

Design for Industry 4.0: Opportunities for an Aircraft Seat Manufacturer

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1. Introduction

The Industry 4.0 revolution consists of a number of disruptive technologies that are enabling the digitalisation within the manufacturing sector. Through the use of technologies such as the internet of Things (IIoT), Big Data, virtual/augmented reality and cloud technology it is possible to integrate and analyse data from multiple sources and companies, sharing results across the value chain, ensuring integration with physical assets, and rethinking the design of traditional manufacturing systems (Mourtzis, et al., 2019). The transformation from today's manufacturing production systems towards Industry 4.0 is based on the adoption of Cyber Physical Systems (CPS) (Monostori, et al., 2016). The increased availability and affordability of sensors, computer networks, data acquisition systems, has made this transformation more accessible (Lee, et al., 2015). Use of such smart sensors results in massive amounts of data, making material and information flow more complex during production and distribution. Smart objects however, can be dynamically reconfigured for high flexibility, while big data analytics can provide coordination and global feedback in order to achieve high efficiency (Wang, et al., 2016).

The opportunities arising from Industry 4.0 are enabling manufacturers to reimagine their production environments. Although, if manufacturers are to stay ahead in this ever-changing world, whereby mass production is rapidly moving towards mass customisation, they must consider embedding Industry 4.0 technologies throughout the life cycle of their products, with significant focus on product design and new product development. This is essential to not only provide the production teams with everything they require to ensure the production system is intelligent and flexible, but also ensuring companies are reactive to the voice of the customer while considering its responsibility towards sustainability.

This report discusses how Industry 4.0 is affecting traditional new product development processes within manufacturing. Furthermore, the report will discuss the emerging technologies that can be applied to 'Design for Industry 4.0' processes within an aircraft seat manufacturer based in South Wales, while considering the societal impacts implementing such technologies may have.

2. Industry 4.0 and New Product Development

The process of introducing a new product to the market, referred to as New Product Development (NPD), encompasses all of the tasks involved in creating a new product, such as concept generation, idea screening, testing, and customer approval. The NPD process has a significant impact across the whole value chain and decisions made at this stage can have a considerable impact on quality, cost, and delivery. Organisations can gain a competitive edge by differentiating their output through process and product innovation (Wijewardhana, et al., 2021). On the contrary, many firms are seeking to add novelty to their new product developments by combining product and process innovation. Wijewardhana, et al., (2021) also adds, that in sectors that are witnessing rapid technological change, such as the manufacturing sector, organisations must consider applying emerging technologies when developing new products and/or process innovations. Kazemi & Fatorachian (2018), state if a company is to be successful within the fourth revolution and beyond, it will depend on their ability to understand the business environment around them, deal with data and information effectively, and convert this knowledge into products or services that are highly sought of by consumers. With this in mind, new product development is increasingly becoming a critical business process that can evolve, whereby companies can use it to their advantage to ensure they stay ahead of the curve as Industry 4.0 sweeps through the manufacturing sector.

Other than the digitalisation of factories and supply chains, Industry 4.0 provides another concept that is changing the world of product development referred to as “Smart Products”, whereby products and their components are also becoming digitalised. Smart products along with the IIoT and the cloud are enabling manufacturers to collect masses amounts of data while products are in service, referred to as a field data (Salimbeni, 2020). For example, data such as operating temperatures, usage times and customer preferences can be obtained from sensors and actuators within the smart products (Tonelli & Demartini, 2018). This field data via industry 4.0 technologies can be incorporated into the product development process and even during the manufacturing process depending on the type of products. By closing the product's information loop, Industry 4.0 and digitalisation makes closed-loop lifecycle management possible (Salimbeni, 2020).

3. Design for Industry 4.0 Technologies

As highlighted by Zheng, et al., (2021), there are many emerging technologies within Industry 4.0 that are being embedded into design processes throughout the manufacturing sector. For example, Dalenogare et al. (2018) demonstrated that big data collected from sensors can have a positive effect on product design within CAD systems as designers are now able to exploit this data and acquire information about potential improvements and design features in order to satisfy customer needs that were not previously accessible.

Visualisation technology, such as Virtual Reality (VR) can also assist the design and product development process by providing an accurate simulation of the final product within its natural surroundings, an aircraft seat within an aircraft cabin for example.

This allows customers to assess the design and aesthetic details prior to moving into the next phase of development (Zhong, et al., 2017). Augmented Reality (AR) is another option; Chen, (2017) states AR technology is enabling designers to create products that feature complex shapes, not previously possible with traditional methods. AR can also support rapid prototyping, obtaining the product components quickly for subsequent testing.

Ang, et al., (2017) discuss how data collected throughout the products lifecycle combined with machine learning can optimise the design of a product. The authors also touch on cloud technology and its ability to deploy functionalities and data such as customer requirements across global networks, by storing this data within the cloud makes it easily accessible for all stakeholders to process and analyse, resulting in a collaborative and distributed product design.

According to Qi & Tao, (2018), Digital Twin (DT) can also play a significant role in design and product development as it replicates the digital representation of a physical product enabling “iterative optimisation of personalised design”.

Finally, Adrodegari, et al., (2018) discusses the importance of big data analytics and the Internet of Things (IoT) while designing for a circular economy perspective. Using IoT allows data to be collected directly from products helping designers to develop future designs in such a way that are reusable or repairable (Langley, 2017).

4. Design for X

Design for X (DfX or Design for eXcellence) is an all-encompassing philosophy of best practices that can be applied during the product design phase. It adopts a systematic and holistic approach, focusing on all aspects of a product, from product development to the end of its life. Applying Design for X will ensure manufacturers are focused on getting the design right first time (Velling, 2021), preventing wasted time, resource and expenditure. There are many elements within Design for X, including design for manufacturing and assembly (DfMA), design for quality (DfQ) and design for sustainability (DfS). The organisation and the products requirements will determine which Design for X practices are a priority or even relevant (Velling, 2021).

5. Design for Industry 4.0: Welsh Aircraft Seat Manufacturer

The aerospace industry is one of the most heavily regulated industries in the world, with aircraft and aircraft components being subjected to stringent testing before they are approved to fly. This ensures manufacturers and their suppliers continuously deliver the highest levels of safety and quality at all times.

For an aircraft seat manufacturer based in South Wales that design and manufacture first-class and business class seats for airlines globally, compliance to the regulations is paramount and therefore primary focus within its Design for X strategy is to ‘Design for Compliance’ (DfC).

By Designing for Compliance, seat designers ensure all legal requirements laid out by the regulatory body (CAA – Civil Aviation Authority) are embedded at the very start of the design process. In order to achieve this, designers must be trained and fully aware of the current regulations within their particular area of expertise. For instance, an electrical designer must be educated on the latest wiring regulations within an aircraft or a seat designer should know the load specifications and safety requirements long before sketching a design.

If such regulations are not adhered to at the start of the design process then this could lead to a complete re-design of the product at a huge cost to the business, especially if customers decide to not with the company as they are unable to meet deadlines. Even worse, in the unlikely (not impossible) event of the product slipping through the net and making it to the aircraft in an un-airworthy condition, this could potentially have devastating consequences.

Industry 4.0 technology, in the form of the Internet of Things (IoT) could solidify the seat manufacturers design process by providing and sharing the latest compliance data compared with recorded data from previous designs to ensure the design is cost effective, light as possible and most importantly, compliant to the regulations.

Furthermore, Industry 4.0 can offer a new aspect of Design for Quality (DfQ), strengthening the net in preventing faulty or uncompliant parts reaching the customer. For example, designing RFID tags or QR codes into the seats can provide an effective method of recording the seats traceability within the factory or when in service. Using RFID can also provide real time quality data to managers and quality teams, allowing them to react to issues as they occur.

Another example where IoT can change the way the company works is to use the technology to access and monitor seat performance while in service. By designing small sensors into the seats in the future, it will be possible to transmit this data via IoT to the cloud, providing the latest data from all of its customers and products. This can also support with in-service issues, for example, if a seat loses power or does not manoeuvre into a flatbed position, engineers at home base will be notified of this in real time, enabling them to analyse the data and root cause the issue. Once a solution has been identified, this can be relayed back to the airline enabling technicians to repair the seat once the aircraft has landed, ultimately providing an efficient aircraft turn around, no loss in sales as the seat would be functional for the next passenger and therefore customer satisfaction.

6. Societal Impact of Design for Industry 4.0 Technologies within the Aerospace Industry

Adopting any of the previously discussed design for industry 4.0 technologies within the aerospace industry will have some significant societal effects. For example, using IoT to monitor seat performance and improve design will result in seats becoming more reliable and suffer less from breakdowns. This will ultimately have a detrimental effect on sales of aftermarket spares for component manufacturers.

Furthermore, having access to endless amounts of data will enable companies to understand their products better and allow them to work on designing components that are lighter, cheaper but still meet the required standards. As a result, parts will be cheaper to manufacture and these savings can be handed back to the customer, encouraging them to fly more often.

The most significant societal impact would be that of working towards cleaner skies ensuring aerospace is playing its part in tackling climate change. Manufacturers throughout industry and specifically aerospace are working towards 'Net-Zero 2050' (Gov.UK, 2021). Industry 4.0 is playing a significant role in this as data capture and technological advances are enabling manufacturers to work more efficiently to design and manufacture components that are making aircraft more environmentally friendly. One example of this is the use of additive manufacturing within GE engines; the company were the first to manufacture fuel valves using 3D printing. This enabled GE to reduce the number of individual welded components from twenty to just one single part, reducing weight by more than 25% percent (GE, 2018).

7. Consideration for the Circular Economy in the Aerospace Industry

Another concept that is making its way into new business models throughout manufacturing is 'Design for Circular Economy'. The circular economy can be defined as a production and consumption system that focuses on maintaining products, components and energy in circulation in order to add and recreate value for as long as possible (Jabbour, et al., 2020). Following criticism of the linear model (cradle to grave), which results in problems such as increased pollution and deforestation, decreased use of natural resources, and loss of biodiversity, the adoption of a circular economy is becoming increasingly significant (Homrich, et al., 2018).

A growing awareness of strategies such as 'Net-Zero by 2050' is forcing the aerospace sector to design greener aircraft and components, changing the design of the aircraft or the fuel used (Gupta et al., 2010). The use of advanced materials in aerospace affects development costs, in addition to large amounts of energy used during the manufacturing process. If these materials were to be recovered it could provide a number of benefits, such as a reduction in natural resources, reduced landfill and environmental impact, increasing job opportunities, and encouraging the market for recycled products (Asmatulu et al., 2013). The adoption of a circular economy concept into aerospace manufacturers business models can help build the company's brand image, increase profitability without further degrading the environment, expand market share since circular economy concepts enable the re-entry of waste back into the design process through remanufacturing, reusing and recycling.

8. Conclusion

The aim of this report was to identify technologies available through ‘Design for Industry 4.0’ and how such technologies are impacting industry and the way manufacturers approach design in the future, specifically an aircraft seat manufacturer based in South Wales.

The research identified that there are many emerging technologies available via Industry 4.0 that are changing the way companies approach new product development and design. Deep diving into the current and future state of product development, it was evident that companies must adapt to stay ahead of the competition and success will depend on their ability to understand the business environment around them and their ability to turn data into knowledge that can be embedded into new products or services that consumers are seeking.

In the literature, there were many examples of where product development is evolving throughout industry. The recurring theme was that of ‘smart products’, whereby products and components are becoming digitalised by adding sensors into the product design. This enables field data to be captured and reported back to designers via the IoT and the cloud, enabling them to use the information to improve future designs and services, ultimately providing closed-loop lifecycle management.

Some of the key technologies making an impact across industry were identified, including virtual reality, big data analysis, IoT and digital twin. This research was considered while reflecting on the current design practices within the aircraft seat manufacturer and how such technologies can be embedded within the company’s business model moving forward.

Despite the vast amount of opportunities available through design for industry 4.0 technologies, there was a gap within the literature in regards to the research around design for industry 4.0 and the aerospace industry. It was also evident that the aircraft seat manufacturer is within the very early stages of its Industry 4.0 journey, although the message is clear that the company are taking design for industry 4.0 seriously, with significant focus on designing for the circular economy.

It is for these reasons that this report recommends the company conducts further research into this area to understand the applicability, benefits and risks that such technologies may present. To ensure the company does not lose focus in Industry 4.0, a recommendation would be to assemble a cross-functional Industry 4.0 committee to focus on ensuring the company does not get left behind in the era of digitalisation.

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