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Role of IoT and AI in Welding Industry 4.0

Tushar Sonar[1], V. Balasubramanian[2], S. Malarvizhi[3], Namita Dusane[4]
[1]G.S.Mandal's Maharashtra Institute of Technology,
Aurangabad - 431010, Maharashtra State, India
[1,2,3]Centre for Materials Joining and Research (CEMAJOR),
Department of Manufacturing Engineering, Annamalai University
Annamalai Nagar - 608002, Tamil Nadu State, India
[4]Department of Computer Science and Applications, Hinduja College of Commerce
Mumbai 400004, Maharashtra State, India
Corresponding author: tushar.sonar77@gmail.com

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Dr. Tushar Sonar : https://orcid.org/0000-0002-3997-5337
Prof. Dr. Visvalingam Balasubramanian : https://orcid.org/0000-0001-7658-6392
Prof. Dr. Sudersanan Malarvizhi : https://orcid.org/0000-0003-3934-3409
Ms. Namita Dusane : https://orcid.org/0000-0001-7798-3891

Abstract

The IoT (Internet of Thing) basically pertains to the concept of linking anything that is powered both to the internet and each other and simulating human intelligence by machines, particularly computer systems is artificial intelligence. It includes learning (acquisition of data and rules for exploiting the data), logic (exploiting rules to arrive at probable or definitive findings) and self-rectification. Many automatic welding machines are now connected to a computer and are fully networked and can be reached anywhere in world from a computer at any time. The first apparent use would be in the evaluation and configuration of the equipment itself, as the equipment must be regularly interfaced with a network to perform these functions. Future IoT technology for the welding sector is likely to emerge largely as part of an artificial intelligence network, as it would be extremely beneficial to control and monitor functions even though the system is not in connection with internet. Simulating human intelligence by machines, specifically computers is known as Artificial intelligence (AI). It includes learning (acquisition of data and rules for exploiting the data), logic (exploiting rules to arrive at probable or definitive findings) and self-rectification. AI is incorporated into a variety of different types of technology. AI will have IoT flexibility which would play a major role in complying the requirements of Welding Industry 4.0.

Keywords: IoT; Internet of Things; AI; Artificial Intelligence; Welding 4.0.

1.0 Introduction

Industry 4.0 highlights the rising trend regarding automation and sharing of data in manufacturing industries, 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**) [1]. The IoT basically pertains to the concept of linking everything that is powered both to the internet and each other. It covers everything from smart phones, household equipment and official devices to turbojet engines and manufacturing equipment on large scale. The step towards wide-scale adoption of IoT has already begun, fuelled by better Internet connectivity, lower cost of technology and connection, increased utilization of smart phone, and the fact that computers, devices and machines are designed with Wi-Fi capabilities [2]. Simulating human intelligence by machines, specifically computers is known as Artificial intelligence (AI). It includes learning (acquisition of data and rules for exploiting the data), logic (exploiting rules to arrive at probable or definitive findings) and self-rectification. AI is incorporated into a variety of different types of technology. The manufacturing industries will endure the most significant influence due to IoT [3].

- **Automation:** It lets a device or system or process to run automatically. RPA known as Robotic process automation for instance, are designed to perform high-volume, repeatable operations typically done by humans [4].

- **Machine learning:** It is the branch of science which makes computers to perform without any programming [5].
- **Machine vision:** The science of making it possible for computers to see. Using cameras, analog-to-digital transfiguration and processing of digital signal, this technology collects and analyses the visual information [6].
- **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 execute reliably for humans [7].

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 [8].

There are three main applications of the IoT and AI in manufacturing industries: -

1. Manufacturing processes
2. Asset management of production and maintenance
3. On-field and off-field service

IoT and AI are utilized in industrial processes for smart manufacturing, performance management and enhancement, man-machine engagement, visualization of operations and planning of production line. About 58% of IoT investment in the worldwide manufacturing sector is associated with the manufacturing processes. IoT and AI are utilized in the asset management of production operations and maintenance work to control the main parameters regarding quality, service performance, failure and breakdowns and other considerations. This shows that IoT is not only utilized for improving the service performance, but also for the preventative maintenance [9].

IoT and AI are used by the manufacturers as they can handle functions of service providers. It involves products and business services that 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 IoT powered manufacturing environment is key [10].

2.0 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 gas and consumables,

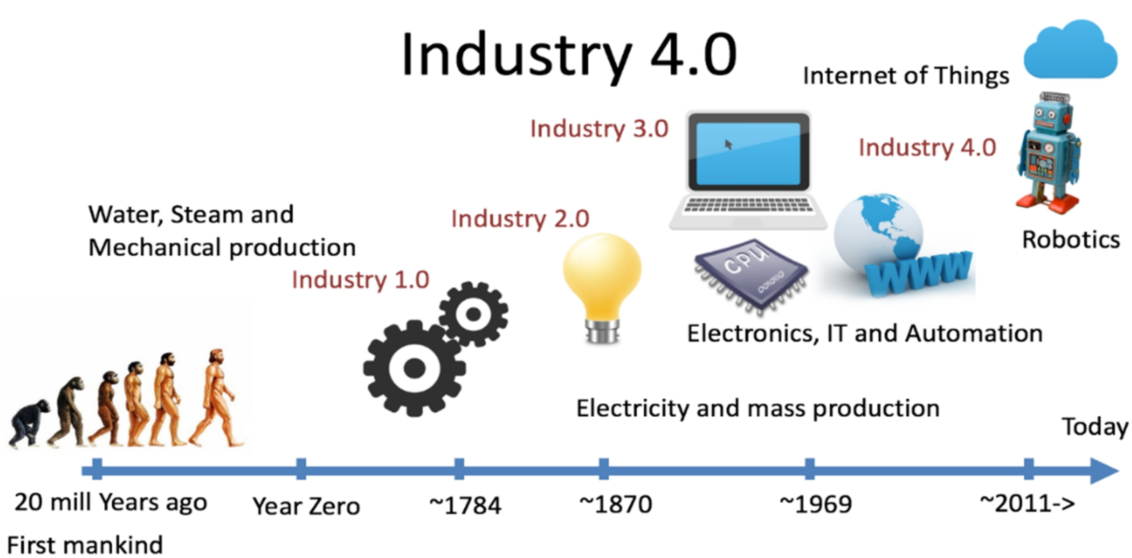

Fig.1 : Evolution of Industry 4.0[1]

recommend training and assist in 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 2022, 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 assisted welding system does not depend as much on a professional welder as on a manual method. If they operate on a computer, equipped with IoT-assisted AI, relatively untrained and unskilled worker may finish 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 shop floor, but IoT aids in a type of automation which is quite distinct from the clumsy robot doing repetitive and simple assembly line works [11]. The concept of welding Industry 4.0, closely associated with IoT, "represents the idea of interconnected factory with online machines that are intelligent and are proficient in rendering its own judgements."

The automated welding procedures turns into complex and efficient in reacting to parameters, job and other extrinsic variables in a welding workshop that is wired into the IoT environment. The welding ultimately becomes a thought object, efficient in responding to changes in a manner a human welder does. This tackles a lack of chronic expertise and allows for highly active workplace. AI and deep learning render it possible to finish tasks more rapidly, while losing efficiency [12]. 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 which is proficient in learning through data input, this is not the case. The IoT and AI are industrial future, and that's the world's future in many respects. All the things will be interconnected, so a failure in investing and learning how to build a linked workplace is a failure in keeping contact with industry's trajectory and customer base which workshops serve [13].

3.0 IoT and Artificial Intelligence in Current Welding Industry

With a single push of button on the controller (**Fig. 2**) you can connect to the expert TIG support team. The experts will review your setup, collaborate to solve challenges and make sure that system is functioning in record time. A Health Review system allows welding experts to review the system for acceptable efficiency and maintenance criteria.

The Wi-Fi of controller and ethernet connectivity enables to import and share welding processes and study and archive extensive welding files. Filled with readily approachable dual-powered USB ports, welders may utilize the controller to charge phones and tablets [10].

Fig. 2 : K-TIG Controller [10]

4.0 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 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.

5.0 What is Internet of Welding?

The Internet of Welding must allow an organization to keep its operating processes leaner or speed up internal processes for minimizing waste. Excellent examples of procedures that can be enhanced with IoW are quality control, organizational logistics and system maintenance. When a welded joint is set for inspection, advanced welding systems know when they are running short of filler wires. 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 [14]. Some criteria for welding applications need to be met for a smart factory to operate more or less autonomously without human interaction:

- The welding machine 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 [14].

5.1 Welding manufacture based on IoT and AI

With the advancement of technology and IoT, the welding manufacturing industry's production method has altered dramatically. **Fig. 3** shows framework of IOT-based smart factory. The smart factory includes 4 layers in the framework:

Fig. 3 : Framework of smart factory [15]

physical resource, industrial network, cloud and terminal layer for supervision and control. The layer of physical resource is focused on intelligent devices that communicates through industrial networks with each other. There are numerous information systems in the cloud, such as the Production Execution System (PES) and Enterprise Resource Planning (ERP), which can capture vast data from physical resources 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 [15].

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**. 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 tough to model and monitor the operation. In phase III, welding automation was made simpler with "teach and playback" robots. It was performed off-line and had minimal capacity to counter disruptions and alterations. Intelligence is added to welding machines to track and regulate the dynamics and efficiency of welding more actively in Phase IV. The human-physical systems (HPS) to human-cyber-physical systems (HCPS) have evolved from manual to intelligent welding systems **(Fig. 5)** [16] [17].

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

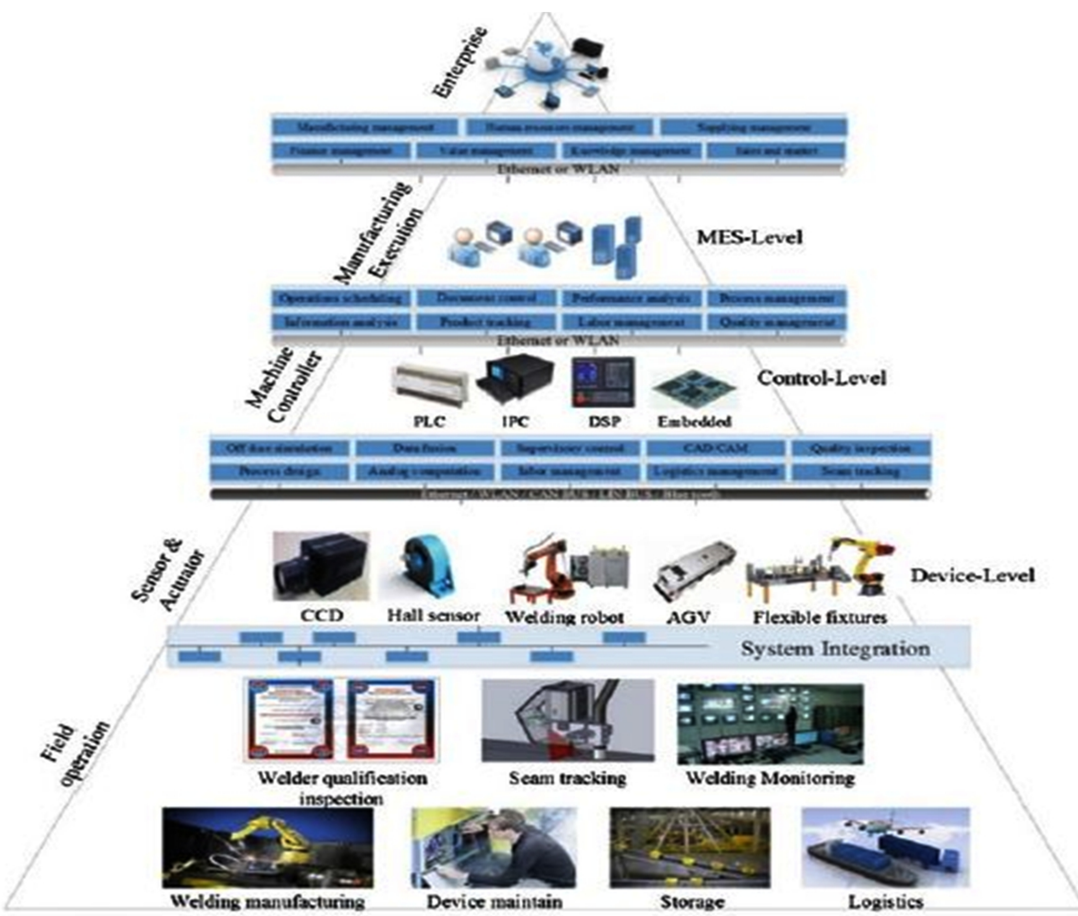

Fig. 4 : Framework of intelligent factory [15]

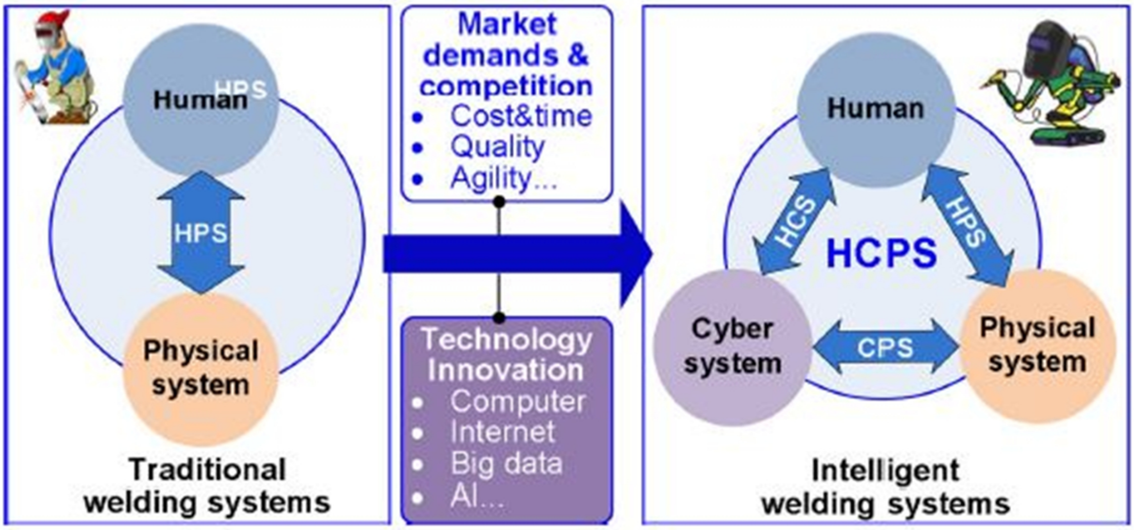

Fig. 5 : Transition from HPS to HCPS [17]

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 [18]. 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. Centre point version 9.0 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.

5.3 Welding Process Insight

To gather knowledge from many models of the company's power sources, Welding Intelligence systems are developed. 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 [19]. 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 [19].

5.4 The Weldcube Documentation and Data-Analysis System

In order to enable detailed and continuous quality assurance and measurement of countless criteria, weldcube documentation and data analysis device is unveiled that links as many as 50 welding power sources. The system is compatible with all digital Fronius machines, including 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 [20]. 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 [21].

5.5 The Weld Cloud

The online Weld Cloud welding-data management system is launched integrating 3G mobile networking technologies with Wi-Fi and Ethernet to allow users to minimize firewall and synchronization problems (**Fig. 6**). The framework runs on the intranet cloud of a company, and it is easily customized because it uses open-source tools. 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 [22]. With information on DATA Analytics of the captured data in the cloud, it is possible to obtain data of every second of each weld on weld deviations from WPS, Generate Alarm on that, Productivity information, Quality Control, Inventory management, Maintenance Alarm etc.

5.6 CheckPoint

The checkpoint, cloud-based production-monitoring network (**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 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.

Fig. 6 : WeldCloud online welding-data management system [22].

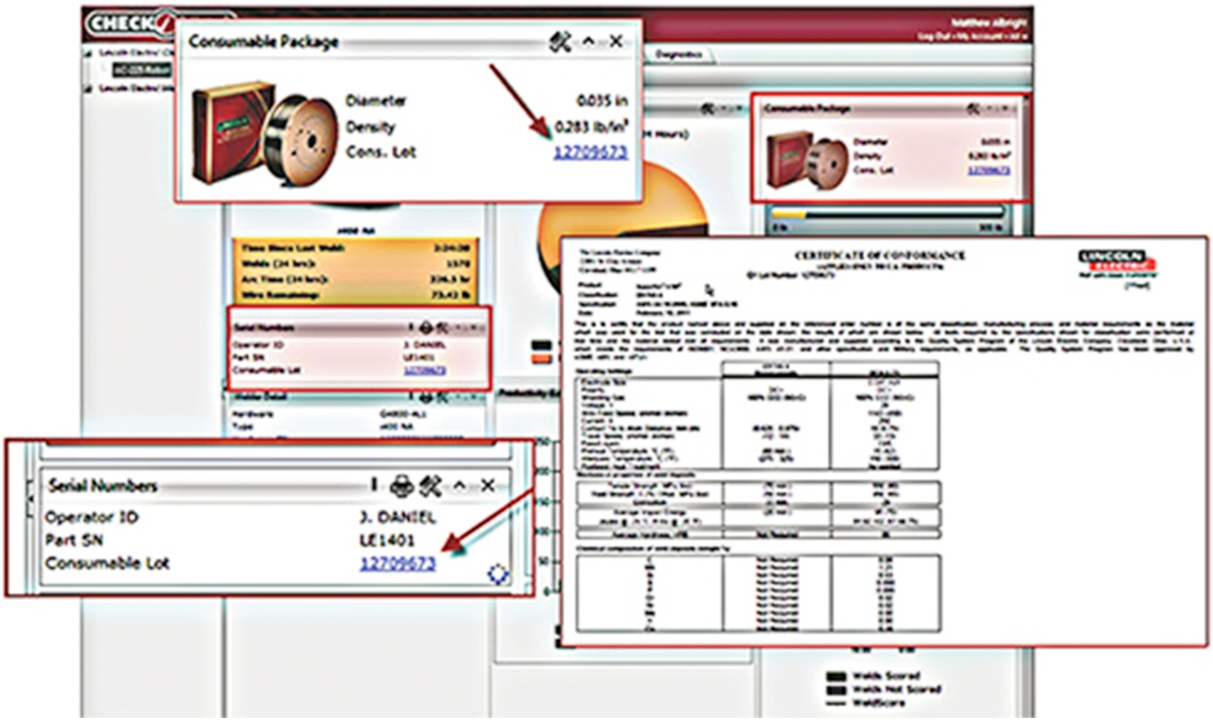

Fig. 7 : The CheckPoint production monitoring network offers much-needed traceability reporting, which can be obtained from a mobile device in complete reporting from a PC or in abbreviated form. This enables manufacturers to produce databases of welding-consumable certifications for consumer evaluation, and to retain records of quality programmes and other related practises [19].

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