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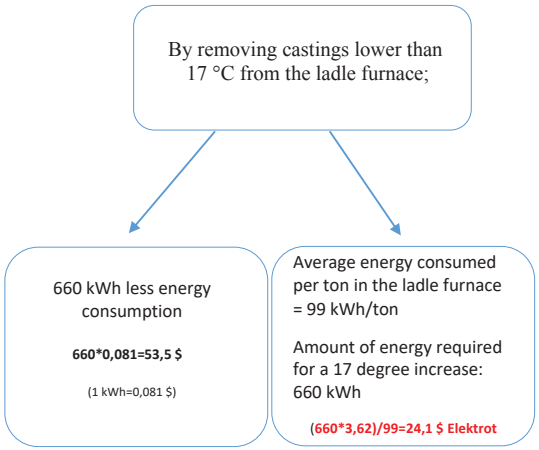
temperatures and follow-up thanks to continuous measurement. Accordingly, approximately 22 kWh/ton energy gain was achieved in unit energy per ton.

With a temperature decrease of only 17 degrees, 660 kWh of energy is saved.

4.CONCLUSION



Green Era in the Iron and Steel Industry

Ezgi KULA, Zuhal AYDIN, Gizem KARABULUT, Nuray BEKÖZ ÜLLEN

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Keywords: Sustainability, Green steel, Carbon emission, Hydrogen fuel

Abstract

The steel industry, which has entered many value chains closely, affecting strategic sectors globally, is responsible for 7-9% of global greenhouse gas emissions. Therefore, the steel industry is among the key sectors in reducing carbon emissions. Providing inputs to many strategically important sectors, the iron and steel industry needs change and transformation in the context of combating climate change. Green steel production is a concept that has become increasingly common in recent times in this regard. The concept involves implementing technologies that generate minimal waste to the environment through technical, economic, and commercial evaluations for green steel production. This approach emphasizes the effective and efficient use of raw materials to preserve our natural resources, contributing to the concept of sustainability. This concept holds critical importance for the sector's long-term success and competitiveness. A sustainable iron and steel industry will not only benefit the environment but also provide significant advantages for the economy and society. This transformation will create new job opportunities, improve energy security and public health, and contribute to building a more livable world. The World Steel Association has set the goal of achieving net-zero emissions by the year 2050. Many companies are investing in low-carbon production technologies to meet this target. ArcelorMittal, the world's largest steel producer, is making various investments to increase energy efficiency and reduce emissions. The company has significantly reduced energy consumption by implementing waste heat recovery systems in its European facilities. Swedish steel company SSAB has set the target of reaching net-zero emissions by 2045. To achieve this goal, the company is investing in new technologies such as hydrogen-based iron production. As the seventh-largest steel producer globally, Turkiye urgently needs to take measures to reduce carbon emissions in production to maintain competitiveness in steel exports to the EU. Otherwise, it may face additional taxes ranging from 8% to 19% under the carbon border adjustment mechanism, depending on the existing conditions. In conclusion, the concerted efforts of all stakeholders in the industry are crucial for significant steps towards sustainable green steel production, making it a necessity from environmental, economic, and social perspectives.

1. Introduction

The journey towards sustainability in the iron and steel sector will not be easy. The transition to a sustainable iron and steel industry can only be achieved through the collective efforts of all stakeholders (such as producers, suppliers, customers, governments, and civil society organizations). Urgent steps are required to be taken for the necessary financial investments, technological innovations, and the development of public policies for this transformation. The steel industry is striving to develop new and sustainable methods to make steel production more environmentally friendly. One of these methods is hydrogen-based green steel technology, which can reduce carbon emissions by up to 95%. By using renewable energy sources such as wind and solar to produce hydrogen fuel and separating oxygen from iron ore, it is possible to achieve "zero" carbon emissions. Steel production using clean energy sources like hydrogen instead of coal or natural gas is referred to as green steel. Hydrogen-based steel production holds significant potential for reducing carbon emissions, making it a critical element in the fight against climate change. The industry is actively exploring and implementing these innovative approaches to pave the way for a more sustainable and environmentally friendly future [1]. The iron and steel industry is directly linked to the economic developments worldwide and the economic strength of countries. The foundation of economic development lies in having a strong iron and steel sector [2]. Steel production methods can vary from country to country. Table 1 provides the distribution of steel production in some countries in 2022 based on different methods. There are two commonly used production methods: (i) In integrated plants (IP), iron ore is used as the primary raw material in a blast furnace; (ii) the Electric arc furnace (EAF) method, on the other hand, uses iron-containing scrap material as a secondary raw material and is considered a recycling method [3].

Table 1. Distribution of Steel Production by Methods Worldwide (2022) [4].

Country	Tonnage (Million tonnes)	Oxygen (%)	Electric (%)
China	1018.0	90.5	9.5
India	125.3	45.8	54.2
Japan	89.2	73.3	26.7
USA	80.5	31.0	69.0
South Corea	65.8	68.5	31.5
Germany	36.8	70.2	29.8
Turkiye	35.1	28.5	71.5
Persia	30.6	8.2	91.8
Egypt	9.8	-	100
Holland	6.1	100	-

When looking at the applications planned or being implemented by leading steel producers worldwide, it is observed that there are some prominent technologies. In integrated steel production facilities where blast furnace technology is used, high-emission coke is used as a reducing agent. Transitioning to EAF facilities, which cause much

lower emissions compared to these facilities, is one of the first applications that come to mind. However, due to the high dependency of EAF on scrap, the complete elimination of steel production from ore is not seen as a very likely scenario. Therefore, alternatives such as hydrogen, biomass, and ferro-coke are being experimented with instead of coke as a reducing agent in blast furnaces. However, these technologies have not yet become fully widespread. Hence, it is considered challenging to reduce greenhouse gas emissions in line with the carbon-neutral target using the current technology in integrated facilities. Studies on the use of hydrogen in steel production as both a raw material and fuel have gained momentum. Prominent options for EAF production facilities include using a high percentage of recycled scrap in production and increasing the share of renewable energy sources in process improvements [5].

2. Concepts of Sustainability and Green Era

The fundamental values of sustainable and green production processes include respecting the environment, embracing and promoting environmental awareness, using all resources efficiently and effectively, and continuously improving environmental performance to leave a livable world for future generations. Various measures have been defined in the field of sustainable environment and production. The Integrated Pollution Prevention and Control (IPPC) Directive, aiming to control pollution at its source originating from industry, imposes various obligations on businesses to prevent environmental pollution. The term "integrated" in the regulation encompasses all dimensions of a facility's environmental performance, from emissions to waste generation towards air, water, and soil, raw material usage and energy efficiency, noise and accident prevention. Globally, numerous actions, agreements, and contracts are being made to prevent climate change. One of these is the Kyoto Protocol signed in 1997 and enforced in 2005. Over time, some have withdrawn from this protocol, rendering it ineffective. The Paris Climate Agreement signed in 2015 is a current action to prevent climate change. The goal of the Paris Climate Agreement is to ensure that global warming stays below 2 degrees by reducing CO_2 emissions in 2050 to half of the CO_2 emissions in 1990 [6].

The iron and steel industry, which largely depends on the presence and continuity of natural resources, should aim to efficiently use its resources and maximize recycling within the green era. In the steel production industry, CO_2 emissions are high. Therefore, reducing CO_2 emissions in the steel production industry is of great importance in terms of complying with the sanctions of the Paris Climate Agreement. When examining global carbon emissions, it is observed that the steel industry produces approximately 8% of all carbon emissions through the use of fossil fuels. Due to the high emissions of the steel industry, businesses prefer green steel production practices and strive to minimize carbon emissions in steel production processes. Reducing carbon emissions not only contributes to environmental sustainability but also benefits companies in terms of competitiveness and market share [7]. In the context of this goal, it is worth discussing whether it is possible to abandon carbon and use hydrogen instead in steel production with high CO_2 emissions.

3. Green Steel

The iron and steel industry, which provides raw materials to many sectors of strategic importance, is undergoing change and transformation in the context of combating climate change. The concept of Green Steel is also among the terms we have recently started to hear frequently in this direction. Within the scope of the European Green Deal announced on December 11, 2019, the European Union (EU) aims to reduce greenhouse gas emissions by 50-55% by 2030 and to be "carbon neutral" by 2050. The Carbon Border Tax, which has been brought up to prevent the transfer of production with low emission reduction targets to countries with lower targets and to ensure the competitiveness of the EU against the cost of achieving the goals stated in the agreement, has become an important issue closely followed by countries exporting to the EU. The regulation aims to tax imports of products to the EU, taking into account their carbon content, which will be determined by the European Commission. The environmental and green movement has become a very serious sanction tool by the EU today. Green steel production represents an environmentally friendly and sustainable approach. This concept includes a range of practices and technologies aimed at reducing the carbon footprint of the steel industry and minimizing its environmental impact by using renewable energy sources such as hydrogen instead of coal or natural gas to produce steel [8,9]. The European Green Deal, presented by the European Commission (EC) at the end of 2019, is the long-awaited and comprehensive climate action plan of the EU. This plan aims to achieve net zero greenhouse gas emissions by 2050, and reduce industrial production and global greenhouse gas emissions, while also aiming to preserve production and employment. The European Green Deal is not only a matter concerning the EU but also relevant to all countries engaged in financial, commercial, and political relations with the EU. Considering the volume of trade, Turkiye, which has close relations with Europe, needs to seriously address its carbon emissions issue. Otherwise, commercial agreements between the EU and Turkiye are at risk of disruption under the Commission's carbon border adjustment mechanism aimed at reducing the risk of carbon leakage [9,10].

The Border Carbon Adjustment Mechanism will involve requesting additional money from countries that do not have carbon pricing in exports to the EU. With this mechanism, the EU aims to protect companies that will bear a cost disadvantage to preserve the climate, minimizing the damage to their competitiveness. Among greenhouse gases, CO2 emissions account for the largest share, with 89% of process-related emissions in the industrial processes sector being CO2. A significant portion of CO2 emissions in the Iron and Steel sector is produced in blast furnaces where iron ore is melted. With current technology, integrated plants emit 1.8-2.0 tons of CO2 per ton of crude steel produced, while EAFs emit 0.2-0.4 tons of CO2. The iron and steel industry, which accounts for 6% of global carbon dioxide emissions with 1.425 million tons and 25% of CO2 emissions from industry, is among the sectors subject to restrictions [11,12].

4. Environmentally Friendly Production Processes in the Iron and Steel Industry

Highlighted methods and steps for reducing carbon emissions within the scope of Green Steel production can be listed as follows [5,13]:

- The use of hydrogen as a reducing agent in production
- The widespread use of production and scrap utilization in EAF facilities
- Direct reduced iron (DRI) in EAF plants
- The use of biomass instead of coal as a reducing agent in production.

Methods planned to reduce carbon emissions vary by country in terms of the adequacy of raw material resources and cost. Recently, many steel producers have started establishing pilot plants and collaborating to experiment with different methods, particularly hydrogen-based steel production, to reduce carbon emissions in the steel sector. Not only steel producers but also iron ore producers, one of the most important inputs in steel production, are taking steps to develop low-carbon iron. Additionally, Germany plans to provide special financing for green steel production under its carbon-free production program [5].

Hydrogen-based steel production is a new and promising technology with a lower carbon footprint compared to traditional methods. In this process, iron ore is directly reduced to metal using hydrogen, significantly reducing greenhouse gas emissions. The first step in hydrogen-based steel production is the production of hydrogen to be used in steelmaking. This process can be carried out using various methods such as electrolysis, methane steam reforming, or biomass gasification. In the electrolysis method, water is split into hydrogen and oxygen by applying a direct current. Figure 1 illustrates the process of hydrogen production using the photovoltaic method. These systems operate with two electrodes and an electrolyte solution in the electrolysis cell. A direct current power source is connected to the electrode, transferring the current from the positive electrode (anode) to the negative electrode (cathode) through the conductive liquid. At the end of the process, water in the electrolyte separates into hydrogen (from the cathode) and oxygen (from the anode). An important point is its ability to provide low cost and high efficiency in the process [9,13].

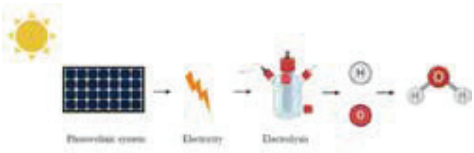

Figure 1. Stages of hydrogen production with photovoltaic system [14].

In hydrogen production from solar energy, the energy obtained is utilized under low and high temperature conditions. The production processes of hydrogen obtained from solar energy are illustrated in Figure 2. While photovoltaic, photoelectrochemical, and photobiological hydrogen production systems are present in low temperature applications, high temperature applications include thermolysis, solar thermochemical cycles, solar reforming, solar-powered gasification, and solar cracking [15].

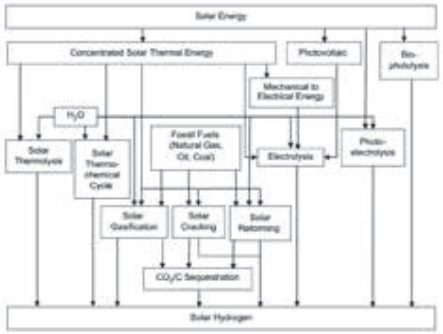

Figure 2. Production processes of hydrogen obtained from solar energy [15].

The technology options in question, crucial for the green transformation of the steel industry, will require a significant transition period and important policy decisions to implement these groundbreaking applications in the steel sector. Forecasts suggest that while the technologies may be ready by the 2030s, their industrial applicability may extend until the 2050s. Furthermore, the experimentation and integration of new technologies will entail substantial investment needs for the industry. It should not be overlooked that there may be some bottlenecks awaiting countries and the private sector at this point [16].

In an environment where potential trade restrictions on scrap metal and border carbon tax implementations are likely to come into effect in the near future, failure to promptly act to accelerate the industry's adaptation to new market conditions could risk losing global competitiveness. As of the end of 2022, Turkish raw steel producers, particularly EAF-based facilities, have plans to increase their production capacities. However, the investment amount towards low-carbon steel production to further enhance energy consumption and emission reduction performance is not at a sufficient level. Therefore, considering the disadvantaged position of planned investments and producers in both raw material procurement and access to financing for low-carbon steel production investments, it will be necessary to design measures that strengthen the sector's competitiveness. Improving decarbonization performance in the steel production and consumption value chain will enhance the capacity to meet the demand from markets seeking low-carbon steel products. Below are some international steps taken in this regard:

- Tosyalı Holding: Implementation of Quantum Furnace technology at the Tosyalı Iron Steel Plant in Iskenderun [17].
- ArcellorMittal: They launched XCarb in 2021, which is a brand encompassing reduced, low, and zero

carbon emissions. XCarb is produced using recycled and renewable methods, utilizing a high proportion of scrap steel and steel produced via the electric arc furnace method using 100% renewable Energy [18].

- Thyssenkrupp: In October 2021, they launched bluemint steel with low CO2 intensity. Bluemint Pure neutralizes all direct emissions stemming from production at the Duisburg facility through process efficiencies, while preserving emissions known as upstream chain emissions. These encompass all emissions arising during the production and transportation of raw materials [19].

As a result, we must come to this point, humanity's performance thus far in the face of this critical issue is not enough to be hopeful. The challenge of decarbonization, which requires us to change our entire way of life and habits, should not be used as an excuse because our future is at stake. The inadequacy of awareness, level of knowledge, problematic problem-solving methods, and biased and erroneous approach to transparent fund management in our country are making the process more difficult.

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Production and Characterization Studies of 60SGH Grade Steel Used as Grinding Rod in the Mining Sector

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Keywords: 60SGH, High Wear Resistance, Mineral Grinding Rod, Coarse Grinding

Abstract

In this study, 60SGH grade 200x200 section steel billet is produced to be used as a grinding rod in the mining industry. Then the billet was rolled into round material with a diameter of 90 mm. A series of mechanical tests and microstructure examinations were carried out by taking samples from the first, middle and end bars of the rolled billets. As a result of the tensile test, the yield strength and tensile strength of 60SGH grade steel were found to be 495 N/mm^2 and 857 N/mm^2 respectively. The average hardness value of the samples was determined as 300 HB.

1. Introduction

Crushing and grinding of ore extracted from mines is a very important process in processing raw materials to prepare them for further operations [1]. One of the important factors in ore beneficiation processes is grain size distribution. Reducing the grain size of the ore includes crushing and grinding processes [2]. Grinding is the final stage of the size reduction process and is applied to grain sizes smaller than 25 mm. In mills, the material to be ground is pulverized by impact, crushing, cutting and friction forces. The equipment used in these stages is called a mill and there are different types of mills with different working principles. Grinding components are the most important element that enables the grinding process in a ball mill. A wide range of studies have been carried out and new studies are being carried out in this field to achieve better grinding [3-6]. The most commonly used mill types are ball and rod mills. Steel balls are used in ball mills to grind the ore to finer sizes. Balls can be manufactured from cast steel or forged steel. It is generally used in the final stage of grinding and produces a finer product than rod mills. This grinding process occurs as a result of point contact of the balls with the ore grains. Rod mills are generally used in the first stage which is wet grinding stage. They are also known as coarse grinders of large size. In coarse grinding, the rods must have high strength due to the loads they are exposed to. Therefore, high carbon steels with high hardness, excellent performance, good wear resistance and outstanding quality are generally preferred for mill rods.

2. Materials and Methods

A billet with a cross section of 200x200 was produced primarily from a casting of 60SGH. The composition of the cast steel is given in Table 1. After this process, the billets were rolled into bars with a diameter of 90 mm. The specimens were subjected to tensile test, impact test and hardness measurements.

Table 1. Chemical composition of 60SG.

Element	C	Si	Mn	P	S	Cr	Cu	Ni
%min-max	0,55-0,65	1,00-1,30	0,90-1,10	0,035	0,035	0,40-0,60	0,25	0,40

3. Conclusion

60SGH grade steel was produced for the first time within the company to be used in the production of grinding rods in the mining sector. After casting and rolling, both the chemical composition and mechanical properties were within the expected values. These results show that 60SGH grade steel can be used in the production of rods used in mineral grinding applications.

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