Deliverable 6.1

Exploitation plan - first version

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Project details

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2.0			
2.1			

Table of contents

List of Figures

List of Tables

Abbreviations and acronyms

CA	Consortium Agreement
CBR	Case-Based-Reasoning
DSS	Decision Support System
EC	European Commission
EAF	Electric Arc Furnace
GA	Grant Agreement
IPR	Intellectual property rights
KER	Key Explotaible Result
RFCS	Research Fund for Carbon and Steel
RTO	Research and Technology Organization
SIM4	Sim4future società a responsabilità limitata semplificata
SSSA	Scuola Superiore di studi universitari e di perfezionamento Sant'Anna
UNICL	Institut Catholique de Lille
UNIRIO	Universidad de La Rioja

1. Introduction

The EU crude steel production in 2023 is 154.318 Million metric tons of which 43,3% are based on Electric Arc Furnace (EAF) process (see Figure 1)

SOURCE: EUROFER

	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	% shares 2023
Basic Oxygen Furnace and other	90,191	92,946	91,526	91,489	93,928	91,937	86,655	74,189	86,261	77,310	56.7%
Electric	64,126	64,119	63,603	62,809	66,941	68,129	63,589	58,018	66,521	59,012	43.3%
Total Crude Steel	**154,318**	**157,065**	**155,129**	**154,298**	**160,869**	**160,066**	**150,244**	**132,217**	**152,782**	**136,321**	**100%**

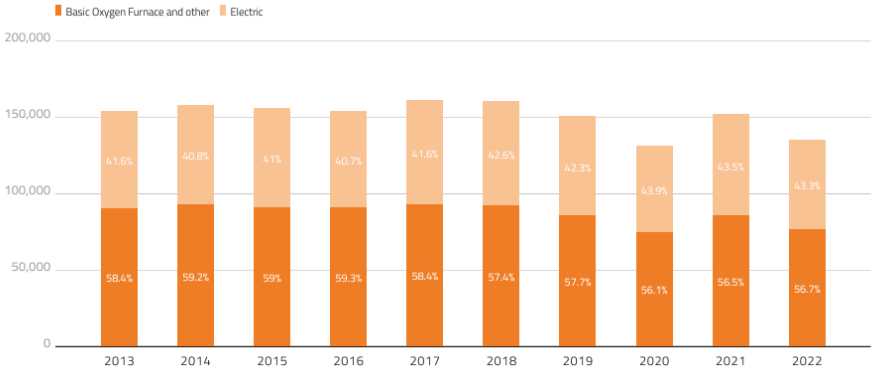


Figure 1: EU crude steel production: by process[1]

The map depicted in Figure 2 shows upstream production sites using the Electric Arc Furnace (EAF) process for secondary steel production in Europe:

Figure 2: Map of EU Electric Arc Furnace sites [2]

[1] https://www.eurofer.eu/publications/brochures-booklets-and-factsheets/european-steel-in-figures-2023
[2] https://www.eurofer.eu/about-steel/learn-about-steel/where-is-steel-made-in-europe

Considering the figures above, the iSteel-Expert Consortium is keen to get maximum exploitation of the project results at all levels, especially considering the pilot/demonstration nature of the project, which will develop a full-scale prototype of a system to improve situation awareness in the EAF area by also implementing advanced training solutions for the operators.

From the technical point of view, the project pursues a modular and integrated approach, which is inherently implementable to any electric steelworks as a full system, including the need sensors based on the starting digitalization level of the plant. So, the different modules, developed by the different partners under the leadership of the coordinator TENOVA, are going to be gradually integrated as building blocks of the system.

That said, also the exploitation strategy considers the different contribution of the partners in the development of the various modules and is basically organized into two stages:

- The first stage focuses mainly on the areas of highest impact of the system, analysis of market trends and patents, identification of strategic stakeholders to be involved as well as potential adopters (see also figure 2), the compilation of detailed description of exploitable results. A first individual exploitation plan is also reported at this stage.
- The second phase addresses the implementation of the exploitation strategy itself, considering the analysis and initial versions of previously mentioned elements. That includes deciding a deployment strategy that fit better on partners' exploitation interests and market around, by defining possible joint exploitation opportunities and the role of each partner in ensuring the sustainability and wide uptake of the iSteel-Expert results especially in the post-project period.

The exploitation actions of iSteel-Expert are in strong interaction with the dissemination and communication actions to foster and promote future usage of the developments in the steel industry. Moreover, they will benefit from the comprehensive transferability analysis to be developed by TENOVA within WP5.

This deliverable is the first version of the exploitation plan, outlining the initial exploitation strategies along with the results obtained in the first stage.

A final and more extended version of the exploitation will be provided at M36 and it will include also the results of the second phase.

This rest of document is divided into 9 main sections:

- Section 2 focuses the areas of impact
- Section 3 and 4 describes market trends and emerging technologies and players through patent analysis
- Section 5 is about targeted stakeholders
- Section 6 focuses on the identification of the first Key Exploitable Results (KER);
- Section 7 describes the outcomes of the gap analysis that was developed for each KER by the owners and interested users
- Section 8 describes the initial individual exploitation plan of the partners for each KER;
- Section 9 summarizes the main principles, definitions and tools established for IPR management and protection.
- Section 10 provides some concluding remarks.

2. Areas of impact

iSteel-Expert will generate substantial benefits for the EU steel sector in terms of resource and energy efficiency, process reliability and workers' welfare and wellbeing, with direct impacts on:

- **Enhanced Efficiency**: Improved precision in steel manufacturing processes leading to higher productivity.
- **Cost Reduction:** Lower production costs through optimized resource usage and reduced waste.
- **Environmental Benefits:** Minimized environmental impact due to more efficient use of raw materials and energy.
- **Innovation and Competitiveness:** Fostering innovation and enhancing competitiveness within the steel industry by leveraging advanced technologies and data analytics.
- **Quality Improvement:** Higher quality of steel products due to better control over manufacturing processes.
- **Safety Improvements:** Enhanced safety in production environments through automated monitoring, simulation-based training and predictive maintenance.
- **Sustainability:** Supporting sustainability goals by reducing the carbon footprint of steel manufacturing processes.
- **Workforce Management Improvement** (safety, knowledge and expertise); continuous training to protect most vulnerable people and workers along with the digital and environmental transition (green skills); better working conditions decreasing avoidable occupational health cases; eduction of occupational exposure (emissions, noise, high temperatures, electromagnetic field, etc.) and contribute to a better perception of steel industry and to attract new young talents.

Considering the present EU steel production scenario (see Figure 1), the impacts collectively contribute to the advancement of the steel industry, making the EAF route more sustainable, competitive, and innovative. However, the on-going energy transition and the consequent modification of production process that envisions the introduction of Direct Reductio Process and the melting of the DRI in EAF open additional possibility for the application of the results of iSteel-Expert project and consequent exploitation.

The map reported in Figure 3 shows examples of 60 low-CO_2 projects currently announced in EU that will start before 2030 and can help to achieve a substantial reduction of CO_2 emissions in the EU steel industry.

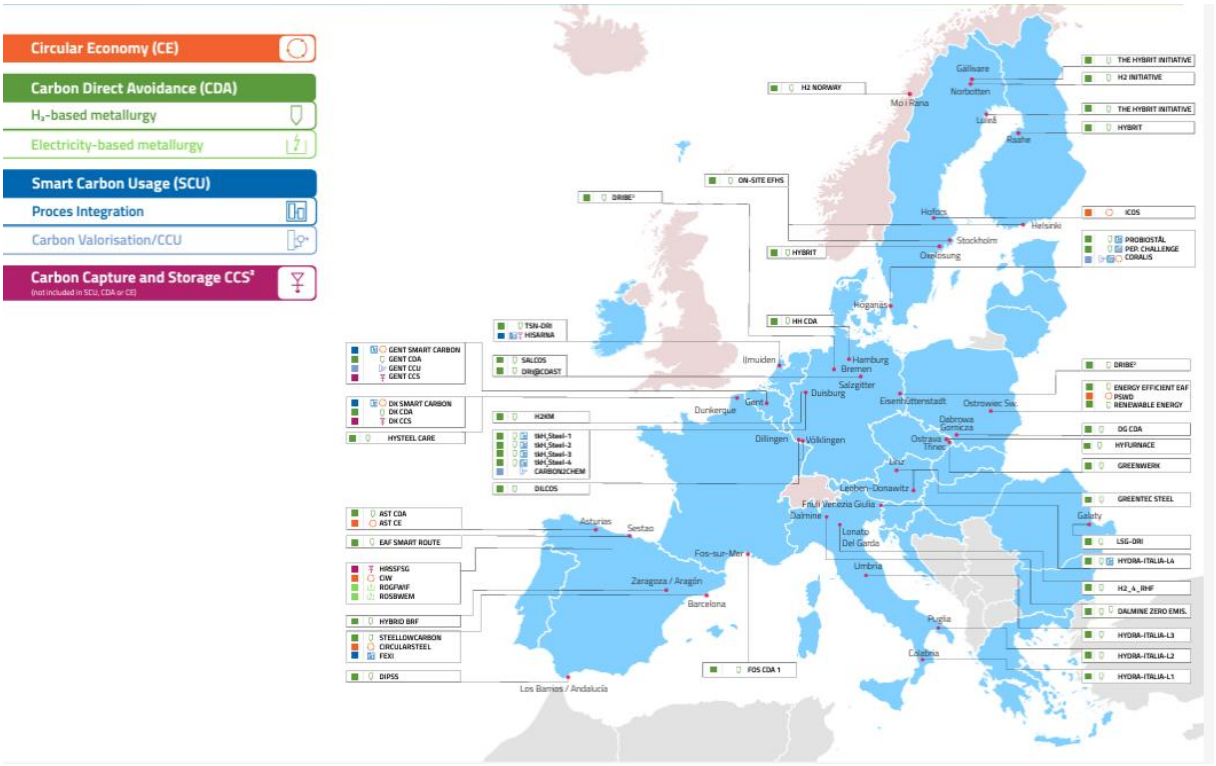


Figure 3: Low-CO_2 emissions projects in the EU steel industry[3]

The iSteel-Expert project is expected to reach the benefits as per the table below:

Table 1. iSteel-Expert impacts, in the medium and longer term

Item	Benefits		Scenario			
	Consteel process	EAF batch process	2030		2050	
			min	max	min	max
Energy	- 11 kWh_e/tls	- 14 kWh_e/tls	- 110 TWh_e/y *(-22000 ton CO_2/y)*	- 140 TWh_e/y *(-28000 ton CO_2/y)*	- 405 TWh_e/y *(-33000 tonCO2/y)*	- 520 TWh_e/y *(-42000 tonCO2/y)*
Electrode consumption	- 0.01 kg/tls electrode consumption	- 0.015 kg/tls electrode consumption	- 360 ton CO_2/y for electrode consumption	- 550 ton CO_2/y for electrode consumption	- 1350 tonCO_2/y for electrode consumption	- 2000 tonCO_2/y for electrode consumption
Yield	+ 0.4% of yield	+ 0.3% of yield	+ 0.4% of yield	+ 0.4% of yield	+ 0.3% of yield	+ 0.3% of yield
Emissions	Reduction of high emission warnings by 50%					
Safety	Reduction of at least 90% of NON-COMPLIANT (unsafe presence of people and machine)					

[3] https://www.eurofer.eu/issues/climate-and-energy/maps-of-key-low-carbon-steel-projects

3. Market trends

In the development of technologies in the EAF sector over the last two years, a prevalent interest has been observed in technology solutions aimed at reducing energy consumption from fossil sources.

This trend affects the offering of specific products, which has not undergone substantial changes. Consequently, very few changes were detected compared to previous findings, confirming the market opportunities for iSteel-expert system.

A short list of industrial systems that can be found on the marketplace is presented in Table 2. It excludes TENOVA's commercially available system.

Table 2. Industrial systems available on the market.

IoTrode™	**"IoTrode™", aimed to monitoring, controlling and reducing the consumption of graphite electrodes in EAF (Electric Arc Furnace). Industrial cameras and machine vision with AI are used to measure electrode consumption in real time.**
SmartFurnace™ **AMI Automation**	**The AMI SmartFurnace™ System improves productivity and reduces energy used per ton of steel. As an Artificial Intelligence Expert system, it dynamically selects the best operating points for electrical and chemical energy input based on the actual heat conditions.**
Optical Foaming Slag Manager **PRIMETALS technologies**	In the products catalogue of "PRIMETALS technologies" it's illustrated the automation module "Optical Foaming Slag Manager" aimed to the efficient use of injection material by determining, with an optical system, the slag height inside the EAF. The Optical Foaming Slag Manager is a closed loop control system, with the only target of real time control of the height of the foaming slag.
QMELT, QSMARTEC Danieli	In the products catalogue of "Danieli" the products QMELT and QSMARTEC are presented. QMELT is a suite of models and AI algorithms for the holistic control of the furnace. QSMARTEC is an electrode cooling optimization technology made of HW and SW that improves water cooling by better delivering the water and controlling water dynamically as a function of the furnace phase. References to sensors and products assembled and tested in collaboration between steelmakers and technology provider as it is in the case of the electrode monitoring system presented at AisTech 2016 by ArcelorMittal Global R&D and the technology provider Tecnalia.

4. Patent trends and emerging players

Document analysis in patent databases is always a useful tool for identifying emerging technologies and players in a given industry sector, thanks to the possibility of doing very detailed searches by keywords, by classification, by owner, and so on.

It was deemed appropriate to run a patent search, at least preliminary at this stage, to identify the most relevant public patent documents, which would provide insight into both technological trends and major players, as well as the state of the art, a key aspect in assessing the patentability of the project results.

Methodology

As is well known, patent documents are classified according to their technical content, assigning each patent application one or more classes according to various taxonomies.

Of these, the International Patent Classification (IPC) is the most widely used international system for patents and utility models. Established following the 1971 Strasbourg Agreement, it is hierarchically structured and divides patentable technologies into eight sections (A - H), which in turn are structured into increasingly detailed levels (subsections, classes, subclasses, groups and subgroups). It is updated periodically: the eighth version has been in effect since 2006, containing about 70,000 entries.

Parallel to the IPC classification, the Cooperative Patent Classification (CPC) is also very important, which is a classification system developed by the European Patent Office (EPO) and the U.S. Patent Office (USPTO) jointly, resulting from a project to harmonize the best practices used by both bodies and their classification systems (ECLA and USPC) into a single scheme. The CPC classification has been active since January 1, 2013, and allows for greater efficiency in retrieving patent information than the IPC, because it is more comprehensive (it contains more than 250,000 symbols compared to the IPC's 70,000), and also classifies all the technical information contained in the individual document and not just the claims.

It is worth noting that CPC and IPC share the same hierarchical structure, but in addition to the eight sections (A - H) of the IPC classification, the CPC classification also includes section Y, which in turn includes three classes:

Classification symbol	Title and description
Y	GENERAL TAGGING OF NEW TECHNOLOGICAL DEVELOPMENTS; GENERAL TAGGING OF CROSS-SECTIONAL TECHNOLOGIES SPANNING OVER SEVERAL SECTIONS OF THE IPC; TECHNICAL SUBJECTS COVERED BY FORMER USPC CROSS-REFERENCE ART COLLECTIONS [XRACs] AND DIGESTS
Y02	TECHNOLOGIES OR APPLICATIONS FOR MITIGATION OR ADAPTATION AGAINST CLIMATE CHANGE
Y04	INFORMATION OR COMMUNICATION TECHNOLOGIES HAVING AN IMPACT ON OTHER TECHNOLOGY AREAS
Y10	TECHNICAL SUBJECTS COVERED BY FORMER USPC

In the iSteel-Expert project, particularly in the WPs of the project dealing with the development of the integrated digital expert system, artificial intelligence technologies are used, aimed at the recognition of electric furnace operation states.

These computational technologies fall into some classes concerning data processing technologies, either in general or based on specific computational models. These are comprised within subsection G06:

Classification symbol	Title and description
G	PHYSICS INSTRUMENTS
G06	COMPUTING; CALCULATING OR COUNTING
G06C	DIGITAL COMPUTERS IN WHICH ALL THE COMPUTATION IS EFFECTED MECHANICALLY (score computers for card games A63F 1/18)
G06D	DIGITAL FLUID-PRESSURE COMPUTING DEVICES
G06E	OPTICAL COMPUTING DEVICES; {COMPUTING DEVICES USING OTHER RADIATIONS WITH SIMILAR PROPERTIES} (optical logic elements per se G02F 3/00; digital storage using optical elements G11C 13/04)
G06F	ELECTRIC DIGITAL DATA PROCESSING (computer systems based on specific computational models G06N)
G06G	ANALOGUE COMPUTERS (analogue optical computing devices G06E 3/00)
G06J	HYBRID COMPUTING ARRANGEMENTS (optical hybrid computing devices G06E 3/00; {fuzzy computing G06N 7/02}; neural networks for image data processing G06T; analog/digital conversion, in general H03M 1/00)
G06K	GRAPHICAL DATA READING (image or video recognition or understanding G06V); PRESENTATION OF DATA; RECORD CARRIERS; HANDLING RECORD CARRIERS
G06M	COUNTING MECHANISMS; COUNTING OF OBJECTS NOT OTHERWISE PROVIDED FOR (counting by measuring volume or weight of articles to be counted G01F, G01G; computers G06C - G06J; counting electric pulses H03K; counting characters, words or messages in switching networks for transmission of digital information H04L 12/08)
G06N	COMPUTING ARRANGEMENTS BASED ON SPECIFIC COMPUTATIONAL MODELS
G06Q	INFORMATION AND COMMUNICATION TECHNOLOGY [ICT] SPECIALLY ADAPTED FOR ADMINISTRATIVE, COMMERCIAL, FINANCIAL, MANAGERIAL OR SUPERVISORY PURPOSES; SYSTEMS OR METHODS SPECIALLY ADAPTED FOR ADMINISTRATIVE, COMMERCIAL, FINANCIAL, MANAGERIAL OR SUPERVISORY PURPOSES, NOT OTHERWISE PROVIDED FOR
G06T	IMAGE DATA PROCESSING OR GENERATION, IN GENERAL
G06V	IMAGE OR VIDEO RECOGNITION OR UNDERSTANDING

Again, considering the activities envisaged in the iSteel-Expert project, the classes that seem most relevant are:

- G06F: here fall "traditional" data processing technologies, also used in the past for specific tasks
- G06K: related to reading graphical data, in combination with classes G06T and G06V (see below)
- G06N: class dedicated specifically to applications of computational methods that also include technologies that fall under the macrodefinition of artificial intelligence
- G06T and G06V: applications of image recognition technologies

In addition to class selection as described above, the search was set on patents containing, in any text field (title, abstract, description or claims), one or more of the words:

- "eaf"
- "electric" and "furnace" with at most two possible intermediate words (thus all of "electric furnace," "electric arc furnace," "furnace of the electric type" are covered)

In this way, patents are extracted that, mentioning an electric arc furnace at least once, describe inventions that apply data processing or artificial intelligence technologies within the iSteel-Expert project.

To limit the breadth of the dataset to be analyzed, the search was limited to international, European, and U.S. patent applications.

The searches were conducted using Derwent™ Innovation from Clarivate™. The results were extracted between July 10th and 12th, 2024: any further patent document published after those dates is not included in the analysis.

With these settings, the search returned approximately 730 occurrences. In this list, 24 documents were selected that are considered to have relevance to the iSteel-Expert project topics. The 24 selected documents are summarized in the Appendix. An overview of the results is provided in the next section.

Results overview

The results were aggregated first by proprietor, as shown in Figure 4.

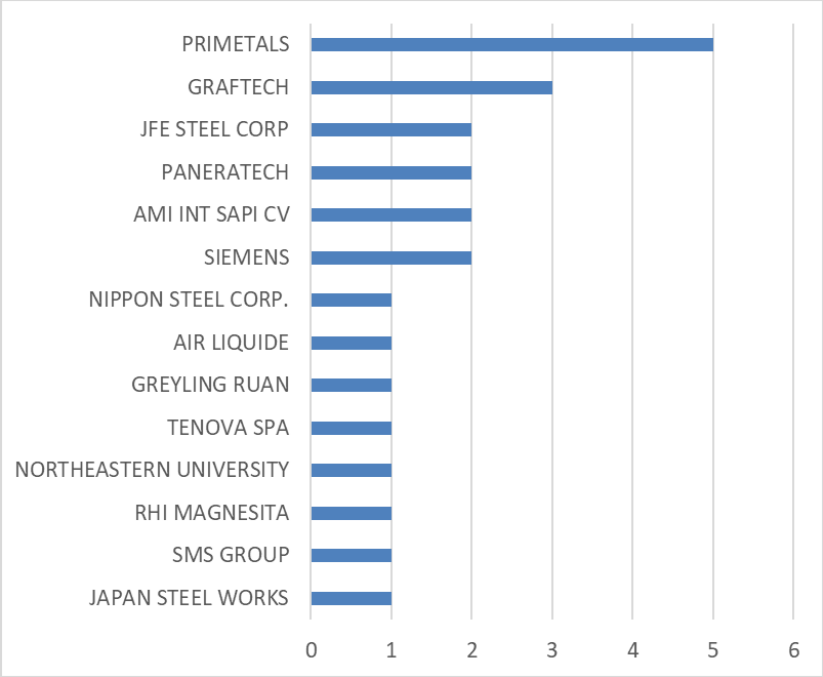


Figure 4: Number of inventions filed by applicant

Note: In the context of this paper, "invention" means the group of patents and patent applications derived from a single first filing, thus relating to a single invention. Therefore, each of the records shown here could contain one or several patent applications in different countries.

NB: no analysis was done on the countries where the patent applications were filed nor on the status of the documents found, i.e., whether the patent applications were granted or abandoned.

As can be seen, among the owners appear:

Leading plant engineering companies in the steel industry: **Primetals**, **Tenova**, **SMS**;

- Steel producers, particularly Japanese: **JFE**, **Nippon Steel**, **Japan Steel Works**;
- Companies specializing on some key supplies for the electric arc furnace: **Graftech** (electrodes), **RHI Magnesita** (refractories), **Air Liquide** (lances, combustion systems);

- Companies specializing in the development of innovative automation systems: **PaneraTech**, **AMI International**.

An analysis was then done by grouping the patent documents into thematic clusters, whose result is shown in Figure 5.

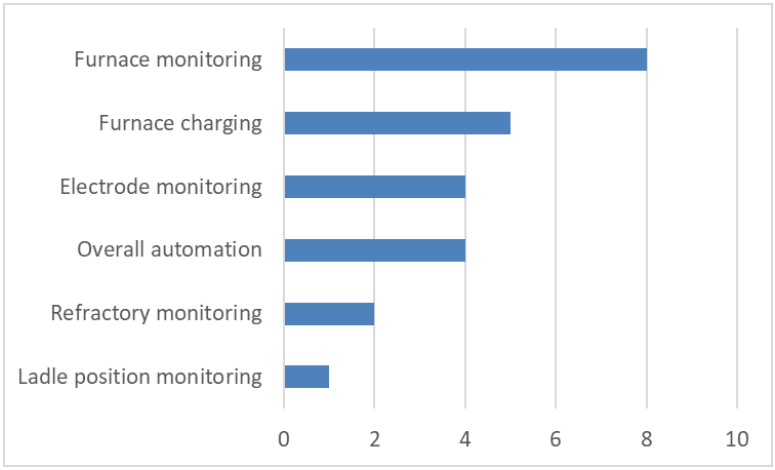


Figure 5: Inventions broken down by thematic cluster

As can be seen, considering how the patent search was set up, most of the results found relate strictly to furnace operation: monitoring the process conducted in the furnace, loading scrap and other materials into the furnace, and monitoring the condition of electrodes and refractory. Other results concern more general aspects of plant automation, including other parts not strictly related to the electric furnace.

Finally, a time analysis was made, considering the date of first filing of the documents found: the results are shown in Figure 6.

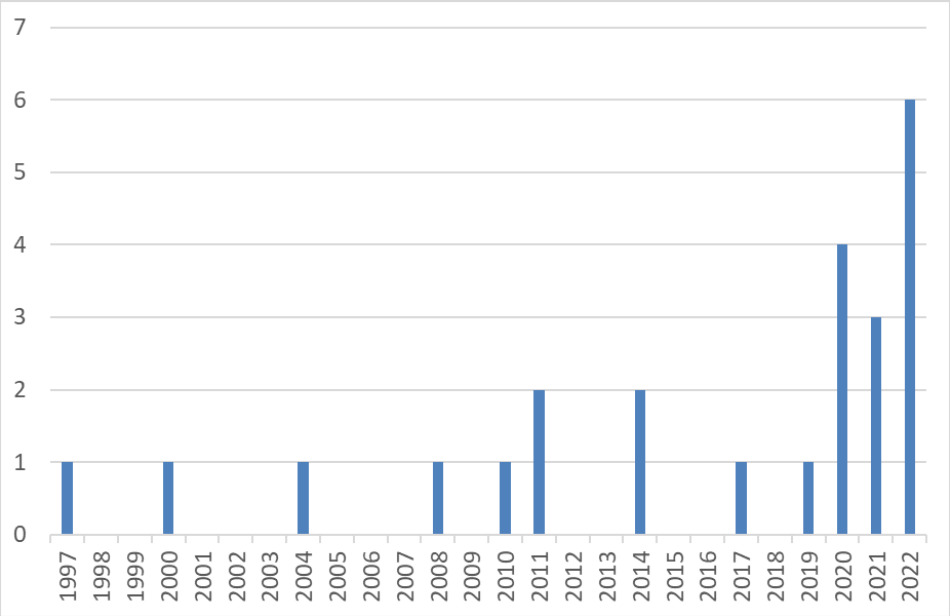


Figure 6: Inventions by date of first filing

It comes out quite clearly that patent activity has considerably intensified in the last 5/6 years. This can certainly be related to the important developments in recent years in machine learning techniques and algorithms that have opened several new opportunities for applications in the steel field as well.

5. Targeted stakeholders

End-users (SIDER and PITTINI GROUP from which the partner belongs) and other stakeholders are committed in the project as they may help guide the work towards applications. In the first year of activities mainly stakeholders at regional level have been involved together with other potential end users in the two countries that has the highest % of steel produced by EAF route: Italy and Spain. In particular the first contacts are envisioned with TENARIS Group Meltshops in Italy and Sidenor Group in Spain.

Moreover, people belonging to national and international networks of the partners of the consortium are permanent followers of the dedicated Linkedin page (766 followers by now).

Mainly targeted stakeholders and provided added value are summarized below.

- **Steel producers**: SIDER will exploit the developed solutions after the project completion. The steel company will be in the position to extend the system to other plants belonging to Pittini Group thanks to the general validity of the approach and the developed guidelines.
- **Technology providers:** TENOVA intends to commercialize the iSteel-Expert immediately to batch and continuous EAF processes. It is expected that in the 5 years following the implementation of the process, iSteel-Expert system approach will be applied at more than 20 plants in Europe.
- **RTOs and spin-off:** SSSA, UNICL, UNIRIO and SIM4 aim at consolidating their value and prestige in the scientific and industrial community especially in activities focused on bridging the gap between Research and Innovation. Moreover, there are many possibilities to transpose this training approach to other sectors of activity by considering the well-being at work at the heart. UNICL, UNIRIO and SIM4 intend to use the experience gained during the project in relation to the simulation-based training framework in other domains.
- **Process engineers, technicians and operators (workers):** new competence, knowledge and awareness in process engineering within and beyond the EU.
- **EC and policy makers:** will benefit from the industrial scale showcase for the significant efforts in digitalization of the production system, improving working conditions and process reliability, implementing training procedures by achieving benefits in terms of workers' satisfaction and upskilling and increasing higher capability to attract skilled personnel and young talents.

6. Identification of Key Exploitable Results

The transferability and deployment of the solutions is one of the final aspirations of the project consortium. iSteel-Expert has a modular and integrated approach, which is inherently implementable to any EAF steel plant as a full system. Data driven models are fully compatible with other batch and continuous EAF processes: the development of the data collection, data analysis and ML models are parametric allowing for easy configuration and tuning for the application of the system to new steel plants.

The clear target is enhancing human management capabilities favoring preservation, transfer and continuous evolution of the industry's wealth of knowledge with significant economic value.

A thorough transferability analysis will be developed in WP5 by TENOVA with the support of all the partners in order to identify customization efforts the deployment of the system in the European steel sector. Detailed guidelines will be developed for transferring the system to other electric steelworks and creating new knowledge (data, indicators, process concepts and performances).

TENOVA will also consider using iSteel-Expert (or a portion of it) for remote servicing and supporting current and new clients. As it was identified during the COVID19 pandemic it is necessary for the technology suppliers to support their customers even if not capable of being present onsite. iSteel-Expert will provide for the opportunity of delivering high level of support even from different geographic locations and time zone. In addition, Tenova is confident that the training module of iSteel-Expert will represent a breakthrough for the continuous development and verification of the workforce. Tenova intends to exploit this service for the betterment of the steel industry.

The main target of the iSteel-Expert system is to develop, implement and demonstrate in industrial environment a remote expert virtual system that monitors 24/7 the progress of the EAF process, analyses the information collected by a suite of different sensing equipment and suggests actions to improve and/or correct steelmaking operations. Therefore, the iSteel-Expert system itself is the **main Key Exploitable Result (KER)** of the project. Such system is composed by a set of modules and is implemented through a suite of hardware and software components, which are customized to the purpose of the project but also hold an intrinsic value, as their outcomes can be adapted to different contexts, therefore they have been considered as side KERs whose exploitation need to be considered in the exploitation plan.

Table 3 summarizes the first identified KERs, with their main owners and the other users or licensed owners within the Consortium.

In the progress of the project other results shall be identified and subject of the next specific analysis, whose definitive results will be available in the next version of the Exploitation Plan.

Table 3. List of KERs of the project identified so far.

KER No	Ker	Main owners	Other licensed owners /users
1	iSteel-Expert System: the first integrated cloud-based intelligent digital expert that enables situation awareness in the EAF area and supports preservation, transfer and continuous evolution of industry's wealth of knowledge.	TENOVA	SIDER
2	Modular sensor suite to monitor the EAF area	TENOVA	SIDER

As the project is still in its early stages, presently only the first individual exploitation plans can be identified at this stage. To this aim, in the first stage of the exploitation strategy, partners involved in each KER developed a GAP analysis related to the KER itself, by considering:

- comparable developments or products available on the market;
- gaps or missing features of existing products
- added value to be achieved within the iSteel-Expert project;
- unique features of the solution to be developed within the iSteel-Expert project.

The outcomes of the gap analysis are described in Section 7.

Moreover, the partners outlined their individual planning to exploit the identified KERs by considering Potential target groups, deployment opportunities especially for an industrial use and further development steps foreseen. The individual exploitation plans of the partners are described in Section 8.

7. Gap Analysis

The outcome of the GAP analysis for each KER identified in the previous Section are summarized below considering all the aspects outlined before.

As concerning **KER 1:**

- **Comparable developments or products available on the market**

Decision support systems jointly exploiting multiple sensing devices, that provide very heterogeneous data and approaches for continuous operators' know-how inclusion and preservation, are uncommon in steelworks and so far, not exploited in the EAF monitoring and management.

- **Gaps or missing features of existing products**

Systems that provide very heterogeneous data and approaches for continuous operators' know-how inclusion and preservation specifically developed for the EAF monitoring and management are missing. Moreover, no application can be found that attempts to correlate process and plant conditions with noise emissions.

- **Added Value of iSteel-Expert**

iSteel-Expert demonstrates a novel integrated approach based on virtual system able to monitor events and suggest improvements based on pre-analysis of the data made by the Machine Learning (ML), with focus on workers' welfare and well-being.

- **Unique features of the developments foreseen in iSteel-Expert**

The iSteel-Expert approach is innovative in the steel industry on the following main aspects:

• incorporates human knowledge in semi-automatic systems supporting human decision through approaches to allow looking the work area FROM OUTSIDE to collect information that are not yet digitized coming from surveillance, visual and acoustic sensors;

• interconnects and takes full use of all the information relevant for plant operation avoiding the expert personnel needs to move to reach the different production area, which generate delays in application of suitable measures, loss of efficiency, possibly loss of productivity, breakages.

As concerning **KER 2:**

- **Comparable developments or products available on the market**

A distinction must be made between market sensors and sensors designed and engineered by TENOVA. The former are available and purchasable as is on the market (thermal camera, optical cameras, accelerometers, microphone). The latter (Acoustic system and off-gas Optical Temperature Measurement (OTM) system) have been devised, designed, and engineered by TENOVA.

Regarding the Acoustic system (hydrophone, protection head, installation modality engineered for application in the exhaust manifolds of the water-cooled panels of the furnace shell), there are no comparable developments or products available on the market.

Similarly, concerning the OTM, there are no comparable developments or products available on the market, considering the ability of OTM to perform off-gas temperature measurements from remote locations.

- **Gaps or missing features of existing products**

The characteristics of the products on the market have been described in section 3. As regards ad hoc developments potentially provided by software developers, they would require to acquire knowledge already incorporated into the isteel-expert offer

- **Added Value of iSteel-Expert**

Modular sensor suite to monitor the EAF area provided by the same supplier of the integrated system developed ad hoc and the EAF itself.

- **Unique features of the developments foreseen in iSteel-Expert**

As the effort is focused on providing the first integrated cloud-based intelligent digital expert that enables situation awareness in the EAF area and supports the preservation, transfer and continuous evolution of industry's wealth of knowledge, KER 2 may be considered as a residual opportunity.

8. Individual exploitation plans

Tables 4 and 5 summarize the individual exploitation plans of the different partners for each KER identified within Section 6.

Table 4: Exploitation plan for KER 1

Question	TENOVA	SIDER	SSSA	UNICL UNIRIO SIM4
Expected result and/ or development	To be the 1st in EU to propose a cloud-based intelligent digital expert that enables situation awareness in the EAF area and supports preservation, transfer and continuous evolution of industry's wealth of knowledge	To be the 1st user of a DSS jointly exploiting multiple sensing devices, that provide very heterogeneous data and approaches for continuous operators' know-how inclusion and preservation in EAF monitoring and management	Customized approaches for data and image processing and strategies for event detection and suggestion of corrective actions	Creation of an innovative simulation-based training system for EAF operators
Value proposition	As supplier of EAF technology, providing a novel integrated approach based on virtual system able to monitor events and suggest improvements based on pre-analysis of the data made by the Machine Learning (ML), with focus on workers' welfare and well-being	To be the 1st steel producer benefitting from using the novel integrated systems with impact on energy and electrode consumption, yield, emissions, safety	Showcasing practical validity and industrial relevance of research outcomes	Introducing new technologies and techniques in training procedures in the steel industry
Potential target group(s)	Steel producers	Own personnel and operators	Steel industry technical and scientific community	Industry operators and scientific community
Stakeholders and decision makers	- EU steel producers - Technical experts, researchers and scientific community networks, associations, and EC	Workers; clients; general public communities	Steel industry, plant builders, researchers, scientists	Industry and scientific community

Platforms to cooperate	ESTEP			
Barriers	No market barriers are predicted by the consortium	People awareness and acceptance	Developments are plant -specific	Mostly tailored for EAF operator role
Strategy to react on barrier(s)	No market barriers are presently forecasted. To overcome any possible barrier and assure achievement of the critical mass needed to create sufficient legitimacy and a profitable business, a thorough assessment of performance, user experience, data protection and cost-efficiency of the system is carried out. Moreover, a series of dedicated activities are designed to analyze market trends and raise interest of selected stakeholders towards concrete exploitation of project's results considering emerging trends and entrepreneurial mindset.	Communication and dissemination activities will aim at reaching all relevant stakeholders, explaining the project benefits and paving the way for results acceptance	In cooperation with TENOVA formalized procedure are developed for rapid customization of the proposed solutions	Modular structure and generalization of logic and interfaces of the simulated environment. Foresee possibility to customize or adjust solution for other roles
Exploitation route	Patents; copyrights and related rights, Trademarks, Sales, licensing	Use of the iSteel-Expert in production activities notably for decision making, control & knowledge management	Commercial agreement with TENOVA to exploit the developed software. Publications in scientific conferences and journals Lessons and training courses	Providing training courses. Knowledge sharing by means of publications, seminars and workshops
Time to market	2026			

Table 5: Exploitation plan for KER 2

Question	TENOVA	SIDER
Expected result and/or development	Modular sensor suite to monitor the EAF area	As user of the integrated systems, the use of single parts may be considered as a residual opportunity
Value proposition	As supplier of EAF technology, providing Modular sensor suite to monitor the EAF area tailored to the needs of the client	As user of the integrated systems, the use of single parts may be considered as a residual opportunity
Potential target group(s)	Steel producers	Own personnel and operators
Stakeholders and decision makers	- EU steel producers - Technical experts, researchers and scientific community Networks, associations, and EC	Workers; clients; general public communities
Platforms to cooperate	ESTEP	
Barriers	No market barriers are predicted by the consortium	People awareness and acceptance
Strategy to react on barrier(s)	No market barriers are predicted by the consortium at this time. Anyway, to overcome any possible barrier and assure the achievement of the critical mass needed to create sufficient legitimacy and a profitable business, a thorough assessment of performance, user experience, data protection and cost-efficiency of the system is guaranteed. Moreover, a series of dedicated activities are designed to analyses market trends as well as to attract interest of selected stakeholders towards concrete exploitation of project's results considering emerging trends and entrepreneurial mindset.	Communication and dissemination activities will aim at reaching all relevant stakeholders, explaining the project benefits and paving the way for results acceptance.
Exploitation route	Patents; copyrights and related rights, Trademarks, Sales, licensing	As user of the integrated systems, the use of single parts may be considered as a residual opportunity
Time to market	2026	

9. IPR management and protection

IPR strategy and Protection Plan of iSteel-Expert complies with the rules defined in Grant Agreement (GA) and Consortium Agreement (CA). The GA establishes the right and obligations between the European Commission and the partners of the iSteel-Expert consortium. The GA number 101112102, Article 16 (Intellectual property right (IPR) – background and results – access rights and right of use), defines the rules for handling Intellectual Property Rights, their use, and dissemination. The iSteel-Expert CA further defines and specifies relevant IP arrangements, in full compliance with the provisions provided in GA.

IPR-relevant key terms in the context of EU-funded projects are: background, results, and access rights. In the following paragraphs, definitions of terms important for consideration of IPR protection as specified in GA and CA, are summarized:

Background means any data, know-how or information — whatever its form or nature (tangible or intangible), including any rights such as intellectual property rights — that is:

(a) held by the beneficiaries before they acceded to the Agreement and
(b) needed to implement the action or exploit the results."

The background included in the Consortium Agreement is reported in Appendix 1

Results means any tangible or intangible effect of the action, such as data, know-how or information, whatever its form or nature, whether or not it can be protected, as well as any rights attached to it, including intellectual property rights.

Access rights — Rights to use results or background.

Dissemination — The public disclosure of the results by appropriate means, other than resulting from protecting or exploiting the results, including by scientific publications in any medium.

Exploitation — The use of results in further research and innovation activities other than those covered by the action concerned, including among other things, commercial exploitation such as developing, creating, manufacturing, and marketing a product or process, creating and providing a service, or in standardisation activities.

Fair and reasonable conditions — Appropriate conditions, including possible financial terms or royalty-free conditions, taking into account the specific circumstances of the request for access, for example the actual or potential value of the results or background to which access is requested and/or the scope, duration or other characteristics of the exploitation envisaged.

Open access — Online access to research outputs provided free of charge to the end-user.

Open science — An approach to the scientific process based on open cooperative work, tools and diffusing knowledge.

Research data management — The process within the research lifecycle that includes the organisation, storage, preservation, security, quality assurance, allocation of persistent identifiers (PIDs) and rules and procedures for sharing of data including licensing.

Research outputs — Results to which access can be given in the form of scientific publications, data or other engineered results and processes such as software, algorithms, protocols, models, workflows and electronic notebooks.

The CA could be regarded as written agreement among the project partners (beneficiaries/parties) on the results ownership, including joint ownership, transfer of results, dissemination of the results, including the unpublished results or background, use of names, logos, and trademarks, and access rights. Therefore, all partners agreed on rules regarding IPR ownership, access rights to results and background for the project execution and protection IPR, and confidential information, as addressed in greater detail in the CA between the partners.

During the project, all partners adhered to these agreements and all project activities were compatible with them.

10. Conclusions

At this stage, the exploitation plan provides a high-level overview focused on the first identified KERs, highlighting the key components necessary for successful development and commercialization.

Here below the main achieved results in the first year of the project:

- additional new sensors from the market have been selected, provisioned, and installed, following the installation guidelines specifically prepared for this use case;
- TENOVA-devised sensors components have been provisioned, assembled and then the sensors installed, following the installation guidelines specifically prepared for this use case;
- basic KPIs to measure the system performance of iSteel-Expert have been defined, relevant to assessing:
  - Work force management
  - Operational efficiency
  - Equipment condition and maintenance
  - Enviromental impact;
- local units of data pre-processing and data move to cloud have been arranged and configured;
- project storage and services of Tenova cloud on Azur have been arranged and configured;
- data acquisition and preprocessing to compute the base line values of the KPI is in progress training procedures currently used have been analyzed and the end-users digital skills assessed;
- development of simulation platform baseline is progressing.

The exploitation of the iSteel-Expert system will be fueled by touting the system dashboards displaying the computed KPI along with the heterogeneous values from the correlated multi sensors.

APPENDIX 1- background of the partners

TENOVA

Background	Specific restrictions and/or conditions for implementation (Article 16.4 Grant Agreement and its Annex 5)	Specific restrictions and/or conditions for Exploitation (Article 16.4 Grant Agreement and its Annex 5)
Design, development, supply and implementation of the Acoustic System composed with Acoustic Sensors, High temperature cables, transmitter cabinet, receiver cabinet, data Acquisition unit, management SW suite	Access to Background shall be subject to specific agreements concerning confidentiality and use restrictions.	Access to Background shall be discussed on a case by case basis.
Design, development, supply and implementation of the EAF vibrations sensing system composed with Accelerometers, High temperature cables, transmitter cabinet, receiver cabinet, data Acquisition unit, management SW suite	Access to Background shall be subject to specific agreements concerning confidentiality and use restrictions.	Access to Background shall be discussed on a case by case basis.
Design, modelling, development and implementation of an advanced image analysis combined with smart processing of the information coming from all the available sensors.	Access to Background shall be subject to specific agreements concerning confidentiality and use restrictions.	Access to Background shall be discussed on a case by case basis.

SSSA

Background	Specific restrictions and/or conditions for implementation (Article 16.4 Grant Agreement and its Annex 5)	Specific restrictions and/or conditions for Exploitation (Article 16.4 Grant Agreement and its Annex 5)
General purpose data analysis libraries (C#, Matlab and Phyton) for variables selection and feature extraction.	These libraries could be used in the project but will not be shared with the Consortium.	Exploitation of the general-purpose libraries will not be granted to the Consortium.
Software libraries for ML-based processing of mono- and multi-dimensional signals (e.g., acoustic signals, vibration signals, images).	ML-based solutions will be developed for the purpose of the project, but the general-purpose libraries used to this aim will not be shared with the Consortium.	Exploitation will be granted only for the specific purposes of the project.

UNICL

Background	Specific restrictions and/or conditions for implementation (Article 16.4 Grant Agreement and its Annex 5)	Specific restrictions and/or conditions for Exploitation (Article 16.4 Grant Agreement and its Annex 5)
BPMN design and implementation for orchestrating the 3D environment, development and integration of 3D environments with discrete-event and agent-based simulation using IEEE HLA or other standard, and data analysis for extracting useful knowledge and adapting the virtual environment accordingly.	No specific restrictions.	No specific restrictions.

UNIRIO

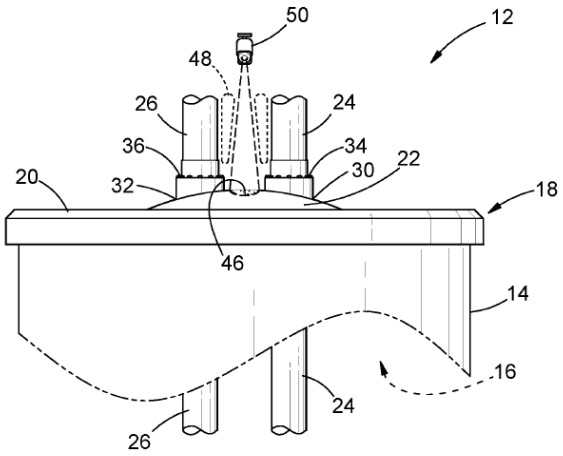
Background	Specific restrictions and/or conditions for implementation (Article 16.4 Grant Agreement and its Annex 5)	Specific restrictions and/or conditions for Exploitation (Article 16.4 Grant Agreement and its Annex 5)
Educational and process models, Simulators for training operators, Training Simulation solutions, Training Sessions specifications and guidebooks	Access to Background is subject to agreement and only to the extent it is needed to carry out the tasks in the Project. Access to Results will be granted as per art. 9.3 of the Consortium Agreement.	Access to Background has to be addressed on a case-by-case basis. Access to Results will be granted as per art. 9.4 of the Consortium Agreement.

SIM4

Background	Specific restrictions and/or conditions for implementation (Article 16.4 Grant Agreement and its Annex 5)	Specific restrictions and/or conditions for Exploitation (Article 16.4 Grant Agreement and its Annex 5)
Models, libraries, modules, data, know-how, information on AI, VR, XR, Digital transformation, Strategic Consulting for application in Industrial Plants Engineering, Production, Oil&Gas, Autonomous Systems, Logistics, Retail, Maritime	Access to Background is subject to agreement and only to the extent it is needed to carry out the tasks in the Project. Access to Results will be granted as per art. 9.3 of the Consortium Agreement.	Access to Background has to be addressed on a case-by-case basis. Access to Results will be granted as per art. 9.4 of the Consortium Agreement.

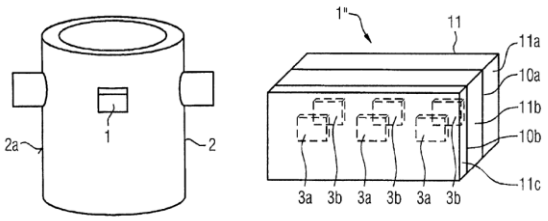
APPENDIX 2- Preliminary results of patent search

ID: 1	Title	Applicant	Priority date	Cluster	Short description
Publ. Nr. EP4361292A1	Furnace with stray-arc protection system and method of monitoring for stray-arcs externally of a shell of a furnace	GREYLING RUAN	2022-10-25	Electrode monitoring	Preventing stray arc



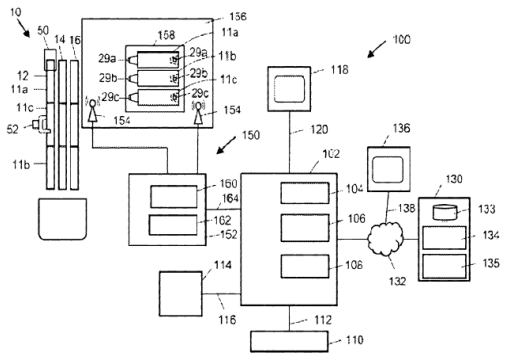
Abstract
A furnace 12 comprises a protection system 10 against stray arcs in predetermined zones 44, 46 externally of a shell of the furnace. The system comprises an electromagnetic signal imaging device 50 mounted and configured to generate data relating to electromagnetic emissions in the predetermined zones. A controller 52 comprising a processor 54 executing a program is connected to the imaging device 50 to receive the generated data. At least one of the imaging device 50 and the program is configured to mask in data from the zone of interest 46 only, and to mask out or discriminate against data from adjacent regions 48. The processor is configured to: process the generated data into intensity data; compare the intensity data to experimentally or empirically predetermined threshold intensity data which is indicative of a stary-arc forming in the zone; and to generate an output when the intensity data exceeds the threshold intensity data.

ID: 2	Title	Applicant	Priority date	Cluster	Short description
US10366256B2	Metallurgical vessel having a plurality of transponders	PRIMETALS	2014-11-11	Ladle position monitoring	Ladle position monitoring by means of transponders (RFID)



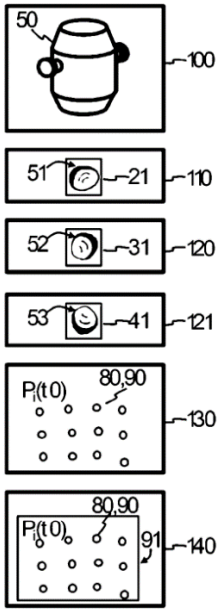
Abstract
A metallurgical vessel (2) having an outer surface (2a) and an identification tag (1, 1', 1") on the outer surface (2a). The tag has a carrier matrix (11) formed of an electrically and thermally insulating material. At least two passive transponders (3, 3a, 3b) are embedded in the carrier matrix (11). Within a metallurgical plant, a reading station (4) for tracking the path of the metallurgical vessel (2) is arranged at a tracking position. An antenna (5) of the reading station (4) initiates activation of the passive transponders (3, 3a, 3b), provided that the metallurgical vessel (2) is in a sensing range of the reading station (4). A reading unit (6) of the reading station (4) reads out the activated passive transponders (3, 3a, 3b) and transmits the result to an evaluating unit (7) of the reading station (4). The evaluating unit (7) determines which and/or how many of the passive transponders (3, 3a, 3b) were actually activated. The evaluating unit (7) thereafter associates a wear state with all the passive transponders (3, 3a, 3b) of the metallurgical vessel (2) as a whole.

ID: 3	Title	Applicant	Priority date	Cluster	Short description
US11499779B2	Systems and methods for graphite electrode identification and monitoring	GRAFTECH	2017-08-25	Electrode monitoring	Electrodes with RFID to monitor their use in heats



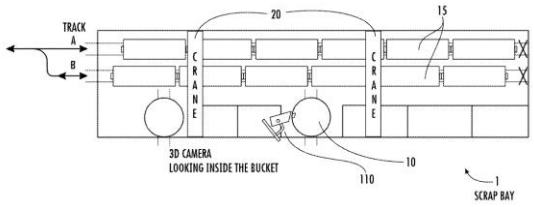
Abstract
A system and method is disclosed for monitoring graphite electrodes for use in an electric arc furnace includes receiving an electrode identifiers from a radio frequency identification (RFID) tag reader configured to interrogate RFID tags in the vicinity of an electric arc furnace (EAF), wherein the RFID tags are attached to electrodes. The electrode identifier is associated with EAF data collected from the EAF and the association is stored in a memory. The association is used for generating current and past operating parameters of the electric arc furnace for specific electrodes. Data for each specific electrode used in the EAF can also be collected for determining performance parameters for specific electrodes.

ID: 4	Title	Applicant	Priority date	Cluster	Short description
US20230051041A1	System and method for determination of a 3d information and of a modification of a metallurgical vessel	RHI MAGNESITA	2020-01-16	Refractory monitoring	Detection of multiple images of the furnace internals and reconstruction of the refractory 3D profile



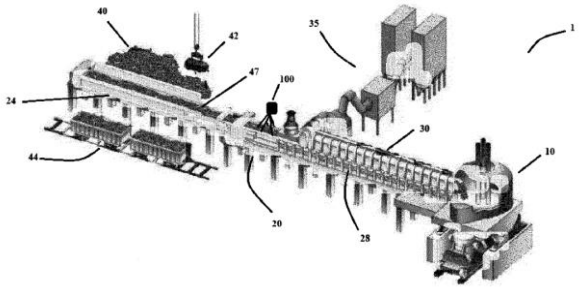
Abstract
Method, imaging system (5), data processing device (60) and system (10) for determination of a 3D information (90), especially of a point cloud (80) or of a 3D surface reconstruction (81) or of a 3D object (82), of an inner part (55) of a metallurgical vessel (50) or of a modification, the method comprising the steps of providing (100) a metallurgical vessel (50); capturing (110) a first optical image (21) of at least one first inner part (51) of the metallurgical vessel (50), from a first imaging device position (22) outside of the metallurgical vessel (50), with a first optical axis (23), by a first imaging device (20); capturing (120) a second optical image (31) of at least one second inner part (52) of the metallurgical vessel (50), from a second imaging device position (32) outside of the metallurgical vessel (50), with a second optical axis (33), by a second imaging device (30); calculating (130) a 3D information (90), such as a point cloud (80) or a 3D surface reconstruction (81) or a 3D object (82), of at least one inner part (55) of the metallurgical vessel (50) from at least the first optical image (21) and the second optical image (31), whereas the first optical image (21) is captured from a first fixed imaging device position (22) with a first fixed optical axis (23) and whereas the second optical image (31) is captured from a second fixed imaging device position (32) with a second fixed optical axis (33).

ID: 5	Title	Applicant	Priority date	Cluster	Short description
US20230288142A1	Batchwise-Charged Electric Arc Furnace System	AMI INT SAPI CV	2022-03-10	Furnace charging	Identification (by means of machine learning model) of the quality and weight of the various charge layers in the bucket



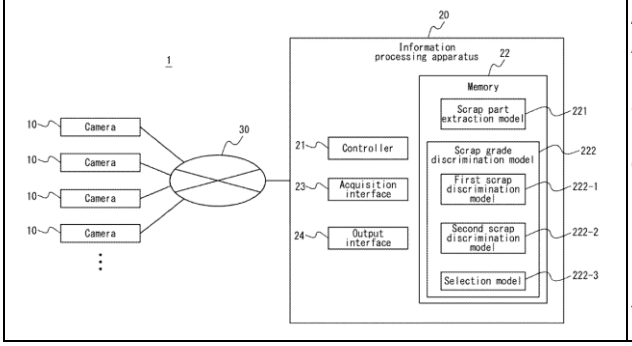
Abstract
Methods and systems for determining a respective mass associated with respective portions of the respective layers of metallic scrap material deposited into a charging-bucket associated with a batchwise-charged electric arc furnace (EAF) are provided, in which the methods and systems determine the respective masses associated with the respective portions of the respective layers of metallic scrap material based on (a) the respective volume of the respective portions of the respective layers of metallic scrap material and (b) the respective assigned densities assigned by a machine learning classification model based on digital images of the respective portions of the respective layers of metallic scrap material.

ID: 6	Title	Applicant	Priority date	Cluster	Short description
US20230314077A1	Continuously Charged Electric Arc Furnace System	AMI INT SAPI CV	2022-03-10	Furnace charging	Determining speed, classification and density of the scrap on the conveyor, to estimate a scrap feed rate



Abstract
Methods and systems for determining a feed rate (unit mass/unit time) of metallic scrap material in real time being charged to an electric arc furnace (EAF) is provided, in which the methods and systems determine the speed of the metallic scrap material in real time and the volume of the metallic scrap material in real time. The methods and systems also classify the metallic scrap material via a machine learning model based on digital images of the metallic scrap material and assign a density to the metallic scrap material. The feed rate is determined based on the speed and volume of the metallic scrap material and the assigned density.

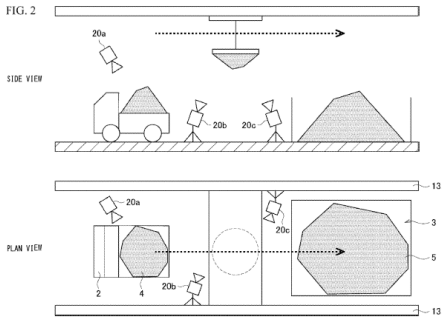
ID: 7	Title	Applicant	Priority date	Cluster	Short description
US20230316489A1	Scrap discrimination system and scrap discrimination method	JFE STEEL CORP	2020-08-14	Furnace charging	Scrap discrimination (incl. grades and ratio of each grade) based on image recognition



Abstract
A scrap discrimination system and a scrap discrimination method that can improve scrap discrimination technology are provided. A scrap discrimination system includes a scrap part extraction model (221) that extracts, based on a camera image, a scrap part located in a central portion included in the camera image with reference to a window (107) defined in advance in an image, a scrap discrimination model (222), generated by teacher data including training images, that sorts grades of scrap and a ratio of each grade from a scrap image extracted by the scrap part extraction

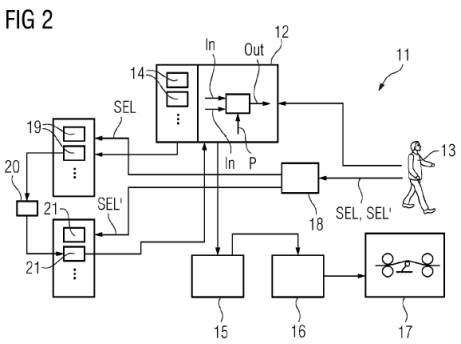
	model (221), and an output interface (24) that outputs information on the grades of scrap and the ratio of each grade as discriminated based on the scrap image using the scrap discrimination model (222).

ID: 8	Title	Applicant	Priority date	Cluster	Short description
US20240177293A1	Monitoring system, monitoring method, program, and computer-readable recording medium in which computer program is stored	NIPPON STEEL CORP.	2021-06-09	Furnace charging	Scrap monitoring system to identify type and position of an object to be removed from the scrap



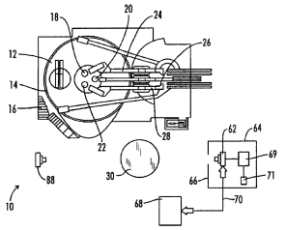
Abstract
A monitoring system that is a system for monitoring an iron scrap, includes a photographing unit that photographs the iron scrap a plurality of times at different viewpoints or at different timings, an incompatible object identifying unit that inputs a plurality of images obtained by photographing with the photographing unit into a learning model to identify each of a type and a position of an incompatible object that is a target to be removed from the iron scrap and a probability of being an incompatible object, and an output unit that outputs each of the type and position of the incompatible object when the probability identified with the incompatible object identifying unit has exceeded a predetermined threshold value.

ID: 9	Title	Applicant	Priority date	Cluster	Short description
EP4290367A1	Computer system	PRIMETALS	2022-06-08	Overall automation	Computer system to manage, simulate, with a GUI, and create programs for automation components of an plant



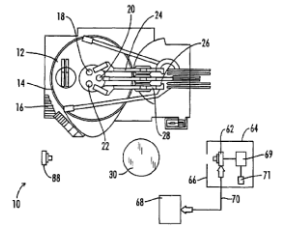
Abstract
A computer system (11) comprises a graphical user interface (12), via which a graphical description of the technological functionality can be specified to the computer system (11) by an operator (13) for components of a group of components of a basic automation system of a plant in the basic industry. It also includes a program generator (15), by means of which the graphic description of the technological functionality can be converted into a uniform computer program (16). It also includes a test environment (17) through which the technological functionality in a virtual plant in the basic materials industry can be tested. The operator (13) can specify a selection command (SEL) to the computer system (11) via an input device (18). This selects one of several groups of components that are known to the computer system (11). The components are functionally similar from group to group, but are different from each other in terms of programming. Using a corresponding program converter (19), a group-specific computer program (20) is generated for the components of the selected group, which can be stored on the computer system (11) and ported from there.

ID: 10	Title	Applicant	Priority date	Cluster	Short description
US6804582B1	Digital electrode observation	GRAFTECH	2000-09-25	Electrode monitoring	System with an off-line imaging station able to take images of electrodes, and detect and classify conditions / defects



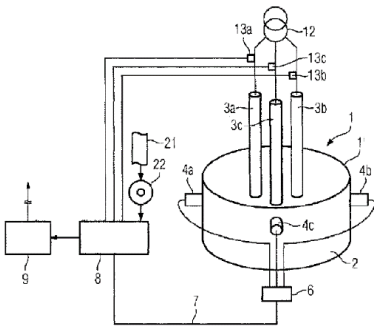
Abstract
A system is provided for recording information relating to the condition of electrodes in an electric arc furnace. An imaging apparatus is provided in a consistent position relative to an imaging station. Periodically, the electrode columns are removed from the furnace and moved to a position such that the electrode column is placed at the imaging station. Then an image of the electrode column is created with the imaging apparatus, and the images are stored in a memory of a computer for subsequent analysis.

ID: 11	Title	Applicant	Priority date	Cluster	Short description
US7386369B1	Digital electrode observation	GRAFTECH	2004-08-09	Electrode monitoring	System with an off-line imaging station able to take images of electrodes, and detect and classify conditions / defects



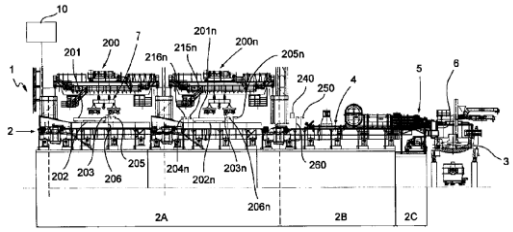
Abstract
A system is provided for recording information relating to the condition of electrodes in an electric arc furnace. An imaging apparatus is provided in a consistent position relative to an imaging station. Periodically, the electrode columns are removed from the furnace and moved to a position such that the electrode column is placed at the imaging station. Then an image of the electrode column is created with the imaging apparatus, and the images are stored in a memory of a computer for subsequent analysis.

ID: 12	Title	Applicant	Priority date	Cluster	Short description
US8412474B2	Method for determining a radiation measurement for thermal radiation, arc furnace, a signal processing device programme code and storage medium for carrying out said method	PRIMETALS	2008-01-31	Furnace monitoring	Determination of thermal radiation to the EAF structure as a quotient / correlation between structure-borne sound and electrode current



Abstract
In a method, a variable characterising an operational state of an electrode of an arc furnace can be determined. An electrode flow guided to the electrode is detected in the method and the structure-borne noise oscillations are detected. From the detected electrode flow, a flow evaluation signal associated with the frequency range of the detected electrode flow is determined. From the detected structure-borne noise oscillations, an oscillation evaluation signal that is associated with a frequency range of the detected structure-borne noise oscillations is detected and a quotient from the oscillation evaluation signal and the flow evaluation signal is formed as a radiation measurement for at least one frequency common to the detected electrode flow and the detected structure-borne noise oscillation.

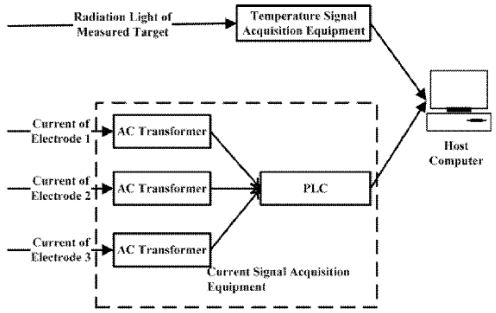
ID: 13	Title	Applicant	Priority date	Cluster	Short description
US9139377B2	Method and control and tracking system of the charge of material transported by a continuous supply conveyor of a metallurgical furnace, particularly an electric furnace for the production of steel	TENOVA SPA	2010-08-18	Furnace charging	Tracking system for controlling the charge fractions on the Consteel and estimate time of arrival into the furnace



Abstract

A method, control, and tracking system of a charge of material transported by a continuous supply conveyor of a metallurgical furnace, for example an electric furnace for production of steel. The continuous conveyor includes, in sequence starting from its inlet end towards its outlet end, a loading section of the charge of material to be supplied to the furnace, a preheating section of the charge of material loaded, and an introduction section into the furnace of the preheated charge of material, and along the loading section at least a first loading station of material.

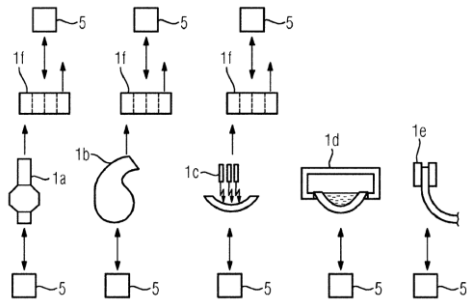
ID: 14	Title	Applicant	Priority date	Cluster	Short description
US9261552B2	Fault detector for operating process of electric arc furnace and method thereof	NORTHEASTERN UNIVERSITY	2011-01-31	Furnace monitoring	EAF fault detector based on a light radiation measurement, electrodes current measurement and statistical analysis



Abstract

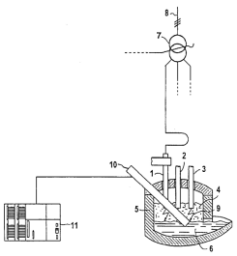
A fault detector for operating process of electric arc furnace and method thereof are disclosed, which belong to the technical field of fault detection. The fault detector includes the temperature signal acquisition equipment, the current signal acquisition equipment and a host computer. The multimode fault monitoring and diagnosis method comprises the following steps: acquiring and standardizing the data; establishing the preliminary monitoring model for the operating process to obtain common subsets of M operating modes and typical subsets of every operating mode; calculating the T 2 statistics and the SPE statistics, and monitoring and diagnosing fault in the operating process. The present invention has the advantages that the colorimetric temperature measurement can improve the calculation accuracy, different equipment becomes compatible, and the fault detector is suitable for operating in industrial production process with a variety of steady modes and can diagnose faults in a certain operating mode.

ID: 15	Title	Applicant	Priority date	Cluster	Short description
US20170322545A1	Operating method for a metallurgical plant with optimization of the operating mode	PRIMETALS	2014-12-17	Overall automation	Continuous optimization of the operating parameters based status parameters and controlling parameters which are continuously re-calculated based on "cost functions"



Abstract
Controlling a metallurgical plant, the plant has at least one plant part (1) operated with first and second operating parameters (BP 1, BP2) at a particular time, and an operating result (BE) is established on the basis of the operation of the plant part (1) according to the first and second operating parameters (BP1, BP2). The operating result (BE) is recorded. At least the operating result (BE) is transmitted from a control device (5) of the first plant part (1) to a computing unit (9). The computing unit (9) varies the second operating parameters (BP2), but not the first operating parameters (BP1), and thereby determines varied second operating parameters (BP2') associated with the first operating parameters (BP 1). The computing unit (9) transmits the varied second operating parameters (BP2') back to the control device (5) of the first plant part (1). The control device (5) of the first plant part (1) uses the varied second operating parameters (BP2'), after the transmission of the varied second operating parameters (BP2'), when the first operating parameters (BP1) are established.

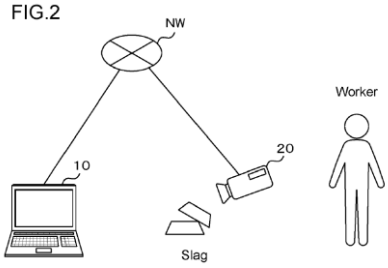
ID: 16	Title	Applicant	Priority date	Cluster	Short description
WO1999023264A1	Method and device for controlling the formation of foamed slag in an arc furnace	SIEMENS	1997-10-31	Furnace monitoring	Slag foaming control method, based on a "foamed slag model" (based on neural networks)



Abstract
The invention relates to a method and device for controlling the formation of foamed slag in an arc furnace (5) to which the carbon is fed in such a way that the arc is at least partially enveloped in the arc furnace (5) and an over abundant feeding of carbon is avoided. The quantity of the carbon which is fed to the arc furnace is thus determined by means of a foamed slag model (25) according to the quantity of at least one of the coating materials comprised of scrap metal, steel, alloy material or admixtures.

ID: 17	Title	Applicant	Priority date	Cluster	Short description
EP4345176A1	Program, information processing device, information processing method, method of generating learning model, and molten steel treatment method	JAPAN STEEL WORKS	2022-09-28	Furnace monitoring	Slag analysis (oxygen content estimation) system based on image recognition. Learning model based on CNN/DNN/RNN

FIG.2

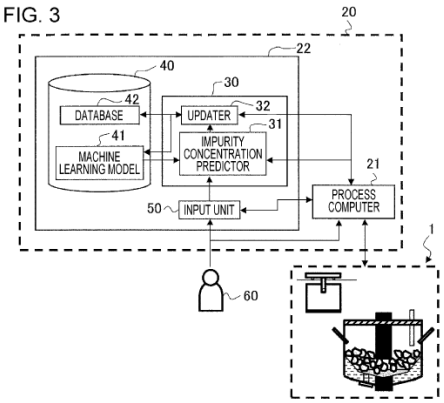


Abstract

A program causes a computer to execute processes of acquiring image data of slag floating on molten steel, and outputting oxygen content information by inputting the acquired image data to a learning model configured to output oxygen content information related to oxygen content in molten steel when image data of slag is input. Preferably, the image data is in an HSV format, and the program causes the computer to execute processes of acquiring image data in an HSV format, and inputting the acquired image data in the HSV format to the learning model.

ID: 18	Title	Applicant	Priority date	Cluster	Short description
EP4394051A1	Method for predicting impurity concentration of molten iron, method for manufacturing molten iron, method for creating trained machine learning model, and apparatus for predicting impurity concentration of molten iron	JFE STEEL CORP	2021-10-12	Furnace monitoring	Method to predict the content of a tramp element based on the market price of that element (the higher the price, the lower the expected content of that element in the scrap)

FIG. 3

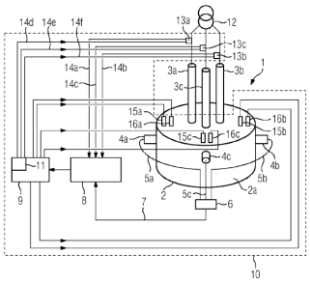


Abstract

"There is provided a method for predicting the impurity concentration of molten iron, in which improved prediction accuracy of the concentration of an impurity, as a tramp element, in the molten iron can be obtained in the refining of the molten iron using an electric arc furnace.

A method for predicting an impurity concentration of molten iron after refining of molten iron to be refined in an electric arc furnace facility includes inputting amounts of individual ferrous scrap materials charged, the ferrous scrap materials being classified by type, and at least one of the impurity concentration of molten iron in a preceding charge, the amount of residual molten iron in the preceding charge, and the market transaction price information of an impurity into an impurity concentration prediction model; and outputting the impurity concentration of molten iron in a subsequent charge."

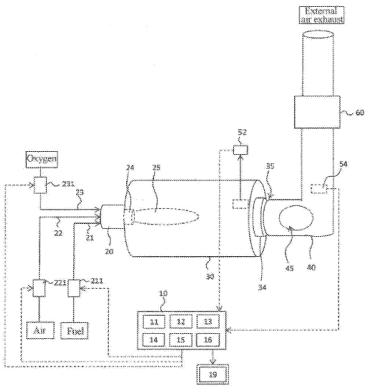
ID: 19	Title	Applicant	Priority date	Cluster	Short description
US20140112365A1	Method for operating alternating-current electric arc furnace, device for performing method, and alternating-current electric arc furnace having such device	SIEMENS	2011-04-13	Furnace monitoring	Slag height control by arc regulation based on EAF wall vibration measurement (fuzzy logic)



Abstract

During operation of an alternating-current electric arc furnace, which has at least one electrode for producing a melt, vibrations are measured at a wall of a furnace vessel, whereby a slag height of the melt is determined. A rapid reaction to the change in the slag height is made possible by adjusting the arc length of the at least one electrode in the case of deviations of a measured actual value of the slag height from a target value.

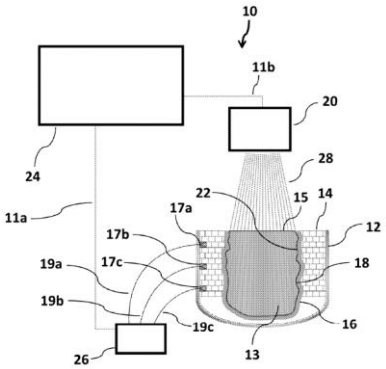
ID: 20	Title	Applicant	Priority date	Cluster	Short description
US20210033341A1	Furnace control system, furnace control method, and furnace provided with same control system	AIR LIQUIDE	2019-08-02	Furnace monitoring	Model to predict the generation of flammable gases from furnaces. Described for several furnace types, including EAF (with actions on the post combustion)



Abstract

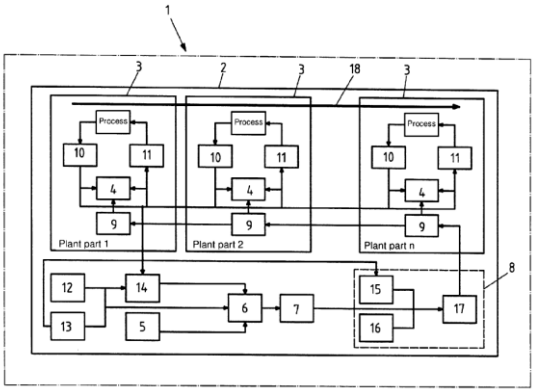
To provide a furnace control system which can predict production of flammable gases produced inside a furnace during melting, incineration, and fusion batch processes and effectively carry out furnace combustion control on the basis of said prediction results in order to reduce the conventional problem of time lag. A furnace control system has a flammable gas quantity of state calculation unit 12 which calculates a flammable gas quantity of state corresponding to prediction factor data using a quantity of state estimation model for flammable gas originating in volatile organic compounds produced using intelligent information processing technology using as learning data past data relating to furnaces, data relating to materials, and data relating to exhaust gases, and a combustion control unit 11 which controls furnace combustion on the basis of the flammable gas quantity of state calculated by the flammable gas quantity of state calculation unit 12.

ID: 21	Title	Applicant	Priority date	Cluster	Short description
US20220196396A1	System and method for evaluating a status of a material in metallurgical vessels	PANERATECH	2020-12-17	Refractory monitoring	Refratory monitoring system with measurement of refractory thickness and refractory roughness to estimate both refractory thickness and slag thickness



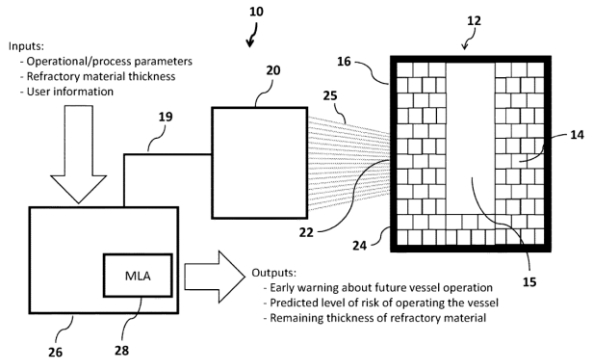
Abstract
Disclosed is a system and method for evaluating a status of a refractory material in metallurgical vessels, including furnaces and ladles, wherein a slag buildup is formed on the surface of such material as a result of scrap accumulation and chemical reactions occurring during the melting of metals in such vessels. The system and method are operative to determine both a rate of degradation of the material under evaluation, including the thickness of such material, and a measure of the slag buildup to predict and extend the operational life and improve the maintenance plan of the vessel. The system is capable of determining the thickness of and the slag buildup on the entire material under evaluation by sampling a number of regions of such material with different types of sensors, characterizing the surface profile of such material, and using appropriate signal processing techniques and artificial intelligence algorithms.

ID: 22	Title	Applicant	Priority date	Cluster	Short description
US20230205185A1	System and method for controlling a production plant consisting of a plurality of plant parts, in particular a production plant for producing industrial goods such as metallic semi-finished products	SMS GROUP	2020-05-14	Overall automation	Plant automation system based on generating models for each part of the plant and having each part running according to an optimized production plan



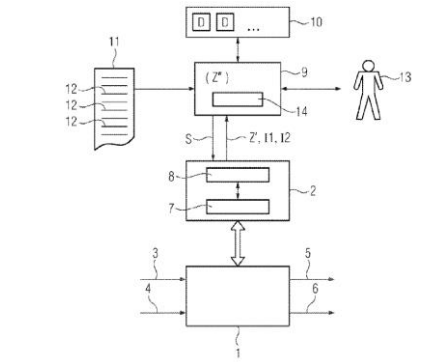
Abstract
A system for controlling a production plant includes a plant automation unit for monitoring and control of the production process within the production plant. A production planning system has information concerning the products to be produced. A model generator generates at least one prediction model for products produced in the production plant. The model generator takes into account the results of the monitoring of the production plant when generating the at least one prediction model. A production optimizer determines an optimized production process within the production plant on the basis of data from the plant automation unit, the production planning system, and the prediction model generated by the model generator. The production optimizer takes into account the production-related specifications of the individual plant parts. A production plant control unit generates target specifications for the plant automation unit on the basis of the optimized production process determined by the production optimizer.

ID: 23	Title	Applicant	Priority date	Cluster	Short description
US20230289625A1	System and method for prediction of operational safety of metallurgical vessels	PANERATECH	2022-03-10	Furnace monitoring	Machine learning model to correlate the IR image of the EAF structure with the risk of crack / failure



Abstract
Disclosed is a system and a method for estimating a level of risk of operation of a metallurgical vessel used in the formation of metals. The system and method are operative to determine a condition and level of degradation of the refractory material of the vessel to early warn a user of the operational risk of continuing operating the vessel, based on thermal scanning and the use of artificial intelligence. The system is capable of determining the presence of certain flaws within the refractory material and the remaining thickness of such material by correlating the results of processing thermal data corresponding to the external surface of the vessel with a machine learning-based mathematical model, according to a set of operational parameters related to the melting process, data from the user, and residual thickness of the refractory material.

ID: 24	Title	Applicant	Priority date	Cluster	Short description
US20240192665A1	Optimization method for operating plants in the primary industry	PRIMETALS	2021-04-09	Overall automation	Overall process optimization based on measured variables, to be compared to a list of records on a minimum "distance" criterion



Abstract
An optimization method in which a computer ascertains expected values (E 1) for actual variables (I1) of a technical process based on values (R) for target variables (Z1) of the technical process that attain the values (R) as far as possible. From data records (D), the computer provisionally selects a number (n1) of records (D) in which the variables (I1) display a minimum distance from the values (E1). The computer then ascertains expected values (E2) for the actual variables (I2) based on the values (R) and the values (E1). From the provisionally selected data records (D), the computer selects a predetermined second number (n2) of data records (D) in which the variables (I1, I2) display a minimum distance from the values (E1, E2). The computer ascertains set values (S) for the variables (Z2) for a yet-to-be-executed cycle to attain variables (Z1) as close to possible to the values (R).