Characterisation of a Whirling Arm Erosion Test Rig

C Mackie[1a], D Boyce, D Nash[1]

[1]University of Strathclyde, James Weir Building, 75 Montrose Street, Glasgow, Scotland, G1 1XJ

[a]cameron.mackie@strath.ac.uk

Abstract

Leading edge erosion of wind turbine blades is a problem costing millions of pounds. To investigate the issue Whirling Arm Erosion Test Rigs are used to artificially simulate rain drops striking a high speed sample. The Energy Technology Centre have constructed a test rig but need to characterise it first to provide efficient and reliable results. Using a high speed camera, ETC examined the strike rate, strike location and droplet diameter. Analysing the footage determines that speeds of 1100 and 1200rpm provide the greatest number of strikes and strikes in the centre of the sample.

Introduction

The wind turbine industry has rapidly increased its installed capacity in recent years due to a wave of social, political and economic pressure. This increase has been facilitated by the construction of larger wind turbines and a greater number of turbines being located offshore. This is causing leading edge erosion (LEE) to become more prevalent, due to the larger tip speeds and more extreme weather conditions offshore. LEE can cause a decrease in annual energy production of up to 2% which costs OEM millions of pounds [1]. After 5-10 years the erosion can become so severe that it becomes a safety risk, which leads to downtime of the wind turbine. The cost of turbine downtime combined with the potential replacement or repair required puts significant financial strain on OEMs.

Whirling Arm Erosion Test Rigs (WARERs) are being used to investigate the phenomena of erosion. WARERs artificially simulate erosion by spinning a test sample at very high speeds with needles dropping water onto the test sample. The exact design of WARERs vary depending on the purpose, with the majority being used commercially Commercial test rigs typically have a large number of needles and a rotating arm capable of spinning at very high speeds (>1200rpm), this decreases the time to cause erosion but is less precise because of this. The Energy Technology Centre (ETC) have constructed their own test rig, with an aim to increasing their understanding of the processes involved.

ETC have been increasing the complexity of their test rig for the last few years, initially starting with only 4 needles. Work has also been carried out to investigate the effects of using two rotating arms. Although this was disregarded due to the large aerodynamic wake present. The addition of a shroud around the needles was also explored, looking into droplet formation with an aerodynamic wake present. This previous work was carried out using a high speed camera to capture footage of the droplets under different setups. As a result of the previous work the setup, as shown in Figure 1, has been settled on as the current best practice. A high speed camera will be used to investigate the strike rate, strike location and droplet diameter associated with this setup to establish the preferable operating conditions.

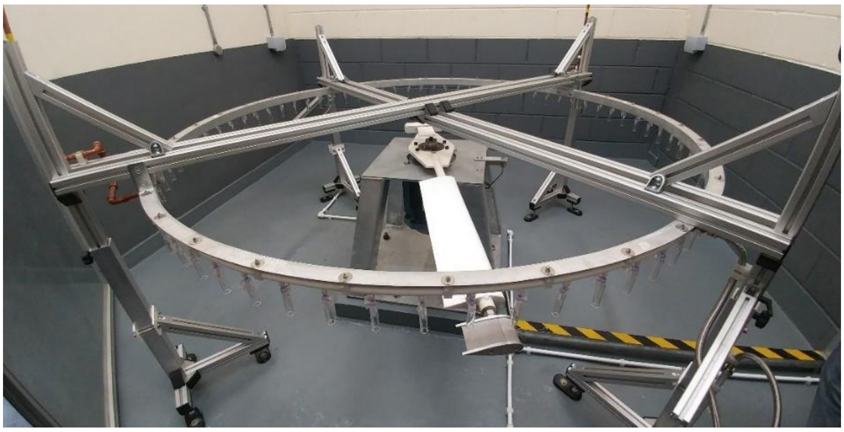

Figure 1- Setup of ETC's Erosion Test Rig

Methodology

The characterisation of the WARER was conducted using a Photron FASTCAM SA-X2 high speed camera. The camera was initially recording at 2000 frames per second and was filming a radial view to determine the strike rate of the droplets at varying rotational speeds and droplet flow rates. Next the frame rate was increased to 40,000 frames per second to investigate the strike location of the droplets. The camera was positioned in a radial and tangential view to determine if the droplets strike the leading edge and the centre of the sample. Finally a Nikon DSLR was used to capture images of the droplets at varying speeds and flowrates to determine the droplet diameter and the variance present. For all tests the rotational speed increased by 100rpm for 700rpm to 1400rpm though a speed of 1000rpm was avoided as resonance incurred at this speed.

Results

The results for the strike rate are shown below in Figure 2. The highest strike rate occurred at 1300rpm, however fewer droplets were formed at this speed meaning the greatest total number of strikes occurred at 1100rpm. The number of droplets/strikes were measured over 25.47s.

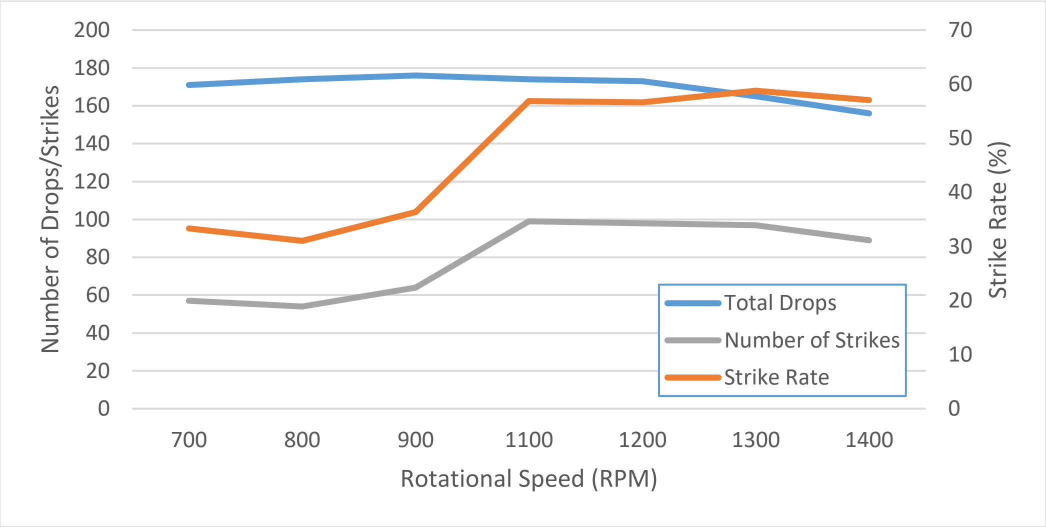

Figure 2 - Number of Strikes and Strike Rate

The location of the impacts showed that a rotational speed of 1100rpm resulted in the most impacts in the centre of the sample for the radial view and a speed of 1200rpm obtained the most central strikes when examining the results from a tangential view.

The results for the droplet diameter show that the droplet diameter decreases at higher droplet flow rates (this was measured without the arm rotating). The droplet diameters were also measured with the arm rotating at different speeds. Again the diameter decreased at higher flow rates however the added aerodynamic wake added a large variance.

Conclusion

From analysing the results it was determined that rotational speeds of 1100 and 1200 RPM provide the highest efficiency and smallest variance in strike location. The higher rotational speeds produce fewer droplets due to aerodynamic wake causing droplet breakup, however, the higher rotational speeds have a higher strike rate due to an increased number of passes during the same time. This leads to the middling values provide a nice balance. Further work could be carried to investigate the middling values at smaller intervals and also provide a larger sample size of results as it is currently unclear whether the variance is solely caused by the test rig or is effected by the small sample size.

References

[1] ORE Catapult. (2018). *Catapult delivers first blade leading edge erosion measurement campaign - ORE Catapult*. [online] Available at: https://ore.catapult.org.uk/press-releases/catapult-delivers-first-blade-leading-edge-erosion-measurement-campaign/ [Accessed 15 Mar. 2018].