Indian railways on fast track with welding industry 4.0: Application of internet of things and artificial intelligence

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ABSTRACT

The objective of this paper is to explain about application of Internet of Things (IoT) and Artificial Intelligence (AI) in welding of Indian Railways. The introduction of welding technology has also been followed by the country's economic growth. Indian Railways has long been the single most significant infrastructure entity in India, with the railway track network expanding for many years. The new manufacturing sector is speeding the transition to digital and intelligent manufacturing, with the ongoing growth and maturity of cloud computing, big data, IoT and other innovations. Welding methods are also one of the fields where AI is tested and used early, with the help of information technology. Train maintenance and repair is usually carried out in demanding working conditions and frequently under demand from time. In such high demand and dynamic activities, it helps to decrease human error. In the welding of rail tracks and machine parts, IoT and AI will certainly offer many advantages in less time and with greater accuracy and precision. It will allow the Indian Railways to become more profitable and effective.

KEYWORDS

Indian Railways, Internet of Things, Artificial Intelligence, Welding 4.0.

1. Introduction

Industry 4.0 highlights the growing trend towards automation and data sharing in manufacturing industry, including: The internet of things (IoT), Smart manufacture, Cyber-physical systems (CPS), Smart factories, Cognitive computing, Cloud computing, Artificial intelligence. The first industrial revolution started with the origin of mechanization, steam and water power. The second industrial revolution followed with its emphasis on mass production and assembly lines powered by electricity. Electronics, I.T. systems and automation ushered in the third industrial revolution, which led to the fourth industrial revolution which is related with cyber physical systems (Fig.1) (Avinash, 2020). The IoT basically refers to the concept of linking anything that is powered both to the internet and each other. This covers everything from smart phones, household appliances and office devicesto jet engines and manufacturing equipment on large scale. The step towards wide-scale IoT adoption has already begun, fueled by better Internet connectivity, lower cost of technology and connection, increased usage of smartphone, and the fact that more and more computers, appliances and machines are being designed with Wi-Fi capabilities (Manca et al., 2013). The simulation of human intelligence by machines, specifically computers is known as Artificial intelligence (AI). These mechanisms include learning (acquisition of knowledge and laws for using data), logic (use of laws to arrive at rules to reach approximate or definitive conclusions) and self-correction. The manufacturing sphere will experience the most significant impact due to IoT (Zhong et al., 2017).

- **Automation:** It lets a device or system or process to run automatically. Robotic process automation (RPA), for instance, can be designed to execute high-volume, repeatable tasks typically done by humans (Schuster et al., 2017).
- **Machine learning:** It is the science of making a computer to perform without any programming (Reisgen et al., 2019).

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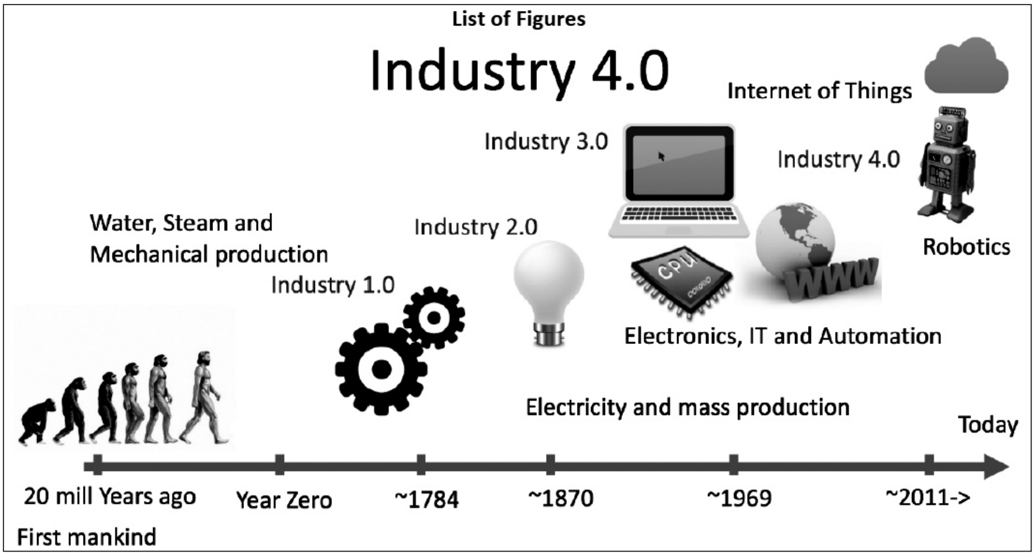

Fig. 1. Evolution of industry 4.0 (Avinash, 2020).

- **Machine vision:** The science of making it possible for computers to see. Using a camera, analog-to-digital conversion and digital signal processing, this technology collects and analyses the visual information (Nizam et al., 2016).
- **Robotics:** An innovation area with an emphasis on the design and manufacturing of robots. Robots are often used to perform activities that are difficult to perform or executereliably for humans (Villani et al., 2018).

The main attractions of the IoT and AI are:

- The "user" of the systems may gain valuable information that they can utilize to maximize their specified circumstances. Usually, the information will be focussed on data obtained from their own smart devices that remote service providers which analyze and interpret the data.To evaluate challenges and trends, the industries and communities will use aggregated data from thousands or millions of sensors.
- For regulatory and analysis purposes, these data may be used for marketing purposes and many other purposes in between (Simoens et al., 2018).

There are three key uses for the IoT and AI within the manufacturing industry:

1. Manufacturing operations
2. Production asset management & maintenance
3. Field service

IoT and AI are used in industrial processes such as for intelligent manufacturing, performance management and enhancement, human-machine engagement, visibility of operations and planning of production line. About 57% of IoT investmentin the global manufacturing sector is associated with the manufacturing operations. IoT and AI are used in the maintenance and management of production operations to control the main parameters related to service performance, failure and breakdowns, quality and other considerations. This means that the IoT is not only used for improving the service performance, but also for the preventative maintenance (Bonomi et al., 2014).

IoT and AI are also used by the manufacturers as they can handle the role of service providers. This involves products and business-related services, which are essential to manufacturers and the larger sectors to provide growth. In enhancing the customer service delivery, the capacity to transfer information across digital networks and an IoT enabled manufacturing environment is key (Latz, 2018).

2. How can the IOT and AI Impact Welding?

Almost any part of a welding workshop can be changed by IoT and AI. It will store the current legislation on welding procedures, maintain and update welders' credentials, provide better quality control, check the quality of the component, detect and position orders for consumables and gas, recommend training and assist in welding project management. A lack of expertise is one of the main challenges that welding industries are facing I developing countries. The American Welding Society (AWS) estimated a shortfall of 4,00,000 welding operators in the US by 202, with the supply-demand deficit as a result of a gaining population (average age of a welder is 57). To such a degree that debilitating capacity shortages of highly trained welders are now imminent, the age demographic of staff within the welding industry has been distorted. We have now progressed far beyond the point of theoretically averting this problem by attracting expertise. In the sense of this unavoidable obstacle, the issue we are now collectively. This concern can be alleviated by IoT and AI in many ways. An IoT enabled welding system does not rely as much on a professional welder as on a manual method. If they operate on a computer that is equipped with IoT-enabled artificial intelligence, an unskilled, relatively untrained worker may complete the same job as highly educated, professional welder. The principle of automation is related to all these principles. For decades now, automation has become part of the factory floor, but IoT ushers in a type of automation that is quite distinct from the clunky robot doing repetitive and simple assembly line tasks (Posch et al. 2017). The idea of Industry 4.0, which is closely tied to IoT, "represents the vision of the interconnected factory where equipment is online, and in some way is also intelligent and capable of making its own decisions."

The automated welding process becomes complex and capable of reacting to parameters, the workpiece and other external variables in a welding workshop that is wired into the IoT environment. The welding process ultimately becomes a thought object, capable of responding to change in the way a human welder does. This not only tackles a lack of chronic expertise, but also allows for a more active workplace. Artificial Intelligence and deep learning render it possible to finish tasks more rapidly, while losing efficiency (Pan, 2016). If humans are forced to work harder, efficiency eventually suffers, which all but cancels any production gains by the need for re-work. For automated welding processes that are capable of learning through data input, this is not the case. The IoT is the industrial future, and that's the world's future in many respects, as we know it. Everything will be interconnected, so a failure to invest and learn how to build a connected workplace is a failure to keep in contact with the industry's trajectory and the customer base that workshops serve (Zhou et al., 2018).

3. IoT and Artificial Intelligence in Current Welding Industry

Using the Controller (Fig.2), you can connect to the K-professional TIG support team with just the click of a button. K-support TIG's engineers will review your setup, collaborate with you to solve any challenges and make sure you are up and running in record time. You can also apply for a Health Review system during which K-trained TIG's engineers review the system for acceptable efficiency and maintenance criteria.

The Controller's Wi-Fi and ethernet connectivity enables you to import and share welding processes and study and archive extensive welding files. Filled with readily accessible dual-powered USB ports, operators may also use the controller to charge other devices such as phones and tablets (Latz, 2018).

4. How the IoT and AI Could Impact the World of the Welder?

In some way or another, several automatic welding devices are now attached to a computer. Many modern sources of welding power include computer-based systems of operation. It is possible to interface several of these power sources with a network. Many power supplies are currently networked and can be reached from a computer anywhere in the world at any time. The IoT has already arrived in the field of automatic and robotic welding in this respect. In diagnostics and configuration of the equipment itself, the first apparent use would be when the equipment must be regularly interfaced with a network to perform certain functions. However, this application will not have a direct impact on the work of the Welder field in a significant way. Future IoT field application Welder is likely to exist mostly as part of an artificial intelligence network, as the artificial intelligence platform

Fig. 2. K-TIG controller (Latz, 2018).

will be extremely beneficial in executing control and tracking functions even though the system is not connected to the internet. Continuous internet access would clearly be needed for continual IoT features.

Artificial intelligence would make it much more powerful to add the Welder to all sorts of sensors to record the parameters and inputs required. This will be the case whether or not the computer is wired continuously to the internet. In conjunction with voltage and current inputs from the welding power source, machine learning vision systems will be able to theoretically perform calculations such as welding travel distance, which is important for real-time welding heat input calculation. An infrared enabled vision scheme will be another very useful sensor. Though welding heat input measurements are commonly used at present, they are not ideal measurements. The real data that we want when calculating the heat input is the weld cooling rate and the base metal heat affected region (HAZ). The cooling rate estimation should be achieved directly using an infrared powered vision system, rather than relying on the imperfect heat input proxy that we are currently relying on. We can provide an almost fool-proof measure that Hydrogen Aided Cold Cracking (HACC) has not taken place, with a continuous record of the weld cooling rate. This would mean that it is possible to limit or in many situations, remove the need for time delays after welding, accompanied by ultrasonic processing. This record could serve as an indication that the microstructures are not degraded in situations where high heat inputs are troublesome, such as with stainless steel welding, enabling the maximum corrosion resistance of the material to be realized.

5. What is Internet of Welding?

The Internet of Welding must allow an organization to make its operating processes leaner or speed up internal processes in order to minimize waste. Excellent examples of procedures that can be enhanced with IoW are quality control, organizational logistics and system maintenance. When a weld joint is ready for inspection or when a job is completed, new welding machines know when they are running short of filler wire. In addition, the consistent implementation of Industry 4.0 will have a decisive impact on the factory of the future, which will become a smart factory (Veikkolainen, 2017). Some criteria for welding applications need to be met for a smart factory to operate more or less autonomously without human interaction:

- The welding machines has to be digitized and prepared in such a way that a computer can make similarly correct choices as an experienced welding technologist.
- High-performance information and communication technology and customized sensors must be equipped with the welding equipment so that all production-relevant information can be digitized and given the system's necessary real-time behaviour.
- The need for large amounts of data to be transferred and stored requires powerful network infrastructures and enough storage capacity (Veikkolainen, 2017).

5.1 Welding manufacture based on IOT and AI

The production mode of the welding manufacturing industry has changed a lot with the technology growth of the Internet of Things (IOT). Fig.3 shows a brief framework of the IOT-based smart factory. The smart factory consists of four layers in the framework: the physical resource layer, the industrial network layer, the cloud layer and the terminal layer for supervision and control. The physical resource layer is focused on intelligent devices that can communicate through industrial networks with each other. There are numerous information systems in the cloud, such as the Production Execution System (MES) and Enterprise Resource Planning (ERP), which can capture vast data from the physical resource layer and communicate across the terminals with individuals. This essentially forms a cyber-physical structure (CPS) that is highly intertwined with physical objects and intelligence entities (Chen et al. 2018).

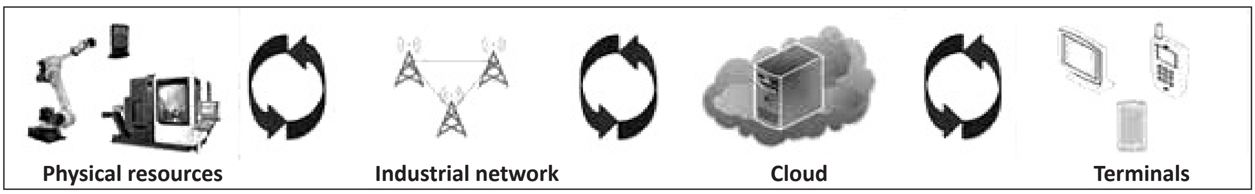

Fig. 3. A brief framework of the smart factory of IoT (Chen et al. 2018).

A pyramid structure to illustrate the IOT-based intelligent factory architecture, from field instruments and programmable logic controllers (PLC) to enterprise-level (ERP) applications via process management and manufacturing execution systems (MES) is shown in Fig. 4 (Ji et al., 2019). The development in welding has gone through four stages. With restricted performance and accuracy, welding was manual in step I. Phase II saw automation, like robotics, being introduced, but it was difficult to model and monitor the operation. In phase III, with "teach and playback" robots, welding automation was made simpler, but it was performed off-line and had minimal capacity to respond to disruptions and fluctuations. In Phase IV, intelligence is added to welding systems to track and regulate the dynamics and efficiency of welding more actively. The evolution from manual to intelligent welding systems is a transition from human-physical systems (HPS) to human-cyber-physical systems (HCPS) (Fig.5) (Wang et al., 2020).

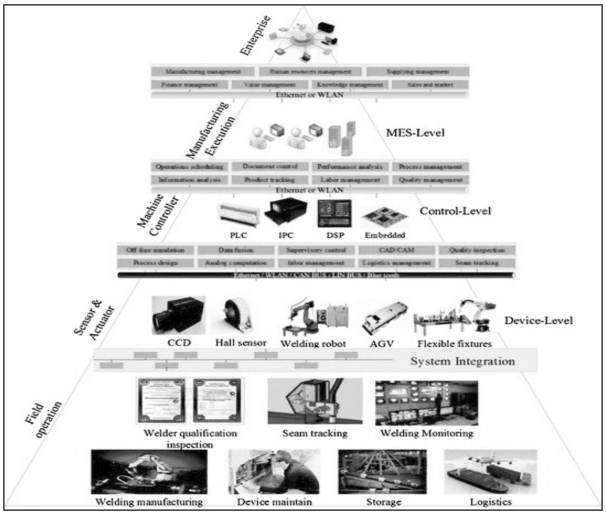

Fig. 4. A pyramid framework architecture of the intelligent factory base on IOT (Chen et al. 2018).

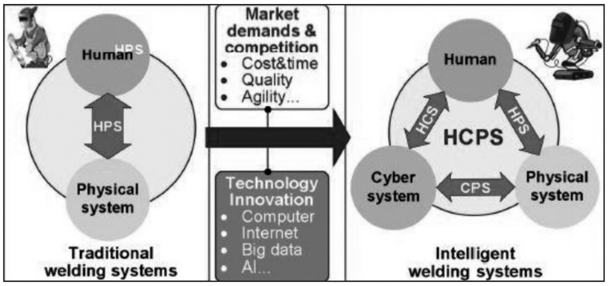

Fig. 5. Welding systems: the evolution from HPS to HCPS (Wang et al. 2020).

5.2 Real-time welding data to optimize quality, efficiency

Welding information management systems capture real-time data from the shop floor, right from the welding machines (semi-automatic or robotic) and provide a live view of each welder and welding cell for management. To allow for remote analysis over the Phone, data can also transfer to the cloud (Internet or intranet). Managers should keep a close eye on various metrics related to efficiency, such as arc-on time and weld metal-deposition levels. The systems can be used by supplier-fabricators to simplify the processing of documents they need to supply to their customers and to relieve welders from having to waste time recording records. And its welding-knowledge base can be centralized by big corporations. Based on design specifics, they will establish standard welding procedures and push those procedures out to their welding cells or to their suppliers' welding cells. Wondering how often (human or robotic) welders have to stop what they do due to excess spatter or poor penetration, so that procedural problems can be evaluated and solved? Welding-information-management systems will also provide that knowledge and enable shops to identify common causes of downtime immediately and address them. Welding-information systems are used by operations managers to seek opportunities to increase productivity while maintaining quality. They can identify which operators are the most productive and which may require additional training, measure real welding costs, discover cost reduction opportunities and measure the impact of initiatives for continuous improvement.

Quality-assurance engineers may trace the output of welds to decide whether improvements are required to avoid potential problems if welds fail. And they will discover which welders work beyond reasonable limits and escape potential incidents. Technicians in operation and servicing who wish to maintain track of all the machines in their fleet will immediately recognize what each machine is doing. The information management system will alert technicians if a computer encounters hiccups so that they can have quick and precise diagnosis. And for a given application, welding engineers may use these systems to modify and refine a welding procedure, validate it and then download the modified parameters to one or more machines in the store. Managers will hold close watch on various productivity-related metrics, such as arc-on time and welding metal-depositing, through welding data management systems. Miller Electric launched its Insight Centre point version 9.0, which includes a Smart Component Monitoring function that automatically measures the amount of weld metal required based on the weld symbol and fillet size of the operator input (Real time welding data, 2021).

5.3 Welding-process insight from miller electric mfg. co.

To gather knowledge from many models of the company's power sources, Miller has developed its Welding Intelligence systems. Data can be transmitted via a wired Ethernet link or via built-in Wi-Fi capability, allowing for fast, simple configuration and shop floor versatility. Version 9.0 of the Insight Center Point platform features a new Library Manager tool that further organizes welding sketches and pictures and a more visual dashboard interface of performance metrics in the speedometer format. Such recent enhancements include smart Component Monitoring, which automatically determines the amount of weld metal required based on the weld symbol and fillet size of the operator-input and standard AWS weld symbols that, relative to previous models, help save development and planning time, which allowed symbols to be produced by the user personally. With the safety data from individual welding machines stored, management may control and measure the efficiency of individual machines relative to other divisions or the organization as a whole. Graphical displays of efficiency and consistency are provided by other dashboards. The quality dashboard monitors the amount or percentage of welds generated for arc voltage and amperage under pre-set reasonable limits, date-stamps each weld and identifies whether quality risks have improved or decreased over a period of time. Managers may also use the knowledge gathered to calculate the performance of welder-training programme (Chantry, 2021).

5.4 The fronius weldcube documentation and data-analysis system

In order to enable detailed and continuous quality assurance and measurement of countless criteria, Fronius unveiled its Weld Cube, a documentation and data analysis device that links as many as 50 welding power sources. The system is compatible with all digital Fronius machines, including the firm's Delta-Spot resistance-welding system and its TPS/i intelligent welding-device platform built on an industry PC with optimized applications. This allows details, including weld current and voltage, wire feed speed, weld speed and time, arc and dynamic correction, and job numbers, to be registered and analyzed by the customer (Data assets, 2021). Users can track and analyse usage data on electricity, wire and power on an ongoing basis. For the entire service life of a welding machine, fixed values, such as job data, can be observed and registered by the system. Users can edit jobs and make distinctions across power sources when used in conjunction with Fronius' new TPS/i welding-device platform (Welding data collection, 2021).

Fig. 6. Weld cloud online welding-data management system (Welding data collection, 2021).

5.5 The ESAB weld cloud

At FABTECH, ESAB launched its online WeldCloud welding-data management system (Fig.6), integrating 3G mobile networking technologies with Wi-Fi and Ethernet to allow users to minimize firewall and synchronization problems. The framework runs on the intranet cloud of a company, and it is easily customized because it uses open-source tools. The new Weld Cloud online welding-data management system made its debut at the ESAB FABTECH booth. It integrates Wi-Fi, Bluetooth, GPS and Ethernet 3G mobile networking technologies to allow users to alleviate problems with firewalls and accessibility. Weld Server, operating on the intranet cloud of a company, is a stable, locked-down mechanism that ensures that information remains fully confidential (ESAB WeldCloud, 2021).

5.6 Checkpoint from lincoln electric

The cloud-based production-monitoring network of Lincoln Electric, Check Point (Fig.7), enables users to access output information from any computer or mobile device through Wi-Fi on their welders and welding operations located at single or multiple locations, without the need for

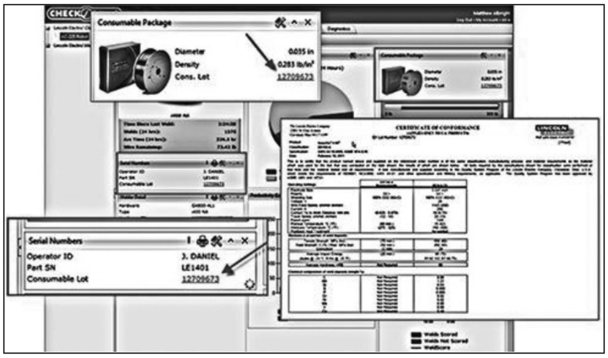

Fig. 7. The check point production monitoring network of lincoln electric offers much-needed traceability reporting, which can be obtained from a mobile device in complete reporting from a PC or in abbreviated form. This enables manufacturers to produce databases of welding-consumable certifications for consumer evaluation, and to retain records of quality programmes and other related practises (Chantry, 2021).

specialised software or IT hardware. Users can monitor the live state of each solder as it sends CheckPoint status alerts before and after each solder. To decide when each welding device will run out of consumable wire, it also uses a patented formula and provides other weld information such as wire-feed speed, voltage and more. Via operator ID, consumable ID and part serial number, users can search welds, and also select customised reports and analyses. The Check Point output tracking network of Lincoln Electric offers much-needed traceability reporting, which can be obtained from a mobile device in complete reporting from a PC or in abbreviated form. This enables manufacturers to produce databases of welding-consumable certifications for consumer evaluation, and to retain records of quality programmes and other related practises (Chantry, 2021).

6. Indian Railways on Fast Track on Fast Track with Welding

Indian Railways has long been the single most significant infrastructure entity in India, with the railway track network expanding for many years. The introduction of welding technology has also been followed by the country's economic growth. With this funding, it is possible that Indian Railways has emerged as the key strength of the Indian economy. Railways were reported that investments in rolling stocks, especially in waggons, would be subject to multiple increases relative to investments made in previous years. As a result, its production will also be improved with the use of welding consumables and tools. Different kinds and fabrics are used by various types of coaches and waggons where there is often a substantial change in the style and configuration of the waggons (Indian Railways, 2020).

6.1 Internet of Thing (IoT) and Artificial Intelligence (AI) in welding of indian railways

The new manufacturing sector is speeding the transition to digital and intelligent manufacturing, with the ongoing growth and maturity of cloud computing, big data, IoT and other innovations. Welding in contemporary industrial production is an important technique and plays an important part in all areas of the manufacturing sector. Welding methods are also one of the fields where AI is tested and used early, with the help of information technology. Train maintenance and repair is usually carried out in demanding working conditions and frequently under demand from time. In such high demand and dynamic activities, it helps to decrease human error. Robotic welding extends the life of the tracks and bridges, which not only makes the operation time-efficient, but also cost-effective. The method of reconstruction takes less than a day and traffic does not need to be blocked. Best of all, without the need for unions or rest, robotics will work day and night. In the welding of rail tracks and machine parts, IoT and AI will certainly offer many advantages in less time and with greater accuracy and precision. It will allow the Indian Railways to become more profitable and effective (Indian Railways, 2021).

Many automatic welding devices are now attached and actually networked to a computer and can be accessed from a computer anywhere in the world at any time. Future field IoT application Welder is likely to exist mostly as part of an artificial intelligence network, as it can be immensely useful in executing control and tracking functions even though the equipment is not connected to the internet. Artificial intelligence can have IoT capabilities. In addition, with the help of AI, an automatic train dispatching system can track previous scheduling decisions and performance to make decisions (machine and deep learning). On 14 September 2017, India laid the framework for the Mumbai-Ahmedabad bullet train line, India's first high-speed rail project. Our metro and bullet trains have a lot of automation. Since human drivers are unable to read signals at extremely high speeds, bullet trains are fitted with a separate type of speed control mechanism, known as Automatic Train Control (ATC), which facilitates the transmitting of speed information along the track and the reception of a signal connected to the driver's seat (Indian Railways, 2020).

6.2 Use of artificial intelligence in testing the quality of rail joints

The railways have put into service a range of innovative equipment, including the state-of-the-art SPURT (Self-Propelled Ultrasonic Rail Testing) vehicle, to detect faults in the rail and welded joints, in an attempt to reduce train injuries vis-à-vis the consistency of the rail joints. Through an on-board machine, when operating at 40 kmph, this car can detect the defects more objectively and precisely. Central Railway has built an AI-powered robot to make trains safer by removing human mistakes, which can click photographs and capture videos of the trains' undergarments and send them for repair and maintenance to engineers. A robot called USTAAD (Under gear Surveillance by Artificial Intelligence Aided Droid) (Fig.8) has been developed by the mechanical branch of the Central Railway's Nagpur division, which analyses parts of the coach with an HD camera in real time and transmits them over Wi-Fi (Indian Railways, 2021). In real time, it records video and still images of the coaches' under-gear components and transmits them over Wi-Fi. Engineers can view and capture these images on the big screen. As per the order issued by engineers, the robot's camera can be rotated in any direction. In case of any uncertainty, it will zoom on the spot as well. It is fitted with Lead flood light and capable of recording both low light and dark mode images. The risk of error and any defect missed by the human eye can be reduced by using this robot, thereby minimizing the possibility of human error. Engineers can clearly see and inspect environments that are difficult to see and difficult to reach, such as cramped or narrow gaps between under-gear modules, with the assistance of USTAAD (Indian Railways, 2020). If some device or item is found damaged during the inspection, the machine will equate the image with the library images and raise an alert in the event of a mismatch to say that the incident is an outline condition and does not seem to be regular.

In order for Welders to be able to use the benefits of AI successfully in field welding environments, engineers will be required to ensure that the

Fig. 8. A robot called USTAAD has been developed by the mechanical branch of the central railway's nagpur division, which analyses parts of the coach in real time with an HD camera and transmits them over Wi-Fi (Indian Railways, 2020).

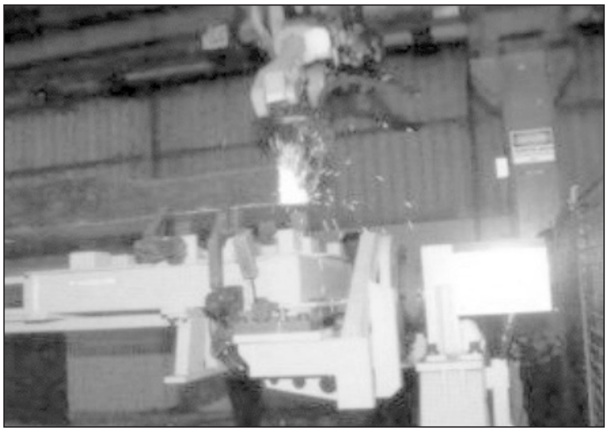

Fig. 9. Robotic welding of a coach at ICF, Chennai (Indian Railways, 2021).

Welders not only operate the equipment, but also that Welders will have "machine assistants" to assist them. In the industrial industry, robotic welding has been introduced. Robotic welding has been started at ICF, Chennai (Fig.9) and also by private companies for production coaching. This method is often used in a small way to produce wagons and bridge girders. For the manufacture of pre-welded long and high-height concrete beams that are used by the railways for their bridges and buildings, some private industries introduce robotic welding (Indian Railways, 2021).

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