Piezoelectric Control of the Boundary Layer

Kenneth Ramsey
kenramsey@startmail.com

Abstract: Aircraft design is reaching a limit on the greatest airspeed obtainable in the atmosphere. A solution might be to control the boundary layer. During the Second World War, an effort was made to manipulate the layer of air that exists at the surface of aircraft. The system used very small holes along the leading edges of the wings. A compressor forced air through the holes and exhausted the compressed air. This did improve the performance of the planes, but the holes required a great effort to keep clear. Here an effort to control the boundary layer is proposed using the piezoelectric effect. A research effort is described.

Piezoelectric Control of the Boundary Layer

An aircraft at 600 mph is moving against an essentially non-moving air mass. However, a thin layer of air at the surface of the vehicle is moving along with the craft at about the same 600 mph. This is called the boundary layer. This difference in speed decreases as the distance from the surface of the aircraft increases. This air resistance greatly increases the fuel consumption of the aircraft and limits the obtainable speeds.

The development of Boundary Layer Suction has been credited to Werner Pferning in the Second World War. The effect has been studied by NASA and several tests have been conducted. Additionally, some prototypes have been built. [1]

Piezoelectric ceramics or polymer films could be used to control this boundary layer. If the boundary layer could be pushed in the opposite direction of travel, with sufficient speed, the speed and fuel economy would increase by several magnitudes. Piezoelectric materials have the characteristic of producing an electric current when the piezoelectric material is deformed. Conversely, piezoelectric material deforms or has a dimensional change, when an electric current is applied. The piezoelectric material can be formed into thin films. These characteristics can be used to mitigate the effects of the boundary layer on high-speed vehicles, especially aircraft.

These films would be attached to the avionic surfaces of aircraft. These piezoelectric films would produce dimensional shifts on the surfaces and could be used to create directional waves or ripples along the surface. These waves would strike or roll with the air molecules at the surface of the piezoelectric film. With the correct control of this effect, the boundary layer could be controlled. The waves or ripples would impact the air molecules at the surface. This would cause the air at the surface to move in the opposite direction of the aircraft and at a rate equal to or greater than the speed of the aircraft. This would lessen the air resistance to the movement of the surface through the air. If the boundary layer can be controlled sufficiently there is the possibility of actually providing propulsion for the aircraft.

The piezoelectric devices being used are generally small or only use one crystal facet (surface.) There are piezoelectric films[2] that measure many square feet, used for the generation of electrical power. In this proposed project, some research is required. There is the need to control the surface effects of the piezoelectric films. Very short electrical impulses applied to the piezoelectric films could be made to create standing waves on the surface of the material. These standing waves could be pulsed to travel along the surface of the films (the aircraft surfaces) and decouple the surface from the nearby air molecules.

The research goal would require controlling surface ripples on large scale piezoelectric films. The steps might be select a material, select an electrical connection type, determined data acquisition type and select the analytical equipment. The first effort: Are the ripples generated and detectable. Is the analysis adequate? What type of electrical wave form works best (sine, square, stepped?) How many electrical connections per unit length are needed?

With this information, a wind tunnel study might be next. The answers sought with the wind tunnel might be: Which piezoelectric material works best? What electrical power levels are appropriate? Since the atmosphere is 80% nitrogen, does the molecules of the film interact with the nitrogen?

Note:

1. Wikipedia F-16XL

2. PolyK Technologies
State College, PA