Applying the benefits of IoT to wind blade manufacturing

Wind blade manufacturers using Industrial IoT software can increase profit over 25% for around a 4% increase in material utilization, research shows

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Executive summary

With continuing rapid growth in energy consumption, and growing awareness of issues surrounding environmental awareness and energy security, comes the challenge of growing renewable energy capacity.
Wind power will be a key sector, and wind turbine OEMs need to prepare to meet future demand, as well as to deal with new competitors. Wind blade manufacturing involves complex kitting and packaging processes due to the need for extremely long nests and multi-layer cutting leading to potential waste of valuable raw materials.
Research has shown that wind blade manufacturers who use IoT-based software can increase their margins by up to 20% for every 1% reduction in material waste.

Definition: Industrial Internet of Things

The Internet of Things is a vision of a fully connected economy where physical objects are constantly communicating with the cloud. In an industrial context, it means that factories and industrial facilities share all their data in real-time, ensuring that managers can constantly track, optimize and improve their operations.

1. Energy: a growing market

The global energy market is growing strongly. By 2040, world-wide energy consumption is expected to have increased by 48% compared with consumption in 2012[1]. Together, the top ten energy consuming countries use the vast majority of generated capacity. The presence of China, India and Brazil in the global top ten is an indicator of future possibilities for energy market growth, if current trends for strong economic growth continue in these countries.

An important trend within the energy market is the move towards renewables that is being driven by increasing awareness around climate change and energy security.

Many militaries, including those of the US and the UK[2], have recognized climate change and energy security as vital national concerns. Renewable energy sources have a key role to play in both, not only by reducing climate impact, but also in providing a secure supply of energy that does not need to be imported. Partly as a result of these concerns, the wind power industry is experiencing rapid growth. Over half of the currently installed global wind power generation capacity of 487 GW has been added in the last five years[3].

In the near future, many more firms will enter the wind market. Companies operating in the wind turbine supply chain need to modernize to ensure they can survive increased competition and meet rapidly growing future demand.

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[1] US Energy Information Agency (2016), International Energy Outlook – 2016, Washington, EIA: 21

[2] Carrington, D. (2016), 'Climate Change Will Stir "Unimaginable" Refugee Crisis, says Military', in The Guardian: https://www.theguardian.com/environment/2016/dec/01/climate-change-trigger-unimaginable-refugee-crisis-senior-military

[3] Campbell, S., 2017, 'Strong growth pushes wind close to 500 GW' in *Wind Power Monthly.* Published 1st March 2017: http://www.windpowermonthly.com/article/1425161/strong-growth-pushes-wind-close-500gw

2. Wind blade manufacturing: a uniquely manual process, ripe for IIoT efficiencies

Compared to most modern manufacturing techniques, wind blade production is traditionally a very manual process. The workforce in a blade factory need strong craft skills, and the ability to read drawings. Most blades are reinforced by layers of fiberglass that are hand-laid, hand-smoothed, and hand-sewn together. Molds are covered with a plastic shell and air is sucked out to make a vacuum. Resin is then pumped in, which spreads due to the vacuum, fusing with the fiberglass to create a strong structure. This is then hand-sprayed with primer and paints.
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2.1 How IIoT can deliver material savings

The main material used in most wind blades is fiberglass. As far as composites go, fiberglass has been around for a long time. Nevertheless, it remains a key ingredient for many cutting-edge products, and modern manufacturing techniques applied to fiberglass can revolutionize the potential (and the margins) of factories that use large quantities of it.

The cutting and packaging process used for wind blade manufacturing is complex due to demands made by blade assemblers. Current processes encourage the waste of large amounts of fiberglass. The primary way that wind blade manufacturers can use IoT to save money is by implementing solutions that reduce fiberglass wastage.

3. Cutting and packaging are the key constraints in the wind blade manufacturing process

The sector is challenged by its use of very long nests and parts, which makes for cumbersome, labor intensive, kitting and packaging processes. The labor cost of the material kitting process is significant, often amounting to 10% of the total labor cost of the factory.

Some manufacturers make the material and the blade, but many make just the material and ship it elsewhere for blade assembly. In either case, at the end of the material manufacturing process, the material must be cut and shipped (even if assembly is happening on the same site).

Restrictions are driven by the packaging. The material is in such long pieces that it cannot just be cut and put in a bag – it usually must be rolled on a piece of board. Factory operators keep these pieces of board under the cutting tables. After material is cut, operators pick a piece of board and roll it.

Rolls are packaged on top of one another and the way they are packaged is specified by the blade manufacturer and is dictated by the way the blade manufacturer has to lay them out.

Usually, the piece that must be laid out first is put at the top of the package, and the last piece is laid at the bottom (Figure 1). In effect, this means that the nest restrictions are driven by the packaging restrictions – a situation that is fairly unique to wind blade manufacturing.
A detailed packaging plan is drawn up in advance for operatives to follow (Figure 2).

Figure 1: Rolls are packaged on top of one another, with the piece that must be laid out first on top, and the last pieces on the bottom.

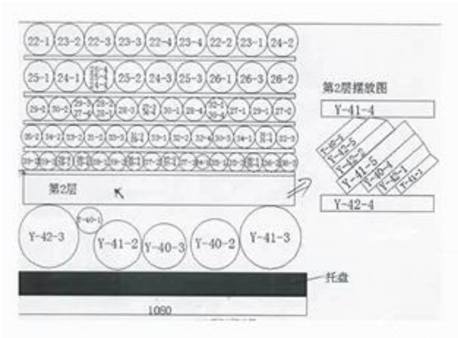

Figure 2: The packaging plan shows factory operators exactly how to pack the wind blade material

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4. Material yields are the key areas for improvements

AI (Artificial Intelligence) software creates ready-to-cut production plans. Wind blade manufacturers that adopt IIoT technologies can achieve very large increases in their margins. The fastest returns on IoT investment in the wind blade business can be attained by using the technology to increase material yields. **In wind blade manufacturing, a material saving of 1% on has been shown to increase margins by about 20%.** In a wind blade, the cost of raw material represents roughly 60% of the total blade cost. IIoT-based software can reduce material wastage by using artificial intelligence software to automate and optimize the production processes.

4.1. Improving wind blade nesting with sections and filler parts

When nesting raw material that will be used to make wind blades, software gives each piece a unique identifier composed of three elements:

1. The part number, which indicates the type of blade that the piece belongs to
2. The index number, which signifies what layer within the blade it belongs to
3. The sequence numbers

Many of the indexes have to be plastered together. Additionally, the nest contains filler parts, which are small parts that are cut and can be used by the blade manufacturer to cover damages (see Figure 3).

In order to save material, the IIoT-based software ideally wants to mix together as many layers as possible. Mixing as many layers together as possible would deliver the greatest material gains, but in practice this is rarely done because of packaging restrictions set by blade assemblers. Traditionally, mixing all layers would necessitate major redesign of the operational and logistical processes of most blade manufacturers, in order to allow the material to be packaged correctly for assembly.

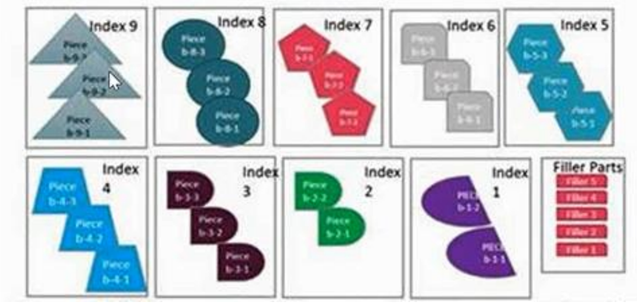

Figure 3: Simple wind blade nesting divided into indexes (layers). Filler parts are visible at bottom right.

The AI abilities assimilated in the software are programmed to understand the ever-changing trade-offs between saving material and saving labor. Parameters provided by the manufacturer are fed into the software, and the nest is designed accordingly.

For example, a manufacturer may want to mix every three layers together into sections (see Figure 4), and he would specify how much of an overlap there can be between the different sections. In this scenario, the customer, who has to assemble the wind blade, has decided on three indexes because it represents the maximum disruption his current packaging procedures can cope with without having to be radically redesigned. A section is a few layers that can be mixed together with some overlap between the groups of layers. Meanwhile, the algorithm calculates the most efficient way to spread the small filler parts across the different sections in the nest.

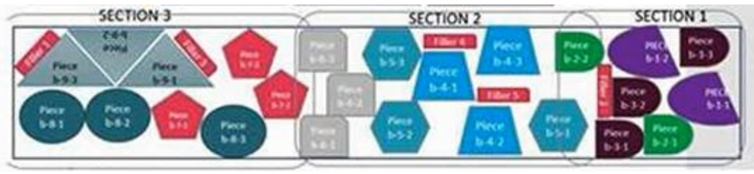

Figure 4: In this image, every three indexes from Figure 3 above have been mixed together to comprise three sections. The filler parts are spread out across all three sections.

A strong configuration tool can control the nesting rolls with great precision. It can nest according to each specific material constraints, or in order to increase material yield.
Different orders can be mixed, and different jobs. Additionally, the software can standardize the nest length to achieve further efficiencies.

4.2. Case Study: material savings of 4% increase profit by 28%

Consider the real-life example below from a wind blade manufacturer that implemented an IIoT-based solution (Figure 5).

	Traditional Processes (in millions)	**With best-in-class AI IIoT-based software (in millions)**
Revenue	**$755**	**$755**
Cost of all material	**$500**	$488
- Cost of fiberglass	$300	$288 (4% of material savings)
Profit	$43	$55

Figure 5: These figures represent revenues, costs, profits and margins both before and after the manufacturer installed IIoT-based software for manufacturing optimization.

The ‘cost of material’ row is $500M. This represents 66% of the total blade cost of $755. Cost of fiberglass is 300M and on right hand of this row, artificially intelligent IoT software has delivered a 4% material saving by using improved nesting, improving the profit by 28% to 55M.

The improved sectional nesting is designed around existing labor constraints, and does not require the manufacturer to make changes to operational or logistical processes. Labor costs are therefore unchanged, and no new or extra machinery capacity is required.
So, profit increased by 28% shows that material saving of few percent puts the factory and the firm in a completely different financial position, with significantly improved margins. Depending on the firm, the numbers may vary to some degree. But the overall trend is clear: every 1% saved on material brings a huge impact on margins for blade manufacturers. Wind blade manufacturers need to be far more aware of how important this can be for their businesses.

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5. Future paths: embracing the potential of IIoT-based technology

There are two clear future paths in wind blade manufacturing. The first is the opportunity to move to more radical methods of wind blade nesting that can save considerably more material. The second is the switch to using carbon fiber instead of fiberglass that will be necessitated by the demand for ever larger wind blades. Both of these trends cause challenges that can be addressed with the application of IoT-based technology.

5.1. Embracing the full potential of material utilization

Though most blade manufacturers prefer to limit the extent of nest mixing so as to minimize the impact on logistics, the huge impact on margins caused by small savings in raw materials, implies they should alter this mindset.

When IoT-based software is given freedom to mix layers, the material yields achieved are much larger. In Figure 6, the manufacturer was making every three layers into a section. Yet this restriction was set by the blade manufacturer. The software could have mixed all 9 layers into a single section to achieve much larger material savings.

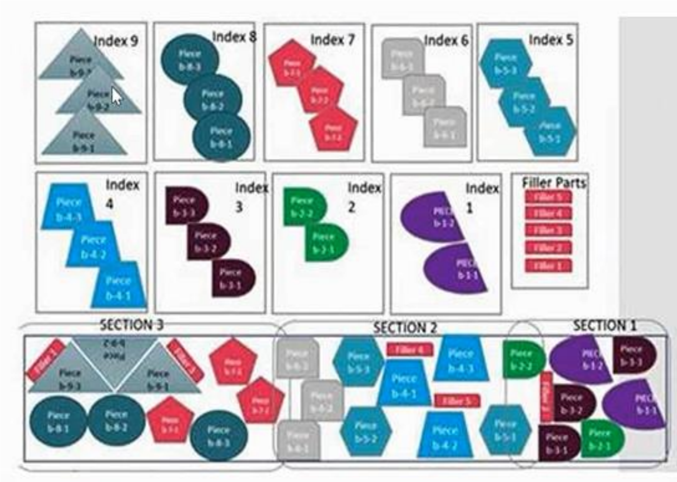

Figure 6: In the image above, every three indexes were combined into a section, to make a cutting plan comprised of three sections. But IoT software could have gone further by making all nine indexes into a single section.

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In the face of such large potential margin increases, higher labor costs for dealing with the extra logistics, are insignificant. It is the best way for wind blade manufacturers to prepare their businesses to cope with the challenges of the future.

5.2 The switch to Carbon Fiber

The most obvious trend in the wind industry is steadily increasing blade size. There is a move towards bigger blades because longer blades give greater force and rotational power. Some of the largest wind blades in existence are over 80 meters long. Such long blades can no longer be made from fiberglass. Instead, they need lighter, stronger materials. The biggest blades use significant amounts of carbon fiber in their construction. In the near future, this trend will increase.

Yet carbon fiber is far more expensive than fiberglass, and so material savings will become an even more important means of cost cutting. Additionally, the use of carbon fiber in the production process will introduce a new level of complexity as the material is time and temperature sensitive, it has a shelf-life and needs to be stored in freezers.

Wind blade manufacturers dealing with carbon fiber will find there is an innovative suite of IIoT-based solutions on offer, set up specifically to deal with the challenges of managing carbon fiber on the production floor.

This innovative solution allows manufacturers to trace and track everything that moves on the production floor in real-time. It collects data from sensors affixed to assets on the production floor – such as raw material, pre-preg rolls, kits, tools and layup molds - and tracks their whereabouts to ensure operators and managers alike always know the exact location and context of each asset as it moves along the production process. While doing so, the constant updated real-time flow of information constitutes a ‘digital thread’ that is recorded throughout the entire lifecycle of the product, from raw material to finished part. The digital thread is used for generation of immediate reports and for future reference should any problem occur or be discovered.

Such technology today is already in use by leading OEM aircraft manufacturers, and as wind turbine manufacturers move across to carbon fiber they follow and adopt it in order to remain competitive.