INCIDENT

Aircraft Type and Registration:	Slingsby T67M260 Firefly, G-BYOB
No & Type of Engines:	1 Lycoming AEIO-540-D4A5 piston engine
Year of Manufacture:	1999
Date & Time (UTC):	3 August 2007 at 1030 hrs
Location:	Stapleford Tawney Airport, Essex
Type of Flight:	Training
Persons on Board:	Crew - 2 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Left brake pedals disconnected
Commander's Licence:	Commercial Pilot's Licence
Commander's Age:	58 years
Commander's Flying Experience:	6,900 hours (of which 156 were on type) Last 90 days - 70 hours Last 28 days - 39 hours
Information Source:	AAIB Field Investigation

Synopsis

As the crew carried out functional checks of the flight controls while taxiing for takeoff, the left wheelbrake master cylinder became detached from the rudder/brake pedal mechanism. The failure was consistent with the effects of previous overload and consequent weakening of the mechanism as a result of inadvertent exceedence of the maximum allowable nosewheel steering angle during ground towing.

The aircraft manufacturer had taken a number of measures aimed at reducing the likelihood of the pedal mechanism being damaged during towing. A relatively minor aircraft modification could probably eliminate the possibility of such damage. Three Safety Recommendations are made.

History of the flight

The planned flight was an instructional sortie with an instructor in the left seat and a student in the right seat. While taxiing for departure, the student carried out rudder functional checks, as usual. The instructor reported that rudder operation was normal when the student applied full right pedal. However, when the student pushed his left pedal there was a loud bang and both left pedals appeared to be disconnected. The flight was cancelled.

Aircraft description

The Slingsby T67 Firefly is a single-engined low-winged monoplane, designed to be fully aerobatic (Figure 1). It is constructed principally of glass reinforced plastic (GRP) and fitted with a tricycle landing gear with a steerable nosewheel leg. Two side-by-side seats are provided. The

Firefly was first certificated in 1983 as the T67M, and a number of other versions were subsequently developed, including the 260 shp T67M260. In total, 280 T67 aircraft have been built. Maximum takeoff weight of the T67M260 is 2,550 lb (1,157 kg).

Primary flight controls are conventional, operated by dual cockpit controls. Rudder/brake pedal assemblies are numbered from 1 to 4 across the aircraft from left to right (Figure 2). The pedals are mounted on crank arms welded to two rotatable cross-shafts in the cockpit, known as rudder bars, with the left pedal of each pair (Nos 1 and 3) fixed to the left bar and the right pedals (Nos 2 and 4) fixed to the right bar. A crank arm on each bar is connected by a cable-fairlead system to operating levers attached to the rudder. The two bars are thus interconnected by the loop formed by the cables and the pivoting rudder. Two springs maintain the rudder bars centralised when the pedals are unloaded. An adjustable primary stop provided for each rudder bar limits the forward rotation of the bar (ie forward displacement of the respective pedals); these stops form the primary travel limiters for the system.

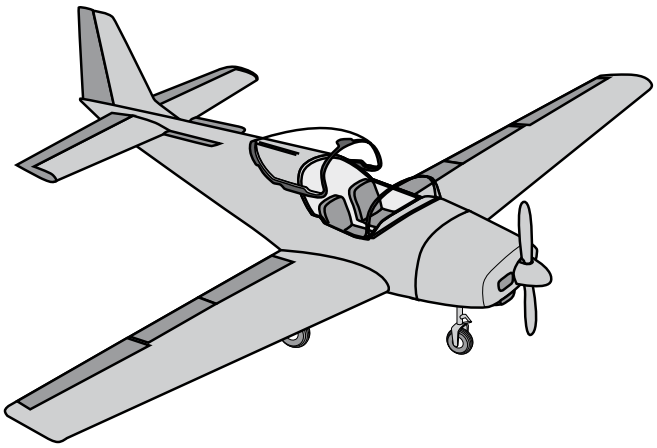

Figure 1

Rotation of the rudder bars also steers the nosewheel leg, via a control rod driven by a crank arm fixed to the right bar (Figure 2).

A slider mounting mechanism allows each pedal to be individually adjusted fore and aft to cater for variation in pilot build and then locked by a pin that locates in one of four holes in the slider.

For each pedal, a pin-jointed parallelogram-type linkage pivoted to the respective rudder bar (Figure 3) maintains

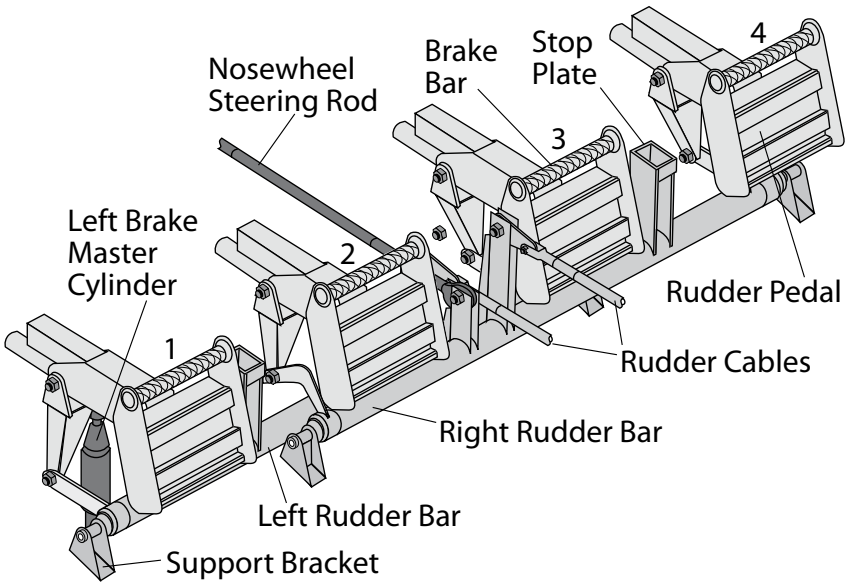

Figure 2

the vertical orientation of the pedal constant as it is displaced fore and aft to operate the rudder (Figure 4). The linkage allows each pair of pedals to be pivoted, by pushing a brake bar at the top of one of the pedals, to drive the master cylinder piston (Figure 5) and hence apply hydraulic pressure to the brake on the respective main wheel.

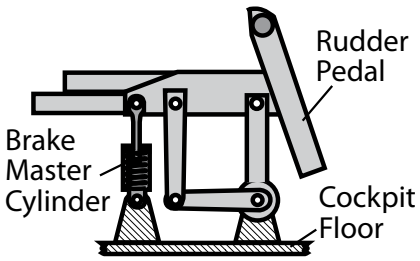

Figure 3

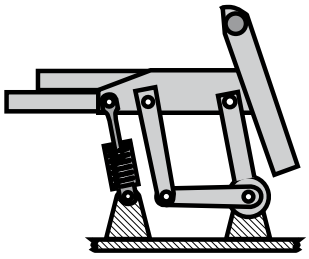

Figure 4

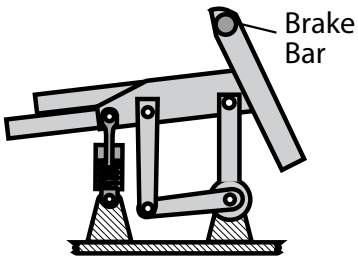

Figure 5

Aircraft examination

Examination by the operator's maintenance organisation revealed that the left wheelbrake cylinder had detached from the No 1 pedal mechanism. It was also found that the composite floor panel had suffered delamination damage in the area where the left mounting bracket for the left rudder bar attached and that the bracket had tilted to the left as a result. The aircraft manufacturer considered that both damage features had been caused by overload as a result of exceeding the maximum nosewheel steering angle while towing.

Aircraft towing

The aircraft can be towed, by hand or by a vehicle, using a towbar fixed to the nose landing gear. When the aircraft is being towed, any steering displacement applied to the nosewheel by the towbar is transmitted to the rudder pedals via the steering control rod, causing the pedals to displace. Two turn limitation lines painted on the lower part of the engine cowl indicate the maximum permitted steering angle in either direction. The limiting angle is reached when the towbar is visually aligned with the appropriate line. A towbar design approved and recommended by the aircraft manufacturer incorporated a device to limit the steering load applied to the nose landing gear.

Excessive nosewheel steering angle

Should the aircraft be towed using a towbar without the load-limiting feature, it is possible that excessive loads would be applied should the limiting steering angle be exceeded during a turn. The nosewheel leg is provided with non-adjustable steering stops but these act as secondary stops only. Travel limiters within the rudder/brake pedal mechanism form the primary stops, which are contacted first when the steering angle exceeds its limit, as follows.

If the maximum allowable nosewheel angle to the right is exceeded while the aircraft is being towed, the steering control rod rotates the right rudder bar forward onto its stop. At the same time the left rudder bar, connected to the right bar by the loop formed by the cable and rudder, is rotated backwards. A further exceedence of the permitted steering angle would apply excessive loads to

the right rudder bar stop and could cause it to deform as a result. The rearward over-travel of the left rudder bar would result in the No 1 pedal mechanism applying an upward load to the left brake master cylinder, which would be bottomed, and additional excessive loading on the pedal mechanism can result. The aircraft manufacturer believed that this could damage the left rudder bar support brackets, the floor at the bracket attachment points, and/or the left brake master cylinder.

The system behaves somewhat differently when the aircraft is towed in a turn to the left. In this situation the steering control rod rotates the right rudder bar backwards. Exceeding the allowable steering angle to the left would apply excessive loads to the right brake master cylinder and could result in damage to the right rudder bar support brackets, the floor and/or the right brake master cylinder. In this case the left rudder bar will not be rotated, as the rudder cable would not transmit a compressive force, and so no excessive loads would be applied to the left pedal system or its stop.

Towing typically involves the use of a 2 metre long towbar pulled by a powerful 4-wheel drive vehicle. The manufacturer noted that if a towbar without the load-limiting feature were used, the loads on the pedal mechanism caused by exceeding the towing angle limits could therefore be exceedingly high. It was considered impractical to redesign the rudder mechanism to withstand such loads.

Airworthiness improvement measures

The manufacturer issued a User Experience Report Action Form on G-BYOB's accident (UER No T67-1253, issued on 29-08-07) which noted that:

> *'The use of specialised towing vehicles which "carry the nosewheel" of the aircraft are not recommended for use with SACL T67 aircraft because it is, at the very least, very difficult to see when you are approaching the maximum towing angle.'*

The UER recommended inspection of G-BYOB's nose landing gear, rudder/brake pedal mechanism, cockpit floor and rudder for damage and recommended a review of towing practices.

The manufacturer also issued an Advance Information Leaflet (AIL No 01/2007, issued 15 November 2007) as an attachment to the T67M260 Maintenance Manual (MM). It was intended that the AIL content would be incorporated in the MM when next reissued, anticipated to be during the first quarter of 2008. The AIL included the following:

> *'Towing*
>
> *CAUTIONS*
> *THE USE OF NON-SLINGSBY TYPE VEHICLE OR HAND TOW BARS OR TROLLEY/CART ARE PROHIBITED FOR USE ON SLINGSBY T67 TYPE AIRCRAFT.*
>
> *WHEN TOWING WITH A VEHICLE THE DRIVER MUST HAVE A CLEAR VIEW OF THE TOW BAR TURN LIMITATIONS MARKINGS ON THE AIRCRAFTS COWLING.'*

The AIL also noted that:

> *'The limits for the nose wheel steering angle are marked on the lower engine cowling. Care should be taken (particularly when the aircraft is being towed by a vehicle) that the nose wheel angle does not exceed that shown.*

WARNING
EXCEEDING THE TOWING ANGLE LIMITATIONS MARKINGS CAN CAUSE DAMAGE TO THE RUDDER SYSTEM WHICH MAY CAUSE AN IN FLIGHT AIRWORTHINESS SITUATION AND POSSIBLE DEATH TO THE OCCUPANTS.'

In addition, the manufacturer re-issued a Service Bulletin (SB No 187, previously Issue 2 of 10 May 2007). This SB originally dealt with the correct installation and adjustment of the rudder/brake pedal mechanism, together with required inspections for damage and the presence of specified clearances for moving parts of the system. The SB re-issue (Issue 3 of 16 October 2007) added requirements, remarks and warnings concerning towing similar to those in the AIL.

European Aviation Safety Authority (EASA) had previously mandated incorporation of the SB by means of an Airworthiness Directive (AD 2007-0132, issued on 11 May 2007). This followed an incident where the pilot of a T67M260 aircraft (registration G-EFSM) had initially been unable to move the rudder pedals when attempting to recover from a spin (AAIB Bulletin 11/2007). Recovery from the spin had been delayed by an estimated two and a half turns. The Bulletin identified an excessive steering angle during towing as a possible cause of the problem. A recommendation was made (AAIB Safety Recommendation 2007-077) for the EASA to review the rudder pedal system of the Slingsby T67 aircraft, including consideration of requiring means to limit the loads applied to the rudder system during towing. The AD required some of the SB measures to be carried out before further flight and some within the next 50 flight hours and for checks to be repeated at intervals of 300 flight hours or 12 months, whichever occurred first.

The above action applied to the T67M260. Discussions indicated that the manufacturer had also re-issued SB No 188 at Issue 3 together with a further AIL to promulgate similar information relevant to the other T67 models.

Further measures aimed at reducing the possibility of damage to the rudder/brake pedal mechanism on all the T67 models had also been taken. These included the development of an improved towbar design, also with a load-limiting device, expected to be released to aircraft operators in early 2008. The manufacturer considered that it was impossible to overload the rudder mechanism when a Slingsby-approved towbar was used.

Modification to convert the nosewheel leg steering stops into the primary stops was considered to be impracticable and could have created difficulties in ensuring the required rudder travel, which is essential for effective spin recovery. The manufacturer had studied a scheme for incorporating a load-limiting device into the nosewheel steering rod in order to preclude the possibility of excessive loads being transmitted to the rudder/brake pedal mechanism. However, the manufacturer considered that the published warnings, to remain within the towbar turn limitations and to use only a Slingsby-approved towbar, would be sufficient to prevent recurrence of rudder mechanism damage.

EASA, in their response to AAIB Safety Recommendation 2007-077, considered the warnings in Issue 3 of SB Nos 187 and 188 and in the AILs to be adequate for preventing further damage to the rudder system during towing. The response noted that SACL had not agreed to implement an aircraft modification to prevent overloading of the rudder system whilst towing.

Discussion

The evidence was consistent with the failure of the rudder/brake pedal mechanism having resulted from overload generated by an excessive nosewheel steering angle during ground towing. Although positive evidence was not available, the manufacturer's researches strongly indicated that the damage had resulted from such an exceedence and it was concluded that this was the most likely cause of the failure.

Towing damage could weaken the rudder/brake pedal mechanism and/or distort it, thereby affecting the clearances of its moving parts from other components; in some areas these clearances are quite small. Such damage could apparently be caused inadvertently, without the towing crew being aware of the problem, and could well remain undetected for a considerable time.

Inadequate clearances, or a subsequent failure as a consequence of damage having weakened the mechanism, as apparently occurred in G-BYOB's case, could severely affect rudder and/or brake operation. In some situations the results would be potentially disastrous. A loss of wheelbraking could be hazardous and any compromise of rudder operation could have severe consequences, particularly as the aircraft type was extensively used for aerobatic flying, including spinning. In the case of G-EFSM's incident a foul of the pedal mechanism, possibly due to distortion caused by overload during towing, had seriously delayed spin recovery.

The design had provided the primary stops for the nosewheel steering system within the rudder/brake pedal mechanism in order to ensure that the accurate achievement of full rudder travel could not be compromised. However, locating the stops in the pedal mechanism, rather than on the nosewheel leg, appeared most unsatisfactory, given the relatively high forces that could be applied through a towbar. Modification to rectify this feature of the system appeared, to the manufacturer, to be impracticable.

It was likely that the manufacturer's specification for towing to be carried out using only a towbar with a load-limiting device and their further emphasis on not exceeding the allowable steering range would reduce the probability of damage. Nonetheless, the manufacturer is not in a position to enforce these prohibitions. It therefore does not seem practicable to ensure that only an approved towbar will always be used or that a vehicle driver will always be in a position to monitor reliably the orientation of a towbar relative to the limit markings. However, it does appear possible that a modification to incorporated a load-limiting element into the aircraft's nosewheel steering rod would eliminate the possibility of the pedal mechanism being vulnerable to inadvertent damage during towing. In view of this, the following Safety Recommendations are made.

Safety Recommendation 2008-006

It is recommended that the UK Civil Aviation Authority ensure that the prohibition by Slingsby Advanced Composites Ltd on using a non Slingsby-approved towbar with T67 aircraft, is made mandatory.

Safety Recommendation 2008-007

It is recommended that Slingsby Advanced Composites Ltd develop modifications for the T67 aircraft, aimed at eliminating the possibility that forces generated during ground towing could cause undetected damage to the rudder/brake pedal mechanism.

Safety Recommendation 2008-008

It is recommended that EASA require the development of modifications for the Slingsby Advanced Composites Ltd T67 aircraft, aimed at eliminating the possibility that forces generated during towing could cause undetected damage to the rudder/brake pedal mechanism.