solid state, this salt is characterised by intensely coloured purple crystals; the same purple colour is shown in an aqueous solution, in which KMnO4

[1] https://pubs.usgs.gov/fs/2014/3087/pdf/fs2014-3087.pdf

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dissolves easily. Being an oxidising agent, its solutions exert antiseptic and astringent action, which are exploited to treat certain skin conditions, fungal infections and wounds.

Manganese has also an essential role in biology. It is contained as a cofactor in several proteins and enzymes that are fundamental for cell functioning, for example, oxidoreductases and superoxide dismutase. In humans, manganese-containing proteins are involved in a number of fundamental biological processes, including the development and functioning of the nervous system, macronutrient metabolism and bone formation.

In the context of magnetic materials, manganese serves as the basis for the production of soft (MnGe, MnAs, MnSb, MnSi and MnP) and hard (MnAl, MnBi, MnGa) magnetic alloys. Some Mn-based alloys with antiferromagnetic properties are also known (*e.g.* MnNi, MnPd, MnPt, MnRh, and MnIr). Of all Mn-based alloys, manganese-aluminium (MnAl) is considered a promising alternative to REE-based Permanent Magnets, due to the low price and relatively high abundance of the raw materials, combined with good magnetic properties.[2]

MARKET

Manganese is the fourth most used metal after iron, copper and aluminium[3]. As already mentioned, its main applications are found in the steel production industry. Consistently, the main manganese alloy market is in steelmaking, followed by welding accessories and foundry (Fig.2).

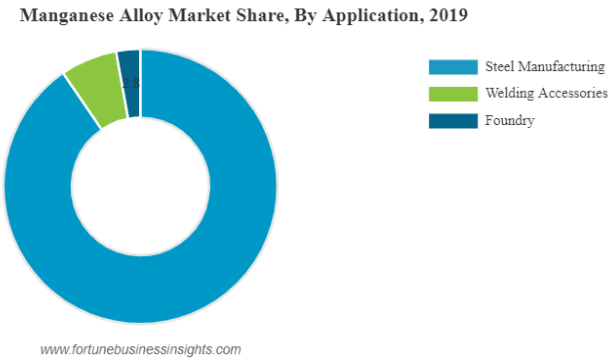

Figure 2. Manganese alloy market, Source: Fortune Business Insights

One of the main advantage of Mn is that it is abundant and cheap. Principal importers of Mn are China and India, which accounted for 75% of global manganese imports in 2020,

[2] Al–Mn Hard Magnetic Alloys as Promising Materials for Permanent Magnets (Review) Article in Russian Journal of Inorganic Chemistry · December 2020

[3] https://www.eramet.com/en/activities/manganese/#:~:text=Manganese%3A%20an%20essential%20metal,for%2090%25%20of%20manganese%20consumption

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totalling around $4.5 billion of manganese ores.[4] However, Ukraine ranks first in the world in terms of proven reserves of manganese ores. The world's largest deposit, the Nikopol manganese ore basin, is in the Dnieper and Zaporozhye regions. The balance reserves of manganese in the Nikopol, Fedorovsk (Dnepropetrovsk and Kherson regions) and Veliko-Tokmak (Zaporozhye region) deposits are 2.2 billion tons[5]. Furthermore, about 20,000 deposits and occurrences of 117 types of minerals have been discovered in Ukraine, in which 30 elements were found out of the34 currently listed as critical raw materials by the European Commission[6]. The EU and Ukraine started a Strategic Partnership on Raw Materials, which involves the European Raw Materials Alliance (ERMA) and the European Battery Alliance (EBA). Key tasks of the partnership are focused on policy and regulatory mining frameworks development and the integration of critical raw materials and battery value chains to develop responsible and sustainable minerals resources in Ukraine[7]. The EU-Ukrainian Strategic Partnership on Raw Materials and Batteries was established by Vice-President Šefčovič and Ukrainian Prime Minister Denys Shmyhal in July 2021.

However, Russia's invasion of Ukraine can undermine European stability and world raw material supply chains with severe disruptions to the global markets of critical raw materials since Ukraine has the largest deposits of manganese[8], iron, titanium, and lithium presently under the control of Russia.

The global manganese alloys market size was 18084.9 MUSD in 2019 and is expected to reach USD 42,004.4 million by 2027 (Fig.3).

[4] https://rethinkresearch.biz/articles/manganese-market-overview-steel-batteries-and-abundance/
[5] Mineral resources of Ukraine, yearbook, Kyiv, 2018.
[6] https://single-market-economy.ec.europa.eu/sectors/raw-materials/areas-specific-interest/critical-raw-materials_en
[7] https://eitrawmaterials.eu/the-start-of-long-standing-cooperation-eu-and-ukraine-sign-a-strategic-partnership-on-raw-materials-and-welcome-a-new-member-of-erma/
[8] https://www.accounting-ukraine.kiev.ua/economy_ukraine.htm

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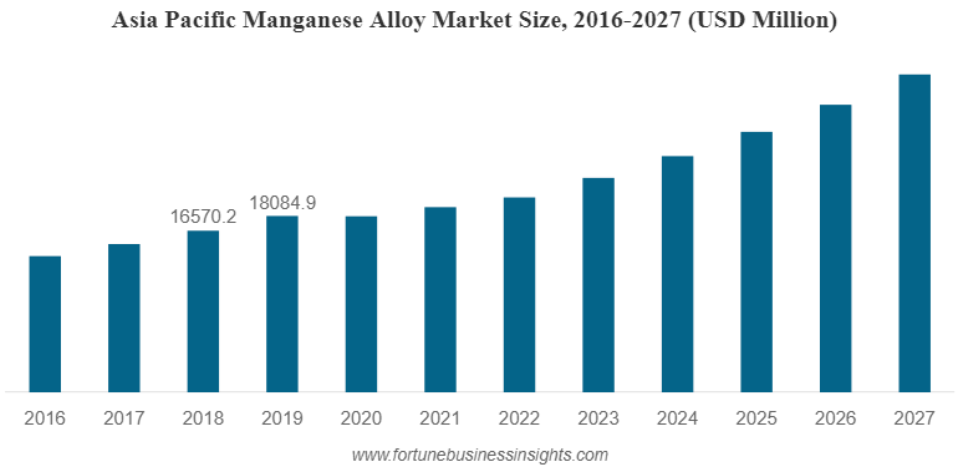

Figure 3. Manganese alloy market since 2016-2027, Source: Fortune Business Insights

RELEVANCE FOR PASSENGER

One of PASSENGER objectives is to support the end of EU's dependence on rare earth elements (REEs) CRMs used in PMs, by developing alternatives to REE-based magnets (e.g. neodymium-iron-boron (Nd-Fe-B) magnets), namely PMs based on magnetic improved strontium ferrite (Sr-Fe) and manganese-aluminium-carbon (Mn-Al-C) alloys. PASSENGER aims to "CRMs substitution" (rather than pursue of "CRMs diversification"), which factor as added value of the project. The raw materials currently used within PASSENGER are widely available in Europe and no sourcing or supply-chain restrictions are expected, in particular for the raw materials needed for Mn-Al-C alloys production. European countries have some of the largest reserves of the minerals necessary for PASSENGER magnetic materials production, for instance, Ukraine[9].

PASSENGER technical objectives related to Mn-Al-C will be the following:

- Produce Mn-Al-C permanent magnets from gas-atomized powder as a REE-free substitute.
- Technology implementation and production upscale
- Validate PASSENGER developments across the production and manufacturing pilots.

Considering the economically viable sourcing and abundance of the needed raw materials, and their magnetic properties, Mn-Al-C-based permanent magnets developed by PASSENGER are promising candidates to replace REE-PMs in specific technological fields.

[9] https://www.accounting-ukraine.kiev.ua/economy_ukraine.htm

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It must be pointed out that Mn-Al-C PMs cannot compete in absolute performance with most common REE-PMs (e.g. Nd-Fe-B), however their performance, coupled with the easy supply of raw materials and economically advantageous sourcing and manufacturing, is optimal for effectively replace REE-PMs in specific applications, namely e-scooters, e-bikes and e-motorcycles, and pump motor rotors. In this framework, PASSENGER objectives and outcome show additional value as they fully align with the European agenda, since e-mobility and water management are strategic technological areas for the EU.

NOWADAYS MANGANESE SUPPLY TRENDS

After 2021, significant shifts occured in geopolitical equilibria that might impact the long-term supply of manganese to the EU. First, this concerns the Russian invasion of Ukraine[10], but also the strains in trade relations with China, being at this point a permanent factor[11]. At the same time, domestic (EU) manganese production is dropping from 32t to 10t[12], primarily due to production shutdowns in Bulgaria and Hungary. These changes should be considered when predicting the reliability of supply. Obviously, manganese, which in 2021 was considered a stable component for the industry, the sources of which are available in sufficient quantities, today shall be double secured by the EU through diversification. This follows from the fact that China and Ukraine are ranked 4th and 8th[13] respectively among the world producers of manganese concentrate. Among the imports of Ukrainian manganese to the EU, one can separately mark the Czech Republic and Poland imports, which amounted to $126k and $99.4kduring 2020-2021 only, with the growth in imports of Ukrainian manganese to Poland increased by $39.1k.[14] And despite the fact that South Africa occupies the leading place in terms of the resource base and current production of manganese[15], Ukraine has the second largest resource potential in the world, and is leading in terms of proven reserves in the amount of 2,175,360,500 tons[16].

Considering the facts mentioned above, it is no coincidence that manganese was included in the list of critical raw materials for strategic technologies and industrial sectors in the EU 2023 (Fig. 4). Not only the steel industry, but also the EU battery industry must be factored.

[10] https://www.dw.com/en/russias-war-in-ukraine/t-60931789
[11] https://www.cliffordchance.com/insights/thought_leadership/2023-trends/trade-in-2023.html
[12] European Commission, Study on the Critical Raw Materials for the EU 2023, Final Report
[13] https://investingnews.com/daily/resource-investing/battery-metals-investing/manganese-investing/top-manganese-producing-countries/
[14] https://oec.world/en/profile/bilateral-product/manganese-ore/reporter/ukr#:~:text=About&text=Exports%20In%202021%2C%20Ukraine%20exported,most%20exported%20product%20in%20Ukraine
[15] https://www.jupitermines.com/tshipi-manganese/tshipi/tshipi-manganese-mine-overview
[16] Mineral resources of Ukraine,annual book, Kiev, 2018.

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Also symbolic is the position of this element as strategic in fifth list 2023 of critical raw materials for the EU.[17]

2023 Critical Raw Materials (*new CRMs in italics*)			
aluminium/bauxite	coking coal	lithium	phosphorus
antimony	*feldspar*	LREE	scandium
arsenic	fluorspar	magnesium	silicon metal
baryte	gallium	*manganese*	strontium
beryllium	germanium	natural graphite	tantalum
bismuth	hafnium	niobium	titanium metal
boron/borate	*helium*	PGM	tungsten
cobalt	HREE	phosphate rock	vanadium
		*copper**	*nickel**

2023 Critical Raw Materials (*Strategic Raw Materials in italics*)			
aluminium/bauxite	coking coal	*lithium*	phosphorus
antimony	feldspar	*LREE*	scandium
arsenic	fluorspar	*magnesium*	*silicon metal*
baryte	*gallium*	*manganese*	strontium
beryllium	*germanium*	*natural graphite*	tantalum
bismuth	hafnium	niobium	*titanium metal*
boron/borate	helium	*PGM*	*tungsten*
cobalt	*HREE*	phosphate rock	vanadium
		*copper**	*nickel**

Figure 4. Manganese mentioned in CRM list 2023 as Critical & Strategical Raw Materials, Source: European Commission

Today, the geopolitical affiliation of the potential of Ukrainian manganese is in question. To restore the stability of supplies, first, it is necessary to deepen cooperation with Africa, mainly targeting countries from among the world leaders in the production of manganese, namely South Africa, Gabon, and Ghana[18]. This will preserve and strengthen short-supply chains in the short term.

Amongst the priority of the EU agenda for Critical Raw Materials (CRMs) there is the need to address the dependency on CRMs, and in this framework an important role is also played by those materials defined as Strategic Raw Materials, which include manganese.

The PASSENGER project started positioning itself as a counterbalance to the diversification of REE - as a worthy alternative both in terms of availability and quality characteristics of the final product.

[17] European Commission, Study on the Critical Raw Materials for the EU 2023, Final Report
[18] https://www.globaldata.com/data-insights/mining/production-of-manganese-in-ghana-1092431/

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