

University of Wales Trinity Saint David

School Of Engineering

M7X01371 – Research Methods

Research Proposal

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MEng Mechanical Engineering

Aim:

The aim of the work to be carried out as part of this project is to work with a company external to the University of Wales Trinity Saint David, United Aerospace Limited, to look at the possibility of improving their composite material manufacturing processes, particularly those involving vacuum forming of composite products. The primary aspect of this aim is to look at the feasibility of the use of these processes in the mass manufacture of products being manufactured or developed by United Aerospace Limited. As part of the improvements that could be made when looking at the process of vacuum forming of composites there is also the possibility of improving the sustainability of the process by reducing the amount of materials necessary for the process to be performed. This forms part of a secondary aim of the project, to look into whether some materials used in the manufacturing process, such as the film used in the vacuum bagging process, can be reused as opposed to being discarded as they are in the current manufacturing process, thus reducing the waste products incurred by vacuum forming composites whilst also providing a small saving on material costs incurred in the manufacturing process. The final aim of the project is to test out the resulting solution to the primary aim of the project, to ensure that the improvements that are theoretically possible, work in practice using the equipment at United Aerospace Limited or possibly the composites manufacturing equipment available for use at the University of Wales Trinity Saint David should they be of comparable and compatible operating specifications.

Background:

United Aerospace Limited is a company based in Pembroke Dock, specialising in composites for a range of sectors, not just aerospace. Their specialism is in providing design, development and manufacturing of composite components, assemblies and products for the aerospace, civil, military, automotive, medical and energy sectors. Their work is particularly notable in things such as the development of composite bodies and components for unmanned aerial vehicles for use in aviation and military applications and in the development of composite components and claddings for medical applications such as scanners where metallic components would adversely affect the operability of the machine or the analysis of the results.

A composite material is defined as; “a combination of two or more materials, where the constituent parts of the composite never actually dissolve or merge into one another but when cured, act in concert with one another” (Taylor-Wilde, p4). In the cases being used at United Aerospace Limited and therefore used for the work entailed, a composite is generally made up of two primary parts; a fibrous component, which is either woven or unwoven in unidirectional fibres which is embedded in a resin matrix, with the fibrous component providing the strength and the resin providing the stiffness found in the final, cured form of the composite. The fibres that are used in composites are often produced from carbon fibres (Carbon Fibre Reinforced Polymer, CFRP), Aramid fibres (Fibre Reinforced Polymer, FRP), or in more historically used forms; glass (Glass Reinforced Plastic, GRP, commonly known by the trade name of fibreglass). These are then embedded in an epoxy resin. The ratio of fibrous material to resin in the composite affects the weight and performance characteristics of the finished composite material and so can be varied in order to provide different effects for different applications. The combination of the fibrous material and the resin can be done as part of the laying up

process which will be discussed later or they can be delivered as what is called 'composite pre-preg' in which the fibrous material and the epoxy resin have been combined before the composite is laid up.

The process of producing composite components and products starts with the creation of a mould, called a 'buck' or a 'plug', for the composite material to be placed into. This mould is an exact representation of the final product that is to be made, meaning that for some shapes there are multiple pieces to the mould to facilitate the removal of the finished product and also there are some geometries possible to produce with composites which require another part to the mould in order to hold them in place. The mould is finally polished to provide the surface quality often seen on composite products and sprayed with an agent to ensure that the composite doesn't stick to the mould during the curing process and can be removed when finished. The fibrous material or pre-preg, depending on which is being used, can then be applied to the mould. This is done until the desired surface area of the mould is covered and is then repeated, adding multiple plies of the fibrous material being used. The plies are generally laid up at different angles relative to one another ($\pm 0^\circ$, 45° , and 90°). The plies are laid up in this way as due to the nature of the materials being used in the composite, it is the fibrous material in the composite which provides the strength and so placing the plies at relative angles to one another means that the fibres of the material are running in different directions which gives the finished composite material strength in more planes. The number of plies placed into the mould varies and is dependent on application, as generally speaking, the higher the number of plies in a composite material, the stronger and stiffer it will be, but the number of plies is often dictated by things such as weight, clearances in the mould and a desire to not use resources unnecessarily. Once the final ply of fibrous material has been added to the mould, the laying up process is complete and if the material being used is not pre-preg, then this is the time when the epoxy resin would be added to the mould. Once the composite material is fully laid up, it requires de-bulking, which is the beginning of the process of curing the composite into the strong, stiff material that is desired. The first step in the de-bulking process is to add a perforated separating film over the top of the composite lay-up, this film will allow air to escape from the laid up composite laminate. Next a layer of breather is added over the top, breather is a woven mixture of polyester and polyamide which has a texture resembling felt which again allows air to leave the composite laminate but also absorbs any of the resin that leaves the laminate during the de-bulking process. A sealant is then added around the edge of the working surface of the mould and around the sealant is placed a layer of vacuum bagging film, creating a sealed environment inside of the mould and around the composite laid up in the mould. The final step in the de-bulking is to remove the air from the mould using a vacuum pump. The removal of the air along with a possibly elevated temperature (up to approximately 60°C), creates pressure around the laminate and causes the laid up plies of the composite to compact together and merge with one another, which makes the material start to act more homogeneously. Once the de-bulk has been completed, the composite material is ready to be cured. Curing is the process of raising the temperature of the resin in the composite material to its optimum curing temperature which accelerates the setting of the resin into its solid form. To begin the curing process the separating film, breather and vacuum bagging film used for the de-bulking is removed and discarded and replaced with another layer of separating film, breather and vacuum bagging film, however due to the temperatures used in the curing process, the vacuum bagging film is one which can withstand higher temperatures. The laid up and vacuum bagged mould then again has the air removed and is placed into an autoclave with the

vacuum pump attached to maintain the vacuum. The first phase of the curing process is the 'ramp' phase in which the temperature of the mould and the composite laminate are raised to the optimum curing temperature of the resin. This is done slowly and can often be done in stages to ensure that temperature of the composite material is even throughout and to allow the resin to flow through and gas to escape from the laminate. Once the optimum curing temperature is reached, this is called the 'dwell' phase, where the temperature is kept constant within the autoclave to keep the resin curing as optimally as possible. Once the required time at the optimum curing temperature has been achieved, the temperature of the mould and the composite can be returned to room temperature in the 'cool down' phase, this is again done whilst maintaining a vacuum around the composite and slowly. The purpose of maintaining a vacuum throughout the curing process is to keep the amount of gas within the composite laminate to a minimum as gas bubbles within the finished composite once the resin has set can compromise the integrity of the composite as the gas bubble is in effect a void from which a crack can form. Maintaining pressure and a vacuum helps to reduce the number and size of the gas bubbles within the composite by effectively compressing them within the matrix and extracting them where possible with the vacuum. Once the mould and the composite held within the mould have returned to room temperature, the vacuum pump can be removed, followed by the removal of the separating film, breather and vacuum bagging film. It is at this point that the finished composite component can then be removed from the mould and the mould cleaned ready for the next use.

Objectives:

The timings for these objectives are at the time of writing this piece unclear, this is due to circumstances dictating that a meeting or correspondence with representatives of United Aerospace Limited to discuss things such as the timescales and finer points of the work has not been possible at the time of writing.

Primary objective:

- Investigate the feasibility of improving the efficiency of the vacuum forming of composites for the applications used by United Aerospace Limited, with a view to the mass manufacturability of the products manufactured using the process.

Secondary objectives:

- Investigate the possibility of being able to reuse some of the materials which using current manufacturing methods are simply discarded after use. The primary resource which is to be investigated in this way is the film used to cover the mould and composite material to form a sealed environment for the vacuum to be applied in the de-bulking part of the vacuum forming process. Other resources which could be investigated in this way are the perforated separating film and the breather which are placed with the composite material before the vacuum bag is sealed on the mould. These however are secondary as they are much less likely to be reusable due to their nature in the process, the breather having absorbed any of the resin which has escaped from the composite laminate in the de-bulking process, meaning that it is much more desirable to discard the breather with the excess resin before the curing process in order to not affect the

final product. The separating film has to be peeled from the composite material after the de-bulking process for much the same reason as the breather is removed but it often tears in the process of being removed which would make it impractical to reuse for the curing process.

- To physically test the solution given for the primary objective in order to ensure that the solution reached is in fact practical and feasible for use by United Aerospace Limited to improve the efficiency of their process of vacuum forming for composite materials. As has been previously stated this will involve the manufacturing of composite products to the same specification as those produced by United Aerospace Limited and investigating whether these products meet the standards required of them, whilst being more efficient in their manufacture than those currently being produced.

Methodology:

The work done will primarily be an exercise in research which will centre on the manufacturing processes for composites and will be dependent on how the processes are used within United Aerospace Limited. This is because how the processes are applied is generally speaking, specific to the product being produced and so to try and improve a system without taking into account the specific applications of the company concerned would render the undertaking of this task null. The aim of the research will be to provide a means of testing the feasibility of mass manufacturing products within United Aerospace Limited and as a by-product increasing efficiency and possibly reducing the amount of waste materials produced in the process of manufacturing composites.

A secondary part to the work could be that once a theoretically satisfactory solution to the implementation of mass production has been reached, some physical testing could be performed using this solution to ensure that the solution that has been reached is feasible for use by United Aerospace Limited. This could be done using the composites production and assembly equipment at United Aerospace Limited or could alternatively be done using the composites equipment available for use at the University of Wales Trinity Saint David, provided that the two sets of equipment are both able to produce products that are of the same required specification.

Resources:

The resources required for the first part of the task outlined previously would be along the lines of literature on the production of composites. This would be down to the overall task being a broadly theoretical exercise to assess the feasibility of the implementation of mass production for some products and components produced by United Aerospace Limited, which therefore should only require literary resources, be they books, journals or online resources. There is also the National Composites Centre in Bristol which could be used as a resource, the National Composites Centre is a government and European Union backed initiative to “accelerate the growth of UK industrial output by enabling design and manufacturing enterprises to deliver winning solutions in the application of composites” (National Composites Centre website). The National Composites centre may be able to provide guidance to assist in the development of

the project or alternatively, they have multiple online resources which could also be utilised in the process. Once there has been a suitable solution reached to the matter of the implementation of mass production however, there would be a dramatic shift in the nature of resources required from literary resources to manufacturing equipment. This would be to test whether the solution devised works to the required standards of the product being manufactured and to the needs of United Aerospace Limited. This would mean that in order to complete this secondary part of the project, the composite manufacturing equipment described in the background section would be required as well as the precursors required to manufacture the composite materials themselves and possibly staffing with experience in the laying up and curing processes in order to ensure they are performed properly.

Constraints:

The main constraint to this project would be that although many of the processes that are used in the manufacturing of composite materials are generic in their nature, the applications of a product quite often make the manufacturing process for different products specialised to that specific product. Therefore, when looking at the feasibility for mass manufacture of a product, it may be possible to use the knowledge gained to improve the manufacturing of other products, however, due to the specialist nature of things such as the laying up of composites and the moulds used, it may not be possible to carry these things over. Therefore it would be concordant to say that the primary constraint of the work would be that the processes to be analysed will be those currently in use at United Aerospace Limited, unless there are plans for the implementation of new processes currently in operation.

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