Industrie 4.0 implementations in the Automotive Industry

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Abstract. To address the challenges imposed by the adoption of new technology to realise the Industrial Internet also known as Industrie 4.0, manufacturing companies are recognising the need to set up and manage “intelligent test factories”. The result is networks of cyber-physical systems (CPS) where software interfaces and services are developed to support interoperability between physical and control structures. A test factory using Radio Frequency Identification (RFID) as a first generation enabler of CPS in industrial production systems is presented in this paper. The research outlined in this paper describes the first generation of CPS that uses identification technologies such as RFID tags embedded into engine components and their carries, which allow unique identification. Data storage, processing and analytics are also provided to support real-time algorithmic intelligent services that may be used in manufacturing operations including supply chain logistics, quality audits and manufacturing strategies.

Keywords. Industrial Internet, Industrie 4.0, cyber-physical systems, automotive, RFID

1. Introduction

The “Fourth Industrial Revolution” also known as Industrie 4.0 [1] is being shaped predominantly by connectivity and production digitisation. Other Information and communications technology (ICT) technologies such the Internet of Things (IoT) and Services and Cyber-Physical Systems (CPS) aim at smart manufacturing ecosystems where a network of autonomous and self-optimising production machines and intelligent products work towards the creation of more sophisticated outcomes.

However, the combination of different aspects like physical infrastructure, communication systems, people and organisations leads to heterogeneous systems that are difficult to deal with. The adoption of new technology relies on implementations that mimic near to real situations. Therefore, by using factories as laboratories, researchers and companies can increase the implementation effectiveness of Industrie 4.0 scenarios, enabling a faster feedback loop for technology adoption, development and validation of new business models, services and products.

The case studies presented in this paper aim to describe the approach used to deploy Radio Frequency Identification (RFID) in a UK’s OEM manufacturing and engine assembly plant. By using RFID, the identification, tracking and traceability of engine components and their carriers (i.e. kitting boxes, separators, stillages) can be supported. Lessons learnt in deploying these factory labs are also presented. Best practice systems engineering principles including requirements definition, modelling and simulation were used to implement these smart factory labs.

2. State of the Art

Radio Frequency Identification (RFID) is a widespread technology, covering all automation industry applications (retail, aerospace, healthcare and automotive [2, 3]). RFID is a technology enabler for Industrie 4.0, as it provides a digital memory for a product that can be carried throughout its lifecycle [4], which can be integrated with its environment. In addition, item identification with passive RFID technology in the Ultra High Frequency (UHF) band (860 to 960 MHz) has many advantages over traditional barcodes and product data marking technologies such as 2DMatrix [5] to meet industrial requirements for product location tracking, traceability and genealogy. UHF RFID has many advantages over other frequency bands such as High Frequency (HF) and Super High Frequency (SHF) including, global functioning, read range from a few centimetres (UHF near field) to more than 10 meters, lower costs and good data transmission performance in environments with high tag density.

Many automotive manufacturing companies have applied RFID technology to increase both supply chain efficiency and transparency and improve their process and assembly operations [6-8]. Other companies such as Jaguar Land Rover have looked at using RFID in returnable transport items (RTI) such as pallets or reusable shipping crates to improve logistic operations and monitor the protection of engine components during transport, storage and handling [9] within closed supply chain loops.

However, despite the fast adoption of RFID in automotive supply chain, its full implementation still faces several challenges, including: i) standardised syntax and semantics for on-tag data to enable sharing information along the supply chain, (ii) reliable RFID system architecture and implementation, (iii) provision of decision support systems via business intelligence services. The challenges associated to implement RFID systems in an automotive manufacturing OEM such as using RFID to tag of engine components (e.g. cylinder heads, crankshafts) and their carriers to improve the management and transport of such items in closed loop logistics is discussed in this paper.

3. Methodology

Five case studies were implemented by following the design and implementation method as described in Fig. 1. Initially, the application requirements were captured through interviews, process observation and process modelling, which support the development of requirements for an RFID system. These requirements include (i) the required RFID read range; (ii) expected RFID tag population size at the point of detection; (iii) speed of RFID tags at the point of detection (static or moving); (iv) level of data storage required (full process history data or solely product identification) and (v) requirements for extreme environmental conditions (e.g. temperature, humidity and impact exposure.

Once system needs and requirements were identified, designing and implementing an RFID solution included studying several interrelated aspects, which cannot be considered in isolation, and can be grouped into three areas: (i) RF Interference Sources Identification; (ii) RFID Tag Engineering and (iii) RFID Portal Engineering.

Understanding the system's working environment allowed the identification sources of RF interference, which were then considered for RFID tagging and portal engineering to obtain a cost effective reliable system. Some of these interferences are intrinsic to the metal environment i.e. automotive engine components are transported in metallic reinforced separators, which in turn are transported by forklifts using metallic stillages).

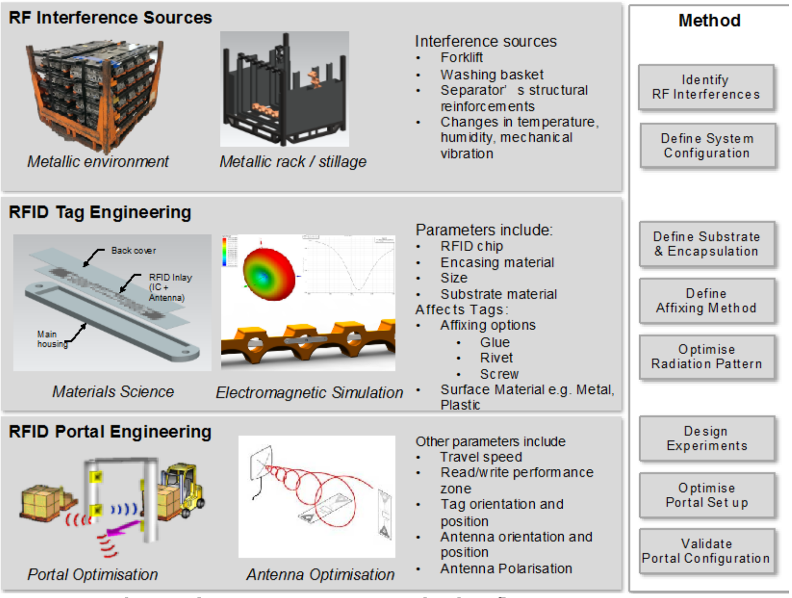

Fig. 1 Approach to Implement RFID Systems on the shop floor

Tag engineering consisted of designing, developing and testing low cost RFID tags that maintain technical performance especially in harsh environmental conditions. Although many commercial RFID tags exist that meet requirements for industrial use, many parameters were engineered to develop cost effective technically robust RFID tags. These parameters included: RFID chip, antenna design, size, encasing material, inlay material and substrate material. In addition, the mounting method and mounting locations can change a tag's performance resulting in changes to tag characteristics such as shifting the resonant frequency, reducing the optimal frequency bandwidth and far-field degradation, which leads to poor RF performance. Tagged items may also be exposed to harsh environments so they need to withstand abrupt changes in temperature, humidity, chemical agents and mechanical vibration during their use throughout the manufacturing plant (e.g. washing, outdoor storage).

The RFID portal set up, e.g. number of antennas, antenna height and orientation, is highly dependent on the RFID hardware selection (e.g. interrogator power, antenna polarisation, antenna radiation pattern and antenna gain), tag population (number of tags to be detected), tag positioning and tag orientation. Evaluating different tag locations required the consideration of various antenna topologies and their relative orientation and position to the portal zone i.e. for a given antenna topology the RF radiation pattern will be better at certain locations.

Single tagged items (e.g. cylinder heads, separators and stillages) and a combination thereof were tested statically and dynamically i.e. entering, passing through and leaving an RFID portal. Various distances from and away the portal centre were tested to fully characterise the system performance.

For all the performed experiments an *Alien ALR9900 + EMA* interrogator with a frequency range of 865.7 MHz – 867.5 MHz (EU regulations) was used. Each interrogator consisted of up to 4 circularly polarised antennas, decreasing the likelihood of a polarisation mismatch, useful in non-line-of-sight applications (e.g. reading separators).

Many objects that were being analysed for the application of RFID offered many options for RFID tag fitment. Thus, many RFID tag positions were tested. However, staking RFID-tagged items such as separators on a stillage often led to EM properties (such as directivity and impedance) detuning, performance degradation and in many cases read/write failure. This problem caused the performance of field deployments in industrial environments to be worse than claimed by technology providers in datasheets or laboratory settings. Therefore, before determining the optimum number and locations of RFID tags on separators and stillages, preliminary tests were undertaken to determine the interference between neighbouring RFID tags.

For all the case studies investigated, the design of experiments (DOE) consisted of a series of tests designed to evaluate the relationships between the RSSI, read success rate and the system requirements e.g. i) type of substrate materials that the RFID tags are attached to, ii) tag position, iii) relative orientation, distance and elevation between the RFID tags and the RFID antenna, iv) RFID tag polarisation, and iv) the environment. Various statistical analyses of changes in RSSI were carried out.

The research value of this study includes a description of the approached followed to implement RFID in an automotive plant for identifying, monitoring and tracking engine components and their carriers. The implemented RFID system overcomes the problems associated to monitoring engine components and their carriers throughout manufacturing and assembly operations. Data obtained by the system can be visualised and analysed through a secure web service by different stakeholders.

4. Results and Discussion

Tag-to-tag interference. The distribution of RSSI values for a control tag when two neighbouring tags are placed at regular distances is shown in Fig. 2. It can be observed that the closer tag's group (35,135mm) influences the control tag with a higher variation Mean=11974.52, (SD=236.9) than tags further apart. The same is observed for tags placed in front and behind the control tag. These tag-to-tag interference experiments provided a basis for tag spacing and thus ensured that subsequent experimentation was reliable. This is, by minimising interference between adjacent tags, further experiments could focus on understanding the interference from the tagged object.

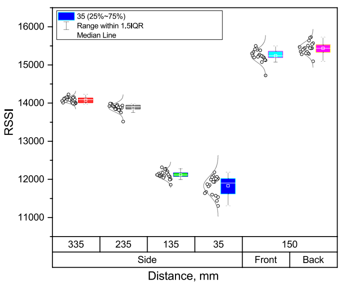

Fig. 2 Control tag interference with neighboring tags

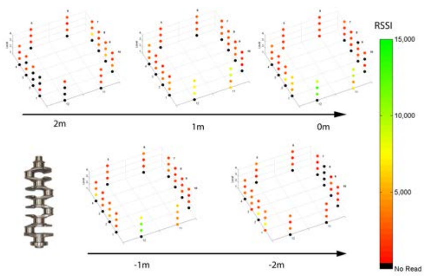

Fig. 3 RSSI of tags placed on crank separators as they pass through a portal.

RFID Tagging of Engine Component RTIs. RSSI and read success rate percentage values were calculated for the tagged RTIs at various distances as they passed through a testing portal. Each tag's RSSI was plotted against distance to visualise its change through the portal, as seen in Fig. 3. From the 3D plots, it can be seen that as the separators approached the centre point of the portal (0m) the RSSI of thirty eight tag locations increases. This was expected, as these tagged separators were closer to the detection antennas. However, it should be noted that on the bottom most separator, only positions 1,5,6 and 11 were detected at some point passing through the portal. This was likely to be caused by the crank separators depth, as the tag becomes positioned very close the metal of the stillage frame, detuning the RFID tag.

Overall it is likely that the crank stillage would need a redesign for the bottom most separators in order to achieve total traceability. For the remaining separator it can be seen that position 5 offers the best overall position as it showed a 12% read rate improvement (969 reads) over the next best location (position 6, 863 reads). Despite having the best-read rate, position 5's total RSSI value (49,709) was lower than the top RSSI performer (position 11, 104,578 RSSI).

5. Conclusions

Applied research and case studies combining such different aspects like sensor infrastructures; communication systems and studying how people and organisations adapt to these changes are required. The case studies summarised in this paper, described the approach where RFID implementations in factories were used as test systems to serve as technology demonstrators. The aim of these demonstrators was to fill in the gap that exists with the lack of identification, traceability, data collection and connectivity of products, machines and processes even in highly automated automotive plants.

The deployed systems stimulated the discussion between the automotive stakeholders and their supply chain on how to make better use of RFID as first generation systems for Industrie 4.0. Technologists at the automotive company, believe that if the simplest sensing capability such as RFID provides greater visibility then more complex sensing technologies can be more easily adopted by an organisation.

To implement the systems industrially, many lessons were learned that can be applied to the design, experimentation and deployment of future RFID systems and can be extended to build digital factories. A key lesson is for companies to enable flexible secure IT infrastructures that can provide open, flexible, secure interfaces for the developed systems. These interfaces will enable multiple devices, people and organisations to connect, collaborate, share and exchange services in real time.

A test factory for RFID as a first generation enabler of cyber physical systems in industrial production systems has described in this paper. Although an open, distributable software architecture independent of the organisation was also deployed that provide analytics to optimise certain production operations, further integration to the organisation's IT backbone is desired to provide more data to the analysis algorithms for modelling and validation. Currently, the RFID systems data analysis services are being used and validated by the organisation over the web. Future work include the development of a generic and adaptable RFID system architecture that can be reused in similar domains. Also, work is being carried out in adding context awareness information in the form of ontologies in order to enable cooperative, collaborative and distributed localisation services, IoT tracking and intelligent inventory.

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