Aviation Investigation Final Report

Location:	IMMOKALEE, Florida	**Accident Number:**	ATL96FA051
Date & Time:	February 20, 1996, 11:43 Local	**Registration:**	N31MX
Aircraft:	Sukhoi SU-31	**Aircraft Damage:**	Destroyed
Defining Event:		**Injuries:**	1 Fatal
Flight Conducted Under:	Part 91: General aviation		

Analysis

The pilot was conducting a practice aerobatic flight, with two aerobatic pilots critiquing him from the ground. About ten minutes into the flight, the pilot initiated a pull toward the vertical with about 360 km/hr and 7 Gs, according to witnesses. This would have been well within the maximum airspeed and load specifications of 450 km/hr and 10 Gs, respectively. The right wing of the airplane separated during the pull up. The airplane entered a right roll and an uncontrolled descent, then it collided with the ground about 1 mile north of the airport. According to witnesses, the engine was developing power until impact, and the pilot did not announce any malfunctions or problems, prior to the wing failure. A postcrash ground fire consumed the fuselage. The unburned right wing was found about 3/4 mile east of the main wreckage. Testing of the wing spar was performed by the NTSB and MAK (Russian Investigative Authorities). Both agencies found numerous voids in the composite spar caps. The investigation revealed evidence that the curing process for the wing spar did not provide adequate vacuum pressure. There was evidence that during the curing process, the fibers separated from each other, which resulted in voids in the final composite material.

Probable Cause and Findings

The National Transportation Safety Board determines the probable cause(s) of this accident to be: the manufacturer's improper composite curing process, which resulted in wing spar voids and subsequent failure of the wing during aerobatic flight.

Findings

Occurrence #1: AIRFRAME/COMPONENT/SYSTEM FAILURE/MALFUNCTION
Phase of Operation: MANEUVERING

Findings
1. AEROBATICS - INITIATED - PILOT IN COMMAND
2. (C) WING,SPAR - DELAMINATION
3. (C) INADEQUATE QUALITY CONTROL - MANUFACTURER
4. WING - SEPARATION

Occurrence #2: IN FLIGHT COLLISION WITH TERRAIN/WATER
Phase of Operation: DESCENT - UNCONTROLLED

Factual Information

HISTORY OF FLIGHT

On February 20, 1996, about 1143 eastern standard time, a Sukhoi SU-31, N31MX, collided with the ground at Immokalee Airport, Immokalee, Florida. The experimental airplane was operated by the pilot/owner under the provisions of Title 14 CFR Part 91, and visual flight rules. Visual meteorological conditions prevailed. A flight plan was not filed for the local, aerobatics practice flight. The airline transport pilot was fatally injured, and the airplane was destroyed. Origination of the flight was Immokalee, Florida, on the same day, about 1133.

The pilot, who was a former member of the U.S. Aerobatics Team, was conducting a practice aerobatics flight in a designated aerobatics box. Two aerobatics pilots were critiquing him from the ground, and witnessed the entire flight. One witness, the U.S. Aerobatic Team coach, was in contact with the pilot via a hand held radio, and the other witness was standing at his side. These two witnesses believe that their estimations of airspeed, G loading, and altitude are accurate. The witnesses stated the following: the airplane had been airborne for about 10 minutes. The same maneuver had been executed during this flight approximately three times prior to the final maneuver. The airplane was about 2,500-3,000 feet above the ground level and began a 35-45 degree dive. The pilot performed three wing rocks to the left to signal the start of the maneuver. The pilot leveled off at 700 feet with about a 6 G pull said one witness. The other witness said, at this point there was neither a rapid pitch rate nor a high G force. The airplane remained level for approximately 1 second, then the pilot initiated a pull toward the vertical about 380 km/hr and 8 Gs. The other witness estimates about 340 km/hr and 4.5-6 Gs. At approximately 15-20 degrees pitch up, the right wing of the airplane separated up and aft hitting the canopy. The airplane entered a right roll climbed for about 200-300 feet, then entered an uncontrolled descent. The airplane collided with the ground about 1 mile north of the airport. According to the witnesses, the engine was developing power until impact, and the pilot did not announce any malfunctions or problems, prior to the wing failure. A post crash ground fire consumed the fuselage. According to witnesses, the unburned right wing was found about 3/4 mile east of the main wreckage.

One of the witnesses had observed all of the flying performed in this airplane on the three previous days. He stated that all of the maneuvers were well within the limits of the airplane.

PERSONNEL INFORMATION

The pilot was certificated as an Air Transport Pilot with F-27 and B-737 type ratings. He had more than 16,000 total flight hours. According to the pilot's friend, the pilot had approximately 800 hours in the SU-26, and about 10 hours of aerobatics in the SU-31. He

added that the pilot had not been feeling well on Thursday, February 15, but did not appear ill on the day of the accident. No pilot logbooks were obtained.

AIRCRAFT INFORMATION

The airplane was registered to the pilot. The original generator had been replaced with an alternator that was 35 pounds lighter. An inspection placing the airplane into service was conducted on February 15, 1996. Maintenance records indicated that 11 hours had been logged on this airframe with 11 hours since the inspection.

Weight and Balance Sukhoi SU-31 S/N 03-03

Item	Weight(kg)	Arm(m)	Moment
Original Empty Weight	733.8	1.339(20.5%)	982.558
Removed Russian Generator	-12.7	0.625	-7.938
Removed Gen. Control Tray	-7.14	1.616	-11.538
Removed Ni-Cad Battery	-3.29	0.816	-2.685
Installed B+C Generator	1.72	0.625	1.075
Installed Sealed Lead Acid Battery	4.76	0.816	3.884
Inst. Russian Comm. Radio	2.83	2.20	6.226
New Empty Weight and Moment	719.98kg		971.582
New Empty Weight C.G.	1.349m 21.01%MAC **Date 15 February, 1996**		
Estimated Fuel	54.4	1.307	71.14
Estimated Pilot Weight	75.22	2.74	206.12
Estimated Weight and Moment	849.6		1248.84
Estimated Airplane C.G.	1.47m 28.87%MAC		

The maximum weight allowed for takeoff in the SU-31 was 1,100 kg., and the maximum landing weight was 1,050 kg. The C.G. in the any weight configuration should have been between 24.0%MAC and 31.5%MAC.

METEOROLOGICAL INFORMATION

Visual meteorological conditions prevailed at the time of the accident. Additional meteorological information may be obtained in this report on pages 3 and 4 under section titled Weather Information.

WRECKAGE AND IMPACT INFORMATION

The wreckage was found approximately one mile north of Immokalee Airport, with the exception of the right wing which was found intact 3/4 of a mile east of the main wreckage. The majority of the wreckage was consumed by a post crash fire.

Examination of the radial engine revealed that the throttle valve was nearly closed, the throttle arm was found one quarter above the idle stop, and the left magneto was destroyed by fire. The composite propeller blades were broken off, and the propeller control arm was broken off. The exhaust system was compressed fore and aft.

The canopy handle was in the locked position. The rudder pedal stops had no evidence of pounding, the rubber bumpers were absent. The rudder cable on the right side showed evidence of tensional overload, 10 inches forward of the rudder horn. The top of the rudder was separated, but the counterweight was in place, severe fire damage was noted here. The left wing was consumed by fire.

The right wing separated from the airframe at the root rib outboard of the wing/fuselage juncture. The web between the spar caps was irregularly torn. The upper spar cap had a white granular substance around the strands of carbon fiber. The integral fuel tank in each wing has a rubberized lining and is bonded to the forward side of the web. The right wing fuel tank was punctured in conjunction with two rib bolts. The root rib aft of the wing spar was deformed and bulged inboard. The top of the wing was compressed and exhibited compressive buckling at the junction of the upper spar cap. A red paint transfer mark was found approximately 12 inches outboard of the wing root, adjacent to the inboard side of the aileron. All three aileron cut outs were crushed aft, and there was a spanwise wrinkle forward of the aileron. The right aileron push/pull rod was fractured 4 inches outboard of the root.

MEDICAL AND PATHOLOGICAL INFORMATION

On February 21, 1996 a postmortem examination was conducted by Marta U. Coburn, MD District 20 Medical Examiners Office, 870 6th Avenue North, Naples, FL 33940. The toxicological examination performed during the autopsy revealed no ethanol or other drugs, but did find 1.8% carboxyhemoglobin.

TESTS AND RESEARCH

Sections of the right wing spar and the right spar attach point at the fuselage were sent to the Safety Board's laboratory in Washington DC for inspection. The inspection started with a basic evaluation of the wing construction. The wing spar was a single unit running from wingtip to wingtip. The spar was composed of a web made from honeycomb and carbon mesh, and upper and lower spar caps. The cross section of the main spar was symmetrical, as was the airfoil. The spar caps were made from unidirectional carbon fiber tape with a few layers of woven fabric. The web of the main spar consisted of a woven carbon fiber fabric and unidirectional carbon fibers bonded to the forward and aft sides of a honeycomb core. The spar cap had a thickness of about 7.84 mm in the area of the fracture. The web and the spar caps were cured at the same time to form a one piece spar. The spar was attached to the airplane skin using doublers that extended about 400 mm outboard of the wing attach fittings. The doublers, the skin, and the spar cap were connected by titanium bolts.

The separation of the wing occurred just outboard of the fuselage attach brackets, approximately in line with the wing rib. The examination of the upper spar cap fracture revealed that most of the carbon fiber layers were broken within 25 mm of each other; typical of compression separation of composite materials. The lower spar cap examination showed that the fibers separated in widely varying locations; typical for tensile separation. However, the fibers at the top of the lower spar cap separated along the same plane, showing compressive separation in that area. The web separation was also studied. The separation of the web occurred within 25 mm of the outboard attach fittings. The lower section of the web separated through the lower outboard bolt hole. No evidence of a progressive fracture through this hole was found.

The next evaluation at the Materials Laboratory was the use of a scanning electron microscope(SEM) on some of the fibers cut from the spar. Most of the exterior bundles examined contained longitudinal drawing marks. The fibers were viewed at high magnification disclosing that some of the fibers appeared to be coated with epoxy. The fiber bundles taken from the aft side of the upper spar cap were broken using a bending motion, and most of them broke on two fracture planes. This contrasts the fibers from the forward upper portion of the upper spar cap. The forward sample of fibers broke on a flat plane and most of the fibers contained evidence of partial or complete disbonding.

The fiber bundles were tested for composition using energy dispersive spectroscopy analysis. The most prevalent material was carbon. Other materials, consistent with the composition of the glass reinforcement fibers of the unidirectional tape, were found between the fibers. Other elements were also present in the sample in small amounts.

After an analysis of the fracture area was complete, testing started on a piece of the right wing front spar that was cut six inches outboard of the fracture area. The composite structure on the both sides of the spar cap had a wavy area that appeared to have been damaged during the wing separation. Another section was cut from the upper and lower spar caps about 28 inches outboard of the separation point. After polishing, a visual inspection revealed numerous delaminations or voids between the layers of the composite material that make up the spar caps. Upon magnification with a SEM, large voids between the fiber bundles were seen. Voids were found between layers of unidirectional tape and carbon fabric. In addition, voids were found between adjacent layers of unidirectional tape. The resin-rich areas between the voids did not show any evidence of delamination or cracking. The same type of voids were seen on both the upper and lower spars at various locations on each spar.

An examination of the forward edge of the upper spar cap showed that the glue used to bond the doubler, the spar cap, and the wing skin was present between the layers of tape. This indicated that these areas were not filled with epoxy resin when the tape was cured.

The inboard portion of the spar was burned severely and was missing the lower spar cap. Examination of the burnt piece showed gross buckling and fractures. The web between the bolt attach points was buckled, with the most severe buckling closer to the top attach

point. In addition, the upper spar cap was displaced several inches outboard relative to the web.

After the testing was complete in the United States, pieces of the spar were sent to Russia for testing, under the auspices of the Russian Interstate Aviation Committee (MAK). The tests performed indicated that the spar cap failed to meet specified material requirements for the following reasons (1) excessive voids, (2) low density, (3) low interlaminar shear strength, and (4) low compressive strength.. The cap material did comply with fiber percentage and resin percentage requirements, and the resin appeared to be adequately cured.

During the MAK investigation, two additional spars were found with voids similar to those in the accident airplane. Additionally, the MAK investigation revealed that the vacuum system used in the spar manufacturing process had been changed, following a closure of the Sukhoi plant in 1994. All three spars had been manufactured following the closure. Prior to the shut down, the spar assembly was placed in a bag to which vacuum pressure was applied for curing. The bag was connected directly to the vacuum source, and a bag of test pieces was connected to the main bag. After the plant's closing and subsequent reopening, the vacuum system was changed. The new process attached the test bag directly to the hose leading into the main bag.

Pilot Information

Certificate:	Airline transport; Commercial; Flight engineer	**Age:**	42,Male
Airplane Rating(s):	Single-engine land; Multi-engine land	**Seat Occupied:**	Center
Other Aircraft Rating(s):	None	**Restraint Used:**	
Instrument Rating(s):	Airplane	**Second Pilot Present:**	No
Instructor Rating(s):	None	**Toxicology Performed:**	Yes
Medical Certification:	Class 1 Valid Medical--no waivers/lim.	**Last FAA Medical Exam:**	September 27, 1995
Occupational Pilot:	Yes	**Last Flight Review or Equivalent:**	
Flight Time:	16000 hours (Total, all aircraft), 10 hours (Total, this make and model), 10 hours (Last 30 days, all aircraft)		

Aircraft and Owner/Operator Information

Aircraft Make:	Sukhoi	**Registration:**	N31MX
Model/Series:	SU-31 SU-31	**Aircraft Category:**	Airplane
Year of Manufacture:		**Amateur Built:**	
Airworthiness Certificate:	Experimental (Special)	**Serial Number:**	03-03
Landing Gear Type:	Tailwheel	**Seats:**	1
Date/Type of Last Inspection:	February 15, 1996 Annual	**Certified Max Gross Wt.:**	2425 lbs
Time Since Last Inspection:	11 Hrs	**Engines:**	1 Reciprocating
Airframe Total Time:	11 Hrs	**Engine Manufacturer:**	Voronezh
ELT:	Installed	**Engine Model/Series:**	M-14P
Registered Owner:	RICHARD V. MASSEGEE	**Rated Power:**	360 Horsepower
Operator:		**Operating Certificate(s) Held:**	None
Operator Does Business As:		**Operator Designator Code:**	

Meteorological Information and Flight Plan

Conditions at Accident Site:	Visual (VMC)	**Condition of Light:**	Day
Observation Facility, Elevation:	APF ,9 ft msl	**Distance from Accident Site:**	30 Nautical Miles
Observation Time:	11:46 Local	**Direction from Accident Site:**	225°
Lowest Cloud Condition:	Scattered / 2400 ft AGL	**Visibility**	7 miles
Lowest Ceiling:	None	**Visibility (RVR):**	
Wind Speed/Gusts:	12 knots /	**Turbulence Type Forecast/Actual:**	/
Wind Direction:	180°	**Turbulence Severity Forecast/Actual:**	/
Altimeter Setting:	30 inches Hg	**Temperature/Dew Point:**	26°C / 17°C
Precipitation and Obscuration:	No Obscuration; No Precipitation		
Departure Point:		**Type of Flight Plan Filed:**	None
Destination:		**Type of Clearance:**	None
Departure Time:	00:00 Local	**Type of Airspace:**	Class G

Airport Information

Airport:	IMMOKALEE IMM	**Runway Surface Type:**	Asphalt
Airport Elevation:	37 ft msl	**Runway Surface Condition:**	Dry
Runway Used:	0	**IFR Approach:**	None
Runway Length/Width:	5000 ft / 150 ft	**VFR Approach/Landing:**	None

Wreckage and Impact Information

Crew Injuries:	1 Fatal	**Aircraft Damage:**	Destroyed
Passenger Injuries:		**Aircraft Fire:**	On-ground
Ground Injuries:	N/A	**Aircraft Explosion:**	None
Total Injuries:	1 Fatal	**Latitude, Longitude:**	

Administrative Information

Investigator In Charge (IIC):	Hicks, Preston
Additional Participating Persons:	RICHARD ARUJO;
Original Publish Date:	October 4, 1996
Last Revision Date:	
Investigation Class:	Class
Note:	
Investigation Docket:	https://data.ntsb.gov/Docket?ProjectID=3647