Question: the low density of a carbon fibre reinforced plastic makes it an ideal material for the blade of a helicopter.

Answer: The statement is partially correct.

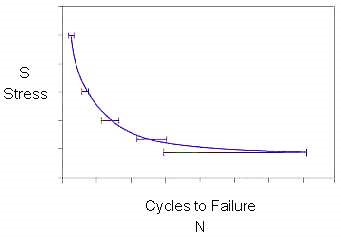
For the past decades, improvements in aeronautics have been amazing. Indeed, if helicopter blades are considered, they were originally made of wood and fabric. Then, in the 1960s[[1]](#footnote-2), materials like steel and especially aluminium were introduced. These metal blades were better in every way especially regarding to cost, ease of manufacture but still suffered from design and structural problems because of the material itself. Indeed, metals usually don’t have a very good specific strength/stiffness to density ratio; they have also fatigue, creep or corrosion problems... It is going to be discussed here if carbon fibre blades are suitable for helicopter and if they can be the answer to the structural problems that have been mentioned.

First of all concerning basic properties of carbon fibre reinforced plastics, they without a doubt surpass aluminium alloy by far. As a consequence as table 1 shows, if the low density characteristic compared to strength is the only one taken into account it would be possible to build blade 5 times lighter than the metal equivalent.

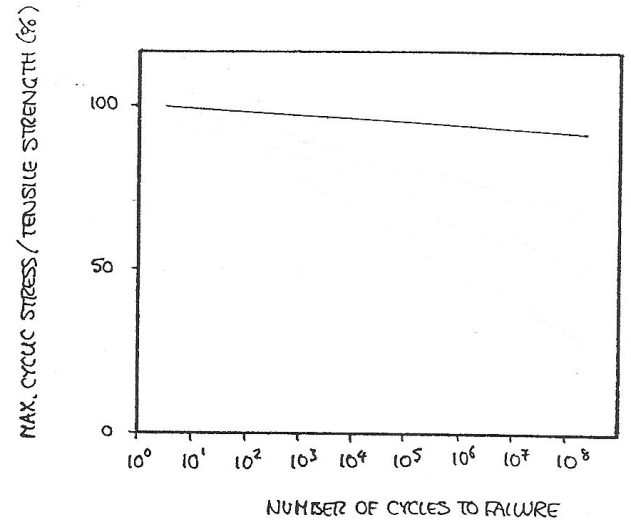
Table 1: Properties of Carbon fibre reinforced plastic and aluminium alloy[[2]](#footnote-3)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Material | Density ρ  (Mg m-3) | young's modulus  E(GPa) | Strength  σy (Mpa) | Fracture toughness  Kc (MPa m1/2) | E/ ρ |
| CFRP 58% uniaxial C in epoxy | 1,5 | 189 | 1050 | 35-45 | 126 |
| Aluminium alloy | 2,8 | 71 | 500 | 28 | 25 |

Furthermore, fatigue resistance is also an important characteristic and again composite based materials are better than metals. As it can be seen in figure1 the shape of the S-N curve for an aluminium alloy shows that under stress, life expectancy of the material quickly decrease. This force designer to oversize aluminium blades compare to the tensile strength of the material which is obviously bad for the total weight of the structure.

   
Figure1: Schematic of S-N Curve for an aluminium alloy

On the other hand, as figure 2 shows, high modulus carbon fibres do not have that kind of behaviour. Indeed they can support without failure a stress very close to their tensile strength (which is already high) for a long time. This behaviour is great especially for helicopters because the weight that can be gained by designing the blades (regarding the fatigue resistance) is significant.

  
Figure 2: Normalised S-N Curve for a high modulus carbon fibre.[[3]](#footnote-4)

Furthermore, CFRP materials do not have any strengh reduction until close to faillure. This can be a good point because it means that this property of the blade will remain the same during its whole life. But is has also bad consequences. Indeed, that kind of material has a “sudden-death” behaviour which leads to catastrophic failures and this is unacceptable for a flying mean of transportation. The lost of the entire crew when the blade fails is not affordable. As a consequence, CFRP blades have to be used with caution and it is necessary to monitor them regularly to avoid these catastrophic failures. This can be done via ultrasonic tests for example by analysing the frequency response of the blade (harmonic and nodes move when the material starts to damage).

As a conclusion, the statement is partially correct. It is true that composite materials allow the creation of rotor blades that far surpass their predecessors in many properties but side effect like sudden death process have to be taken into account. That kind of blades are also very expensive to manufacture and that could prevent metallic blade from totally disappearing at least in a near future.

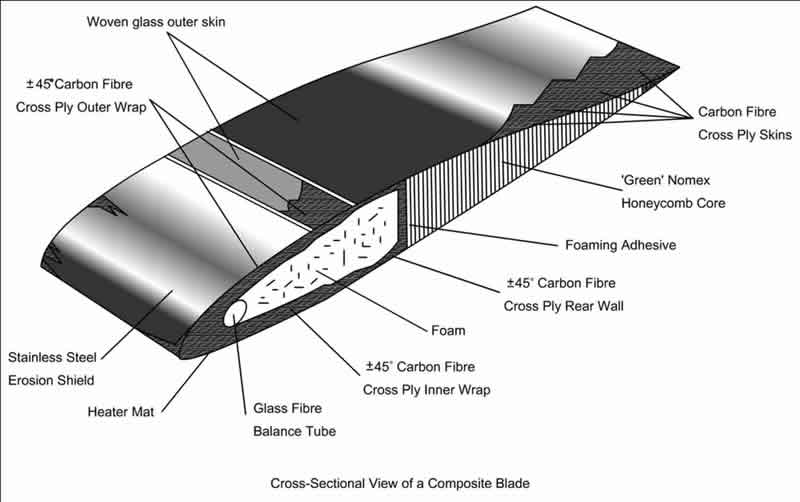


Figure 1: Cross sectional view of a composite blade.[[4]](#footnote-5)

1. http://www.whystudymaterials.ac.uk/casestudies/helicopter.asp [↑](#footnote-ref-2)
2. Ashby, M. F., Jones D. R., (2005), *Engineering Materials 2*, Butterworth Heinemann, p. 293 [↑](#footnote-ref-3)
3. After Jones et al 1984, Harris 1986 [↑](#footnote-ref-4)
4. http://www.whystudymaterials.ac.uk/casestudies/helicopter.asp [↑](#footnote-ref-5)