A MULTI-FUNCTIONAL DEVICE APPLYING FOR THE SAFE MAINTENANCE AT HIGH-ALTITUDE ON WIND TURBINES

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ABSTRACT

The development of wind energy has been continuously promoted in Germany and is increasing since renewable energies law (EEG) took place in 2000. This trend combined with the aging of wind turbines blades (WTB) requires periodical and effective maintenance throughout the year. The biggest challenge of maintenance companies is to reach repair heights of up to 200 meters during difficult weather conditions. This motivated University of Applied Sciences Aachen to come up with a device (patent registration DE 102012001725 A1), which is able to offer a widespread response to the industry needs regarding this matter.

The roll of Universities to reduce the risk for industry or start-up companies by the help of government funding for new technology developments is very essential. Nevertheless, it is important to work as closely as possible with maintenance suppliers, as University of Applied Sciences Aachen attempts, to answer one of the most important questions: How effective, how fast and at what cost, is sufficient to respond to the increasing pressure and demand of service.

In the first instance this complete solution, by applying so called SMART platform (Scanning, Monitoring, Analyses, Repair and Transportation), contributes to effectiveness. Seasonal periods can be increased from today approximately six to eight months, seven hours a day, to up to full year service, twenty-four hours a day – being weather independent. Furthermore it goes far beyond the effectivity only. The safety of staff in each weather condition and working to ideal conditions to ensure best quality is as important to the success of this solution. The cabinet isolates the staff, as well as scanning and repair devices from disturbing influences due weather conditions and a fixed attachment to the tower takes care of wind forces, to eliminate shaking. This hermetically isolated and tempered workspace enables the crew to make best use of suited tooling and procedures, which enhances service quality.

Finally, SMART aims to operate autonomous, guided by 3D sensors and virtual reality. The tools will be handled by a tele operative industrial robot and optional staff can operate from the ground. To make this possible automatic scanning and repair procedures need to be down-scaled and further developed for mobile applications.

1 INTRODUCTION

The idea developing SMART (Scanning, Monitoring, Analyse, Repair and Transportation), is to bring all the existing mobile-, as well as stationary-, maintenance solutions together and compromise them to a single mobile platform, which can offer a complete response to the increasing demand of maintenance of WTB and wind turbine towers WTT. SMART attempts to provide a whole new level of service capability in high altitude without being forced to dismount and exchange the rotor blade.

One of the challenges to handle is the climbing of very thin steel structures such as wind turbine towers without an attached rope – frictionally engaged climbing is a potential solution. A friction based climbing process is able to compensate high wind forces from all directions of impact and allows transporting a significant payload.

Once, a robust service platform for wind turbines exists, implementation of advanced measurement and repair technologies will follow. Still, mobile applications have special requirements, like light weight construction, robustness, energy efficiency and environmental sustainability. One the one hand, stationary repair processes for WTB, like composite material repair by scarfing, need to be scaled down. On the other hand, measurement technologies to visualize internal body structures, like ultrasonic-, or thermography-techniques, need further development to become more efficient and robust.

SMART intends to combine a selection of measurement devices, to detect critical failure, like cracks and delamination, with corresponding repair tools and to automate the whole workflow as far as possible. Operation staff shall be enabled operate from safe ground, ensuring no dangerous risks are taken, and the service quality will be enhanced.

2 STATE OF THE ART

Today, the inspection of WTB is accomplished by visual inspection. This happens either through height workers, conventional climbing frames (see figure 1), or photography from the ground and unmanned aerial vehicles (UAV), without being able to detect cracks and defects inside of the body structure, e. g. blades, or towers. Minor surface repairs are carried out by height workers, as well as, by crews of conventional climbing frames.

Figure 1: Conventional climbing frame for WTB [2]

This happens only seasonally and requires adequate weather conditions, which in long run will not cover the future quality and effectiveness requirements. It is highly uncertain, as the quality standards evolve, whether repairs by height workers will be accepted by the insurances companies and wind farm operators in case of future damage.

Periodically it comes to damages on WTB, which cannot be repaired within an economically justifiable framework and leads to the exchange of WTB. The replacement of one single blade needs a lot of preparation, heavy cost and longer downtime of the wind turbine. In some cases the cost of cranes, transport and logistics rises enormously, e. g., depending on wind turbine size, up to 200.000 €, apart from environmental burden due to road preparations. The number of installed rotor blades on wind turbines in Germany is about 100.000 and continuously increasing.

3 REQUIREMENTS FOR A SERVICE PLATFORM

3.1 Weather conditions in heights up to 200 m over ground

The weather conditions throughout the year in the height of WTB rise many challenges for the service crew of wind turbines. To perform suitable, efficient service and maintenance, weather independency is of major importance. The crew often arrives at wind parks and has to wait for many days until suitable weather conditions occur. The wind speed should be below 8-10 m/s, it must be dry and a temperature above 10 °C is required. In addition, most countries forbid operation during night. Those conditions need to be stable and predictable for at least 1 hour, because the climbing process up and down to the height of action must be considered.

In conclusion SMART-platform needs to absorb as much wind forces as possible, including those that affect the turbine blade and cause vibrations, if possible. The climbing process should be fast and secure. The workspace must be tempered and illuminated. And finally, the working area, e. g. the surface of the blade, should be isolated from all weather conditions as well.

3.2 Stability of wind turbine towers

The research and development of SMART-platform required distinct analyses of the structure of wind turbine towers in general. To establish a friction based climbing device the stability of thin pipes, made from structural steel, has to be understood. In contrast, reinforced concrete tower parts can absorb these forces easily [1].

A high static force needs to be initiated, which compresses the tower horizontally in a circular pattern. To ensure a secure climbing process, even on an icy surface, this force needs to be up to 10 times the total load of the platform. This load needs to be combined with a vast quantity of different stresses and strains, like wind-forces, self-weight of the turbine, rotor, blades and tower segments and dynamic forces, as well. Advanced FEM-Analyses - carried out with ANSYS and InfoGraph, including second-order tensions, non-linear buckling and material imperfections - enabled the development of a mechanism that evenly distributes the load to avoid local deformation. The final result, based on simulations, stresses the structure far behind the limit.

3.3 Transport and installation of heavy machinery

State of the art service platforms, like conventional climbing frames, already fill up conventional trailers and hit the limits of standard transportations. One further prospect of such a multifunctional service platform must be, to consist of modular, small, light-weight and easy to manage components. Those shall be transported in a standard ISO-container and be installed without need for cranes or frameworks. A modular concept could also be employed to cover the huge variety of turbine towers, especially regarding the energy productions. The tower size and the individual load limit scale together with the wind turbine power. A multifunctional container can be easily prepared and shipped over sea without extensive packaging of each component.

3.4 Service situation for wind turbine blades

State of the art surface repairs encounter mostly aerodynamic deficiency, while the more important internal structural damages are consciously neglected. In most cases surface defects allow water to enter the internal structure of the blade and the extreme temperature variations in those heights, during day and night, between minus 20 °C and up to plus 45 °C, can cause significant corrosion – often referred to as delamination. This can affect the stability of the structure after a short amount of time. Wind turbine producers, as well as, operator companies face a difficult situation. Hence, there is no cost-efficient solution, to determine the status of the internal structure of the tower, or the blades, available.

A complete chain of inspection, consisting of scanning, monitoring and analysing, is becoming more essential the more the energy production capability of wind turbines increases. The reason is big cash loss, even if only one blade has to be dismounted for repair, or exchange. University of Applied Sciences Aachen and project partners are about to develop a multifunctional scanning device by combining different scanning technologies to a multimodal measurement system for mobile applications. This newly developed device can provide trend monitoring for wind turbine blades, based on digital fingerprints, to visualize the status of the surface and internal structure. The digital record can accompany a WTB the full life cycle and will be updated with each new scan. Issues, which got eliminated by SMART-platform or other service providers, will be tracked and traced back. This will allow further improvements of the production of WTBs as well.

Most of today WTB consist mainly of uni-, or biaxial glass fiber reinforced plastic (GFRP) – an application for composite materials that faces a very unique set of challenges. The reproducibility of large scale composite structures is an unsolved problem. Thus, each blade is different and shape deviations have a decisive role regarding structural strength and stability.

4 THE CONCEPT OF SMART-PLATFORM FOR WINDENERGY MAINTANANCE

The development of SMART is divided into a sequence of different phases to minimize risks. Phase 1 characterizes the realization of a demonstrator scaled 1:3, to proof and explore the capability of climbing on the surface of wind turbine towers. A further aspect is transportation of a certain payload up and down. Alongside, feasibility studies regarding high wind forces during operation and cold weather conditions will be carried out. The demonstrator is studied carefully and to compare physical effects with results of advanced kinematic and dynamic simulations, based on ADAMS, to predict the behaviour of a full scale prototype. A digital mock-up is a key enabler to transfer this new technology from laboratory to an industrial environment. Timing period will be from September 2014 up to March 2016.

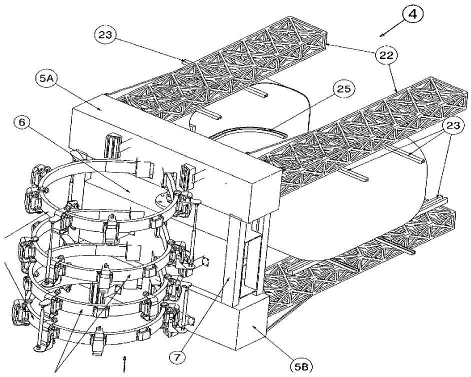

Figure 2: Development progress on SMART platform

Phase 2 starts with the successful end of phase 1 and aims to develop a 1:1 prototype for the application on wind turbine towers up to 2.5 MW. Timing period will be from March 2016 up to March 2018.

Phase 3 includes the development of a multimodal scanning, monitoring and analysing device for composite materials regarding mobile applications. Timing period will be from March 2016 up to March 2018, in parallel to phase 2.

Phase 4 will be detailed feasibility-studies to investigate optional transportation of high payloads, even complete wind turbine blades with a special handling device. Developing a transport system to be able to exchange blades, which can be adapted to SMART, is desirable, because such system can eliminate crane application and heavy costs. Timing period will be from about June 2018 up to June 2020.

5 NON-DESTRUCTIVE TESTING METHODS (NDTM)

A single NDTM is unable to detect all the different failures, which occur on rotor blades, from small cracks to wide-area delamination. All NDTM methods provide a characteristic area resolution, scanning depth and analyse speed. Thus, in principle the combination of different methods is the solution for sufficient overall damage detection. Challenges to apply current scan technologies in mobile applications for WTB are: 1) heavy weight, energy consumption, susceptibility and big volume, 2) their effectivity, in terms of scanned area per time period.

There are many stationary NDTM used today for damage detection on WTB, mostly in factories or labs on the ground. Ultrasonic testing, conventional tapping technique, active thermography, X-ray imaging, computed tomography and CT-2D-laminography, microwave- and terahertz-technology for example.

To be able, to apply a sufficient combination of those technologies, will inter alia require a validation procedure regarding the usability of each technology for WTB, or composite materials in general. The final idea is to develop a multimodal scanning device to be able to provide a whole report of defects in the structure of WTB. The results will be visualized in a 3D image. Potential issues shall be detected by different systems to enhance the probability of recognition and to provide full information regarding the volume, size and geometric location. These are based on defined defect classes and appropriate choices of parameters for each testing method.

6 MOBILE REPAIRING SOLUTIONS AND AUTONOMOUS OPERATION

The detection System explained in section 5 will provide the location and the size of detected damages. An optional operator can validate the defect and approve reparation. Furthermore, machine learning based on data mining could be enabled for advanced analysis, to classify defects, instead. This will allow non-experts to gather all important information for a profound diagnostic. Subsequently CAM methods, based on 3D surface- and the internal-structure-scans, will be implemented to operate the repair tools. There are few repair technologies on the market, e.g. milling devices for scarfing, so called PM3 developed by PRIMACON, as well as, laser material processing (LMP) developed by SLCR in Germany. These technologies are waiting to be implemented immediately as soon as SMART-platform is established. These technologies are already applied on the ground.

Still, of major importance is high precession and stability of the machine base. SMART-platform will provide stable basis, but not all vibrations can be suppressed. A potential solution is to use light weight, high dynamic, industrial robots, like a delta-kinematic to compensate movements with an active damping algorithm.

Once this task is fulfilled SMART will perform all processes from area preparation, like scarfing or lamination, up to the finishing. A light-weight tool changing system can obtain all the requirements for such a flexible system.

7 CONCLUSIONS

Today, no effective tooling exists, which is light weight, robust and small in size to be used on mounted WTBs to scan and repair all surface-based and internal failures. Not only the tooling, but also the autonomous operation will be a future requirement. These essential needs of components answers the upcoming maintenance needs. Innovative tools are demanded from research and development, which overcome all existing challenges, like mobile applications in those heights including the precessions and flexibility required.

The idea is to provide the demanded working conditions within a multifunctional platform, called SMART. This cabinet shall provide all the capability, precessions and possibilities needed to apply autonomous scanning as well as repair technologies – being independent of weather conditions. Most of the scanning and repair technologies used on the ground, within the factories, are heavy, voluminous and cannot be used in mobile applications.

By utilizing point cloud liberty (PCL) perception of failures within the structure, localization and visualisation in reliable quality is possible. Using these detection data will lead the autonomous repair. The development of this process can enable trend monitoring for wind turbine blades, based on digital fingerprints, to visualize the status of the surface and internal structure.

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