

Sikorsky S76 Main Rotor Blade Failure

A previous QinetiQ investigation into a failed Sikorsky S76 main rotor blade (QINETIQ/FST/SMC/LR024608) found that failure occurred due to a fatigue crack initiating and propagating in the titanium spar. Fatigue striations measurements were carried out and an estimate of the crack life was determined. It was requested that a representative crack at different stages of propagation be introduced into a full size blade at the failure location to determine if the amount of blade droop changed with increasing crack length.

Rotor blade serial no. A086-00180A, which was fitted to the aircraft at the time of the accident but had remained relatively undamaged, was used in this experiment. The blade was bolted to a fixed bed at the root end through three of the available five fastener holes and the tip was allowed to drop freely. The distance from the floor to the top of the blade at the root end was measured as 1159mm. With the blade in the as-received condition, the distance from the top of the blade tip to the floor was measured as 617mm, which represents a natural blade droop of 542mm.

A position at the trailing edge of the erosion strip on the top surface of the blade 1950mm from the root was marked as the origin of the fatigue crack and a 30mm transverse slot was cut into the blade at this point to represent a crack propagating in the leading edge direction for 14mm and the trailing edge direction for 16mm. The distance between the blade tip and the floor was measured and the slot extended to represent increasing crack lengths. In total, the blade droop was measured at four different crack lengths. The different crack lengths are represented in figure 1 and the results of the blade droop are shown in table 1. Figure 2 shows a series of photos taken from a fixed camera position at the various crack lengths. Figure 3a shows the blade tip before cutting and figure 3b shows how the position changed after each cut. For each cut the blade is coloured differently and the results overlaid. The results of the blade droop are also shown in graph form in figure 4.

From the experiment, it was found that at a crack length of 19mm in the leading edge direction and 22mm in the trailing edge direction (cut 2), there was no increase in the blade droop. Fatigue striation measurements carried out in QINETIQ/FST/SMC/LR024608 and reported in QINETIQ/FST/SMC/LR026770 indicated that an approximate time before failure at the crack length of cut 2 was 5hrs 20mins which corresponds to the evening before the day of the accident when a visual inspection of the aircraft was carried out. Approximately one hour before failure, a pre-flight inspection was also carried out. The corresponding crack length at this time (cut 3) produced an increase in blade droop of 23mm over the blade length of approximately 6m.



Figure 1. Cross section through spar showing crack positions.

Cut ID	Crack length (mm) Leading / trailing edge direction	Approx. time before failure (mins)	Blade root distance from floor (mm)	Droop (mm)	Change in droop (mm)
No cut	0	N/A	617	542	0
1	14 / 16	460	617	542	0
2	19 / 22	320	617	542	0
3	44 / 58	60	594	565	23
4	58 / 84	Time of failure	554	605	63

Table 1. Results.

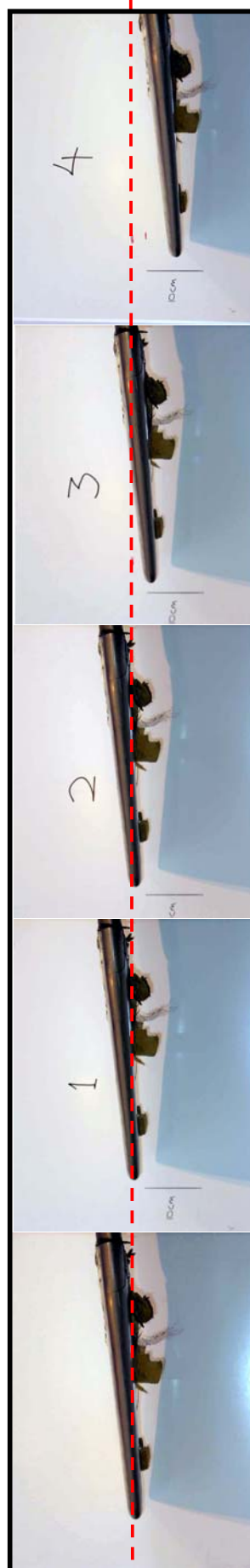
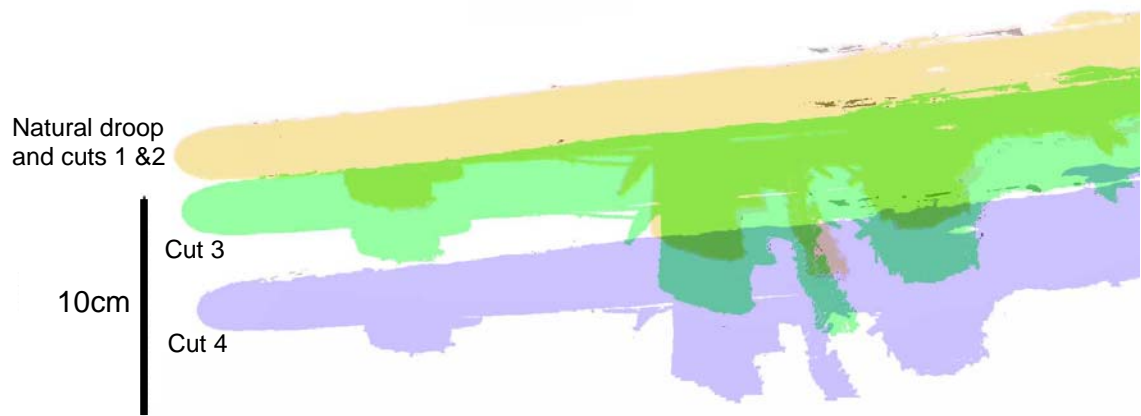


Figure 2. Blade droop at various crack lengths



a)



b)

Figure 2. a) blade droop, b) change in droop at different crack lengths.

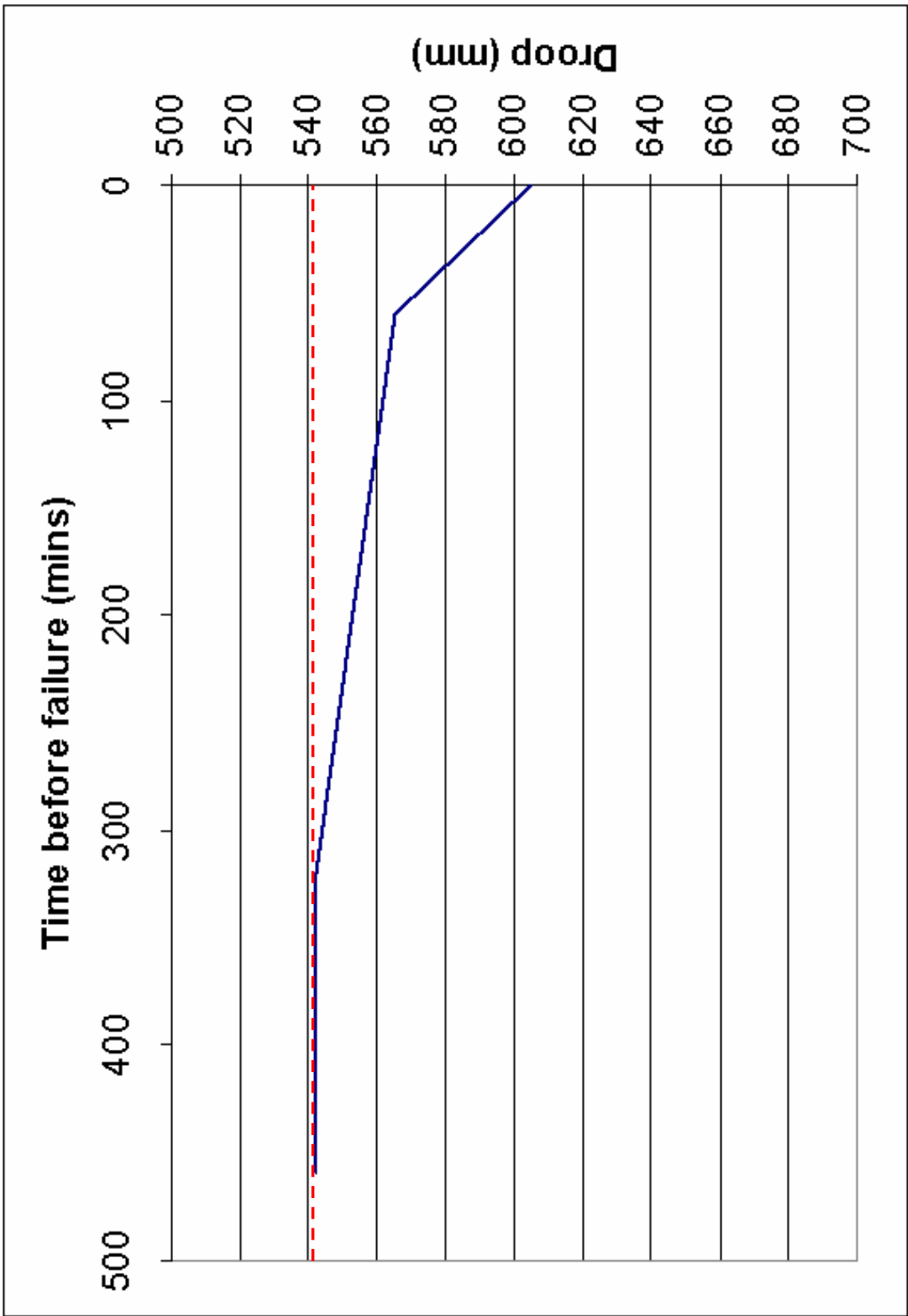


Figure 3. Graph of blade droop results.

In order to cut varying crack lengths in the spar during this experiment the external composite material and titanium erosion strip was also cut. A crack in the composite may not have been present during the actual failure especially around the leading edge and erosion strip and therefore this may have provided some resistance to the drooping that was observed during this experiment. Also the blade was slightly heavier due to ingress of water which may also have increased the amount of droop observed. Finally the "crack" introduced during this experiment was relatively wide (i.e. slitting wheel) when compared to a fatigue crack which may also have affected the degree of droop that was observed.