Choosing Best Material to Tolerate Cracks in Aircraft Structures
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Cracks are all around us and are unwanted; be it in a window of your car, your Ipod screen or the corner of an aircraft window. Although cracks on the aircraft windows are a threat to passenger safety, we cannot stop them from emerging and growing. Famous De Havilland Comet aircraft crashes in 1954 were some early ones that suffered such disastrous failures due to cracks extending to the aircraft windows (see fig. 1). As a result, the aircraft industry conducted intensive research to understand the possible locations where cracks are likely to initiate (i.e. regions with high applied loads) and how cracks grow (i.e. what factors drive crack growth). It was learnt that in certain metals (e.g. aluminum), cracks take time to develop to a particular length that may cause failure. The solution is to ensure that the time it would take the crack to grow to a failure point is less than the service life of an aircraft. The technique of inspecting the aircraft to find and replace cracking parts is called damage tolerant (DT) design philosophy.

Different materials (e.g. 7075 and 7475 aluminum alloys) exhibit different resistance to crack growth i.e. some resist growth of crack better than others (i.e. 7475 is better than 7075). To measure such resistance, a small crack of known length is put at the center of a rectangular metal plate as shown in fig. 2, and then the two ends of the plate are pulled apart and released multiple times by using a computer controlled machine to extend/grow the crack. Imagine that you take a wire and keep on bending it back and forth until it breaks. The number of times it will take to pull the plates to make crack grow to a specific length and causes failure (where failure means that plate ends up in two pieces) is what we want to ultimately know. Such experiments would help in finding out which materials take longer to fail than others. But more interesting is the fact that if one repeats the experiment on same material multiple times, it will give different values every time (a scatter, see Fig. 3) which makes it difficult to say that certain materials are better than other.

The challenge then is the decision to choose the best alloy for resisting crack growth in aircraft structures. You will be surprised to know that there is no requirement defined by Federal Aviation Administration (FAA, government agency for making sure that aircraft design is safe) that accounts for the scatter in crack growth life while choosing alloys. So, aircraft manufacturers (e.g. Boeing, Airbus, Bombardier, and Cessna) base their alloy choices on their previous experience of designing parts using a particular alloy. The choices are driven largely by comparing average values of crack growth life for different alloys. Usually, companies ‘do the necessary work’ as mandated by FAA for certification of their aircrafts. As the research in the field progresses, there soon will be the requirement by FAA to require companies to take scatter in crack growth data into account. Recognizing such a paradigm shift, my research focuses on studying different alloys and the scatter for their resistance to crack growth based on rigorous statistical analysis. The relevance and importance of such a study to the aircraft industry is reflective in the interest shown by the ‘Cessna Aircraft Company’, who were willing to share their material testing data (despite of the fact that material testing data are best kept secrets!!) for various aluminum alloys to carry out this study. My research would not only let companies choose more efficient material but will also enhance the flight safety for travelers around the world. Have a safe flight and Bon Voyage!!!