Junior Research Associate Scheme 2022 - Student Application Form

JRA projects can take place on campus or online as long as you follow the government and University Covid guidance in place at the time. Due to the pandemic, it is possible that projects will have to be undertaken remotely if the situation changes before summer. Please ensure you include in your application how you would adapt to online research and supervision, should that be required.

Before completing this form, please ensure you have read and understood the Conditions of Award and Further Information for the Junior Research Associate Scheme 2022 (JRA), and have read the applicant guidance on the website carefully.

When completed, this form should be sent to undergraduate-research@sussex.ac.uk along with the following documents:

1. **Academic CV** - this should focus on your academic experience and be no more than two sides of A4. It must include all modules and grades.
2. **Academic Reference**
3. **Proposed Research Supervisor Statement**

Both the Academic Reference form and the Proposed Research Supervisor Statement form can be downloaded from the JRA Application Pack webpage. If your referee or supervisor does not want to disclose their statement to you, they can be sent separately to undergraduate-research@sussex.ac.uk.

The submission deadline is **12:00 noon on Monday 28th March 2022**. Incomplete and/or late applications will not be accepted.

If you need further information or have any queries please email undergraduate-research@sussex.ac.uk.

1. About you

Are you a First Generation Scholar? (delete as appropriate) *NOTE: This is not a selection criterion*		Yes	
Name:		**Student registration number:**	
Year of study:	2	**School of study:**	Engineering and Informatics
Department/Subject Area:	Mechanical Engineering with Robotics		
Email:		**Telephone:**	
Address:			

2. About your research

Name of your proposed supervisor:		**Name of your Mentor, if you have one:** *Your mentor is usually a PhD student or Postdoc who offers additional support. If not known now, their details can be added later.*	
School of your proposed supervisor:	Engineering and Informatics		
Full title of your research:	Experimental Investigation into using Targeted Surface Microjets to Control Flow Separation over Compressor Blades		
Research Summary: *Must be short and non-technical; max 150 words*	The research will be to investigate the effectiveness of using active flow control methods, to control flow separation in a compressor blade like pressure gradient. Flow separation is a massive problem in compressor sections of turbomachinery as it causes large losses in efficiency of the whole machine. This contributes to increased fuel consumption and emissions. Hence, assuming this research proves successful in controlling separation, it will aid in reducing the environmental impact of gas turbines and hence the aviation sector.		

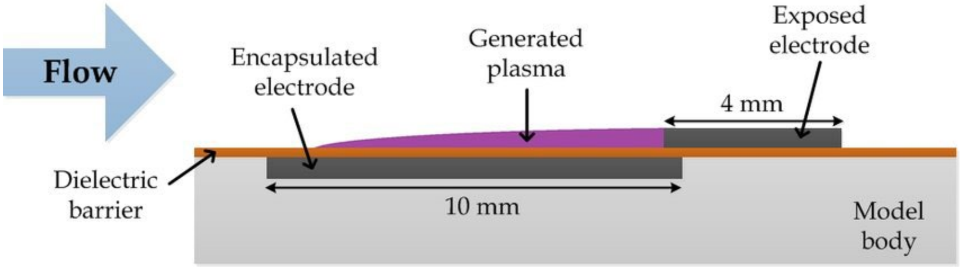
	Preliminary research analysis shows a distinct lack of experimental investigations into this, but in related simulations, it appears to be promising. If results are successful, future studies can explore and compare different active flow control methods for this purpose in more detail, and then go on to conduct the tests on an actual compressor blade airfoils under different loading conditions as a potential PhD.
Online delivery: Outline how the JRA research and supervision will be undertaken virtually, either as the expected mode or the fall-back if Covid rules change and online research and supervision is required. Max. 100 words	While it is naturally a hands-on project, if covid restrictions prevent this I will use this time to build an extensive background about work done by other researchers in this area and use the knowledge from this literature survey to setup a typical case study based on published data and perform numerical evaluation of it. Supervision and progress checks can then occur by regular Zoom/Teams meetings.
Motivation: *What is your motivation for undertaking a JRA research project? How will it benefit you / your future plans? Max. 200 words*	I have always been really fascinated by research, reading papers and journals in a multitude of fields. I just love learning about new discoveries and how we are advancing our knowledge. I'm currently trying to decide what to do after my degree, whether to go into industry or pursue a research career, by undertaking an MSc and PhD, I really want to be working at the cutting edge of engineering, exploring new ideas and furthering the field. This JRA scheme will give me the perfect opportunity to really explore what research is like and whether it is suited for me, in a topic which I have specifically given a lot of consideration and really enjoy. Additionally, most year 3 engineering projects are more industry based intended to improve employability but not necessarily research focused, so I won't get the necessary experience from that. I strongly believe I have the ability to go into research; I'm very independent but also collaborate well with others, and I excel academically, receiving the top year 1 student award in my department. Even if I undertake the JRA and decide research isn't the path for me, it will give me many useful skills and opportunities for networking. Hence the JRA is an amazing opportunity for me and my career, I would be so grateful for the opportunity.
Full Research Proposal/Statement: *Max. 1,500 words*	**Experimental Investigation into using Targeted Surface Microjets for Flow Separation Control over Compressor Blades** **Introduction** Flow separation is a major problem for many aerodynamic applications, it results from an adverse pressure gradient opposing the flow. As flow in the boundary layer close to the surface has low momentum, particularly in the laminar regime, it is vulnerable to being reversed in direction causing it to separate from the airfoil. This causes large losses in efficiency, reducing the lift and causing a low-pressure region behind the airfoil [1], subjecting it to axial drag forces. Due to the nature of how turbomachinery operates, many parts are susceptible to flow separation. In particular, the compressor stages are subject to large adverse pressure gradients due to flow being progressively compressed. In addition, when at high altitude the Reynolds number is low and hence flow disturbances are damped by viscosity, so laminar boundary

	layers dominate which are more likely to separate. Flow separation from these compressor blade surfaces has detrimental effects on engine performance, potentially leading to stall. This causes a massive reduction in lift of the compressor blade and hence the pressure increase from the compressor section is reduced, in turn lowering engine efficiency. The difference in pressure between the two surfaces of the compressor blade due to separation also causes axial drag forces, which will increase the power wasted in turning the compressor and increase the forces experienced by the blades. This will lead to earlier failure, increased fuel consumption and more environmental impact. By controlling flow separation over the airfoil, we can delay it to reduce some of the negative impacts of separation as previously mentioned. This is done by controlling flow transition. A turbulent boundary layer is much better at mixing flow and hence higher velocity air is transferred down close to the surface, thus increasing momentum. This higher momentum flow will be less affected by adverse pressure gradients and hence be less susceptible to separation. However, turbulent boundary layers incur increased frictional losses. Therefore, one should aim to suppress separation and delay transition at the same time to achieve improved results. There are multiple ways to control the state of the boundary layer, both passive (such as vortex generators) and active methods. Active flow control uses an external source of energy and a controller [2] to alter flow characteristics, it is ideal compared to passive, as when they are not in use, they produce little to no parasitic drag. Active methods can then be split into further subcategories based on their functioning: Plasma, synthetic jet, active vortex generators etc. [1]. Each has its own advantages and disadvantages regarding power requirements and effectiveness. I would like to continue some of the work which Dr XXXXXX undertaking this year which will look at using targeted surface micro jets to modify and control flow separation on compressor blade surfaces, and some ways this can be implemented. **Problem statement** It is well-known that with current battery technology, electric aircrafts are unfeasible in most situations [3] due to the increase in weight and decrease in cabin space from the battery requirements. Hence in order to meet sustainability targets and reduce the impact on the environment, the efficiency of current turbofan engines and aircraft external aerodynamics must be improved. Over recent decades there has been many advances in altering flow characteristics in gas turbines for optimum performance and efficiency, some passive and some active. However, there is a distinct lack of research into active methods applied to the compressor stages specifically for separation control, especially using experimental methods. Considering the effect that the compressor stage has on overall engine performance; "Improved compressor efficiency has a two-fold effect on overall engine efficiency" [4], it is clear that optimising the compressor stage is a key component in improving performance and reducing environmental impact through lowering fuel consumption and increasing part life. With active flow control showing promising results in simulated studies and other applications [5] it is necessary to experimentally verify its effectiveness and to test its feasibility in a part so important to overall efficiency.

Objectives

The goal of this research will be to investigate the effectiveness of using active flow control methods, such as dielectric barrier discharge (DBD) plasma jets, to control flow separation over a compressor blade like pressure gradient on a flat plate. If results are promising, future studies can explore and compare different active flow control methods for this purpose, and then go on to conduct tests on realistic compressor airfoils under different loading conditions at more advanced facilities.
Dielectric barrier discharge actuators use AC electricity to supply the flow with momentum, this can either be steady or unsteady. They function by creating a high voltage between the electrodes creates weakly ionised gas plasma discharge on the surface, this creates momentum via the electrohydrodynamic effect [6]. The basic structure of a DBD plasma actuator consists of an exposed and embedded electrode as seen in figure 1.

Figure 1 – Schematic of DBD Plasma Actuator [7]



Preliminary Literature Review

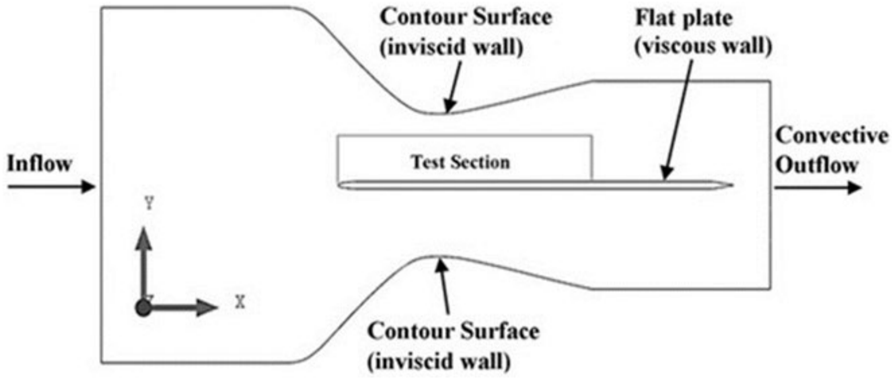
There has been a lot of research into the area of active flow control focusing on simulation and numerical modelling of flow separation control, much of which has proven successful; a study by Ekaterinaris showed that for mildly separated flow, effective control was achieved [8] and even for massively separated flows, the airfoil was enhanced [8]. Specifically for separation control, a numerical simulation study by Hua Shan [9] comparing passive and active flow control over a NACA airfoil, showed that active flow control was more effective than passive vortex generators and worked so well that the separation zone previously observed was not visible in the averaged results. While there are numerous numerical simulation studies, there is less experimental work, however there is a relevant experimental study by G. Zoppini [10] which specifically investigated using DBD on a NACA airfoil for separation control; the results showed it was very effective at delaying and reducing separation over the airfoil. A turbomachinery flow control literature review by Tiainen showed the clear benefits of using DBD actuators, referencing their "low power requirement, light and simple configuration (no moving parts, cavities or holes), no mechanical vibrations and fast dynamic response" [2]. Suggesting DBD actuators are a good starting point for our investigation. Amongst all this, there is a lack of research applying it to compressor sections of turbomachinery in general, but there are almost none into flow separation in these sections specifically. There was one study which investigated the ability of active flow control to reduce rotating stall, which is a result of a different type of separation caused by a high angle of attack. This showed a 23% reduction in rotating stall mass [11] indicating it must have delayed this separation, further hinting at the ability of AFC for this purpose.

Methodology

This study will be highly experimental, hence in order to learn the instrumentation, an initial experiment on a standard NACA aerofoil in a small wind tunnel will be carried out. This will involve making measurements for separation control. The next stage will be to simulate a compressor blade pressure gradient on a flat plate using specifically modified contoured walls in the wind tunnel, Dr XXXXX has previously shown this method to accurately 'capture the separation bubble formation and flow diffusion' [12], active flow control methods such as DBD can then be implemented and investigated to attempt to control separation over the flat plate. A flat plate replicating the pressure gradient is used here rather than the actual compressor blade airfoil as it is much easier to make accurate measurements with. This can then be further developed in future studies (during a potential PhD research) to test the actual compressor blade airfoils under different loading conditions at more advanced facilities.

Figure 2 – TFRC Wind Tunnel and Test Section [13]

Figure 3 – Potential Modification to Test Section to impose Pressure Profile on Plate [13]



References

[1] - Douglas, John F. "Fluid Mechanics" 2011, 6th edition, Prentice Hall, Harlow.

[2] – Tiainen, Jonna. "Flow Control Methods and Their Applicability in Low-Reynolds-Number Centrifugal Compressors—A Review" https://www.mdpi.com/2504-186X/3/1/2/pdf

[3] - Hepperle, Martin. "Electric Flight – Potential and Limitations" (PDF). Institute of Aerodynamics and Flow Technology, https://www.mh-aerotools.de/company/paper_14/MP-AVT-209-09.pdf

[4] – Christopher A. Snyder & Douglas R. Thurman, "Effects of Gas Turbine Component Performance on Engine and Rotary Wing Vehicle Size and Performance",

	https://ntrs.nasa.gov/api/citations/20100042404/downloads/20100042404.pdf [5] – Jahanmiri, Mohsen, "Active Flow Control: A Review", https://publications.lib.chalmers.se/records/fulltext/local_131464.pdf [6] - Ashpis, David E. & Thurman, Douglas R. "Plasma Actuators for Flow Control in Turbine Engines: Simulation of Flight Conditions in the Laboratory by Density Matching", International Journal of Turbo and Jet-Engines, July 31, 2018 https://ntrs.nasa.gov/citations/20180008630 [7] – "Mechanisms of Control Authority by Nanosecond Pulsed Dielectric Barrier Discharge Actuators on Flow Separation" - Scientific Figure on ResearchGate. https://www.researchgate.net/figure/Scheme-of-the-dielectric-barrier-discharge-DBD-actuator_fig2_334711580 [accessed 28 Feb, 2022] [8] - John A. Ekaterinaris, "Prediction of active flow control performance on airfoils and wings", https://ntrs.nasa.gov/api/citations/20100042404/downloads/20100042404.pdf [9] – Shan, Hua. "Numerical study of passive and active flow separation control over a NACA0012 airfoil". Computers and Fluids 2008. https://doi.org/10.1016/j.compfluid.2007.10.010 [10] – G. Zoppini. "Stall Control by Plasma Actuators: Characterization along the Airfoil Span" https://www.mdpi.com/1996-1073/13/6/1374/pdf [11] - Paduano, J. D., Epstein, A. H., Valavani, L., Longley, J. P., Greitzer, E. M., and Guenette, G. R. (January 1, 1993). "Active Control of Rotating Stall in a Low-Speed Axial Compressor." ASME. *J. Turbomach*. January 1993; 115(1): 48–56. https://doi.org/10.1115/1.2929217 *[12] - Kanjirakkad, V.; Irps, T. Some Observations of the Behaviour of an Adverse Pressure Gradient Laminar Boundary Layer under Wake Impingement. Fluids **2021**, 6, 199. https://doi.org/10.3390/fluids6060199* [13] – Images supplied by Dr Vasudevan Kanjirakkad for use in this proposal.
Widening Participation Statement (Optional): *Max. 250 words* *See the JRA website for guidance on writing a WP statement.*	
Ethical Approval *Does this research require ethical approval? If you are unsure, please refer to Sussex's self-assessment checklist. If your project does require ethical approval, it will be your responsibility to ensure such approval is attained before the JRA project commences.*	Not required.

Fieldwork *Does your research involve fieldwork away from the university campus? Any students wishing to undertake off-campus fieldwork must ensure that they attain ethical approval for the proposed fieldwork and must subsequently complete the necessary risk and insurance applications. If your fieldwork takes you outside of the UK, you will need to apply for insurance cover. For more information on the University's insurance policy, please consult the* University's *Travel Risk Assessment webpages. (Note: this does not involve trips to museums and archives).*	No.

If you have any questions regarding this form please email undergraduate-research@sussex.ac.uk