

Destructive Evaluation of Four Aircraft Representative of the General Aging Aircraft Fleet

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ABSTRACT

Due to current economic conditions, aircraft companies of today are experiencing an increasing need for their fleets to maintain safe operation beyond their original design life. The result is a growing percentage of aging aircraft that must maintain their airworthiness by utilizing standard methods of inspection and repair.

In order to determine if potential continuing airworthiness problems exist for the general aviation fleet as a function of the aging process, the Federal Aviation Administration (FAA) established a research program at the National Institute for Aviation Research (NIAR), Wichita State University, to conduct destructive evaluations on four aged general aviation airplanes. The intent of the program is to provide insight into the condition of a typical aged airplane and to see if a correlation exists between its maintenance history and current condition from a safety of flight perspective.

Four airplanes used in commuter service – a 1969 Cessna 402A, a 1979 Cessna 402C, a 1975 Piper Navajo Chieftain, and a 1993 Beechcraft 1900D Airliner – have been evaluated in the research program. In order to achieve the level of inquiry desired, the aircraft were assessed during two phases of research.

The “Inspection Phase” included a survey of the maintenance records; non-intrusive visual inspection of the aircraft structure, systems, and wiring; and supplemental nondestructive inspections (NDIs) of critical structural areas.

The “Teardown Phase” consisted of detailed structural disassembly; intrusive visual inspection of aircraft wiring and system components; close visual inspection of internal structure; microscopic examinations of suspect and critical structural areas; and fractographic analysis of defects identified during the “Teardown Phase.” Results of the teardown evaluations illustrate the typical condition of an aged general aviation aircraft and show how

differences in operational environment impact the aircraft’s airworthiness. The teardown evaluations involved a comprehensive look at each airplane as a whole, including airframe, wiring, and systems.

The results of the overall research program point to some recommended actions that may improve the continued airworthiness of aging general aviation airplanes. Some recommendations are specific to an airplane model, while others pertain to the teardown evaluation research program itself and its use in future investigations into the aged general aviation airplane fleet. Detailed results of the program are documented in technical reports for the FAA, the Cessna Aircraft Company, New Piper Aircraft Company, and Hawker Beechcraft Corporation. These results provide valuable information to guide the continued safe operation of aging aircraft and give new insight into the field of aging aircraft research.

INTRODUCTION

Economic and market conditions of present day aviation companies are requiring the use of airplanes far beyond their original design life objectives. This aging airplane concern exists for all types of airplanes including commercial, military, and general aviation. The concern is being amplified as more companies use aged aircraft and rely on standard inspection practices for an assurance of airworthiness. Standard practices to ensure continuing airworthiness include scheduled inspection and maintenance tasks contained in maintenance manuals, Instructions for Continued Airworthiness (ICA), and service bulletins. These practices are not just limited to structural integrity but also include wiring and systems integrity as well. These initiatives have provided timely preventive maintenance recommendations that permit the continued safe operation of aging airplanes until retirement from service for economic reasons.

Although the general public is primarily concerned with the airworthiness of commercial airplanes where most research funding resources and efforts have been focused, a growing concern also exists in the small airplane fleet. While numerous investigations are being conducted on the aging aspects of large transport and military airplanes, limited resources are being expended to understand the aging aspects of the small airplane fleet. The investigations on large transport and military airplanes have focused on the structural integrity as well as wiring and systems related aging problems. The results of these investigations can benefit a similar research program that investigates small airplanes.

Small airplanes are generally classified as general aviation airplanes. When one mentions general aviation, the traditional image usually involves a four-passenger airplane like a Cessna 172. However, general aviation covers a wide range of airplanes. In the context of this program, a general aviation airplane will be defined as a 14 CFR Part 23 (or predecessor CAR 3) airplane, which includes normal, utility, acrobatic, and commuter category airplanes. This classification includes airplanes operating commuter, cargo, or taxi service under 14 CFR Part 135.

The general aviation fleet includes approximately 210,000 fixed wing airplanes with about 71% being single-engine piston aircraft, 10% being multi-engine piston aircraft, 10% being experimental aircraft, and 9% being classified as turboprop, jet, glider, or lighter-than-air. Usage of the general aviation fleet is categorized as follows: 60% for personal use, 21% for business use, 6% for instruction, 4% for aerial application/observation, 3% for commuter service, 2% for public use, and 4% for other usage.

PROGRAM OBJECTIVES

Due to the large number of general aviation airplanes and their wide usage, the aging aspects of these aircraft must be addressed. In September 2002, the Small Airplane Directorate and William J. Hughes Technical Center of the FAA established a research program in order to begin addressing the aging concerns regarding general aviation airplanes. The research program focused on conducting destructive teardown evaluations on aged airplanes used in commuter service to determine if potential continuing airworthiness problems exist for the general aviation fleet as a function of the aging process. The intent of this program is to provide insight into the condition of a typical aged small airplane and to determine if a correlation exists between its maintenance history and the apparent condition of the airplane from a safety of flight perspective. The research program is primarily conducted by the Aging Aircraft Research Laboratory at NIAR, Wichita State University.

Much of the current concern related to aging effects on aircraft focuses on calendar age as opposed to flight hours. For instance, deterioration of wiring, aging effects on aircraft systems (control systems, seals, cables, etc.), and corrosion are calendar related, and these effects

may possibly be a continued safety of flight concern. For example, major attachments, such as wing-to-fuselage attachments, are typically never removed and inspected. These areas of concerns are the areas that the research program primarily focuses on to begin addressing and providing insight into the aging general aviation fleet.

The short term objective of the research program is to determine if potential continuing airworthiness problems exist for the general aviation fleet as a function of the aging process. The long term objective is to establish guidance to ensure current maintenance programs of small general aviation airplanes are providing acceptable levels of continued airworthiness. Achievement of the short term objective should determine if generic degradation indicators exist in the small airplane fleet. These indicators will likely include structural (corrosion/cracking); electrical systems or wiring; aircraft systems, such as fuel, hydraulic, pneumatic, mechanical, and flight control; and maintenance, service, and inspection quality. Determination of generic degradation indicators will assist in providing initial generic inspection guidance, such as:

- Do maintenance inspection programs address all areas of concern appropriately?
- What was found in areas that normal maintenance would not see?
- Are additional inspection criteria required for aged airplanes?
- Should specialized one-time inspections at some age be required?
- Should inspections and maintenance programs become more extensive as the airplane ages?

PROGRAM TEAM MEMBERS

NIAR and the FAA developed an advisory committee, consisting of FAA personnel, NIAR personnel, original equipment manufacturers (OEM) of general aviation aircraft, teardown experts, NDI experts, and a commuter aircraft operator to review the technical approach, findings, and conclusions of the teardown examination program. Figure 1 provides an overview of the key team members from each organization involved. This advisory committee was important to the success of the teardown examination program.



Figure 1 – Program Team Members

MAIN SECTION

AIRCRAFT SELECTION

The first teardown examination was performed on a 1969 Cessna 402A model (tail number N812BW), which had accumulated 19,698.9 airframe hours. The aircraft, shown in Figure 2, was most recently operated in commuter service by Sunshine Airlines for tourism flights from Las Vegas to the Grand Canyon. The second airplane selected was a 1979 Cessna 402C model (tail number N780EA), which is shown in Figure 3. This aircraft had 25,546.6 total airframe hours and was most recently used by Cape Air/Nantucket Airlines of Hyannis, Massachusetts, flying in and around Cape Cod, the Florida Keys, and the Caribbean Islands. The third aircraft selected for destructive evaluation was a 1975 Piper Navajo Chieftain PA31-350 model (tail number N61510), which is pictured in Figure 4 and had accumulated 17,269.9 total airframe hours. The Piper aircraft was operated all across the United States with the majority of the time spent on the West Coast and Alaska. The final aircraft selected for teardown examination was a 1993 Beechcraft 1900D Airliner (tail

number N856CA), which is shown in Figure 5. It had accumulated 15,203 total airframe hours and was operated on the East Coast. Logbooks, the Airworthiness Directive compliance list, and FAA 337 forms were included in the purchase of each airplane. Table 1 provides more detailed information regarding each aircraft.

The two Cessna 402s and Piper Navajo models were selected because they represent a large portion of the small airplane commuter fleet. These aircraft models share many design commonalities with other small twin class airplanes. The design concepts of the structures (layout and materials) are similar model-to-model and manufacturer-to-manufacturer. Therefore, findings from the destructive evaluation of these aircraft models would be applicable to all general aviation models regardless of manufacturer. The Beechcraft 1900D was selected since it was a larger commuter aircraft with a pressurized cabin.

Table 1 – Aircraft Specifications

Aircraft Model	Cessna 402A	Cessna 402C	Piper Navajo Chieftain PA31-350	Beechcraft 1900D
Aircraft Type	Turbo-Charged	Turbo-Charged	Turbo-Charged	Turbo Prop
Airframe Hours	19,698.9	25,546.6	17,269.9	15,203
Airframe Cycles	--	--	--	23,260
Number of Engines	2	2	2	2
Passenger Capacity	6-8	6-8	8	19
Range (Miles)	416	416	833	860
Length (ft)	36.5	36.5	34	57.9
Height (ft)	11.6	11.4	13	14.9
Wing Span (ft)	39	44	40.8	54.5
Take Off Weight (lbs)	6,500	6,500	7,000	15,245
Cabin Type	Not Pressurized	Not Pressurized	Not Pressurized	Pressurized
Operating Environment	Grand Canyon Tour Service (Fatigue)	Cape Air East Coast/ Island Commuter Service (Corrosive)	West Coast Alaska Commuter (Mixed Environment)	East Coast Commuter (Corrosive)



Figure 2 – 1969 Cessna 402A, Tail #N812BW



Figure 4 – 1975 Piper Navajo Chieftain, Tail #N61510



Figure 3 – 1979 Cessna 402C, Tail #N780EA



Figure 5 – 1993 Beechcraft 1900D, Tail #N856CA

OVERVIEW OF THE “INSPECTION PHASE” AND THE “TEARDOWN EXAMINATION PHASE”

The evaluation of each of the aircraft is divided into two main phases, the inspection phase and the teardown examination phase. In the inspection phase, three sub-tasks were performed: a survey of the aircraft maintenance records, routine visual inspection of the airframe and wiring, and structural supplemental inspections. A wiring assessment was not performed on the Beechcraft 1900D as most of the wiring and systems components were removed from the aircraft prior to its arrival at NIAR. The teardown examination phase involved the disassembly of the airframe, close visual inspection of the internal structure, post disassembly NDIs, microscopic examination of suspect and critical structural areas, and fractographic analysis of selected cracks found during the examination to determine extent and failure mode (i.e., fatigue, overload, stress corrosion, etc.).

A survey of the aircraft maintenance records was conducted in an effort to correlate aircraft condition with aircraft usage and maintenance history. Maintenance logbooks, service bulletins, airworthiness directives, and FAA 337 forms for major repairs and modifications were reviewed in this survey. The general condition of each aircraft was evaluated through the routine visual inspections of the airframe and wiring. Airframe visual inspections were performed according to the appropriate maintenance manual, which were supplied by the OEMs. These visual inspections are typically required on an annual basis. The wiring assessment was performed on the Cessna 402A and 402C, and Piper Navajo by a basic visual inspection of all accessible wiring to check the condition of the wires for any defects or flaws, which could pose a risk to flight safety. Wiring finding types included chaffing, rubbing, burning, tearing of the insulation, etc. The intent of the wiring and airframe visual inspections was to identify and characterize the severity and location of each finding prior to the teardown examination phase of the program. This approach would allow the NIAR team to determine which findings could be identified in the field. The results of the routine visual inspections were reviewed by a licensed airframe mechanic to determine which findings were “noteworthy.” Noteworthy findings are findings that would require further maintenance action. Supplemental inspections were performed on the Cessna 402A and 402C aircraft according to Cessna’s Supplemental Inspection Document (SID). Supplemental inspections are comprised of NDI techniques that target principal structural elements. The Piper Navajo did not have an OEM developed SID. NIAR engineers used engineering judgment, structural similarity to the Cessna aircraft, and maintenance history to develop a set of supplemental inspections that were performed on the Piper Navajo. To address structural concerns on the Beechcraft 1900D, the Hawker Beechcraft Structural Inspection Manual (SIM) was used during the routine visual inspections.

At the conclusion of the inspection phase, the teardown examination phase was performed in order to find defects not found by typical maintenance or supplemental inspections. Every finding or NDI indication identified during the inspection phase and teardown examination phase was further investigated during the microscopic examination portion of the teardown examination phase. The Cessna 402A, 402C, and Piper Navajo were disassembled into the major airframe sections including: wings, forward fuselage, aft fuselage, cabin, landing gear, horizontal stabilizer, and vertical stabilizer. All wiring and systems components were removed at the beginning of the teardown examination phase to facilitate easier detailed disassembly. At the time of acquisition, the Beechcraft 1900D was already disassembled into major sections and the systems components and wiring had already been removed. As detail parts were being removed from the airframe, close visual inspections were performed to document existing damage prior to coatings removal. All paint and primer were removed using mechanical techniques (solid media blasting). Fluorescent liquid penetrant (FLP) inspections were performed on all details after disassembly to identify structural defects. These details were then examined microscopically to identify and characterize any defects in the structure. Certain cracks were sectioned and mounted for fractographic analysis to determine the extent of the flaw and the mode of failure (i.e., fatigue, stress corrosion cracking, etc.).

SUMMARIES AND EXAMPLES OF TYPICAL ROUTINE INSPECTION FINDINGS

The routine visual airframe inspections were performed with the intent of finding and documenting every detectable flaw on the aircraft. This inspection approach led to a large number of documented flaws. The results of these inspections on each aircraft were reviewed by licensed airframe mechanics to determine which findings were noteworthy. Most of these flaws were deemed minor, meaning no further maintenance action was required. In general, the combined routine visual inspection results of the four evaluated aircraft revealed similar findings typically addressed in the maintenance field. With an aged aircraft, flaws such as minor cracks, scratches, dents, paint chips, and slight corrosion were to be expected and posed no immediate threat to the safety of the aircraft. In addition to dents and areas of missing paint, slight to moderate corrosion was noted on a majority of the screws on the assessed aircraft. It was also noted that some of the disposable parts on these aircraft such as seals and hoses were due to be replaced. Figure 6 and Figure 7 show examples of typical minor defects observed during the routine visual inspections.



Figure 6 – Paint Bubble in Skin that Cracked Paint



Figure 7 – Corroded Screw Heads

During the routine visual inspections on the Cessna 402A, 1,930 defects were identified with only four deemed noteworthy by a licensed airframe mechanic. This number of defects is much higher than any other aircraft; however, the inspections on the Cessna 402A were performed by different individuals than the Cessna 402C. Many more extremely minor defects were reported on the Cessna 402A than on any other aircraft; therefore, one should not conclude that the Cessna 402A was in worse condition than the other aircraft simply due to the high number of routine visual inspection findings. On the Cessna 402C, 357 findings were observed during the routine visual inspections with only three findings determined to be noteworthy. Only eleven noteworthy defects were identified on the Piper Navajo, while forty-nine of the 194 routine visual inspection findings on the Beechcraft 1900D were classified as noteworthy.

Figure 8 and Figure 9 show the frequency of different categories of findings for the Cessna 402A and 402C, respectively. These charts illustrate that the same finding types, in general, occurred on both aircraft with

about the same frequency. It is important to note that since corrosion and rusted screws are related, at times these categories may have been used interchangeably. The breakdown of findings locations for the Cessna 402A and 402C are provided in Figure 10 and Figure 11.

These charts also illustrate similarities in the frequency of findings in major airframe components. These trends in both the finding type and finding location were observed on the Piper Navajo and Beechcraft 1900D as well.

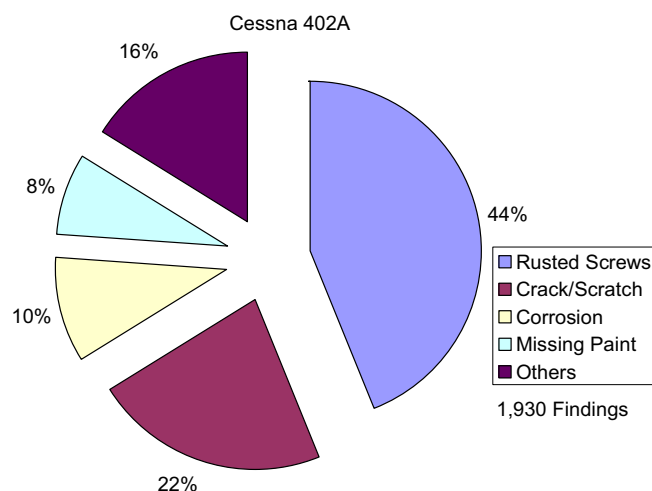


Figure 8 – Findings by Type, Cessna 402A

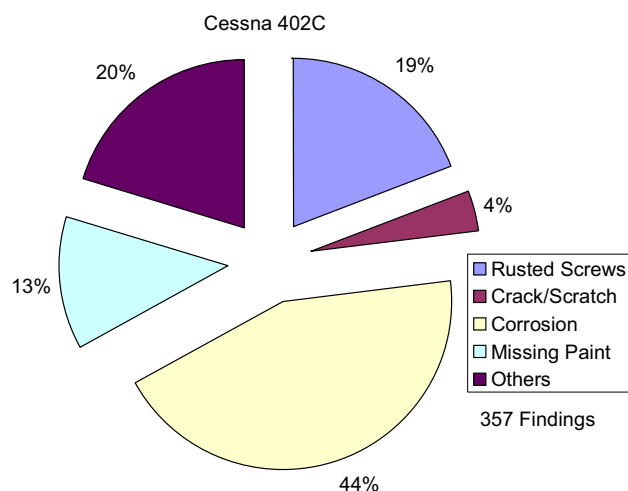


Figure 9 – Findings by Type, Cessna 402C