Air Vehicle Which Flaps Its Wings and Flies

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The amazing phenomenon present in nature has inspired humans for years to invent many things for survival and ease problems. One of these inspirations from birds and flying insects led to the invention of air craft. The research discussed here is also inspired by the flight of the dragonfly. You may have witnessed and enjoyed the flight of the dragonfly sitting near a fountain in a park and amazed by it flying at high speed and hovering. The flight mechanics of the dragonfly is one of the most complex mechanics. A tiny creature, thus, opens many doors for research such as aerodynamics, material science and control system.

Translating the physiological phenomenon of this tiny insect into engineering design can pave a path to a non-conventional type of air vehicle which will have wings that will flap to fly and hover. The kind of air vehicle that is discussed here is generally called Micro Aerial Vehicle (MAV) which is a class of Unmanned Aerial Vehicle (UAV). Building a flapping wing MAV is a very large project. The research discussed here restricts to the mechanics of material involved in the flapping of the wings. The research being done will not only help to build the MAV but will also be used in other applications such as structural health monitoring and biomedical instrumentation.

While building any MAV there are numerous design parameters which are to be considered, such as flight duration, maximum height during the flight, distance travelled in a flight, etc. Currently available MAVs have complex mechanisms to control the flapping of wings, which increases the weight of MAV and eventually the parameters considered are compromised. This is the focus of our research - to find a solution to minimize the complex mechanism and, therefore,

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minimize the weight of the MAV. The non-conventional or engineered materials theoretically proves to be a solution to this problem. The smart materials can be considered to completely replace the complex mechanism used to flap the wings.

Engineered materials are made artificially by adding two or more different materials having different properties. The material formed has properties different from those of the ingredients that help you achieve the property you wish to have in your material. One such engineered material is fiber reinforced composite (FRC) in which there are mainly two ingredients, one is matrix and the other is fiber. It is like the reinforced cement concrete (RCC) which is used in the construction of our houses. In RCC the steel rods play the role of fiber and the mixture of cement concrete plays the role of matrix. With this example it is clear that the role of matrix is to hold the fibers together just as the steel rods provide strength. The benefits of using RCC instead of just cement concrete lies in the name i.e., it provides extra reinforcement/extra strength to the bare cement concrete. In FRC the arrangement of fibers and the matrix is similar to RCC but at a very small length scale i.e. the fibers have very small diameters of the order of micrometer. So, to achieve a feasible size of the FRC to be used in the structure they are made up of layers just like the plywood used in our house or office to make furniture. The material used as fibers are glass, carbon, jute, etc. while the matrix material is generally resin, metal.

What if there is a layer at the top of the FRC which behaves differently than that of the other layers. By differently I mean if I apply pressure on that layer it produces electricity and vice versa i.e. if we apply electricity the layer expands or contracts. This phenomenon is known as piezoelectricity and is observed in some of the naturally occurring materials like quartz crystal, topaz, etc. and some chemically prepared compounds like lead zirconatetitanate, barium titanate, etc. You would have also observed this phenomenon in your kitchen. The lighter used to light the gas stove uses this phenomenon. You apply the pressure on the central rod of the lighter and the spark strikes as a result of the electricity produced in response to your pressure. Such, FRC's with piezoelectric fibers comes under the category of *smart materials*. The top layer is prepared by adding the fibers of piezoelectric materials in the matrix. This layer plays a very important role of binding other layers. But, how? Imagine only two layers of same size, the upper layer with piezoelectric fibers and the lower layer with conventional fibers, both held together with proper adhesive bonding, restricting any kind of relative motion between them. Positive electric potential is now applied on the upper layer, the effect of which is the extension of the fibers and, therefore, of the layer. But as there is no sliding motion between the layers, the top layer will try to push the lower layer to form a convex shape. If the electric potential is reversed, then a concave shape is achieved. Now, imagine that one end of the layer is fixed by some means resulting it to behave as a cantilever beam. If the electricity is applied in a cycle of positive and negative electric potential the beam flaps up and down. Thus, a material is now available which can itself flap without any complicated mechanism by just applying electric potential across it.

But, this is not the happy ending! This is just the broader picture of the concept to be used in building flapping wing MAV. The main research lies within the layers of the smart FRC. The interaction between each fiber and the matrix surrounding it and the interaction between each layer. These are the areas of research targeted by our research group at the Indian Institute of Technology (IIT), Ropar, supervised by Dr Srikant S. Padhee. As stated above, the research is divided in two parts, the first one deals with the mechanics of the fiber-matrix interface, and the other focuses on stacking of different layers and the mechanics at the layer interface. The author deals with the first part i.e. the fiber-matrix interface mechanics. As this study deals with dimension in micrometer scale, the analysis is called micromechanical analysis of FRC.

The objective is to find a solution to the problem, such as: 1) What happens when a single fiber breaks in the layer with the application of the load? Does it affect the other fibers? 2) What is the role of fiber arrangement in a layer of FRC? Do the randomly arranged fibers enhances the effect of fiber break? 3) What is the mechanics of the piezo fiber-matrix interface? 4) How to implement the current study in other applications as well? The answer to the first three questions will be addressed by developing mathematical equations which will be then validated using commercially available software. These mathematical equations that can prove to be a great help to other researchers and designers who encounter similar kind of problems. The benefits of this mathematical modelling will include reduction in the time taken by the commercial software to achieve the solution and, thus, will then be an easy task of number crunching.

The other part of the research is being done by Mr Nishant Shakya. His research focuses on the 1) stacking sequence of the layers in the FRC and the mechanics involved in between the two layers, how the consecutive layers behave under different loading conditions. 2) How to amplify the bending and twisting effects due to the application of small electric field so as to reduce the weight of the MAV by avoiding larger power supply. 3) How to control the flapping of wings. As the other part of the research is on the stacked layers, it covers a larger dimension and, hence, the analysis is called the macro-mechanical analysis of FRC.

The research will be helpful in building a MAV without compromising on the design parameters. The MAV will find applications, like in defence, in traffic control systems, pollution inspection, police surveillance, etc. As mentioned earlier this research can be applied in the field of structural health monitoring and biomedical as well. Structural health monitoring means to check the reliability of the existing structures like buildings, bridges, railway tracks, etc. The reverse phenomenon that made the wings to flap, i.e., the applied pressure will generate electricity that in turn can be used to check the health of the structure. Similarly, in biomedical instrumentation one can think of monitoring the motion of the joints in the body and to predict the conditions of the joints. One can check the health of the implants placed in the body. This can be digitalized, and one can check his/her joint conditions and implant strength through his/her mobile phone.