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Development of Augmented Reality applications for the entire spectrum of the screw compressor manufacturing process

Whitepaper

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Introduction

Abstract

Augmented Reality (AR) in industrial applications connects users across digital and physical worlds and coupled with rapid return of investment, easy adoption, and as a meaningful way to stand out from the competition, AR is quickly becoming increasingly common in the industrial world.

This paper first provides the reader with a description on what exactly is augmented reality and the difference between augmented reality and virtual reality, before moving onto describing the scope of this new application for an organisation like Howden. A brief analysis of how augmented reality is quickly finding a footing within this sphere is offered alongside an overview of the main players and actors. The paper then focuses on how the 3D CAD modelling already completed by the research and development, bareshaft engineering and package engineering teams can be utilised in the rapid development of augmented reality applications. Examples of how Howden is developing and using these AR applications are then given with specific reference to the screw compressor sales teams using them to show prospective clients the model of their equipment; the screw compressor package build teams sharing knowledge using AR during package fit-out and hazard and operability studies; the bareshaft compressor test team using AR within their acoustic enclosure and finally the impact of AR in the service teams.

The paper concludes with how, as this technology becomes more mainstream, manufacturers adopting AR can significantly add value to their customers experience both in terms of service and satisfaction but also to differentiate themselves from their competitors.

The difference between augmented reality and virtual reality

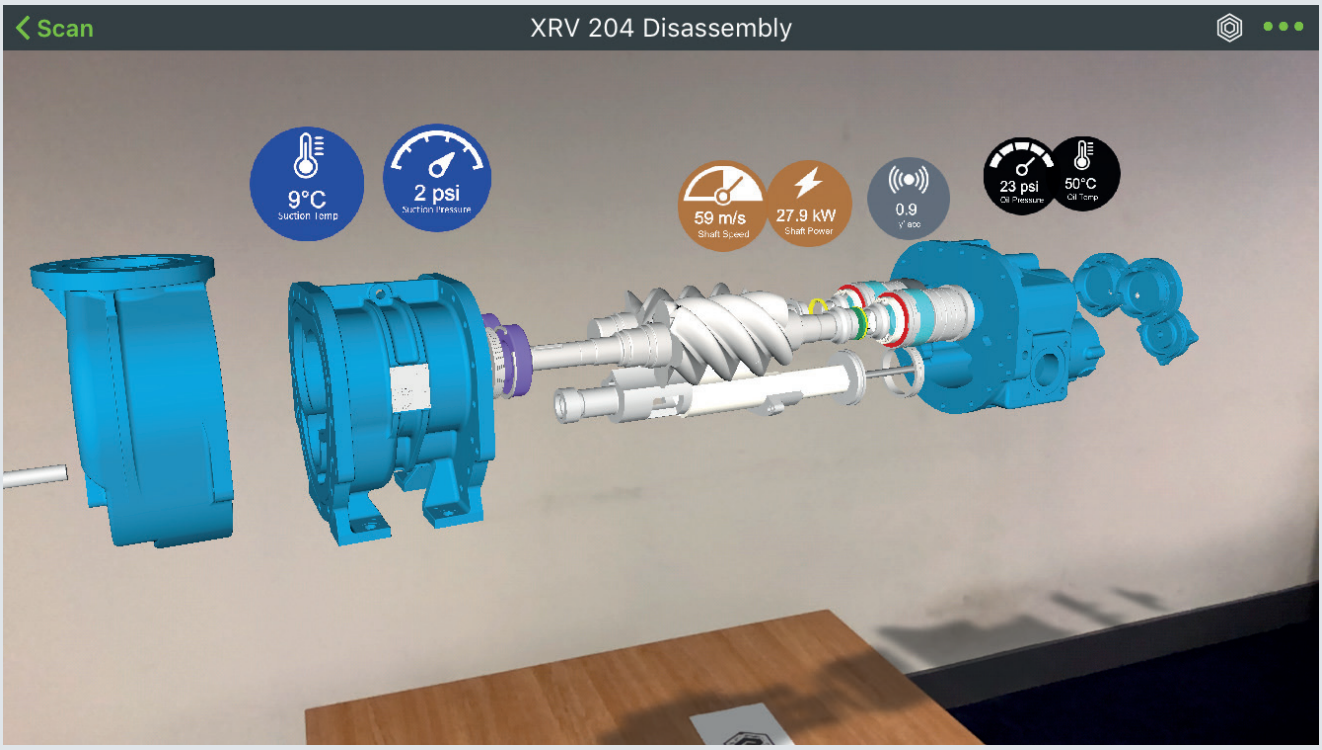

Figure 1: A scaled augmented reality exploded view of a Howden XRV 204 compressor.

A virtual reality experience is fully immersive - that is, it creates a whole world within a digital environment. Whereas an augmented reality experience keeps everything in the real world, and simply adds to it.

Augmented reality is a set of technologies that superimposes digital data and images on to the physical world, where the user can still see and interact with the real world, but has this digital information display wrapped around it [1]. Virtual reality (VR) has evolved into a variety of configurations based on head mounted displays, PCs, immersive rooms and large screen systems. Essentially VR systems describe a computer technology that enables a user to look through a special display and instead of seeing the normal world they see an entirely computer-generated one. The users head movements are monitored and fed back to the computer creating the images. So as the user moves their head the objects in the scene remain stationary as they do in real life. Most head mounted devices prevent the user from seeing the real world to achieve an immersive experience [2]. Whereas AR is the real-time use of information in the form of text, graphics, audio and other virtual enhancements integrated with real-world objects. It is this 'real world' element that differentiates AR from VR. AR integrates and adds value to the user's interaction with the real world versus a simulation [3].

This paper focuses on the AR technology and how it can be applied within an air and gas handling organisation.

AR promises to close this gap and release untapped and unique human capabilities. Though still in its infancy, AR is poised to enter mainstream within the organisation and will disrupt the company. In the coming months and years, it will transform how associates learn, make decisions, and interact with the physical world. It will also change how the company serves its customers, trains employees, designs and creates products, and manages the supply chains, and, ultimately, how it competes. Internally, associates in the design office will learn about the product by stripping and re-building compressors on their desk in the office using AR compressor animation experiences. See **Figure 1**, it is an exploded view of a Howden XRV 204 screw compressor with rotating screws and nominal values. New associates on the shop floor will be able to produce better, quicker results by following these same AR experiences and work instructions. AR experiences overlaying a 1:1 model of a screw compressor package over the top of an empty base frame have already been used in the factory setting. This allows the compressor fitters working on the shop floor to explore the finished build using their own smart phone. See **Figure 2**, it is a model of a compressor package sitting directly on top of an empty base frame. Design reviews and hazard and operability studies become more useful as the designs can be viewed in augmented reality as opposed to on a computer monitor. The AR animation can be put on the table and the participants can explore the design with a phone, tablet or HoloLens device. These will all be discussed in turn later in the paper.

The difference between augmented reality and virtual reality (continued)

Figure 2: An augmented reality package model sitting directly on top of an empty base frame.

Externally the end user can also benefit massively from the AR progress that is being made: situations where the screw compressor is being operated in extremely remote locations, such as offshore Falkland Isles or on a cargo ship, places where it is extremely hard to get a service technician. Now the maintenance crew can access the AR maintenance experiences and using their supply of spare parts carry out the servicing of the machine by following the AR guides. If the service technicians have wearable technology such as the Microsoft HoloLens, then they can have the real machine on a bench with the AR machine sitting beside it, watch the step by step guide of the tear down on the AR machine including pausing it when they need to and then, with their hands free, carry out the same procedure on the actual machine.

Some AR applications such as Vuforia Chalk and some HoloLens applications such as Holostream also allow remote users to see and hear what the wearer is seeing, so again thinking from a customer servicing perspective the customer can show the manufacturer their on-site machines and get real time assistance from them.

Another realised benefit of AR is the ability to turn any mobile phone or tablet into a human machine interface (HMI). Live instantaneous values can be superimposed onto the top of any machine. This allows operators of screw compressor packages with a supervisory control and data acquisition (SCADA) system, which is located in a nice warm control room 50m from the actual package, to see live values of all the transmitters and vibration instrumentation without returning to their control room. Another use case that has been deployed is the removal of operators from potentially dangerous areas: packages can often be located in extremely oppressive areas from a temperature (hot or cold) or noise point of view. The live values can be brought to the outside of the package area to prevent operators having to go too close to see the live values. To access these values the operator simply scans a QR code with an app on their phone and the app then displays the live values. These values can be shown in a tabular form, see **Figure 3**. You can also see the data from the sensors on the machine or the virtual view of the parts moving inside where the graphics ‘stick’ to the real thing as users walk around [4], see **Figure 4.**

Analysis of the AR market

Gartner sees immersive experiences such AR and VR as changing the way that people perceive the digital world and lists them in the top 10 strategic technology trends for 2018, alongside such things as artificial intelligence, digital twins and continuous adaptive security [5].

What they see emerging as the immersive experience of choice is where the user interacts with the digital world and real-world objects while maintaining a presence in the physical world, and expect the smartphone battle for this mixed reality to heat up. Within industry the evidence [6] is pointing to industrial companies using AR to differentiate their product or service offerings and as an improvement to sales and marketing with the biggest use cases for adoption being service manuals and instructions; service inspection and verification and operator and assembly work instructions. The same companies are focusing on design, manufacturing, service and finally training as the four users/roles that are being empowered with AR adoption, with 80% of the experiences being delivered by smartphone, 71% by tablet and 37% by digital eyewear [7]. It should be noted that a lot of experiences can be published for all three devices at the same time rather than publishing one experience for one device and then another experience for another. Many AR experiences are device agnostic.

Figure 3: Showing tabulated live data at the entrance to an area.

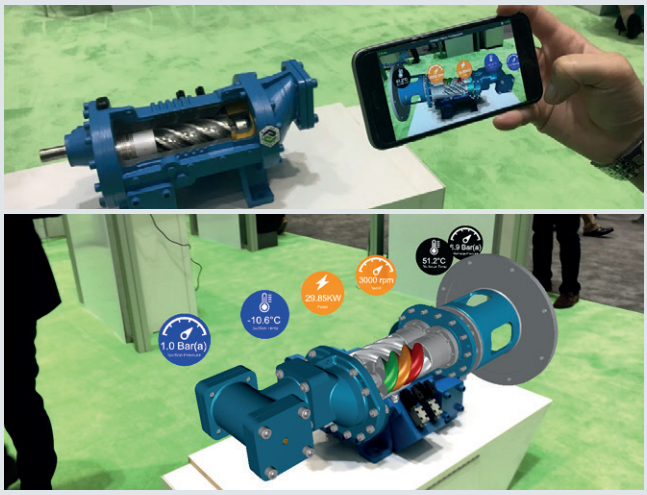

Figure 4: Live data projected over the compressor model.

Some of the key players in the augmented reality market include Google, PTC, Upskill, Magic Leap, Samsung, Facebook, Apple, Qualcomm, HTC, and Microsoft. Large corporations such as Qualcomm, Apple, and Google are investing heavily in R&D to improve the quality of both hardware and software offerings. Like a lot of emerging technologies the AR industry is typically made up by a large number of small players that include platform providers, software developers, hardware device manufacturers, and content providers. One of the strategies adopted by the market leaders is the acquisition of small players and start-ups, to gain substantial market share and gain advantage over their competition.

Developing the experiences

It is actually remarkably easy for an organisation like Howden to venture into the AR world and to create experiences for the full spectrum of the screw compressor manufacturing process.

As the original equipment manufacturer (OEM) of the bareshaft screw compressor, and also as a packager and as an aftersales supplier, Howden already have 95% of the modelling and data required to produce the animations displayed above. To go the next step has required the team to come out of their silos and integrate with the different departments around them. For instance, to generate the AR tear down and re-build experience, the 3D CAD model was taken from the engineering department, and in only a few iterations, with the aftersales department and the fitters on the shop floor for guidance, the AR animation specialist (read 3D CAD modeller) applies the knowledge from aftersales and shop floor to the 3D model using the AR platform. To develop the remote data experiences, where the pressure and temperatures hang around the machine or in tabular form, the same AR animation specialist, this time in dialogue with an instrumentation engineer, picks up the live data tags from the control system or industrial internet of things (IIoT) platform and deploys them relative to the QR code.

To develop the actual experiences, the 3D CAD model of the bareshaft machine is exported from the 3D CAD modelling software as a standard CAD file. Typically on the experiences shown in this paper the models were all imported as .stp files. This allows the file to be generated in Autodesk's Inventor software, which Howden uses around the world, and imported into PTC's Vuforia software. It is important to note that the 3D CAD file does not have to be generated in PTC Creo. So the importance of already having the CAD models available is where all the work is done. To emphasise this point on a large screw compressor package, two stage oil-free, with a main drive motor and winged pinion gearbox, gas conditioning vessels (knock-out drums and coolers) and an oil system to lubricate it all, the mechanical engineering team may take up to 2000 hours to develop that model and associated drawings. Once completed, the model is simply imported into Vuforia. If it is simply getting used for design reviews or to be accessed by the sales team, with no service animations or live data tags, then the publishing of that experience will take one hour. It should be noted that if service functions, how to change an oil filter for instance, have to be animated then additional time will be needed to complete these relative to how complex the task is but contrast that to the year spent developing the model and the importance of already having the model created for the AR experience is evident, which is why it is easy for an organisation like Howden with all their in-house CAD experience. To try and develop an AR experience from scratch and not have a model available makes the process time consuming and costly.

When importing the CAD file, it is sometimes prudent to complete some shrink wrapping of the model. An example of this would be if a screw compressor is getting used and the client just wants some live data tags of their process surrounding the machine, with no service animations. There is no point using a model of the screw compressor that has all the internal components such as rotors, seals, slide valves all detailed to perfection. All that is going to do is slow the download of the experience for no obvious benefit. So in an experience like that a shelled out screw compressor would be used, one that has no internals modelled, to allow the experience to download almost instantaneously.

In Howden's case, once the AR experience has been published, it sits within a virtual server maintained by the global IT team. To access the experience, during the publishing process the experience is given its own QR code, sometimes referred to as a ThingMark by PTC. By downloading the free Vuforia View app on an Apple or Android smartphone, the end user opens the app, scans the ThingMark, and the app contacts the server, downloads the model depicted by a green flash circling around the ThingMark, and then displays the experience. The experience can either be tied to the ThingMark, meaning it stays in a location relative to the ThingMark or it can be downloaded and placed where the user wants to interact with it. So when displaying live data on top of a compressor the data is tied to the ThingMark. The value stays in the correct location but when carrying out the design review of a package the user may want to place it on the middle of a conference table so that experience would then be free to be placed where the user or users can interact with it.

Figure 5: ThingMark for a WRV510 Screw Compressor

The full spectrum of the manufacturing process

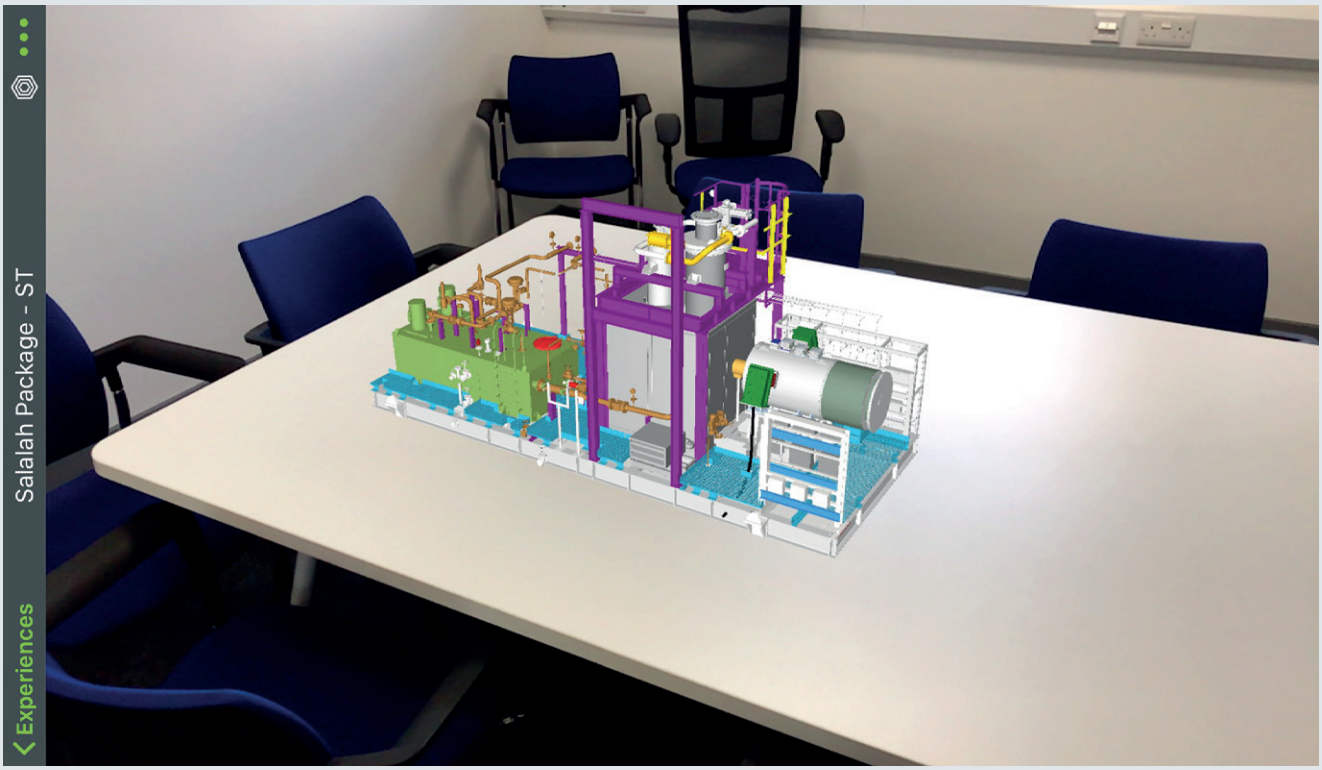

Figure 6: An example of a screw compressor package placed on a desk, allowing walk arounds.

The AR experience for the sales teams demonstrations are packages that have been built previously and published as an experience so the potential buyer can understand the size, scale and complexity of the packages and the capability of Howden as a compressor packager.

They get a better understanding of these with the AR experience than if they were looking at a brochure or presentation slide. The sales team use the AR experience as a differentiator over their competitors and to show how innovative Howden is as a company.

The next AR experiences available in the screw manufacturing lifecycle are in the bareshaft assembly. Assembly instructions have been given an AR experience to allow new fitters and new apprentices the ability to follow guided work instructions whilst wearing the HoloLens on how to assemble new machines. They see the animation of what component to select, where to place it, and text instructions detailing the same. This drastically reduces the time taken to get new associates building the machines correctly with minimal supervision.

Once assembled the machine moves into the acoustic enclosure to complete a performance test. Historically this meant the end-user, or third-party inspector, coming to witness the test. The client or their representative arrives, inspects the machine, then the test is started and they continue to stand beside the machine for at least the next four hours marking down performance and machine health values every fifteen minutes. As part of an internal safety workshop held in Howden, this process was transformed. The client can still come to the facility and inspect the machine, but as the machine starts the client has the option to move into a test studio where they can watch the test from behind a sound proof window. They are able to view the test studio SCADA system, which has live instantaneous values of the same process and machine health values they would see out at the actual bareshaft machine. Embedded within the SCADA system is a number of IP cameras that the client can control to see what is happening out at the test. Crucially, the Howden test engineer can put the HoloLens on and feed back to the SCADA system what they are looking at. AR experiences have been developed for the test beds to show the live instrument values above their relevant positions. So if the test engineer is looking at the suction pipework, the suction pressure, temperature and flow values all appear above the pipework and the client can see this HoloLens camera feed on the SCADA screens.

Once the machine has been successfully tested it makes its way down to the package, where the fitters have been assembling it. Normally a ‘big red book’ of manufacturing assembly drawings is taken down by the mechanical engineering team when a base frame arrives and the fitters use these drawings to assemble all the sub-components into the package. This is still the case, but they can now get a better understanding of the size, scale and complexity of the package by scanning the ThingMark on the baseframe and revealing the life-size view of the package using a mobile phone.

The full spectrum of the manufacturing process (continued)

At certain points within a package project, design reviews are held. These design reviews can either be internally with Howden employees only or externally with Howden, main contractors and end users all participating.

Normal historical procedure is two weeks prior to the design review the package 3D CAD model is sent to the main contractor in the requested file type. They then import that into their own larger model of the refinery, or topsides, or other process, and everyone then convenes somewhere to look at the model on a large screen. This will also continue, but now a ThingMark can be placed on the table and everyone can scan it with only their phone and go a walk around the package in 3D allowing better consultation, collaboration and explanation. This experience with the phones is a good way of some person having an idea, around the location of a ladder for instance, and then getting the others in the group to see at the same time what they are thinking about. For a more immersive experience, a 1:1 walk through a package could happen using the HoloLens but the collaboration aspect is not quite as good as the others in the group can only watch what you see on a television screen. Hazard and operability studies (HAZOPs) can also benefit from the experiences described above. They are similar to design reviews but focus on the safety of the package taking each line on the piping and instrumentation diagrams in turn and looking for parameters that may cause harm or damage and then putting measures in place to reduce the risk. One of the benefits of the design review experiences are the ability to demonstrate accessibility to locations for maintenance purposes very easily either with only a phone or a HoloLens device.

The last place in the screw compressor lifecycle is the service area. While developing the AR experience for the building of the screw compressors it became necessary to develop the reverse process allowing not only Howden fitters to tear machines down following the correct procedure, but could also give access to these animations to the end user maintenance teams. Animations have also been developed for turbo compressors, for example if a gearbox bearing temperature starts to rise or vibrate excessively, a work instruction telling you to replace the bearing and showing the maintenance team where on the machine it is.

Conclusions and future work

In summary, we created AR experiences to be used in the sales environment, the bare shaft assembly environment, the package assembly environment, the aftersales environment and finally, overarching all of these, in the training environment thus truly spanning the full spectrum of the screw manufacturing process. AR will succeed in the coming years in becoming adopted mainstream by almost all industries including our own.

What will allow a more rapid adoption is the integration of this technology with the CAD, advanced manufacturing and the IIoT technologies that run beside it, and thankfully humans are still required to do the integration, for now. Future work will see the assembly instructions AR experiences tied in with the manufacturing build records where, as an example, the assembly instruction will call for a particular torque setting, the live value from the torque wrench will be displayed on the HoloLens and the process will carry on only after the correct torque has been achieved. This means there will be a set procedure followed and a record of who completed the build and for quality purposes the torque setting of each bolt.

Collaboration with the HoloLens is going to improve as well in the next six to nine months as at the moment the HoloLens wearer can only show others what they see by casting it onto a television. The launch of the HoloLens 2 allows separate HoloLens wearers to scan the same ThingMark and share the same experience so two people can go a walk through a package at the same time and discuss the design. They can even do it remotely and see the others avatar as they share the experience.

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