ACCIDENTS INVESTIGATION BRANCH
Department of Trade and Industry

Brooklands Mosquito Mk II Gyroplane G-AVYW. Report on the Accident at Tees-Side Airport, Middleton St George, Co Durham on 9 March 1969

LONDON: HER MAJESTY'S STATIONERY OFFICE
1971

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Department of Trade and Industry
Accidents Investigation Branch
Shell Mex House
Strand
London WC2

4 November 1971

The Rt. Honourable John Davies MBE MP
Secretary of State for Trade and Industry

Sir,

I have the honour to submit the report by Mr G M Kelly on the circumstances of the accident to Brooklands Mosquito Mk II Gyroplane G–AVYW which occurred at Tees-Side Airport, Middleton St George, Co Durham on 9 March 1969.

I have the honour to be
Sir,
Your obedient Servant,

V A M HUNT
Chief Inspector of Accidents

Accidents Investigation Branch

Civil Accident Report No EW/C309

Aircraft:	Brooklands Mosquito Mk II Gyroplane G–AVYW
Engine:	Brooklands Aero
Owner and Registered Operator:	Ernest Brooks
Crew:	Pilot – Ernest Brooks – Killed
Passengers:	Nil
Place of Accident:	Tees-Side Airport, Middleton St George, Co Durham
Date and Time:	9 March 1969, at about 1424 hrs.
	All times in this report are GMT.

Summary

The aircraft went out of control in a zoom during a demonstration flight. The blades of the rotor disintegrated after striking the tail unit. No evidence was found of pilot incapacity or failure of the aircraft prior to its having gone out of control.

The report concludes that there is insufficient evidence to establish the cause of the accident, but considers it likely that instability of the rotor in the pitching plane at the high end of the speed range was a significant factor.

1. Investigation

1.1 History of the flight

The aircraft took off from the taxiway in the southwest corner of the airport at approximately 1408 hours to carry out a demonstration flight observed by four friends of the pilot, two of whom were interested in the commercial possibilities of the aircraft. The history of the flight has been derived from their recollections, in which there were a number of differences. They all agreed that between the take-off and the commencement of the fatal manoeuvre the pilot carried out his habitual programme which included:

(i) Shallow dives from 100 feet to about 4 feet from the ground, followed by low level high speed runs at speeds estimated at 70 to 80 mph, ending with a zoom to 100 feet ready for the next manoeuvre.

(ii) Low level slow flying about 5 feet above the ground at about 30 mph.

(iii) Flight at minimum speed at full power with the nose well up and the aircraft either stationary in relation to the ground, or going backwards with the wind.

They all agree that before the final manoeuvre the aircraft flew at minimum speed at 800 to 1,000 feet about 500 yards from where they were standing and that it then nosed over into a shallow dive apparently still under full power. They estimated that it dived down to a height of 150 to 200 feet and flew level at a speed of some 80 mph before pulling up into a steep zoom to 250 to 300 feet. One witness emphasised that the climb was 'tremendously steep'. At this point the descriptions diverge.

One witness, who had discussed looping with the pilot and had advised him never to attempt it, said that the aircraft carried on into a loop until it was almost inverted and that then there was a loud bang and pieces fell off. Two of the others thought the aircraft performed a partial bunt at the top of the climb and that the bang occurred at this point. One of these two said that towards the end of the bunt when the aircraft was almost vertically nose-down he could see the pilot in an upright position with his hand on the control column and his arm stretched out forward. It was generally agreed that the aircraft somersaulted out of control, and remained out of control until it crashed about 100 yards from where the witnesses were standing.

A fourth witness described the same sequence of events, including the partial bunt, but reported appreciably lower heights, slower speeds and a less violent zoom.

1.2 Injuries to persons

Injuries	*Crew*	*Passengers*	*Others*
Fatal	1	–	–
Non-fatal	–	–	–
None	–	–	–

1.3 Damage to aircraft

Extensive.

1.4 Other damage

None.

1.5 Crew information

Mr Ernest Brooks, aged 40, a motor engineer, learned to fly Austers in 1960 and then devoted his time to gyro aircraft. In 1962 he began flying a gyro-glider. Three years later he was flying a powered gyroplane and in 1968 he obtained a private pilot's licence for helicopters and gyroplanes. This licence was endorsed for single seat gyroplanes and carried a rating for the Brooklands Mosquito and a restricted flying instructor's rating for ultra light single seat gyroplanes. It was current at the time of the accident.

His total flying time amounted to 24 hours in fixed wing aircraft, 86 hours in gyrogliders and 161 hours in gyroplanes of which 43 hours 36 minutes were in G–AVYW. His flying time during the 28 days prior to the accident amounted to 1 hour 20 minutes, of which 30 minutes were on the day before the accident. The accident flight lasted 15 minutes.

In his capacity as an instructor Mr Brooks prepared a flight conversion syllabus for the Brooklands Mosquito in which he included the note 'Use full throttle at all times'.

1.6 Aircraft information

The Brooklands Mosquito gyroplane was an ultra light single seat aircraft developed by Mr Brooks from a Bensen gyroglider. The aircraft had a normal operating weight of approximately 200 kilograms and was intended for sale either as a complete aircraft or in kit form for amateur construction. It was of metal and fibre glass construction with a tricycle undercarriage, the nose wheel of which was steerable and fitted with a brake. A small solid tail wheel was also fitted. The single seater cockpit was partially enclosed and equipped with a conventional control column operating the rotor spindle tilt mechanism and rudder pedals interconnected with the nose wheel. Two levers located on the left side of the fuselage operated the throttle and the rotor pre-rotation mechanism. The instrument panel housed a compass, air speed indicator, altimeter and rotor speed tachometer. There was no radio. The aircraft had a fin and rudder, but no tail plane or elevators.

Propulsion was by means of a 50 inch diameter fixed pitch wooden two-bladed pusher propeller driven by a Brooklands aero engine, a converted 1600 cc Volkswagen motor car engine, mounted behind the pilot's seat above a 5 gallon fuel tank.

The aircraft was fitted with a 'spindle' type rotor head, and lift was provided by a freely rotating two bladed rotor 21 feet 4 inches in diameter. The blades were of wooden aerofoil section mounted on a tapered steel spar, and were fitted with balance weights and fixed trim tabs. They were attached to a light alloy hub fitted to the rotor spindle which allowed the rotor to tilt or 'teeter' independently within limits met by a teeter stop plate. Springs equivalent to a total load of 65 lb were incorporated in the control linkage to counter-balance the tendency of the rotor to tilt backwards under the influence of aerodynamic lift and drag. These springs were adjustable on the ground only and had been set to neutralise the load on the control column at the normal cruising speed of 50 mph.

On G–AVYW the rotor blades were of the standard used by Mr Brooks on his other gyrocopters but the rotor hub was unique and allowed a greater angle of teeter, having been designed for experimental and development purposes.

G–AVYW was constructed by Mr Brooks and registered in his name in 1967. It was first issued with a permit to fly on 24 January 1968, which was renewed on 24 January 1969 and was current at the time of the accident. This permit included a requirement that 'the aircraft shall not be flown unless it is in an adequate state of repair and in sound working order; any alterations, replacement or repairs which significantly affect the constructional features of the aircraft shall not be made'.

No record of flying times for G–AVYW have come to light, but, apart from an estimated 15 second flight in 1968 by one other pilot that ended in an accident it appears that Mr Brooks was the only person to fly the aircraft. The times recorded in his pilot's flying log book have therefore been used as an indication of flying times. They indicate that the aircraft had flown for a total of 43 hours 36 minutes and the engine for 29 hours 1 minute. The fuel used was ordinary 100 octane motor car spirit.

1.7 Meteorological information

The weather was fine with good visibility, the wind 030° at 8 knots and the temperature +3.5°C. There was no turbulence.

1.8 Aids to navigation

Not relevant.

1.9 Communications

None.

1.10 **Aerodrome and ground facilities**

The area being used by the gyrocopter was off the manoeuvring area about a mile from the air traffic control tower among a number of disused Nissen huts and aircraft dispersal points.

1.11 **Flight recorder**

Not fitted and not required to be fitted.

1.12 **Wreckage**

Inspection at the scene of the accident showed that the rotor and propeller blades had disintegrated. Two consecutive strikes of the rotor blades had cut through the fin and rudder and a third strike had caused the main fuselage member to fracture and the whole tail section to break off in flight. The wreckage sustained further damage when it hit the ground. The pilot's seat was torn from its mounting and bent backwards. Rescuers had unfastened the safety belt to release the pilot, but the anchorages were secure.

The spherical self-aligning rotor bearing was intact but its die-cast zinc alloy roller cage had failed. One of the arms of the pitch control fork had fractured through a brazed joint, as had the related side support bracket.

The modified hub, which was comparatively undamaged in the accident, was fitted to a similar aircraft and it was found that with the rotor stationary, the control column fully back and the rotor tilted to the aft limit on the teeter stop plate, the rear blade touched the side of the rudder approximately 3 inches below the top, but cleared the propeller blade tips by 1¼ inches. With a standard Brooks hub the blade cleared both the top of the rudder and the propeller tips by 3¼ inches.

1.13 **Fire**

There was no fire.

1.14 **Survival aspects**

Since the aircraft had fallen vertically from a height of some 250 feet it is considered that the accident was not survivable.

The airport fire service reached the scene almost immediately. The ambulance, in response to an emergency call on the post office telephone system arrived 18 minutes later.

1.15 Tests and research

1.15.1 *The fractured pitch control fork arm and associated side support bracket*

Laboratory examination of the fractured pitch control fork arm and side support bracket revealed that the breakages had occurred under conditions of considerable overload at brazed joints of poor quality; it was concluded that the fractures were secondary to some other failure.

1.15.2 *The failed rotor head spherical bearing*

Laboratory examination of the failed rotor head spherical bearing revealed rub marks between the rollers and the central ball, and in places a transference of metal from one to the other. This evidence is consistent with heavy loads at ground impact. There were also rub marks of a lighter nature on the central ball forming a distinct pattern. These marks were in three separate bands and from this evidence it was deduced that the bearing was subjected to three heavy loads while the rotor was still rotating and tilting before the aircraft struck the ground.

Five of the roller cage fingers had broken off and were loose in the mechanism. The fractures were due to reverse bending loads, but it was not possible to state the number of load reversals that took place before the fracture occurred. Comparison of the bearing from G—AVYW with other failed bearings of a similar type suggests that the failures occurred only a short time before ground impact.

1.16 Other information

1.16.1 *Handling and flying characteristics*

Mr Brooks had been developing the Brooklands Mosquito himself and he left no record of any assistance to the investigation. Therefore, since there appears to have been no formal test flight programme recorded for gyroplane aircraft, it has been necessary to refer to several other gyroplane pilot/constructors for information concerning research on the aircraft they have built for themselves and to seek from them their views on the general handling and flying characteristics of gyroplanes. Understandably in these circumstances there were differences of opinion, some of which could not entirely be resolved. Some questions relevant to the present investigation are set out below:

(a) Does a rotor with a spindle type head become unstable in pitch with changes in pitch attitude or speed of the aircraft?

The majority view is that instability sets in with increased speed.

(b) Does the amount of flexing in the rotor blades vary when the aircraft or rotor is subjected to varying 'g' loadings?

Most thought that the amount of flexing would be slight because the increasing rotor speed associated with increasing 'g' provides a compensating increase in centrifugal stiffness.

(c) What would be the effect of applying negative ‘g’ to the rotor blades or, more likely, the application of less than ‘1 g’ by harsh handling of the controls?

The majority view was the negative ‘g’ of any magnitude to the whole aircraft would be dangerous whilst some thought it impossible to apply negative ‘g’ to the rotor blades.

1.16.2 *The rotor head bearing*

The spherical rotor head bearing fitted to G–AVYW was a Shafer type A9R roller bearing. This is similar to the types A9 and A8 which had failed in other gyrogliders and gyroplanes in the United Kingdom. These bearings are known as ‘rod end bearings’, and are intended for use where large angular movements at slow speeds and light loadings are to be applied; in the drawings and instructions for the Bensen aircraft from which the Brooklands Mosquito gyrocopter was developed a BA-A8 bearing of aircraft quality is recommended.

2. Analysis and Conclusions

2.1 Analysis – The flight and the final manoeuvre

The accident occurred in excellent flying conditions when Mr Brooks was carrying out a demonstration in front of people who were interested in the aircraft's commercial prospects, one of whom had agreed to buy a major interest in his company. No doubt he was determined to demonstrate the aircraft to the full. However there seems to have been no recorded programme of flight testing of this type of aircraft and there is no reason to believe that he knew what the ultimate flight limitations of this particular aircraft were.

From the evidence of the witnesses it is apparent that each saw or remembered only parts of the aircraft's last manoeuvre and none was certain of the attitude and position of the aircraft when the accident occurred. On balance an evaluation of their evidence indicates that the aircraft zoomed steeply then bunted before somersaulting forwards and that at some point not precisely determined, the tail and the rotor came into contact with each other.

2.2 Factors that could be associated with the cause of the accident

Despite the lack of precise visual evidence, a reconstruction of the final manoeuvre outlined above was attempted since it gives some indication of a number of factors that could be associated with the causes of the accident.

(1) Loss of rotor stability in pitch associated with spindle type rotor heads.

(2) The design of the rotor head itself.

(3) The failure of the spherical rotor head bearing.

(4) The failure of control system components.

(5) Loss of control at the top of an attempted loop.

(6) Loss of control at the top of the zoom.

(7) The effect of changes of 'g' loading and attitude on the rotor disc.

These factors are discussed below.

2.2.1 *Loss of stability in pitch associated with spindle type rotor heads*

Gyrocopters fitted with spindle type rotor heads sometimes display an instability in pitch associated with changes in the pitch attitude and speed of the aircraft. Since the airflow through the rotor is upwards and rearwards aerodynamic drag makes the rotor tend to tip backwards, and this tendency has to be controlled and it is neutralised at a chosen speed by the tension of springs that can be adjusted on the ground. However as the speed increases beyond the chosen speed the rearward load on the control column increases and affects the pilot's ability to prevent the aircraft climbing or adopting an increasingly steep nose-up attitude.

Although it may be assumed that an experienced gyrocopter pilot is unlikely to be misled it must be borne in mind that at this time nothing is known about how far a pilot can safely allow the speed and consequent rearward stick load to increase without losing control.

Two possibilities suggest themselves as relevant to this accident. First, if the speed became excessive in the dive preceding the final zoom the control column load could have overcome the pilot's strength. The aircraft would then have gone of its own accord into a zoom. Second, the load on the control column could have exceeded the pilot's strength as soon as he eased the control column backwards to initiate the climb and the aircraft would then have gone into a far steeper zoom than the pilot intended. In this context it is worth noting that in his flight conversion syllabus for the Mosquito Mr Brooks advocated the use of full throttle at all times.

2.2.2 *The design of the rotor head itself*

The rotor head was an experimental one designed by Mr Brooks to give a greater range of tilt than the standard head. When the aircraft was on the ground the extra tilt eliminated the clearance between the rotor disc and the tail and much reduced the clearance between the rotor and propeller, so that with the rotor stationary and tilted fully aft the rotor blades touched the rudder 3 inches below the top. With the rotor turning, centrifugal and aerodynamic forces on the blades would have prevented this overlap occurring in flight unless some force brought about a change in the relationship between the rotor and the body of the aircraft. It is known that stops limiting the amount of tilt have not prevented rotors on other similar gyrocopters from striking the fin and it is therefore concluded that the extra latitude in tilt allowed in the Brooks design was unlikely to have been a factor in the accident.

2.2.3 *Failure of the spherical rotor head bearing*

The five 'fingers' of the roller cage in this bearing that were found to have broken off and became loose inside the bearing case could have caused the bearing to jam or seize, although it is more likely that any rollers released from constraint by the broken fingers would have twisted in the races and caused a far more serious jam. If this had happened before the accident, even momentarily, the resulting instability would have been transmitted to the rotor disc and magnified, producing a sudden and unexpected flapping of the rotor. At normal flying speeds a flapping rotor could lead to a loss of control. At very high speeds it could lead to collision between the rotor blades and the tail.

The damage to the central ball of the bearing is evidence of heavy loads consistent with ground impact and of three moderately heavy loads while the rotor was tilting consistent with the rotor blades having struck the tail and fuselage structure. The nature of the fractures of the fingers suggests that they occurred only a short time before impact with the ground and could therefore be related to the disturbance that caused the rotor blades to hit the tail. However, it cannot be determined with any degree of certainty from this evidence whether the cage failure led to the tilting of the rotor disc or whether some other circumstance promoted the tilting which in turn caused the cage to fail.

2.2.4 *Failure of control system components*

The fractures of the pitch control fork arm and the associated bracket could have led to a loss of control. There was no evidence of any other failure or malfunction of the control system revealed in the examination of the wreckage. However, laboratory examination of the fractures showed that they had failed as a result of overloading and the nature of the fractures indicated that they were secondary to some other failure and may well have occurred when the aircraft struck the ground. It is considered that they were therefore a result, not a cause, of the accident.

2.2.5 *Loss of control at the top of an attempted loop*

The pilot had discussed looping the aircraft with two of his associates and the resulting opinion had been that it was not a manoeuvre to be attempted. Several gyroplane pilots acquainted with Mr Brooks unanimously endorsed the view that he would not have attempted such a manoeuvre and his reputation and experience argue strongly against the likelihood that he would have done so, especially at such a low height. One witness was of the opinion that he was watching the commencement of a loop, but there is no other evidence to support this view. In essence it is an interpretation of the pilot's intention, since a zoom and the beginning of a loop would look the same. It is concluded therefore that Mr Brooks was not trying to loop the aircraft and it follows from this conclusion that an attempt to loop was not the cause of the accident.

2.2.6 *Loss of control at the top of the zoom*

Easing back the control column to tilt the rotor of a gyrocopter backwards normally results in the aircraft going into a simple climb, assuming that the power and speed are great enough. To zoom, a surplus of energy must be built up by diving. The potential danger is then that the aircraft could run out of momentum while it is still in the steep attitude of the zoom. In the extreme case the aircraft would become stationary and a reduced airflow through the rotor disc would lead to a loss of control.

It is not possible at this time to predict what would happen to the rotor or the body of the aircraft if the pilot inadvertently or by force of circumstances found himself in this predicament, but it is conceivable that the rotor would become unstable, control would be lost, and the rotor blades and body of the aircraft could come into collision while the aircraft was falling and before enough speed had been regained to re-establish the airflow through the rotor.

2.2.7 *The effect of changes of 'g' loading and attitude on the rotor disc*

As the aircraft pulled out of the shallow dive at high speed into the zoom and settled in the subsequent climb the rotor would have undergone a considerable and rapid variation in 'g' loading and attitude. The effect of such large and rapid variations is not at present known with any useful precision, but the possibility that an uncontrollable tilting of the disc or excessive flapping could have been brought about cannot be overlooked.

2.2.8 *Review of the part played by the factors described in 2.2.1 to 2.2.7*

Of the seven factors four could have played some part in causing the accident:

(1) Loss of stability in pitch associated with spindle type rotor heads (2.2.1).

(2) Failure of the spherical rotor head bearing (2.2.3).

(3) Loss of control at the top of the zoom (2.2.5).

(4) The effect of changes in 'g' loading and attitude on the behaviour of the rotor (2.2.7).

Instability of the disc is implicit in all these factors. The evidence indicates that the instability was mainly in the pitching plane.

2.3 While this investigation was in progress there have been three further accidents to gyroplanes in flight in which the rotor and the tail came into collision. No evidence so far has come to light to indicate the cause or causes of this phenomenon although it may be significant that in this case and in two other instances there was evidence that the aircraft was operating outside the normally accepted range of manoeuvre.

2.4 **Conclusions**

(a) *Findings*

(i) The pilot was properly licensed.

(ii) The aircraft had a valid permit to fly and had been properly maintained.

(iii) In the absence of a recorded flight test programme the limitations of the aircraft's performance were largely unknown.

(iv) The aircraft's final manoeuvre was not an attempt to loop.

(v) The spherical bearing in the rotor head was not of a suitable type.

(vi) The zoom at the end of a high speed run at low level, probably, as a result of the characteristics of the spindle type rotor head; was steeper than the pilot intended it to be.

(vii) During the zoom in the final manoeuvre the rotor became unstable and came into contact with the tail.

(b) *Cause*

The accident was due to a loss of control which resulted in the tail of the aircraft coming into contact with the rotor. There was insufficient evidence to establish the reason for the loss of control.

G M KELLY
Inspector of Accidents

Accidents Investigation Branch
Department of Trade and Industry
November 1971