Castelliccio Paramotor

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Aircraft Type and Registration:	Castelliccio Paramotor
No & Type of Engines:	1 Castelliccio Paramotor
Year of Manufacture:	Not Known
Date & Time (UTC):	8 July 1999 at 1045 hrs
Location:	Hawk Green, Marple, Stockport
Type of Flight:	Ground Run
Persons on Board:	Crew - 1 - Passengers - N/A
Injuries:	Crew - Nil - Third Parties - 1
Nature of Damage:	Propeller destroyed
Commander's Licence:	
Commander's Age:	
Commander's Flying Experience:	N/A
Information Source:	AAIB Field Investigation

A British Hang Gliding and Paragliding Association (BHPA) member had obtained a paramotor fitted with a laminated 4-bladed propeller supplied by the original equipment manufacturer. This original propeller became damaged when an exhaust component detached during an engine run, and the owner decided, on the grounds of cost and availability, to buy a replacement from another manufacturer of wooden propellers. The replacement was copied directly from the original and manufactured from Beech wood. It was the largest propeller that this manufacturer had made.

The owner considered that the replacement propeller was excessively thinned, but the manufacturer assured him that it had been caused by balancing, and was satisfactory. He ground-ran the motor at different times for a total of approximately 8 minutes, and reported that, during the penultimate run at approximately half throttle, the thrust increased abruptly to a level that he could only just hold.

The next run was carried out at idle speed using a float bowl full of fuel. As the fuel ran out the 2-stroke engine speeded up momentarily and the propeller disintegrated, striking an onlooker in the face.

The AAIB submitted the propeller to the Timber Research and Development Association (TRADA) Laboratories for assessment. The principal TRADA findings are reproduced below:

'Examination of the broken propeller showed that the principal parts of the two separate components were present. The two components were designed to fit against each other at the boss position to permit the four individual blades to run in a more or less continuous plane. This involved the corresponding recessing of the boss sections. The two components of the four bladed propeller had failed in distinctively different ways. The rearmost component had failed through a relatively abrupt failure at the transition between the boss and the blade whilst the forward component had failed through an extended failure at the boss position combined with long failures down a full blade length close to the leading edge.

Form of Construction

Both components were manufactured from single pieces of solid timber. The timber species was confirmed by TRADA as Beech (Fagus sylvatica).

Examination of both forward and rear components showed the general quality of the timber to be high with no evidence of obvious inherent wood defects in the regions of failure. The grain of the timber in both components was not perfectly aligned with the main blade axis but lay at a slope of approximately 1 in 12. In practice, perfect grain alignment is rarely achievable and 1 in 12 would be considered relatively straight grained in relation to the timber Beech.

The rates of growth of the timber and its general density were assessed as within the range that would be considered normal for this species.

Mode of Failure

The mode of failure shown by the forward component, which had failed across the blade boss and showed extended longitudinal cracking, was considered to be characteristic of a failure which would be associated with very high loadings and the absorption of considerable energy. The failure of the rear component involved a line of fracture which was relatively abrupt, and involved the detachment of more or less the whole of one blade area with no extended damage, within either the boss portion or the detached blade. This was considered to be consistent with a failure at a relatively low loading and where relatively small amounts of energy would have been absorbed.

The pattern of failure of the rear blade component was considered relatively unusual and indicative of failure at a position that was relatively weak.

The appearance and characteristics of these failures strongly indicated that the primary cause of failure was attributable to the initial failure of the rear component and that the detachment of a blade end resulted in excessive loading and possibly impacts upon the forward component leading to its subsequent failure.

Discussion

Rear Component

The fracture of the rear component, which was considered to be the primary cause of the propeller failure, occurred over a relatively short distance and was associated principally with failure through separation of the wood fibres along the grain. There is little evidence of fibre failure in their length. Wood fibres are relatively strong in resisting tensile forces in their length but relatively weak in resisting splitting forces acting between the fibres. For this reason components which may be subject to either tensile forces or bending forces should maintain a high degree of fibre continuity throughout their length.

Examination of the rear component design showed that there was a relatively small amount of fibre continuity between the boss and the blades. This was caused by the cutaway section of the component at the boss position to accommodate the forward component, illustrated in the attached sketch. It was noted that the thick leading edge of the blade that would be expected to provide a major contribution to the component strength was cut away as it approached the boss position. The wood fibres at this transition point therefore had no continuity, and tensile and bending forces would therefore tend to split the fibres apart rather than subjecting them to forces along their length.

When viewed on edge, the trailing edge of the blade appeared to lie in plane with the boss position and might therefore have been expected to maintain some fibre continuity through this zone. However, this was significantly reduced by the cutaway of the trailing edge as it approached the boss position. This can be seen in the attached sketch.

Although the timber from which the component was made was considered to be relatively straight grained, there was a slight grain angle at the position of failure which lay obliquely to the transition between the blade and the boss, further aggravating the lack of fibre continuity. This was considered to be a contributory, but not principal, cause of the failure. The principal cause of failure related to the transition to the reduced section at the boss to accommodate the forward component.

Forward Component

Consideration of the forward component showed that although this was also cut away to accommodate the rear component. The cut away portion reduced fibre continuity on the trailing edge of the blade but the thick leading edge portion of the blade, which provided most of the component strength, had almost continuous fibre continuity through the boss.

Assessment of Propeller Loading

A detailed analysis of the stresses in this propeller design was beyond the scope of this inspection. However a simple analysis of the failure of the rear component was undertaken. Calculations at rotational speeds of 1,000, 2,000 and 3,000 RPM were undertaken to assess the centripetal force. This force was then compared with the longitudinal shear strength of Beech timber of a grade appropriate to that involving a slope of grain of approximately 1 in 12. The calculations took no direct account of the additional bending forces known to be present on the blades due to the thrust that they develop or dynamic forces associated with vibration.

These calculations indicated that at rotational speeds of 1,000 and 2,000 RPM the shear stresses parallel to the grain were not in themselves apparently excessive, but that approaching 3,000 RPM the centripetal forces alone became a significant potential source of failure.

Additional Consideration

It was noted that at the transition point between the blade and the boss, abrupt irregularities in the machining of the blade were present which were likely to act as locations at which stress concentrations would occur. The region of failure of the rear component coincided, in part, with a position where such an irregularity occurred. Although not considered a primary cause of the failure, such irregularities, commonly known as "stress raisers", should have been avoided.

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Conclusion

From the examination of the propeller and from the details provided in relation to its history and usage, TRADA would consider that the failure was attributable to an inherent weakness within the rear component due to its design profile, which reduced fibre continuity.'

The abrupt increase in thrust observed at half throttle on the penultimate run may have been produced by aeroelastic forces causing the blades to twist in a direction that increased the angle of attack as they came under load. If this were the case, it is also probable that the principle damage was caused on that run, leading to the subsequent failure at low power.

The AAIB considers that the manufacture of joggled blades without due consideration of aeroelastic forces or fibre continuity in the load path is inherently dangerous, and recommends that the BHPA should advise their members against the use of propellers from sources unqualified to assess such risks.