

Helicopter Tail Rotor Blade from Composite Materials: An Experience

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ABSTRACT

In this paper the design, fabrication and analysis of behavior by full-scale verification testing for the tail rotor blade of composite laminated materials for a heavy transport helicopter is given.

The verification test program for the tail rotor blade encompassed static and dynamic testing. The static tests of the blade involved experimental evaluation of torsional and flexional blade stiffness and its elastic axis position. Dynamic tests involved testing of vibratory characteristics and testing of blade fatigue characteristic. In structural vibration tests natural frequency, vibration modes and damping ratio for the structure were measured. The fatigue analysis of the structure of blade root section was performed after fatigue test cycles for detection of laminate separation, tolerance and distortion of crosssections of structure.

INTRODUCTION

In general, high-performance composites exhibit high strength and stiffness, low density, and good resistance to fatigue and corrosion, properties that make them very well suited for many aircraft and aerospace applications. The use of fiber-reinforced composites in flight critical structures in helicopters is growing rapidly. But, the introduction of composites has not been without problems. These include development of entirely new design, fabrication, and qualification discipline, difficulty in analyzing internal stresses, demonstrating this technology to certifying agencies, determination of adequate test criteria, and quantifying environmental degradation [1, 2].

The development and qualification of the helicopter components and system includes a heavy emphasis on a full-

scale test approach independent from the design process. In the case of fatigue-loaded flight-critical components, a laboratory fatigue program is conducted, supported by static and vibratory tests, stress surveys and coupon or subelement programs [3, 4].

The importance of full-scale testing in the development (and/or redesign) process for fiber-reinforced composite helicopter blades is discussed, and illustrated by means of an example drawn from Aeronautical Department (Faculty of Mechanical Engineering, University of Belgrade) experience in the use of composites in a wide variety of structural applications. The laboratory investigations of the structural properties are conducted at Aeronautical Department on all flight-critical dynamic components in order to determine structural adequacy in designing process [4].

In this paper the design, fabrication and analysis of behavior by full-scale verification testing for a tail rotor blade of composite laminated materials for a heavy transport heavy transport helicopter is given (see [Figures 1](#) and [2](#)).

DESIGN AND FABRICATION

A development of a tail rotor blade was performed in four phases: (1) the blades design on the working station using designing system Howard-Hughes and automated Gerber-marker making system (see [Figure 3](#)), (2) preparation and cutting of blade components on the Gerber-Garment cutting system ([Figures 4,5,6](#)), (3) blade manufacturing in a two-section metal die ([Figure 7](#)), and (4) final verification testing.

In the blade manufacturing procedure the conventional composite materials with epoxy resin matrix, a fiberglass filament spar, an eighteen-section skin of laminated fabrics ([Figure 4](#)), some carbon filament embedded along the trailing edge, a core, leading edge protection strips of polyurethane

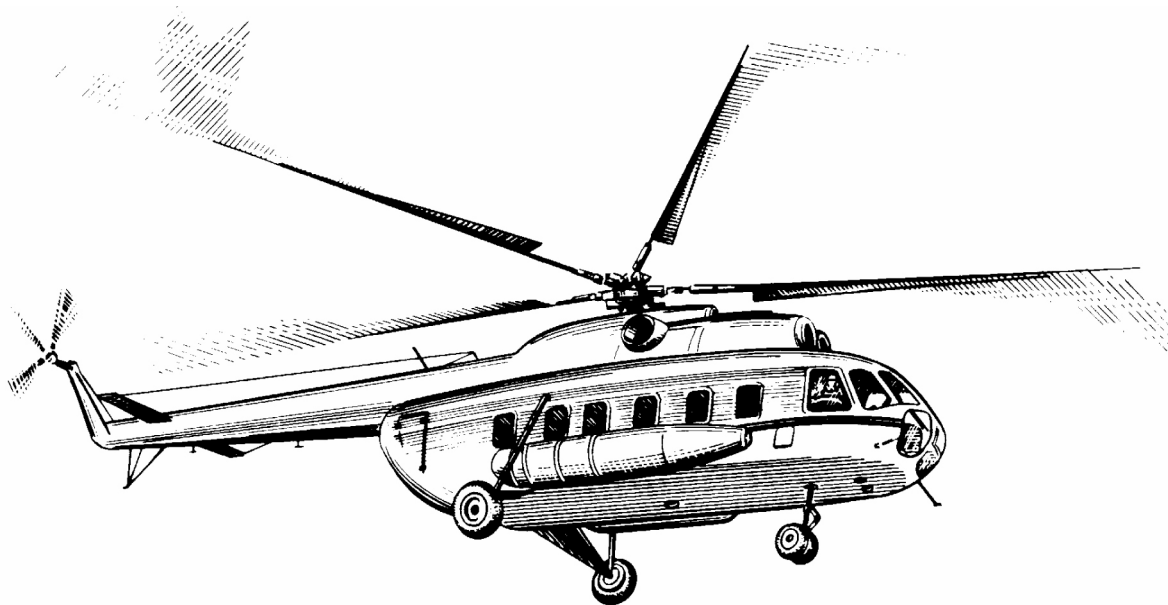


Figure 1. Heavy transport helicopter.

and stainless steel etc. were used. All the used materials are standard products fabricated at Ciba-Geigy, Interglas GmbH, Torayca and others [5,6,7,8,9,10].

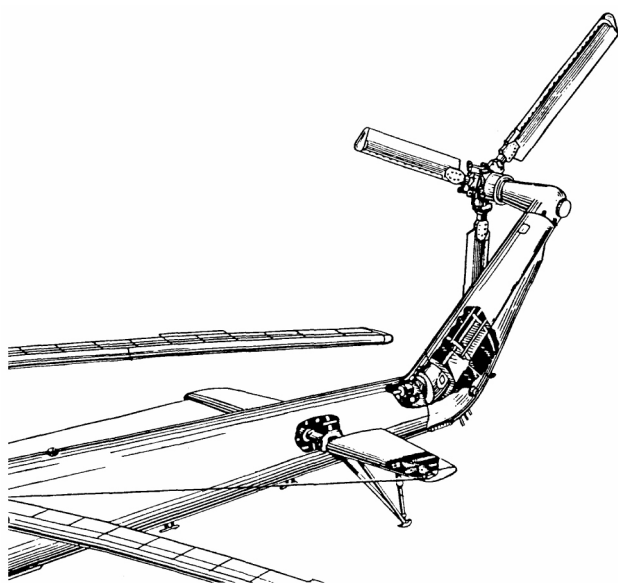


Figure 2. Heavy transport helicopter tail rotor.

Each blade paddle consists of a fiberglass-epoxy spar and a fiberglass blade section which is fastened to the outboard end of the spar. Unidirectional fiberglass-epoxy is used to provide a high modulus in the axial direction and adequate torsional stiffness for full pitch change motion of the blade. Similarly, flapping (out-of-plane) motions are accommodated through elastic bending of the spar. The spar cross section provides

the high edgewise (in-plane) stiffness required for an aeroelastically stable rotor.

The inboard or torque tube portion of the blade is not supported by core and is designed to provide high torsional rigidity. The trailing edge contour of the airfoil is formed by a continuous structural pocket which has a Rohacell polyurethane foam core and a fiberglass skin. The upper and lower skins are fabricated from woven fiberglass that is laid up with the fibers oriented at $\pm 45^\circ$ and $0^\circ/90^\circ$ to the blade longitudinal axis. On the blades, the inplane blade natural frequency is tuned by stiffening the trailing edge of lower skin with some carbon filaments.

The leading edge contour is formed by a fiberglass leading edge piece which is protected from erosion by a combination of "C" shaped stainless steel and polyurethane erosion strips which are bonded to the blade leading edge. A series of counterweights are bonded to the leading edge of the spar to provide the required chordwise blade balance. The counterweights are moulded of elastomer with lead shot embedded in the matrix of fiberglass with lead rod in the laminate. The counterweights fill the area between the leading edge piece and spar [10].

In assembly, the first process is to cut the fiberglass fabrics to the require shape and stacking it to build up the required shapes (see Figures 4,5,6).

Next stage is wovenwrap and placed it in a matched metal tool, together with the fiberglass filament spar, uncured trailing edge skins, the Rohacell polyurethane foam core and tool transferred to heated platten press (see Figure 7).



Figure 3. Automated Gerber-marker making system.

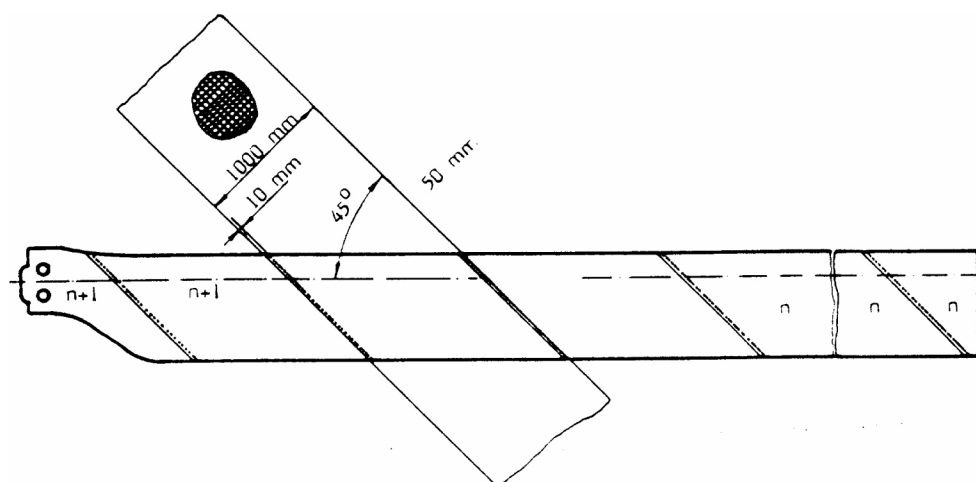


Figure 4. The sections of a skin woven.

The resin (Ciba-Geigy type) used in blade manufacture is cured in two stages. In the first the component is warmed (70°C to 90°C, the duration of 2 hrs) until the resin becomes fluid. The matrix is then consolidated and shaped by pressure. This reduces the bulk of the material drives out included air. The component may then be fully cured by raising the temperature to 120°C (1 hr).

TESTING AND RESULTS

The verification test program for the helicopter blade encompassed static and dynamic testing [4]. The static tests of the tail blade involved experimental evaluation of torsional and flexional blade stiffness and its elastic axis position. Dynamic tests involved testing of vibratory characteristics and verification testing of blade fatigue properties

The purpose of the static tests was to evaluate experimentally torsional and flexional stiffness and elastic axis position of the blades. The employed techniques and methods at the testing are the usual practice at all aerospace research centers [4].

To fit the blade model, a robust facility frame made of steel L and U-profiles was employed. For load application, i.e. for force and torque, an airfoil clamp and system of wheels and cables mounted on a special frame made of steel profiles were used (Figure 8). For displacement measurement, comparators with an accuracy of 0.01 mm were used.

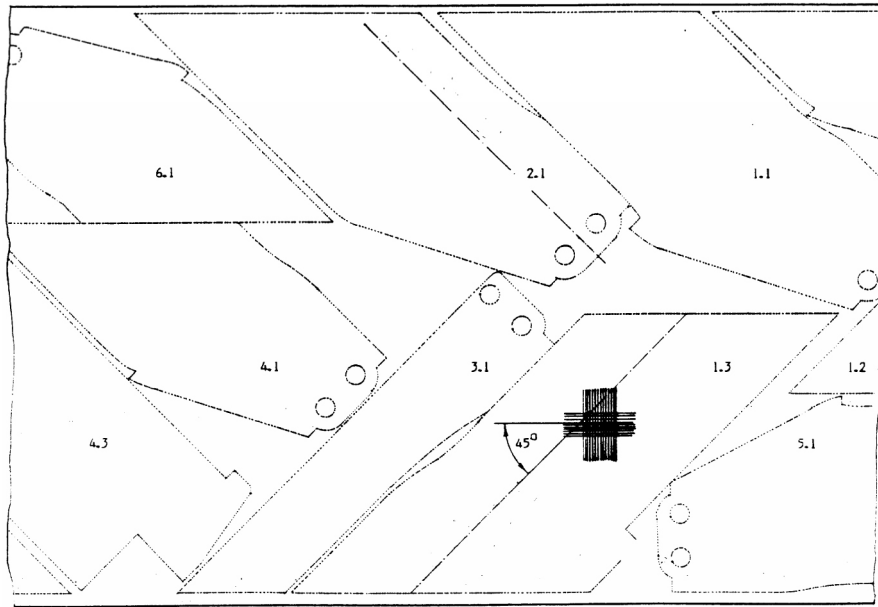


Figure 5. The woven sections for cutting prepared by computer.

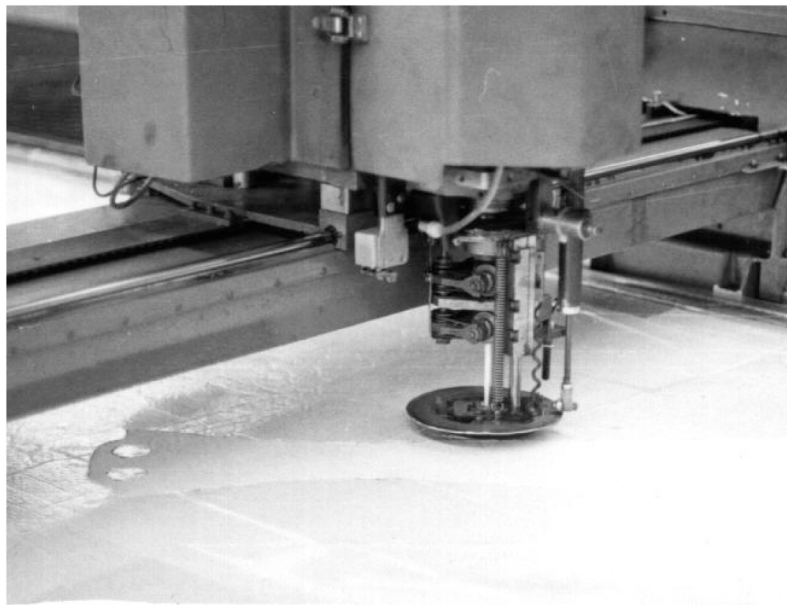


Figure 6. Automated Gerber-Garment cutting facility.