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AIRCRAFT ACCIDENT INVESTIGATION REPORT

SHIZUOKA PREFECTURAL POLICE
AGUSTA A109K2(ROTORCRAFT), JA11PC
SHIMIZU-KU, SHIZUOKA CITY, SHIZUOKA PREFECTURE, JAPAN
MAY 3, 2005, AROUND 16:28 JST

April 27, 2007

Aircraft and Railway Accidents Investigation Commission
Ministry of Land, Infrastructure and Transport

The investigation for this report was conducted by Aircraft and Railway Accidents Investigation Commission, ARAIC, about the aircraft serious accident of SHIZUOKA PREFECTURAL POLICE AGUSTA A109K2 (ROTERCRAFT), JA11PC in accordance with Aircraft and Railway Accidents Investigation Commission Establishment Law and Annex 13 to the Convention of International Civil Aviation for the purpose of determining cause of the aircraft accident and contributing to the prevention of accidents and not for the purpose of blaming responsibility of the accident.

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Norihiro Goto,
Chairman,
Aircraft and Railway Accidents Investigation Commission

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MAY 3, 2005, AROUND 16:28 JST

March 28, 2007
Adopted by the Aircraft and Railway Accidents Investigation Commission
(Air Subcommittee Meeting)
Chairman Norihiro Goto
Member Yukio Kusuki
Member Shinsuke Endo
Member Noboru Toyooka
Member Yuki Shuto
Member Akiko Matsuo

1. PROCESS AND PROGRESS OF ACCIDENT INVESTIGATION

1.1 Summary of the accident

On May 3, 2005 (Tuesday, national holiday) around 16:28*[1] Japan Standard Time, an Agusta A109K2 helicopter, JA11PC, operated by Shizuoka Prefectural Police, crashed into a residential area in Kusanagi, Shimizu-ku, Shizuoka City, Shizuoka Prefecture during a road congestion survey flight.

All five persons on board the helicopter (Pilot in command (PIC) and four other persons) were fatally injured.

The aircraft was destroyed and a post-crash fire broke out.

1.2 Outline of the accident investigation

1.2.1 Investigative organization

The Aircraft and Railway Accidents Investigation Commission assigned on May 3, 2005 an investigator-in-charge and two other investigators for the accident. On May 18, 2005, the commission assigned an additional investigator.

1.2.2 Accredited representative and advisor from foreign state

An accredited representative (and technical advisors) of Italy as the state of design and manufacture of the accident helicopter, and an accredited representative (and technical advisors) of France as the state of design and manufacture of the engines installed on the helicopter, participated in the investigation.

1.2.3 Implementation of the investigation

May 4 and 5, 2005	On-site investigation, examination of the helicopter wreckage and interviews
May 17, 2005	On-site investigation and examination of the helicopter wreckage
May 18, 2005	Examination of the engines
June 8 and 9, 2005	Teardown examination of the transmission, main rotor (MR) control and MR head (carried out with cooperation from the Italian accident investigation authority (ANSV))
June 8, 2005	Teardown examination of the instruments (torque meter)
June 14 – 16, 2005	Teardown examination of the engines (carried out with cooperation from the French accident investigation authority (BEA)).
June 29, 2005	Examination of the helicopter wreckage and

*1: All times in this report are indicated in Japan Standard Time.

	interviews
Around September 19, 2005	Reproduction of the flight leading to the crash with a simulation (carried out at the designer and manufacturer of the accident helicopter, using a simulation of the same type helicopter)
October 27, 2005	Investigation of a helicopter of the same type
March 2, 2006	Examination of the helicopter wreckage and interviews
March 9, 2006	Interviews

1.2.4 Status Report

On May 26, 2006, ARAIC submitted a status report of investigation to the Minister of Land, Infrastructure and Transport based on the facts found up to that date.

1.2.5 Comment from party relevant to the cause of the accident

The comments were submitted from the parties concerned.

1.2.6 Comment from participating State

Comments were invited from the participating states.

2. FACTUAL INFORMATION

2.1 History of flight

On May 3, 2005, the Agusta A109K2 helicopter, JA11PC, ("Fuji No. 1" [named by the operator]; hereinafter the accident aircraft is referred to as "the aircraft") operated by Flying Squad, Community Police Affairs Division, Community Police Affairs Department, Shizuoka Prefectural Police Headquarters (hereinafter called "the flying squad"), took off from Shizuhama Aerodrome around 14:42 for road congestion survey, with five persons on board. The PIC took the flying-pilot's seat (right seat), one of the survey officers took the doctor's seat [mid cabin, rear facing], and other three took the rear seats.

According to the original plan, road congestion survey flight on that day was to be conducted using the "Fuji No. 2" [named by the operator] helicopter (Eurocopter AS365N3). However, because of the malfunction developed after the takeoff, it was brought back to the Aerodrome, and the survey team was transferred to the aircraft and took off again.

Summary of the aircraft's flight plan reported to Japan Air Self-Defense Force (JASDF) Shizuhama Control Unit was as follows.

Flight rules:	Visual flight rules
Departure point:	Shizuhama Aerodrome
Estimated off-block time:	14:45
Cruising speed:	120kt
Cruising altitude:	VFR
Route:	Hamamatsu → Shizuoka → Gotemba
Destination:	Shizuhama Aerodrome
Estimated time of arrival:	16:45
Purpose of flight:	Road traffic congestion survey
Fuel load in terms of endurance:	2 hours and 20 minutes
Number of persons on board:	Five

According to the communication record and other available information including the statements of the interviewed witnesses and persons concerned, the flight history of the aircraft up to the accident is outlined as below.

2.1.1 Statements by the pilot who was on board Fuji No. 2

On the day of the accident, I reported for duty at 07:55 and then performed a communication test of police radio and pre-flight check of Fuji No. 2.

The PIC, the chief of the flying squad, reported for duty around 08:00.

Around 12:15, I submitted a flight plan of Fuji No. 2.

At 13:20, four officers of the Traffic Regulation Division of Headquarters arrived at the office and received a pre-flight briefing from the PIC. Flight for the day had been planned to cover the eastern area of the prefecture, but they asked to include congestion survey on the Tomei Expressway in Hamamatsu area [western area]. By order of the PIC I changed the flight plan accordingly.

Around 13:45, we boarded Fuji No. 2 and took off at 14:00. At 14:10, near the Makinohara Service Area [of the Tomei Express way], the helicopter developed a malfunction. We turned back to the Aerodrome (landing time: 14:15). While on board Fuji No. 2, the PIC told me and a mechanic to switch to the aircraft.

As the maximum gross weight of the aircraft was lighter than that of Fuji No. 2, the PIC ordered a mechanic and a pilot (me) to get off, meaning that the PIC and the four officers from the Traffic Regulation Division would be aboard the aircraft. When I returned to the office, I saw the PIC talking on the telephone. I thought that he was filing the aircraft's flight plan. After that, the PIC asked me to log the pre-flight engine run, and the PIC, the four Traffic Regulation Division officers and I went to the aircraft together. The PIC performed an exterior check. After that, the PIC and I took the pilots' seats, started the engines at 14:33, checked the instruments and logged the record. Since the records were barely different from those of the previous run, I reported [to the PIC] "No anomalies exist." and got out of the aircraft at 14:38.

The aircraft took off at 14:42. After seeing the aircraft off, I stayed in the office and logged the position reports from the aircraft [as follows]. I think that the times in the log should be almost accurate as I checked the clock each time I logged.

15:12: Proceding east over Iwata.

16:10: 1,500ft over Numazu. Operations normal.

16:25: Over Shimizu. Landing soon.

I recognized the PIC's voice on all these reports to be as usual with no indication of abnormality.

Position reports are usually made every half hour. Before landing, pilots usually radio saying "Will arrive soon" or "Landing soon" to have ground personnel prepare for landing.

The traffic pattern altitude of Shizuhama Aerodrome is 1,000ft. However, considering noise abatement, there is an agreement to maintain around 1,500ft up to about five nautical mile radius of the Aerodrome before descent. At the time of position report over Shimizu, I thought that nothing was unusual.

Between 16:30 and 16:33, by monitoring the police radio I learned a helicopter accident. I tried to reach the aircraft by the police aviation radio but in vain.

2.1.2 Fuel on board

According to the statement by a mechanic of the flying squad, the aircraft's fuel on board was 462kg (fully loaded in the left hand (LH) and right hand (RH) main fuel tanks and the supplementary fuel tank) with no fuel load in the auxiliary fuel tank.

2.1.3 Flight route, altitude and speed

The aircraft's estimated flight route was generated based on radar records of Hamamatsu Aerodrome, records of the radio communications regarding road traffic conditions, record of the PIC's position reports, and digital photos taken by a person on board. In addition, many witness statements were obtained for a period of approximately three minutes until the crash. By cross-referencing these pieces of information, the aircraft's flight route, flight altitude and flying speed were summarized below.

(1) Flight from takeoff to Shimizu-ku [ward]

After taking off from Shizuhama Aerodrome, the aircraft flew westward along the Tomei Expressway and National Route 1 to the vicinity of Hamamatsu City. The aircraft then flew eastward via Shizuoka City and Fuji City, and flew northward to Gotemba area. The aircraft then flew southward via Numazu City and Fuji City, and flew along the coastline to Shimizu-ku ward.

Aerial photos taken with the digital camera showed that they were taken from a height of 1,000 – 1,500ft (above ground level), but those photos taken after passing Fuji City to a point just before entering Shimizu-ku ward show a height of 1,000ft or below. Also, by connecting the positions fixed by those photos, the aircraft's ground speed along the estimated flight route (covering approximately 195nm from the takeoff to the crash site) was determined to be approximately 110kt.

The last photo was taken at 16:23:26, approximately five minutes before the crash.

(2) Flight from approximately 6km before the crash site (approximately three minutes before the crash) to approximately 500m before the crash site

The PIC made a position report using onboard radio to the flying squad at 16:25, and a person on board reported road traffic conditions over the police radio at 16:26:33. They were the last radio transmissions from the aircraft. Neither of them showed any difference from usual communications.

There were many pieces of witness information along the estimated flight route from Shimizu-ku ward to the crash site being summarized as below. There was no information of any other aircraft flying near the estimated route on the day of the accident.

a. In an area around 10km northeast of the crash site, there were many witnesses stating that a helicopter was flying southwest in normal manner, however, at a significantly lower altitude than that of helicopters usually seen flying. In an area around 5km away from the crash site, there was a witness stating that a helicopter was flying so low that it looked as wide as the width of human shoulders and it was frightening.

b. In an area around 3.5km northeast of the crash site, at a point approximately 500m northwest from the southwesterly route flown before, there was a witness statement of meandering flight that a helicopter flew overhead toward southeast at low altitude, and then it flew from east to west at low altitude when the witness was seeing south-southeast.

c. Multiple witness statements were obtained in the hilly area on the east side of the crash site on the aircraft conditions immediately prior to the crash. Seeing from this hilly area, Mt. Kajiwarayama (elevation 304.3m) stands in the north with an urban area of Shimizu-ku in between, the witnesses described the flight altitude in terms of relative positions to the mountain. Statements were summarized as follows. The witnesses had been accustomed to see helicopters flying higher than the mountain, but on that day they saw a helicopter flying horizontally at the foot of the mountain. Its altitude was approximately 300ft over a distance of approximately 700m (from the point approximately 1,200m from the crash site to the point where the sound of the helicopter changed (approximately 500m away from the crash site). None of the witnesses noticed anything abnormal about the helicopter except the lower altitude. Subsequently, as the helicopter neared Shimizu 7th Junior High School, its sound changed, the engines went silent, something fell apart, the MR rotation slowed down, and the helicopter pitched down and crashed.

(3) Flight from the point approximately 500m away from the crash site to the crash site (all distances below are measured from the crash site)

Many pieces of information about the aircraft provided by witnesses are summarized as below.

a. At the point approximately 500m away from the crash site, flying altitude was approximately 300ft.

b. In the area mentioned in a. above, sound of the aircraft changed and went silent.

c. At the point approximately 150m away from the crash site, something fell away from the aircraft.

d. In the area mentioned in c. above, the aircraft was silent with the MR blades almost stationary.

e. At approximately 100m, the aircraft's attitude changed greatly into a nose-down attitude.

f. The change of altitude from a. to e. was 10 – 20m.

g. In the area mentioned in e. above, the aircraft's course changed to the left.

The accident site is a flat area located between an apartment house and the Kusanagi River near Kusanagi, Shimizu-ku, Shizuoka City, Shizuoka Prefecture. The time of the accident was around 16:28.

(See Figures 1 and 2 and Photos 1, 2 and 3.)

2.2 Injury to persons

The PIC and all of four persons on board, in total five persons, were fatally injured.

2.3 Damage to aircraft

2.3.1 Extent of damage and fire

The aircraft was destroyed and a post-crash fire broke out.

2.3.2 Damage to each part of Aircraft

Fuselage	Destroyed and burned out
Tail boom	Aft section was fractured.
MR blades	Destroyed and burned

Tail rotor (TR) blades	Damaged
LH engine	Damaged and burned
RH engine	Damaged
Transmission	Damaged and burned

2.4 Damage information on property

A part of the eave of a two-story apartment house, adjacent to the crash site was damaged. A minicar parked in front of the apartment house was damaged by its front section.

(See Photo 1.)

2.5 Crew information

(1) PIC Male (59 years old)

Commercial pilot certificate (rotorcraft)	June 18, 1981
Rating: multi- engine - turbine aircraft (land)	June 18, 1981
1st class aviation medical certificate	
Valid until	July 11, 2005
Total flight time	9,101 hours and 10 minutes
Flight time in the last 30 days	31 hours and 40 minutes
Flight time on the same type as the aircraft	398 hours and 10 minutes
Flight time in the last 30 days	7 hours and 25 minutes

(2) PIC's experience on type aircraft and other related information

In December 2000, the PIC and another pilot of the flying squad received flight training in Italy on the type aircraft. In 2001, the aircraft was delivered to the flying squad and the PIC and the pilot carried out its operational test. Subsequently, the PIC, as an instructor, conducted type transfer training for other pilots.

2.6 Aircraft information

2.6.1 Aircraft

Type	Agusta A109K2
Serial number	10038
Date of manufacture	December 4, 2000
Certificate of airworthiness	No. DAI-16-511
Valid until	December 21, 2005
Airworthiness Category	Rotorcraft Normal (N) or Special Aircraft (X)
Total time in service	1,327 hours and 25 minutes
Time since last periodical check	
(100-hour check conducted April 15, 2005)	36 hours and 05 minutes

(See Figure 4.)

2.6.2 Engine

(1) LH engine

Type	Turbomeca Arriel 1K1
Serial number	16086
Date of manufacture	March 4, 2000
Total time in service	1,327 hours and 25 minutes
Time since last periodical check (100-hour check conducted April 15, 2005)	36 hours and 05 minutes

(2) RH engine

Type	Turbomeca Arriel 1K1
Serial number	16085
Date of manufacture	March 4, 2000
Total time in service	1,327 hours and 25 minutes
Time since last periodical check (100-hour check conducted April 15, 2005)	36 hours and 05 minutes

2.6.3 Weight and balance

At the time of the accident, the weight of the aircraft was estimated to be 2,536kg, and the center of gravity (CG) was estimated to be at 340.3cm longitudinally and 4.3cm laterally (right). Both the weight and CG were estimated to be within the allowable limits (maximum gross weight: 2,850kg, CG corresponding to aircraft's weight at the time of the accident: 328.0 – 350.0cm longitudinally and 7.2cm left – 7.2cm right laterally).

The above estimation was based on the off-block weight of 2,938kg. With the assumption of before-takeoff fuel consumption to be 30kg maximum, the aircraft takeoff weight would have been 2,908kg, meaning the aircraft took off exceeding the maximum gross weight by 58kg.

2.6.4 Fuel and lubrication

The aircraft used aviation fuel Jet A-1 as the fuel and Mobile Jet Oil 254 as the lubricating oil.

2.7 Meteorological information

Weather data provided by the Shimizu Meteorological Observatory (located about 10km northeast of the crash site) for the period corresponding to the accident time was as follows:

16:00 Wind: east-southeast at 1 m/s;
Temperature: 20.6°C; Hours of sunshine: 0.5 hours

17:00 Wind: east-southeast at 1 m/s;
Temperature: 20.5°C; Hours of sunshine: 0.8 hours

2.8 Information on Communications

The aircraft's radio transmissions were carried out as usual with the Shizuhama Aerodrome Control and Hamamatsu Terminal Control. Radio transmissions with the flying squad and road traffic congestion survey were also carried out normally.

2.9 Accident Site and Wreckage Information

2.9.1 Accident site

The accident site is located in the residential area of Kusanagi, Shimizu-ku, Shizuoka City, Shizuoka Prefecture, and is a flat area used as a parking lot and a road, sandwiched by the apartment house and the Kusanagi River.

The aircraft rested on its left side with its nose orienting to southwest. The cockpit was jammed into a road fence [on the edge of the river embankment].

The fuselage was destroyed and nearly burned out. All four MR blades were broken but still connected to the MR head. The tail boom was fractured in the middle. The forward half of the tail boom was folded forward onto the fuselage and the rear half was found on the riverbed several meters below with the TR blades still attached. There were traces of leaked fuel on the embankment.

(See Photos 1,2 and 3.)

2.9.2 Location of retrieved major components

A lot of fragmented plastic and metal parts were retrieved from the area along the flight route leading to the crash site. The area extended approximately 140m to the north and approximately 50m to the south of the crash site. The locations of retrieved major components are as follows (with reference to the crash site).

(1) Bolt fragments (oil reservoir retaining bolt)
Approximately 140m north.

(2) Two pieces of metal fragments (portions of oil reservoir)
Approximately 125m north.

(3) Damper rod
Approximately 75m northwest.

(4) Fragments of the flap-hinge-side upper flap stop
Approximately 75m north-northwest.

(5) Two lead-lag dampers
Approximately 15m southwest and approximately 35m west-southwest.
(See Figure 2 and Photos 6 and 7.)

2.9.3 Details of damage

The extent of damage to the aircraft's major components is outlined as follows.

(1) Fuselage

Most of the fuselage was burned out except for engines on the upper side and aft fuselage. Fuel tanks were also burned out.

(2) Tail boom

The tail boom was fractured at mid section. The forward half was attached to the rear of the fuselage but folded to the direction of upper ceiling of the fuselage, which rested on its side.

The separated aft half remained with the elevator and the TR blades still attached.

The TR drive shaft was fractured at the same point of the tail boom fracture, but there were no signs indicating fracture during rotation (twisting).

(3) MR blades

The four MR blades (grip, metal spar and tip cap) were attached to the MR head with each grip. Leading edge of the blades (metal spar forming the leading edge of airfoil) had no traces of abrasion. One tip cap had contact damage.

(4) TR blades

One of the two blades had no major damage but the other was crushed towards the root like a bellows. Neither of blades showed any trace of collision while turning.

(5) Engines

The surface of the LH engine was discolored into black by fire. No fire-caused discoloration was found on the RH engine. Both engines retained their almost original shape but drive shafts were not rotated by hand. The gearbox of the LH engine, which was at the bottom when the aircraft crashed, had cracks.

(6) Transmission

The entire transmission was damaged by fire.

Casing of the coupling gearbox was burned out, and its internal parts, such as steel bearings and gears, scattered around. The gears were scorched black but had no cracks, chips, wear or deformation.

Upper casing of the transmission was partially missing, exposing the gears and other internal parts.

The joint connecting the coupling gearbox and the transmission drive shaft, which transmits torque from the engines to the transmission, was fractured but had no traces of twisting and the surface of the shaft had no traces of rotational damage.

(7) MR head

All four upper flap stops on the MR hub were damaged.

Two of the four lead-lag dampers still remained attached to the MR head. Three of the damper rods of the lead-lag dampers remained attached to the MR head.

(8) TR gearbox

TR gearbox showed no damage. The electric type magnetic plug was free of metal fragments and the like. There were no anomalies inside the gearbox. The gears rotated freely.

(9) Flight controls

The collective pitch lever and other flight control system parts were broken, burned out, or damaged by fire.

(See Figure 6 and Photo 5.)

2.9.4 The conditions inside the cockpit including the position of the typical controls such as switches and levers, were as follows:

Instruments	Damaged by fire

[The torque meter, because of its readable condition, underwent teardown examination.]

Circuit breaker panel	Damaged by fire
Autopilot control panel	Damaged by fire
Annunciator panel	Damaged by fire
Power levers	Broken (both levers).

[Each power lever assembly has sectors with detents to retain the power lever in the OFF, IDLE, FLIGHT or EMERGENCY positions. The power lever consists of a clevis and a handle. The clevis is located between the sectors, and its opposite end of pivot is connected to the engine by cable. On the root of the handle, protrudes a projection that engages a detent of the sectors to prevent the power lever from moving inadvertently. Of the LH and RH power levers, only the clevises remained and the handles were fractured off. The LH clevis was found in OFF position while the RH clevis was found beyond OFF position. There were dents on the parts flanking each handle; plate and separator. The dent corresponding to the LH handle was on the plate somewhere between FLIGHT and IDLE positions (closer to IDLE position). The dent corresponding to the RH handle was on the separator very close to FLIGHT position.]

(See Figure 6 and Photo 4.)

Rotor brake lever		OFF
Fuel pump switches	PUMP 1	ON
	PUMP 3	ON
	PUMP 2	ON
	PUMP 4	Missing
Fuel valve switches	LH	ON
	RH	Missing
Cross-feed switch		OPEN

2.9.5 Conditions of fuel supply system's major equipments and battery were as follows.

LH fuel valve	OPEN
RH fuel valve	OPEN
Cross feed valve	OPEN
Battery	Dislocated

(See Photo 2.)

2.10 Search and rescue

Officers from the Shimizu Fire Station of Shizuoka City and the Shimizu Police

Station of Shizuoka Prefecture arrived at the accident site and transferred the five persons on board to the Shimizu Police Station. Designated doctors for Shizuoka Prefectural Police confirmed the decease of all five.

2.11 Autopsy

According to Shizuoka Prefectural Police Headquarters, on May 6, 2005, judicial autopsy was performed on the PIC at Forensic Medicine Laboratory, Medical Department, Tokai University. It was reported that cause of the PIC's decease was not specifically contradictory to crush of whole body due to the crash, but does not exclude the other possibilities such as pathological attack. It was also reported that PIC was tested negative for alcohol and drug substances.

After the judicial autopsy, examination was conducted on heart and brain tissue with the result stating that "No positive lesions could not be found.".

2.12 Fire and firefighting

2.12.1 The summary of firefighters' statements

Responding to a 119 call, firefighters from the Shimizu Fire Station of Shizuoka City arrived at the scene at 16:41 and fought the fire. The fire was extinguished at 16:58.

A total of 30 absorbent mats were used to collect oil that had flowed into the Kusanagi River.

2.12.2 Photos of the accident aircraft after the crash, taken with a digital camera by a witness near the accident site, show chronicle of the fire breakout approximately 3 to 4 minutes after the crash.

16:30 Smoke was seen coming out from the engine area. No flame was visible. Fuel was trickling down embankment of the Kusanagi River.

16:31 Small flame was visible in the engine area.

16:31 Flame erupted from inside the fuselage.

16:32 Flame engulfed the entire fuselage.

16:37 Flame subsided, but still visible on the fuselage and on the riverbed.

(See Photos 1 and 2.)

2.13 Fact-finding tests and research

2.13.1 Teardown examination of the engines

Both engines of the aircraft underwent teardown examination at the company that designed and manufactured the engines. The examination was conducted from June 14 through 16, 2005 with witness of a BEA investigator.

Result of the teardown examination was as follows:

(1) LH engine

On the rotating parts and their circumferences of the gas generator and the power turbine, deformation and dents were found, but there were no marks indicating damage during rotation, which indicates that the engine was stopped when the aircraft crashed.

No anomalies were confirmed on the engine and its accessories that would have occurred before the crash.

As to the fuel control unit (FCU), a part of the unit was found detached from the engine, and no fuel was found in it. Fuel filter in the FCU was damaged by fire.

(2) RH engine

On the rotating parts and their circumferences of the gas generator and the power turbine, deformation and dents were found, and damages without heat-discoloration were found on the gas generator, indicating that at the time of the crash the gas generator was rotating at low speed but generating no power.

No anomalies were confirmed on the engine and its accessories that would have occurred before the crash.

FCU was found separated from the engine, and some fuel was found remaining in the unit. Fuel filter in the FCU was clean.

2.13.2 Teardown examination of transmission, MR control and MR head

The transmission, MR control and MR head underwent teardown examination at the company that designed and manufactured the aircraft (hereinafter referred to as "aircraft manufacturer"). The examination was conducted on June 8 and 9, 2005, with witness of an ANSV investigator.

Result of the teardown examination was as follows, and no damage was confirmed on these parts that would have occurred before the crash.

Inspection of the fracture surfaces of the broken parts (attachment bolts, rod ends, and others) using a scanning electron microscope (SEM) resulted in no marks of fatigue fracture.

Rotating parts of the transmission could be rotated freely except for seizure by deformed accessory drive gears. MR control and MR head parts were damaged by overload. Attachment parts of the MR blades, such as flap hinges and lead-lag hinges, moved freely. The MR cover was deformed due to contact with the MR blade attachment (flap hinges), and upper flap stops of both the MR head and the flap hinges were damaged.

(See Figure 6 and Photo 5.)

2.13.3 Flight simulation

Using a simulation of the type aircraft, the relationship between control inputs and MR blades' dynamic behavior after both engines power loss was examined at the aircraft manufacturer. The results are as follows.

Conditions

Gross weight	2,500kg
CG	330.0cm

Pressure altitude	1,500ft
Outside air temperature	25°C
Speed	120kt, level flight

(1) The case where flight controls were fixed at the position of both engines power loss.

After the loss of both engines power, the MR speed of rotation (rpm) gradually dropped. With the drop of MR rpm, flapping*2 and lead-lag*2 of MR blades increased. Approximately seven to eight seconds after the loss of both engines power, flapping and lead-lag started to exceed the allowable limits. The MR rpm at that time registered approximately 60%*3.

(2) The case where collective pitch lever was pulled up after both engines lost power

After the loss of both engines power, the MR rpm dropped rapidly. The MR blades' flapping and lead-lag increased rapidly. And approximately four seconds after the loss of both engines power flapping and lead-lag started to exceed the allowable limits. The MR rpm at that time registered approximately 40%.

(See Figure 3.)

2.13.4 Teardown examination of the torque meter

As the retrieved torque meter showed readable indication, teardown examination was performed at an aircraft instrument maintenance service provider.

The torque meter readings were approximately 5%*4 for LH engine, approximately 8% for RH engine, and approximately 13% for total torque.

The maintenance service provider reported as a result of the examination that it was unlikely that the needles of the meter had been deflected by mechanical impact and that the readings correctly represented signals that the meter had received.

2.14 PIC's medical history and flight training, and flight practice of the Flying Squad

2.14.1 Medical history of the PIC

In 2004, the PIC underwent a comprehensive medical examination and was diagnosed as having slightly higher-than-normal values for hyperlipemia and hyperuricemia.

For these two conditions, the PIC had been seeing a doctor since 1995. The PIC had been diagnosed as constitutional disposition, and had been taking prescribed preventive medication once after every evening meal.

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*2: Flapping means MR blade vertical movement around the axis of the blade attachment (flapping hinge).

*3: Lead-lag means fore-and-aft movement of MR blades on the blade rotation plane around the blade attachment (lead-lag hinges).

*4: MR rpm is indicated in percentage on the instrument of MR rotation. 100% corresponds to 384rpm, which is the maximum speed of rotation.

*5: Engine power is indicated in percentage on the torque meter. A reading of 100% corresponds to maximum continuous power (1,68Nm) with both engines operating.

Since May 2003, in order to relax and ease difficulty in falling asleep, the PIC had been prescribed one tablet of medication at a time, which was a smaller dose than normal. However, the medication was terminated in November 2003 by the PIC's request.

2.14.2 By cross-referencing the statements of the flying squad's pilots and mechanics, the PIC's training proficiency and flight practice of the flying squad are summarized as follows.

(1) The PIC was relatively cautious when piloting and was strict during training.

(2) As to the autorotation[*6] training as a means of emergency procedures, it was planned and conducted for each pilot, including the PIC, at least once every month. As the flying squad had three kinds of helicopters, autorotation practice using the aircraft was sometimes carried out only once per three months.

(3) The PIC received autorotation full landing (autorotation landing procedure up to touchdown without using engine power) training on the type aircraft in Italy. After the flying squad introduced the aircraft, the PIC intended to provide autorotation full landing training to other pilots, but he decided to abandon this plan because he was not confident to take over the controls at the moment of touchdown.

(4) The PIC, who had been operating large-sized aircraft, had a tendency to move the controls rather liberally, but not in a manner of rough maneuvering.

(5) The flying squad had established "The Flight Safety Standards" per the internal police directive concerning aircraft operations. The standards stipulate that "The operation manager shall be responsible for crew assignments" and that "The crew shall in principle consist of a PIC and another pilot who is qualified for PIC duties." However, in emergencies or when needed to fly all three helicopters at the same time, there were cases where just one pilot flew a helicopter.

For all three helicopters owned by the flying squad, the minimum required number of crew is one pilot.

(6) In five years since the introduction of the aircraft into the flying squad, there had been only two cases where FUEL LOW caution light illuminated during mission flights. One of the two occasions occurred when the aircraft was still under operational test just after the introduction. In both cases, flight phases were immediately prior to landing. The flying squad had so far conducted operation with ample fuel remaining.

(7) On normal missions, flying speed is approximately 100kt and flying altitude is 1,000 – 2,500ft. However, a helicopter may fly at slower speed and lower altitude to check situation if its crew discovers or is informed of a crime or an accident while in flight. But on the day of the crash there were no occurrences or reports of crime or accident in Shimizu-ku

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*6: Autorotation is a flight condition of a helicopter in case of engine stall. Lift is obtained from the action of the air driving the MR blades (wind-milling) during descent. TR blades and accessories are driven by the rotation of MR blades, making it possible to land safely.
If the collective pitch lever is held in position of the engine stall, MR rpm will decay rapidly and the lift is lost. Immediate push down of the collective pitch lever is indispensable to enter autorotative stage and maintain the MR rpm within the operating limit.

ward or in its vicinity.

(8) There had been no significant difference in fuel consumption between LH and RH engines of the aircraft, meaning no significant difference in indicated fuel level between LH and RH fuel tanks.

(9) Shizuoka Heliport is located approximately four kilometers northwest, and Miho airstrip is located approximately eight kilometers east-northeast of the crash site. Takeoffs and landings were frequently performed at these locations. Refueling were possible there.

2.14.3 The "Rules on Police Aircraft Operations" (National Police Commission regulations) requires that "The chief officer responsible for aircraft operation shall assign the PIC." and "If the chief of the flying squad is an airman, such chief shall also be able to hold the post of chief officer responsible for aircraft operation."

In the flying squad, the chief of the flying squad held the post of the chief officer responsible for aircraft operations and was the PIC of the flight involved in the accident.

2.15 Other relevant information

2.15.1 Outline of the aircraft fuel supply system

(1) Fuel tanks

Fuel tanks consist of elastic cells made of rubber-coated fabric.

a. Each of LH and RH main fuel tank consists of a front cell and a rear cell. Each main tank has a usable capacity of 181.5kg (with unusable capacity of 4.5kg). Fuel filler is located on the RH rear cell. The LH and RH fuel tanks are connected by a hose that run between the lower part of the rear cells. Rear cells are located at higher level than the front cells in order to equalize the amount of fuel between LH and RH main fuel tanks.

b. In addition to the standard LH and RH main fuel tanks, the aircraft was also equipped with a supplementary fuel tank and an auxiliary fuel tank.

The supplementary fuel tank consists of a single cell with usable capacity of 99kg (127ℓ) (unusable capacity of 0.0kg). It is located above the front cell of the RH main fuel tank and is connected to the upper part of the front cell.

The auxiliary fuel tank consists of three cells with usable capacity of 120kg (150ℓ) (unusable capacity of 2.4kg). The auxiliary fuel tank was not loaded at the time of the accident.

Unless otherwise indicated, all fuel load values [in the following part of this report] mean usable fuel quantities and do not include unusable quantities.

(2) Fuel pumps

The aircraft is equipped with a total of four fuel pumps, two each in the front cells of LH and RH main fuel tanks to supply the engines with fuel. These pumps are driven by electric motors, and on-off control of each motor is possible by fuel pump switches in the cockpit. These pumps are normally kept activated during flight. Check valves are installed at the outlets of the fuel pumps to prevent fuel movement between the LH and RH fuel tanks while the cross-feed valve is in the "open" position and to enable the engine-side fuel pumps to suction-feed the fuel in the event of inoperative fuel pumps.

(3) Fuel supply system valves

A fuel valve is installed in the fuel supply line between each main fuel tank and the corresponding engine. Both fuel valves are driven by electric motors and are opened/closed independently by the fuel valve switches in the cockpit. The valves are normally kept open during flight.

The LH and RH fuel supply lines are connected each other with a single cross-feed valve. The cross-feed valve is driven by an electric motor and its opening/closing operation is controlled by the cross-feed switch in the cockpit. The valve is normally kept closed during flight.

The above-mentioned three valves are of the type with a spherical shutter, which is rotated 90° by an electric motor to open/close the fuel passage, and it takes approximately 0.5 to 1.0 second to activate the shutter. The design does not allow the easy rotation of shutter by external shocks. While electric power is being supplied, these valves are controlled by the switches in the cockpit. When power supply is interrupted, the valves maintain their position at the moment of power interruption irrespective of the position of the cockpit switches.

(4) Use of cross-feed valve

In normal aircraft operations, the cross-feed valve is kept closed except for the following situations in which it is opened.

a. The case where fuel is supplied from one fuel tank to both engines

Under dual-engine operating conditions, the cross-feed valve is opened to eliminate the difference in the quantity of remaining fuel between the LH and RH main fuel tanks or when the main fuel tank on one side is empty. In these cases, the fuel pumps for the tank with less remaining fuel or for the empty tank are turned off.

b. The case where fuel is supplied from one fuel tank to the opposite side engine

Under single-engine operating conditions, the cross-feed valve is opened to eliminate the difference in the quantity of remaining fuel between the LH and RH main fuel tanks by supplying fuel from the tank on the inoperative engine side to the operating engine. In this case, the fuel pumps of the fuel tank from which fuel supply is to be interrupted are turned off.

(See Figure 5.)

2.15.2 The Flight Manual of the aircraft

The Flight Manual of the aircraft specifies the minimum crew and provides the procedures to follow in the event of fuel system or engine failure. The following are excerpts from the manual.

Chapter 2 Limitations

2-5 Number of persons on board

The minimum flight crew consists of one pilot, [who shall operate the helicopter from the right crew seat.]

Chapter 3　Emergency Procedures

3-3　Warning Systems

CAUTION lights (amber)

Panel annunciation	*Failure*	*Procedure*
FUEL PUMP 1 (3)	*Fuel pump in tank 1 failed*	*Affected fuel pump OFF.*
FUEL PUMP 2 (4)	*Fuel pump in tank 2 failed*	*Affected fuel pump OFF.*
#1 (#2) FUEL LOW	*Remaining fuel is low.*	*When each engine is drawing fuel from corresponding tank, the remaining flight duration is approximately 15 minutes from caution light illumination. When both engines are drawing fuel from one tank, the remaining flight duration is approximately 6 minutes from caution light illumination.*

2.15.3　Fuel consumption of the aircraft

(1) Operational test of the aircraft

Upon introduction of the aircraft by the flying squad, the PIC conducted an operational test of the aircraft with a pilot who had accompanied him to Italy.　The following is an excerpt from the operational test report.

Operational test results of the A109K2 helicopter:

1 – 3　(Skipped.)

4.　Specifics

(1) – (3)　(Skipped.)

(4)　Verified endurance and other information with maximum fuel load

i.　(Skipped.)

*ii.　Fuel load:　582kg in total including 462kg in the main tanks[*7] and 120kg in the extra tank[*8]*

iii.　Flight time versus fuel consumption (when maintaining a speed of 120kt)

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*7: Sum of the fuel quantity of LH and RH main fuel tanks and supplementary tank

*8: Quantity of fuel in the auxiliary tank.

(Table skipped.)

iv. Endurance at 120kt is 2 hours + 15 minutes(by reserve fuel)
Flight exceeding 120kt merits no advantage, on the contrary only fuel consumption increases.
(Skipped.)

The table under 4 (4) iii above provides records of fuel gauge readings associated with the elapsed times. From the records, the estimated rate of fuel consumption was 233kg/h.

(2) According to the aircraft fuel consumption rate data logged by the flying squad, the average fuel consumption rate for all missions in April 2005 was approximately 200kg/h. Patrol missions including traffic and crime overwatching marked approximately 207kg/h, the highest average fuel consumption rate, compared with the rates in other missions including training flights (191kg/h). The flying squad uses a fuel consumption rate of approximately 200kg/h for flight plan, and a fuel load of 462kg corresponds to 2 hours and 20 minutes as expressed in endurance.

The flying squad calculates that 30kg of fuel is consumed from engine start to takeoff at Shizuhama Aerodrome.

(3) According to the CRUISE CHARTS in SECTION 9 SUPPLEMENTAL PERFORMANCE INFORMATION of the Flight Manual, issued by the aircraft manufacturer and on which the Flight Manual of the aircraft is based, the fuel consumption rate at ambient temperature of 20°C and indicated air speed of 120kt is shown in the table below.

Aircraft gross weight (kg)	Rate of fuel consumption (kg/h)	
	Pressure altitude 0ft	Pressure altitude 2,500ft
2,850	245	241
2,720	242	236
2,600	238	233
2,400	233	228
2,200	229	223

The CRUISE CHARTS also list the speed at which the maximum endurance is attainable and the optimum cruising speed (at which the maximum range is attainable). According to the CRUISE CHARTS for an ambient temperature of 20°C and pressure altitude of 0 ft and 2,500ft, the maximum endurance is attainable at indicated air speed of approximately 60kt and the maximum range is attainable at indicated air speed of approximately 140kt.

2.15.4 FUEL LOW caution lights

The aircraft’s FUEL LOW caution lights are designed to illuminate when the remaining fuel quantity in each main fuel tank drops to 30kg or less.

3. ANALYSIS

3.1 The PIC held an airman license in accordance with applicable regulations and a valid airman medical certificate.

3.2 The aircraft had a valid certificate of airworthiness and was maintained in accordance with applicable regulations.

3.3 Relations to weather conditions

It is considered very likely that the accident involving the aircraft had no relations to the weather conditions prevailing at the time of its occurrence.

3.4 MR drive and control systems

3.4.1 MR rotation

According to the witness statements described in 2.1.3 (2) and (3), the condition of MR blades described in 2.9.3 (3), and the condition of TR drive shaft described in 2.9.3 (2), it is considered very likely that the MR rpm started to decay at about 500 meters before the crash site and had nearly stopped at the time of the crash.

3.4.2 Condition of the transmission and MR mast

As described in 2.13.2, visual inspection of the transmission gears, bearings and other parts of transmission revealed no damage that would have existed before the crash. Also, the fracture surfaces of the broken parts in the MR mast joint showed no sign of fatigue fracture. Based on these facts, it is considered probable that these parts did not have anomalies.

Also, as described in 2.13.2, rotating parts of the transmission did not have seizure except for the one by the accessory drive gear which is estimated to have been deformed by the crash as described in 2.9.3 (6), there were no anomalies in gears of the coupling gearbox except for discoloration which is estimated to have resulted from post-crash fire, it is considered probable that the transmission did not affect MR rotation with seizure.

Based on the mentioned above, it is considered probable that the decay in MR rpm described in 3.4.1 would not have been caused by the failure of MR drive system.

3.4.3 Condition of MR head and MR control parts

Because it was proved that the breakage and failure of the MR head and MR control parts were caused by overload as described in 2.13.2 and because the fracture surfaces showed no sign of fatigue fracture, MR head and MR control parts were considered to have been free of anomalies.

Based on the MR blade dynamic behavior learned from the simulation described in 2.13.3, it is considered very likely that the damage to the upper flap stops on the MR hub described in 2.9.3 (7) and the contact marks on the MR cover caused by the flap hinges described in 2.13.2, resulted from decay in MR rpm, followed by excessive MR blades flap beyond the allowable limits.

Considering the mentioned above, the witnessed falling objects from the aircraft described in 2.1.3 (2) and (3) were fragments of the oil reservoir, hub damper attachment pins, and the like that were retrieved from the areas away from the crash site as described in 2.9.2. It is considered very likely that the falling of these objects from the aircraft during flight was not due to damage and breakage resulting from defects originally present in these parts but due to damage and breakage resulting from the decay in MR rpm that led to excessive flapping and lead-lag movement beyond the allowable limits of the MR blades.

3.5 Fuel condition

3.5.1 Flying speed

As described in 2.1.3 (1), it is considered probable that the flight route of the aircraft did not significantly deviate from the road traffic congestion survey purpose and corresponded to the flight plan until it reached Shimizu-ku ward. Also as the aircraft's ground speed of 110kt mentioned in 2.1.3 (1) has been calculated from the straight line distance (approximately 195nm) connecting the points where the photos were taken and the corresponding flight time (approximately 1 hour and 46 minutes), it is considered probable that the actual flying speed was 110kt or faster, considering that the actual flight route could not consist of straight lines. On the other hand, as described in 2.15.3 (1) the PIC commented in the operational test, that "flying at a speed exceeding 120kt merits no advantage while only fuel consumption increases", it is considered probable that the PIC was flying the aircraft not exceeding indicated airspeed of 120kt.

3.5.2 Quantity of remaining fuel at the time of the accident

(1) It is considered very likely that usable fuel on the aircraft at takeoff was approximately 432kg. This is because usable fuel was estimated to be 462kg on the day, and as described in 2.15.3 (2) the flying squad had the record of before-takeoff fuel consumption for the aircraft as being approximately 30kg.

(2) As described in 3.5.1, it is considered probable that the aircraft was flying at indicated airspeed of 120kt at the maximum.

(3) It is considered very likely that flight time until the accident was approximately 1 hour and 46 minutes.

Based on the mentioned above, fuel remaining at the time of the accident can be calculated to be approximately 20kg and approximately 11kg, when the fuel consumption rate of 233kg/h (the aircraft operational test result described in 2.15.3 (1)) and the fuel consumption rate in the Flight Manual mentioned in 2.15.3 (3) are applied respectively. Consequently it is considered very likely that when the aircraft reached Shimizu-ku ward, while fuel gauge indicated near zero, fuel was not yet depleted at the time of the crash.

According to the statements described in 2.14.2 (8), which were provided by the flying squad's staff, there had been no significant difference in fuel consumption rate between LH and RH engines and in fuel gauge indications between LH and RH fuel tanks. These statements are, however, estimated to be applicable only when the aircraft has relatively large amount of remaining fuel. In addition it is not reasonable to consider that fuel in LH and RH tanks is consumed equally. Therefore, it is considered possible that either LH or RH fuel tank was empty at the time of the accident when remaining fuel was low even though it is estimated that fuel was not depleted.

3.5.3 Flight plan

As described in 2.1.1, it is considered very likely that the flight plan was filed by the PIC. Its content was the same as the flight plan which flying squad had used for the aircraft in the past flights. It included fuel load of 462kg equivalent to the endurance of 2 hours and 20 minutes including 20 minute reserve fuel.

From the mentioned above, it is considered probable that, when switching from Fuji No. 2 to the aircraft, the PIC would have been positive that the flight plan with the same content as before could apply, if number of persons on board was reduced by two to meet the limit of the gross weight.

However, fuel consumption is a function of such parameters as gross weight and flying speed. It is considered probable that fuel consumption during the accident flight was greater than the value used for preparation of the earlier flight plans because the takeoff weight was considered heavier than the maximum gross weight and the flying speed was considered as high as 110 – 120kt. (As described in 2.15.3 (3), up to a speed of approximately 140kt, increment of speed has larger effect on range than increment of fuel consumption rate. However, with increment of flying speed, fuel consumption rate becomes bigger and endurance becomes inversely smaller.) Based on the above, it is considered very likely that fuel depletion did not exist at the time of the accident, however, it is considered possible that with the estimated remaining fuel (approximately 20kg of fuel by the fuel consumption rate of 233kg/h and approximately 11kg of fuel by the rate indicated in the Flight Manual) the aircraft would not have been able to fly back to Shizuhama Aerodrome (approximately 14nm away from the accident site).

Summarizing the mentioned above, it is considered probable that the submitted flight plan would have been unfeasible.

3.6 Operation of engines

3.6.1 Conditions prior to the loss of both engines power

(1) Both fuel valves and cross-feed valve

As described in 2.9.5, each valve retrieved from the wreckage was in the open position, and it is considered possible that, as described in 2.15.1 (3), those positions were not changed by the impact of the crash, but were set by the PIC before the crash.

Consequently, it is considered probable that, immediately before both engines lost their power, the PIC tried to supply or was supplying fuel via cross-feed valve. Also, it is considered possible that, as described in 2.15.1 (4), when the PIC manipulated the valve, fuel quantity imbalance existed between LH and RH fuel tanks, or one of the fuel tanks was empty, or one of the engines had already stopped.

(2) The power levers

As described in 2.9.4, both power levers lost their handles and retained only their clevises. LH clevis was found in OFF position while RH clevis was found at a position beyond OFF position. Since power levers with their handles broken away and only their clevises remaining can easily be moved by such external force generated by cables connected to the engines, it is considered very likely that the impact of the crash broke off the handles and moved the power levers with only the remained clevises to the above-mentioned positions.

With regard to the dents that were found on the part that flanked each power lever handle (plates and separator) (near IDLE between the FLIGHT and IDLE positions for LH lever and nearly at FLIGHT position for RH lever), it is considered probable that they were made when the handles broke off by the impact of the crash. Based on the mentioned above, it is considered probable that, immediately before the crash, the power levers were positioned near the IDLE position for LH and nearly FLIGHT position for RH.

If both engines were operating normally, both power levers were set at FLIGHT position. As described earlier, these levers are designed to prevent inadvertent movement. Consequently, it is considered possible that LH power lever being found near IDLE position indicates that the PIC retarded it there.

For the above-mentioned reasons, it is considered possible that LH engine stopped first and, in response to this, the PIC retarded the LH power lever to near IDLE position, followed by the RH engine stop.

3.6.2 Loss of power of both engines

Based on the results of the engine teardown examination as described in 2.13.1, it is considered very likely that, at the time of the crash, neither engine was generating power. LH engine was stationary while RH engine's gas generator was rotating at low speed.

As to the cause of power loss of both engines, as described in 2.13.1, no causes were found in the engines themselves. However, based on the conditions prior to the loss of power of both engines as described in 3.6.1, the low level of remaining fuel as described in 3.5, and the fact that fuel remained in the RH engine FCU but not in the LH engine FCU as described in 2.13.1, following reasons can be listed but they were not confirmed.

(1) It is considered possible that the LH engine ran out of fuel and stopped, because small amount of fuel remained and no fuel was found in the LH engine FCU. (Nevertheless, the engine was affected by fire and it was not possible to determine whether the fuel depletion from FCU was caused by engine consumption or influence of fire.)

Based on what is described in 3.6.1 (2) and high likeliness that gas generator of RH engine would have been rotating at low speed at the time of the crash, it is considered probable that, when LH engine stopped, RH engine was still running normally.

Also, because it is considered possible that the PIC was not aware of low fuel as described later in 3.9.1 and 3.9.2, and because it is considered probable that engines and airframe did not have mechanical faults, it is considered possible that stall of the LH engine took place beyond the PIC's expectation.

(2) It is considered probable that the RH engine was in the state of terminating at the time of the crash, judging from the low-speed-rotation of gas generator and remaining fuel in the FCU.

It is considered probable that the LH engine had already stalled when the RH engine lost power. Because the power lever for RH engine was found very close to the FLIGHT position and the cross-feed valve was found open, it is considered possible that, following the LH engine stall, the PIC might have taken inappropriate actions, such as incorrectly operating fuel valves and pumps, power levers, or confusing LH and RH controls, resulting in loss of power of the RH engine.

Based on the mentioned above, it is considered possible that the loss of power of RH engine would have occurred against the PIC's intentions.

(3)In addition to the possibilities described in (1) and (2) above, it is considered possible, that during the actions taken to stop, recover or otherwise handle the malfunctioned engine, the PIC would have moved the controls quickly (such as rapid collective lever movements and corresponding rapid cyclic stick movements) to control aircraft attitude, which would have resulted in loss of power of the other engine against his intentions.

3.7 Torque meter indication

As described in 2.9.4 and 2.13.4, the torque meters indicated remaining small amount of torque for both engines and it is considered very likely that these torque indications correctly reflect the (electrical) signals received by the torque meters. On the other hand, as described in 2.13.1, it is considered very likely that engines were not generating power (torque) at the time of the crash.

Engine-generated torque (rotational force generated in power turbine) is converted to hydraulic pressure equivalent to the axial force generated in the (helical) reduction gear. This hydraulic pressure is picked up as the signal to torque meter.

As for the reason of remaining small torque, it is considered possible that the torque meters indicated small torque because the impact of the crash may have generated hydraulic pressure in the sensing system or electrical signals in the electrical signal converter in the torque meters.

3.8 Post-crash fire

As described in 2.12.2, the photos taken approximately three minutes after the crash showed thin smoke, but no visible flame, while the photos taken approximately four minutes after the crash showed flames.

As the battery of the aircraft had fallen off, it is considered very unlikely that the battery played a role of electrical ignitions.

It is considered probable that as a heat source, residual heat in the engines immediately after the crash or sparks generated by the crash impact ignited the leaked fuel and small flame was generated. Subsequently this small flame ignited vaporized leaked fuel and it developed into a fire and engulfed the entire fuselage.

3.9 Flight leading to the crash

3.9.1 Flight from takeoff to Shimizu-ku ward

As described in 3.5.1, it is considered probable that the aircraft flew the entire route at speeds of 110 – 120kt. Also, it is considered very likely that, as described in 3.5.2, the fuel gauge indicated near zero when the aircraft reached over Shimizu-ku ward.

As described in 2.1.1, when switching from Fuji No. 2 to the aircraft, the PIC reduced the number of persons on board from seven to five in order to reduce weight of the aircraft not to exceed its maximum gross weight and he filed the flight plan. Based on the mentioned above, it is considered probable that the PIC was aware of the weight and usable fuel quantity (462kg) of the aircraft.

Considering the situation that the flight route from takeoff to Shimizu-ku ward almost corresponded to the flight plan as described in 2.1.3 and that the fuel load indicated in the flight plan was for 2 hours and 20 minutes, it is considered possible that the PIC was flying the aircraft as per the flight plan without noticing a low fuel level.

Then, as described in 2.15.4 and 3.5.2, it is considered probable that when the aircraft reached Shimizu-ku ward, FUEL LOW caution light(s) had already illuminated. However, considering that normal communication was made approximately three minutes before the accident, and that precautionary landing was not made, it is considered probable that the PIC was flying the aircraft without noticing illumination of FUEL LOW caution light(s).

3.9.2 Flight in Shimizu-ku ward

It is considered probable that the aircraft flew approximately 7 to 8km over a built-up area at low altitude on a route not usually taken before reaching the accident site. As described in 2.1.3 (1) and (2), it is considered very likely that the aircraft flew at an altitude of about 1,000ft or below after entering Shimizu-ku ward, and at an altitude of about 300ft over the area approximately 500m and 1,200m away from the accident site. They are estimated to have been low altitude equal to or below the minimum safe altitude*9 not usually flown. Also, it is considered very likely that the flight route was meandering approximately 3.5km before reaching the accident site.

Because there were no crimes or accidents that would require low-altitude flight as described in 2.14.2 (7), and because the aircraft was not staying over a specific place, it is considered probable that the flight was not made in order to find something unusual on the ground.

Because the aircraft was under low remaining fuel condition when it reached Shimizu-ku ward as described in 3.5.2, it should have made precautionary landing. Considering a normal operation with low fuel, it should have climbed and flown straight to the aerodrome. However, it is considered very likely that the aircraft was making low altitude meandering flight. It is considered possible that the PIC was flying the aircraft unaware of low remaining fuel and illumination of FUEL LOW caution light(s). It was not possible to confirm why the pilot made an unusual flight (low altitude and meandering flight) even if he was unaware of low fuel.

As to the possibility of mechanical trouble with engines or airframe, considering the following points, no possibility existed on the route up to the point approximately 500m away from the accident site.

(1) Many witnesses in the areas near the flight route stated that there was nothing abnormal in terms of sound or flying condition of the aircraft except for its low altitude.

(2) Up until reaching the area approximately 500m away from the accident site, the aircraft maintained a level flight, although low in altitude, it was not the flight condition in which altitude could not be maintained.

(3) There are a number of elementary and junior high schools along the flight route within approximately 1km perimeter of the accident site. The schoolyards were deserted as it was holiday. In addition, there were many other places where forced landing could be made safely. Based on the mentioned above, it is considered possible that the aircraft could have made forced landing if it had malfunction.

(4) The Shizuoka Heliport and Miho airstrip are located nearby. It is considered probable that the aircraft would have made a precautionary landing at one of these facilities

*9: The minimum safe altitude is the flight altitude specified in Article 81, Civil Aeronautics Law. The law states that no aircraft shall be flown, except for takeoff or landing, at an altitude lower than the stipulated altitude, taking the safety of persons, properties on land or water and the aircraft into consideration. The minimum safe altitude is stipulated in further detail in Article 174, Civil Aeronautics Regulations.

if it had been experiencing malfunction which would have prevented flight to Shizuhama Aerodrome.

(5) It is considered probable that the PIC would have contacted the flying squad or the Shizuhama Aerodrome Control if any problem had arisen before reaching the point approximately 500m away from the crash site.

Even if one engine were inoperative, it is considered probable that the aircraft had sufficient single engine performance to climb with estimated weight at the time of the accident and to maintain level flight.

Based on the mentioned above and what is described in 3.6.2, it is considered possible that the aircraft developed LH engine stall before reaching the area approximately 500m away from the accident site (possibility exists that it stalled during the meandering flight) and, without time to report it, RH engine also lost power before reaching the area approximately 500m away from the accident site.

3.9.3 Flight leading to a point approximately 500m away from the accident site

(1) The estimated flight route and elapsed time derived from the statements of witnesses in the area approximately 500m from the crash site, where both engines were estimated to have lost their power, were compared with the dynamic behaviors of MR system after loss of both engines power, which was calculated by the aircraft manufacturer using its flight simulation.

The simulation revealed that the conditions where MR flapping and lead-lag exceed allowable limits within the duration of approximately eight seconds during which witnesses stated that engines stalled, parts fell and the aircraft crashed, corresponded to the simulated conditions where the collective lever was raised after the both engines stall.

In any other conditions, flapping and lead-lag never exceeded the allowable movement range within approximately eight seconds.

Based on the mentioned above and what is described in 3.4, MR drive and control systems had no anomalies. It is considered possible that after both engines lost power the MR rpm decayed sharply because the collective lever was mistakenly pulled up.

(See Figures 2 and 3.)

(2) As described in 3.6.2, it is considered very likely that both engines had nearly stopped at the time of the crash, and based on the witness statements described in 2.1.3 (2) and (3), and that both engines lost power before reaching the point approximately 500m from the crash site. At that time, it is considered probable that the aircraft was flying at an altitude of approximately 300ft at a speed of 110 – 120kt as described in 3.9.1 and 3.9.2. If both engines had lost power at the above-mentioned altitude and speed, it is considered probable that autorotation landing could be conducted by proper piloting. However, it is considered very likely that the aircraft did not enter autorotation because the MR was not rotating at the time of the crash judging form the damage to the MR and other parts as described in 2.9.3 (3), (4) and (6), and because of the witness statements described in 2.1.3 (2)

and (3).

Based on what is described in 3.9.3 (1) and that the MR drive and control systems had no anomaly as described in 3.4, it is considered possible that the autorotation landing was not made because PIC's aircraft control would have been inappropriate. The PIC was possibly affected by the following; excessively low-flying altitude, unexpected stall of both engines, or second engine stall that occurred against his intentions while he was dealing with the first engine that had stalled earlier. The reasons, however, could not be confirmed.

It is considered probable that, after both engines had lost power, the aircraft, without entering autorotation, experienced rapid decay of MR rpm, excessive MR blade flapping and lead-lag movement beyond allowable range leading to breakage and falling apart of the oil reservoir and lead-lag dampers on the MR head.

By that time, it is considered probable that the MR blades, with decayed rpm, almost lost their lift and then the aircraft entered the condition of mere falling. It is considered probable that slight lift generated by the MR blades with decayed rpm or the difference in air drag between left and right might have caused the aircraft to change course to take a curved trajectory as it fell.

3.10 PIC

3.10.1 Crew assignments

As described in 2.14.2 (5), the Flight Safety Standards of the flying squad stipulate that "in principle, crew shall, in addition to PIC, include a person who is qualified for PIC's duties." This is based on the idea that twin pilot operations are safer than single pilot operations. Under normal situations, the pilot not flying is expected to assist a pilot flying with looking outside, radio communications and other jobs. While it is considered very likely that flights are usually conducted by two pilots at the flying squad, at the time of this accident the PIC was the sole pilot and no other person qualified for PIC's duties was on board.

As described in 2.1.1, the original plan for the traffic congestion survey flight was to use Fuji No. 2 helicopter with two pilots including the PIC. It is considered very likely, however, that after the decision to switch to the aircraft, the PIC excluded the other pilot from his crew in order to meet the takeoff weight limitation of the aircraft. It is considered very likely that this judgment was at his own discretion who was the PIC, the chief operating officer and the chief of the flying squad as described in 2.14.3.

In emergencies or when it is necessary to fly all three helicopters owned by the flying squad, there were cases where each helicopter was flown by single pilot as described in 2.14.2 (5). Because each aircraft Flight Manual specifies that one pilot is the minimum required number of persons on board, it is estimated that there existed no problem for continued safe flight, even though the PIC was the sole pilot on the aircraft. However, it is considered possible that the PIC did not make appropriate judgments or management over the flight distance and fuel, because he was the only pilot on board and due to the following reasons.

(1) Because Hamamatsu area was added to the original flight route and the aircraft was unexpectedly switched to the aircraft of a smaller takeoff weight within duration of approximately 30 minutes (from the landing of Fuji No. 2 to the takeoff of the aircraft) due to the problematic Fuji No. 2., it is considered probable that psychological burden on the PIC was increased.

(2) It is considered probable that the PIC was not able to psychologically adapt to the change from Fuji No. 2 (a longer range aircraft) to the aircraft (a shorter range aircraft) before the takeoff.

(3) It is considered probable that the PIC had a wrong impression of being able to fly for at least 2 hours and 20 minutes (fuel load in terms of endurance), as usually written in flight plans.

3.10.2 Unreasonable flight

There were many witness statements about the flight after the PIC radioed landing notification to the flying squad approximately three minutes before the crash. By cross referencing these pieces of information, flight route and its altitude were quite unreasonable from the viewpoint of ordinary flight mission.

The reason why the PIC performed such an unreasonable flight could not be confirmed with the following reasons.

(1) As described in 2.14.1, it is considered very likely that PIC's health condition didn't develop any problems (at least until reaching the point approximately 500m away from the crash site).

(2) It is considered possible that the PIC had unxiety of possible forced landing upon realizing low fuel. However, concerning his piloting skill as described in 2.14.2 (1), (2) and (4), the PIC had sufficient experience in normal procedures and had not previously demonstrated any strange behavior.

(3) As described in 2.14.2 (7), there were no crime occurrences or accidents in Shimizu-ku ward and its vicinity, no reason was considered possible why the aircraft flew over Shimizu-ku ward at altitude as low as 1,000ft or below.

3.10.3 Procedure for transition to Autorotation

Based on the communication records between the PIC and the flying squad and the statements provided by those who made the communications, it is considered probable that mental and physical conditions of the PIC were normal at least up until approximately three minutes prior to the crash. On the other hand, it is considered possible that, after both engines lost power, the PIC would have operated the aircraft in a manner unimaginable under normal circumstances, and concurrently his physical condition might have suddenly deteriorated. This, however, could not be confirmed.

4. PROBABLE CAUSE

It is considered very likely that this accident was caused by the crash of the aircraft, preceded by both engines power loss, no autorotation maneuver, MR rpm decay, and uncontrollable conditions, while the aircraft was flying on a road traffic congestion survey mission toward Shizuhama Aerodrome at low altitude on low fuel. The aircraft was destroyed and burned with five fatally injured onboard.

Causes of both engines power loss and why the aircraft did not enter autorotation were not confirmed.

Although it is considered probable that continued flight on low fuel and of low altitude contributed to the occurrence of the accident, reasons for these could not be confirmed.

5. SAFETY OPINIONS

It is considered very likely that this accident occurred in the situation where the aircraft did not autorotate and crashed after both engines stall during the road traffic congestion survey mission.

While the reason could not be confirmed why both engines lost power and why the aircraft did not autorotate, it is considered possible that the followings would have cumulatively acted as contributory factors to the occurrence of the accident. As the accident might not have occurred if any one of them had been cleared, persons concerned should keep the following items in mind as they perform operations.

(1) Flight operations became unreasonable after the unexpected change of flight plan

It is considered possible that the fuel load would have become insufficient for the flight after the flight route was extended from the original plan and aircraft were switched from Fuji No. 2 to the aircraft. Furthermore, it is considered very likely while higher flying speed increased the range and fuel consumption, it reduced the endurance. In addition, it is considered very likely that the aircraft eventually took off with exceeded maximum gross weight and this also would have contributed to increased fuel consumption. As fuel consumption is a function of such factors as gross weight and length of flight, all persons concerned should have carefully checked the fuel consumption and other parameters involved and operated the aircraft with feasible flight plan.

(2) Single pilot operation

Because minimum required number of persons on board the aircraft was specified as one pilot, single pilot operation is admissible. However, since unexpected occurrences are foreseeable, persons concerned should have as much as possible abide by "The two-pilot rule for safe flight", which was stipulated in the voluntarily established Flight Safety Standards. In case where single pilot operation is a compelling need, crew assignment should not have been left solely to the discretion of the single person responsible for the mission assignment (the person who has the final authority to approve the pilot(s) for duty on each flight), but all persons concerned should have been involved to make such assignment in accordance with clearly defined criteria, which excludes consecutive flights of different types of aircraft.

(3) Low altitude flight

The aircraft was considered to be in a condition of flying at an altitude of a few hundred feet and at a speed of 110 – 120kt when both engines lost power and this condition is within the envelop of possible autorotation. Autorotation trainings are usually conducted from an altitude with sufficient safe margin. In this accident it is considered possible that low flying altitude at the moment of loss of engine power constituted a factor that prevented the aircraft from autorotation. If the PIC had maintained flying altitude as high as possible to secure sufficient time for gliding, it is considered possible that the PIC would have been able to make the transition to the autorotation with relative ease.

Minimum safe altitude stipulated in the Civil Aeronautics Law is a basic for aviation safety and should have been observed by all persons concerned.

6. Comments from France

Comments were presented from the accredited representative of France, the state of engine design and manufacture. Comments not reflected upon in this report are appended in accordance with the article 6.3, Annex 13 to the Convention on International Civil Aviation.

(See attachment 1)

Figure 1 Estimated Flight Route

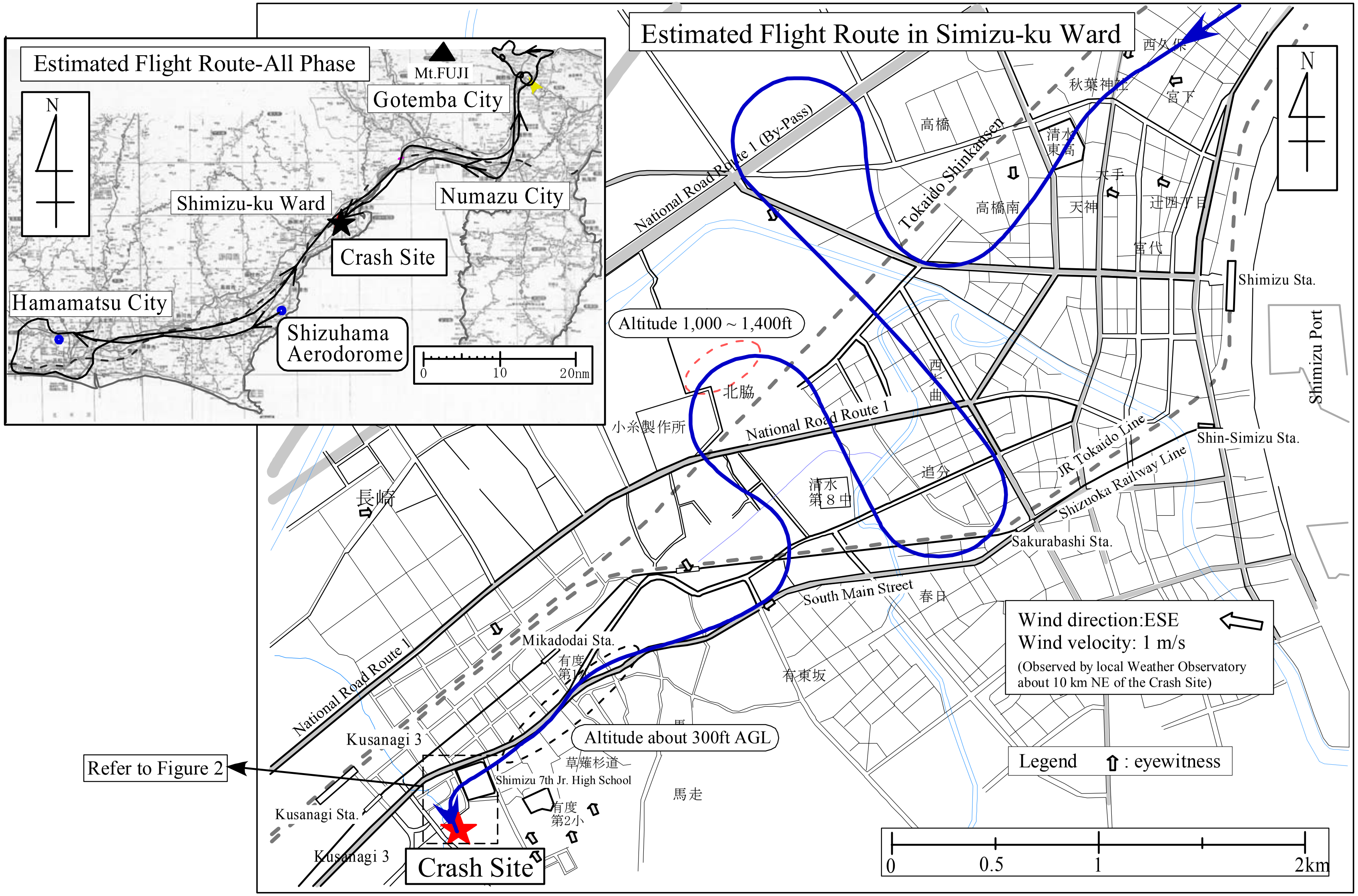
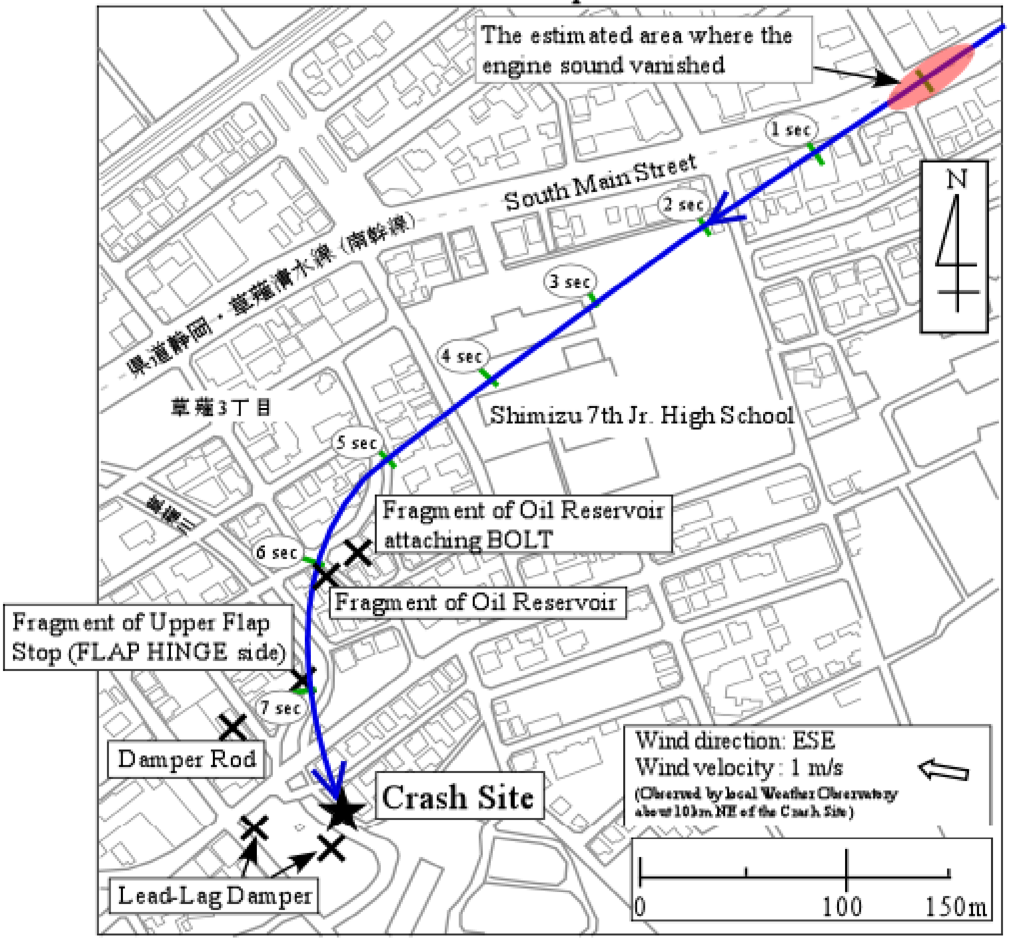
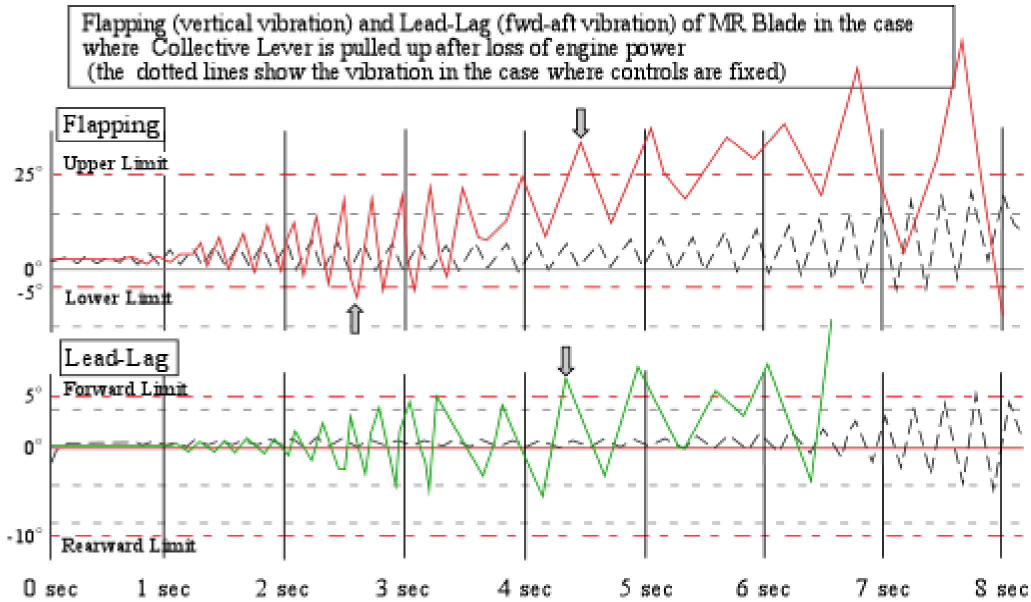


Figure 2 Estimated Flight Route and Locations where detached parts were collected



Note: Distance divided by tick marks with time tag show the traveled distance by the aircraft at 120 kt

Figure 3 Flapping and Lead-Lag of MR Blade



Elapsed time after loss of both engines power

Figure 4 Three-Angle-View of AGUSTA A109K2

unit: m

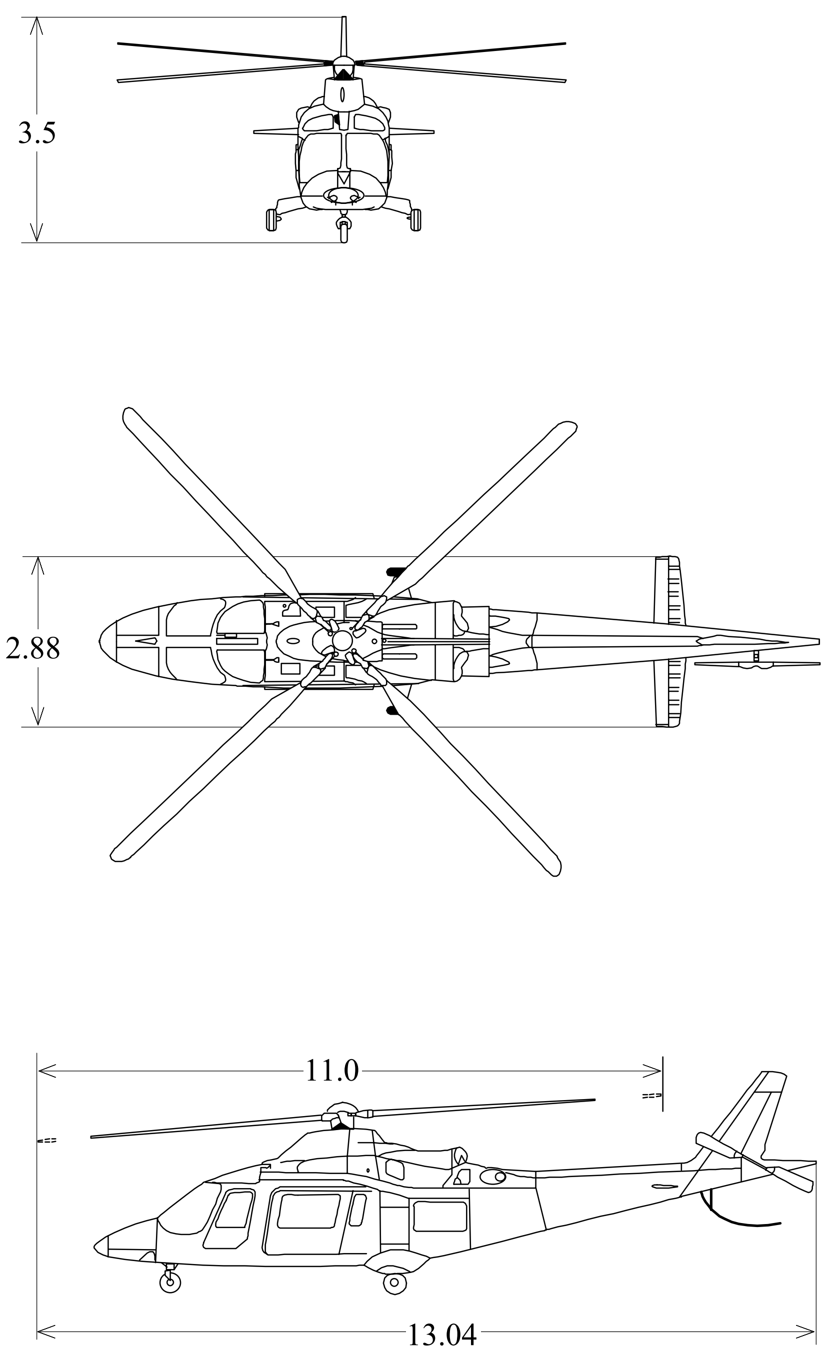
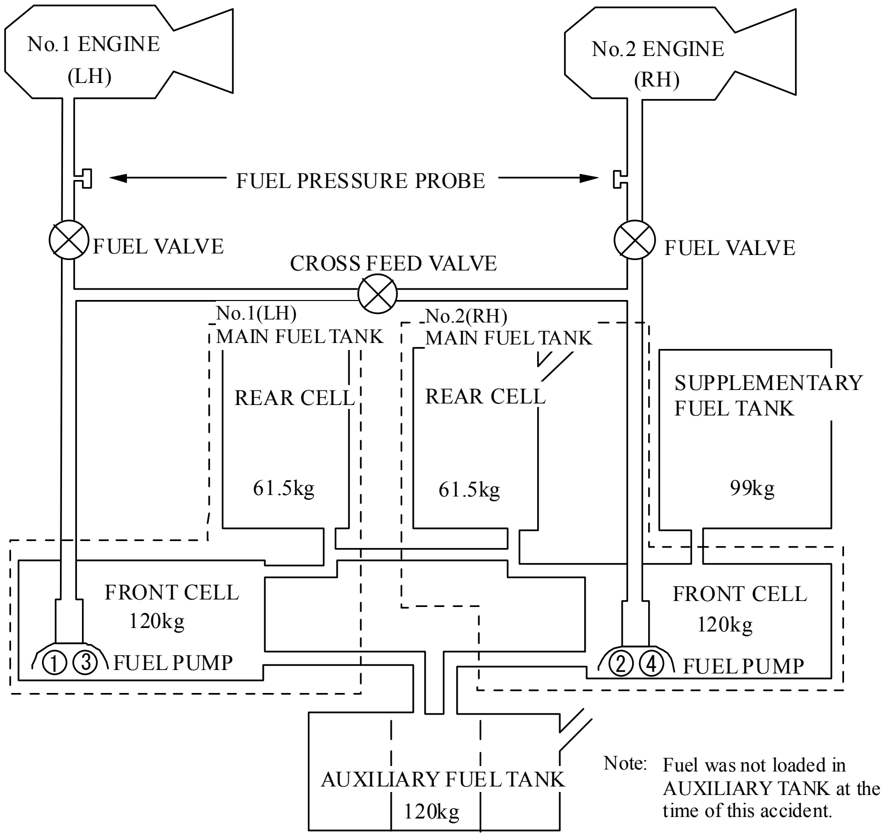


Figure 5 Fuel system schematic



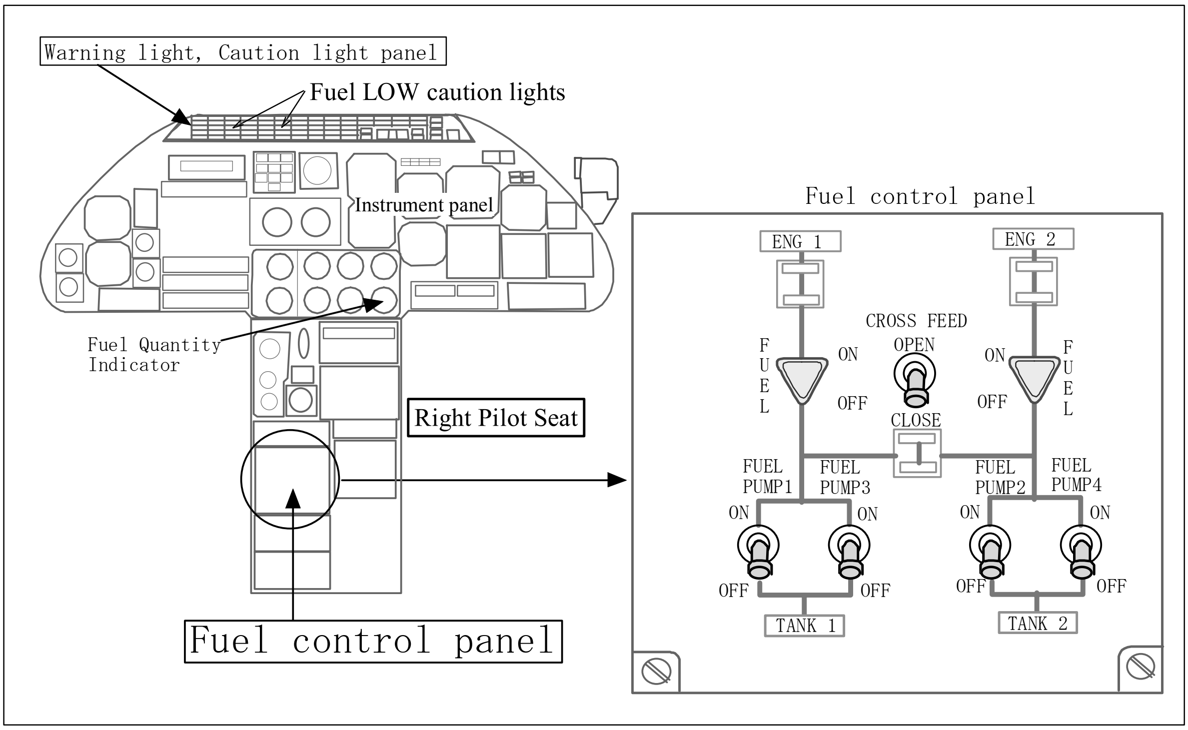


Figure 6 TRANSMISSION, MR CONTROL, MR HEAD and POWER LEVER ASSEMBLY

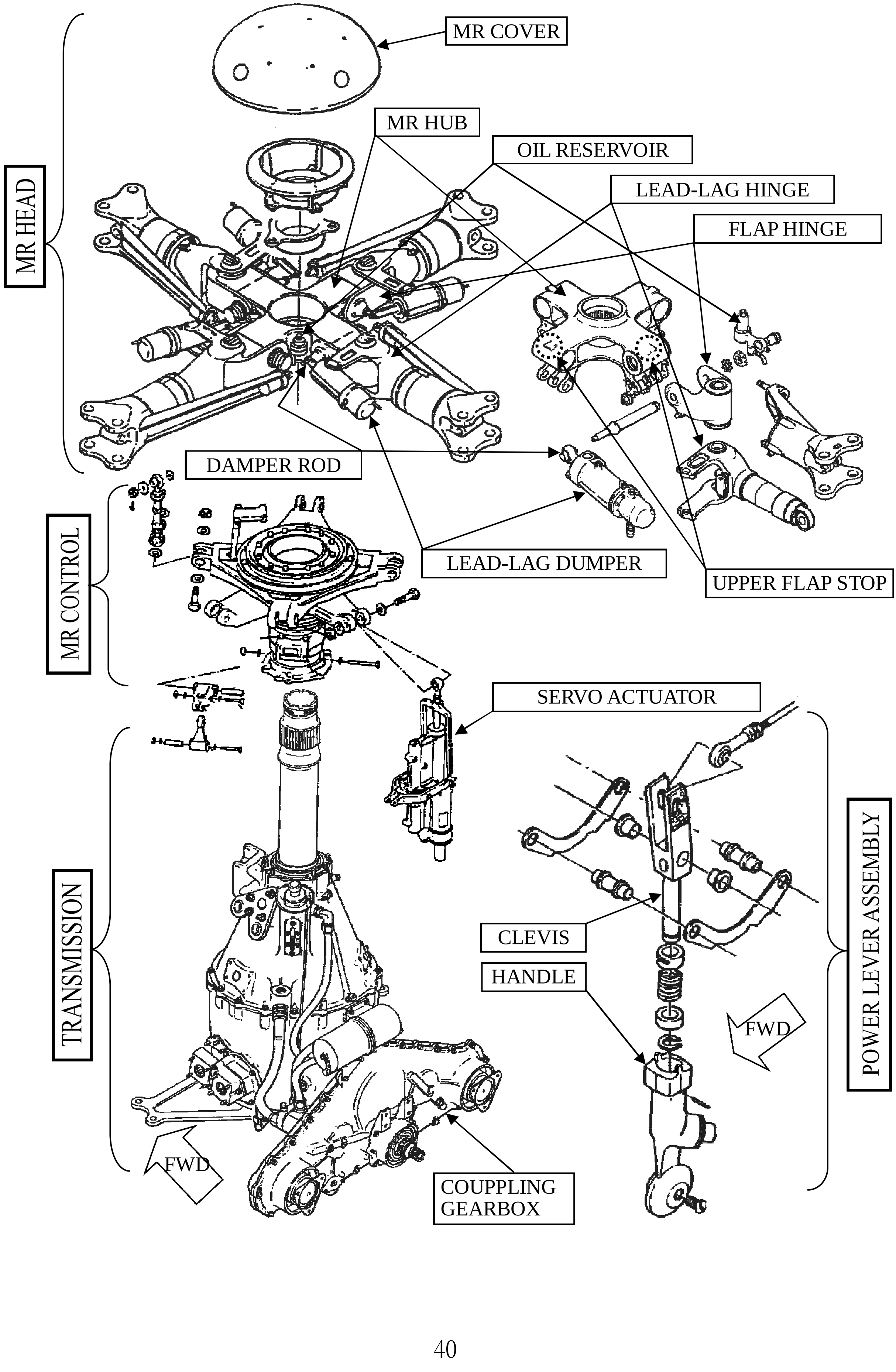


Photo 1 Crash site (1)

(At 16:30:32 Flame is not observed although smoke rises from the vicinity of the engine.)

Photo 2 Crash site (2)

(At 16:31:08 Flame is visible.)

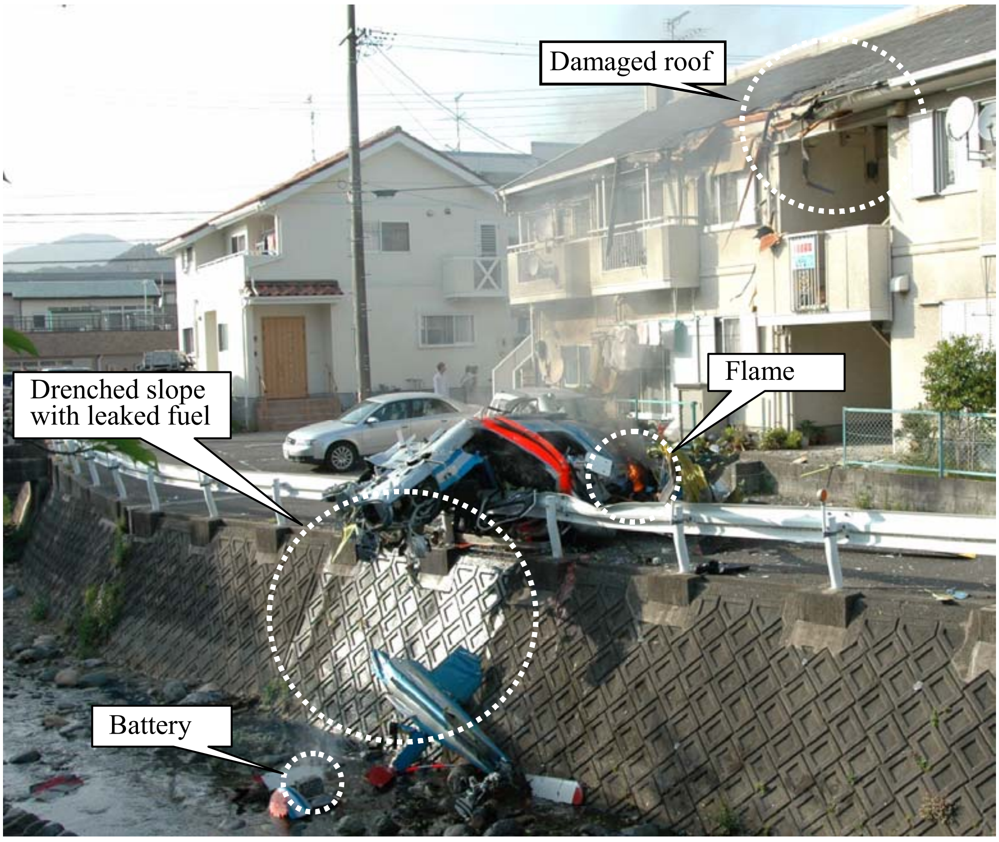


Photo 3　Crash site (the next day of the accident)

Photo 4　POWER LEVER ASSEMBLY

(Located on the ceiling of the cockpit)

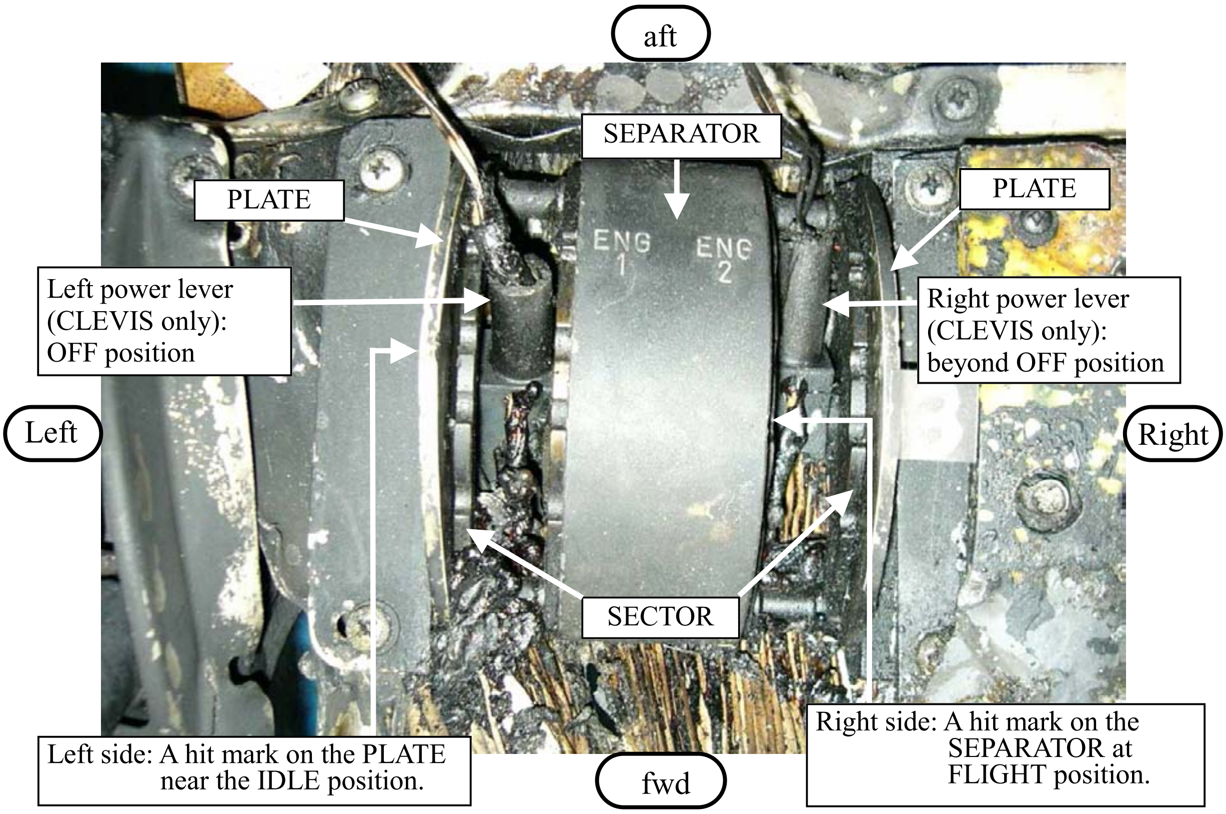


Photo 5　MR HEAD

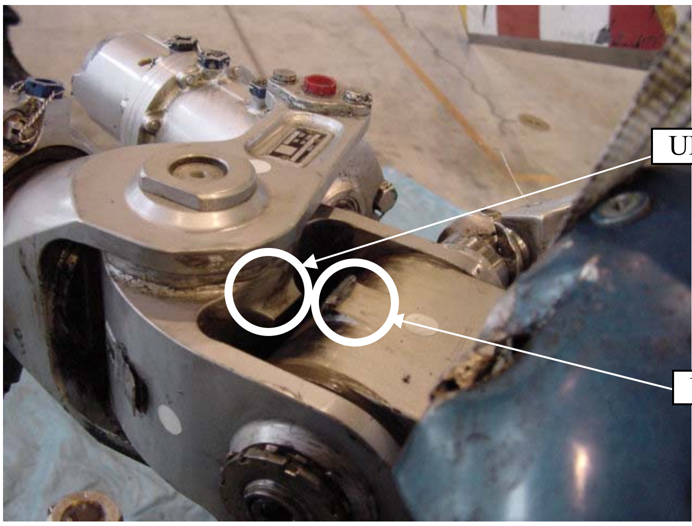
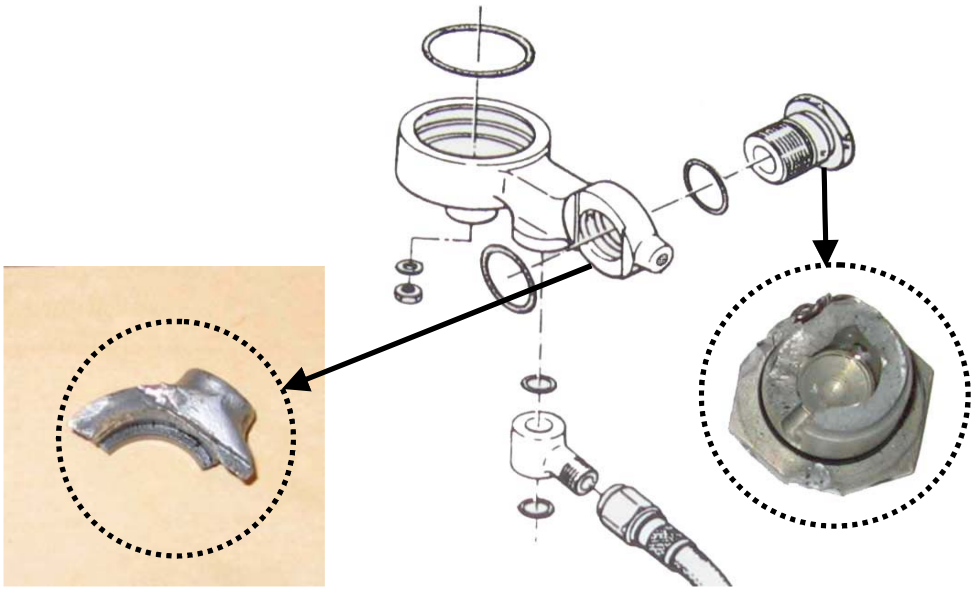


Photo 6　MR DAMPER ROD

Photo 7　Fragments of MR HINGE LUBRICATING SYSTEM



Comments from France

Comments on the draft final report on the accident of the AGUSTA A109K2 registered JA11PC in Shizuoka (Japan) on May 3, 2005.

Concerning the chapter 4. PROBABLE CAUSE

After detailed examination of the draft final report, we suggest a modification to the proposed text. In the chapter 4, we would wish to put more clearly in evidence comparison or connexion between the small quantity of fuel present into the tank and the loss of power of engines. For that purpose, we propose you the later substitution text:

Instead of :
"Causes could not be determined why both engines lost power and why the aircraft did not enter autorotation."

Change to read :

It could not be clearly determined why both engines lost power, but no anomalies were confirmed on the engines and their accessories that would have occurred before the crash. Furthermore, the probability of simultaneous in flight shutdown of both engines for technical reasons is very low. The most probable cause seems to be interruption of fuel supply.
Causes could not be determined why the aircraft did not enter autorotation.