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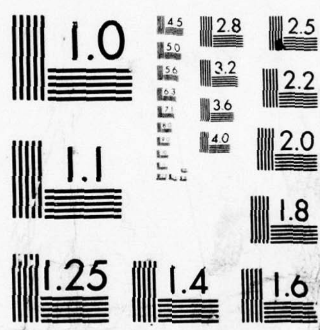

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RAM PROJECTIONS FOR AIRCRAFT ROTOR BLADES

ISRAEL NUSSBAUM

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FINAL REPORT

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number):

Data was collected and a comparative analysis was performed on the estimated Reliability and Maintainability (RAM) characteristics of the main rotor blades belonging to two groups of four Army aircraft systems each. The first group is composed of aircraft in the current Army inventory, while the second consists of developmental and PIP aircraft which will be using the new composite rotor blades. The study was initiated internally as a result of wide discrepancies observed among various aircraft programs in the assumptions, definitions and methodologies

20. ABSTRACT (CONTINUED)

used in projecting rotor blade RAM characteristics. The need became apparent to develop and apply a set of factors and criteria that could be used to help achieve uniformity, consistency and validity in the RAM projections.

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RAM PROJECTIONS FOR ROTOR BLADES

1. OBJECTIVE: This study was internally generated in anticipation of future requests from outside activities for aircraft rotor blade and other component RAM data. It was felt that work in this area now would permit quick reaction whenever specific RAM data requirements for TOE construction arise in the future. In addition to outside requests, this data is needed internally as direct input to life cycle cost estimates and updates for developmental aircraft systems. Specifically, the purpose of this study is twofold:

a. To collect and compile realistic RAM data on several current aircraft rotor blade systems.

b. To obtain the latest available RAM projections for rotor blades on several developmental and PIP aircraft systems which are expected to utilize the new composite blades.

2. SCOPE: The scope of this study is limited to analysis of RAM data on the main rotor blades of the following aircraft systems:

a. Current Systems: AH-1G, CH-47C, OH-58A and UH-1H.

b. Developmental Systems: AH-1S, AH-64 (AAH), CH-47D (MOD) and UH-60A (BLACK HAWK).

3. BACKGROUND AND DISCUSSION:

a. This study was initiated as a result of the wide discrepancies found among the various aircraft programs in the assumptions, definitions and methodologies used in estimating rotor blade RAM characteristics. The need became apparent to develop and apply a set of factors and criteria involving a step-by-step procedure that could be used to help achieve uniformity, consistency and validity in the RAM estimates and projections. This procedure would be similar to that used in a previous study on aircraft RAM data (reference 1), and would be applied to both current and developmental rotor blade systems.

b. It should be noted that RAM is only one of the many considerations involved in the decision to utilize rotor blades made of composite materials, including fiberglass, rather than conventional metal rotor blades. A list of the projected advantages of using fiberglass blades over metal is contained in Appendix A. For further background, a general discussion of Army helicopter composites is contained in reference 2.

c. The composite rotor blade program for the Army is considered a major PIP effort. The importance of this program is emphasized in the original DA tasking letter, dated 18 January 1977, which formally initiated the Army's Composite Rotor Blade (CRB) program. (Reference 3)

4. APPROACH AND METHODOLOGY:

a. As indicated in paragraph 1, RAM rotor blade data and projections will be provided for both current and developmental/PIP aircraft systems. In addition, an attempt will be made to compare the newer rotor blades with the older ones to see if there are significant RAM improvements resulting from the use of composite blades.

b. The RAM characteristics of prime interest are as follows, although it should be noted that data is not available for all them:

(1) Mean Time Between Repair/Replace (MTBR) for inherent failures and for all causes.

(2) Mean Time to Replace/Repair (MTTR) in the field (AVUM and AVIM levels) and at the depot level.

(3) Maintenance Manhours per Flight Hour (MMH/FH) in the field and at the depot.

(4) The expected service life or retirement life of the blade.

c. As a check on the RAMMIT data for the current systems, that data will be compared with field demand data for main rotor blades. The latter will be shown in terms of a parameter identified as Mean Time Between Demands (MTBD), which is defined as total flight hours during a given reporting period divided by total demands for the item during that period. Thus, MTBD can be compared with MTBR for all causes. Although MTBD is not expected to be identical with MTBR, it should dovetail closely with it, since demands are a reflection of the need for replacement. In fact, the MTBD figures should be roughly 60% greater than MTBR (meaning that demand frequency is less than the removal rate) due to field repairs, swapping or cannibalization of blades, and time lags in ordering. It should be noted that if the monthly demand per aircraft is known, the MTBD parameter can be computed as follows:

$$MTBD = \frac{\text{(Avg. flight hrs/mo.)* (No. blades/acft) * (No. acft in fleet)}}{\text{Total demands/mo.}}$$

d. After the RAM data on the current blades is obtained and validated by comparison with demand data, it can be used as a check on the RAM projections for the new (developmental or PIP) blades, which are obtained directly from the proponent PM offices for each aircraft system. The current data serves as a basis for challenging the PM's figures on the new blades if they are suspected to be too high or too low. The PM office would then revise its data or at least provide an appropriate explanation for the anomaly.

5. <u>RESULTS TO DATE</u>: Due to the difficulty in obtaining good data, the results to date should be regarded as tentative. However, enough data is available to do at least a preliminary comparative analysis.

a. Current Systems - Figure 1 and 2 contain RAM data and Field Demand data, respectively, on the four current systems listed in paragraph 2. The MTBR data shown in Figure 1 consists primarily of replace actions recorded in the field on DA Forms 2140, whose contents are the main source for the RAMMIT analyses of the raw TAMMS data (Reference 4). Unfortunately, the only data currently available is from the 1970-77 time period, which is largely influenced by the Vietnam experience. An attempt to isolate more recent data is currently in progress. In the meantime, comparison of the MTBRs with the MTBD data in Figure 2 would not be valid because of the different reporting periods of the data. However, it may be observed that the MTBDs are indeed greater than the MTBRs, as expected. What is not expected is the excessive magnitude of the differences. Hopefully, when the more recent MTBR data becomes available, the differences may be narrowed more closely to the expected 60% differential.

b. Developmental Systems - The data on these systems is rather sketchy, being based primarily on development estimates and program objectives. Figure 3 shows the current projections for each of the four developmental systems listed in paragraph 2. Although the UH-60A system does have some test data available, the figures shown are reliability growth projections, which are influenced by test results. The

FIGURE 1

RAM DATA FOR MAIN ROTOR BLADES - CURRENT SYSTEMS

ACFT SYSTEM	NO. BLADES	MTBR[1/] (INHERENT)	MTBR[1/] (ALL CAUSES)	MTTR FIELD REPL.	RETIREMENT LIFE	MMH/FH SCHED.	MMH/FH UNSCHED.
AH-1G	2	214 hrs	204 hrs	3.79 hrs	1,100 hrs	--	.0186
CH-47C	6	1,781	237	4.15	5,000	--	.0175
OH-58A	2	459	410	4.11	2,400	--	.0100
UH-1H	2	729	446	3.87	2,500	.1300	.0089

1/ Primarily replace actions.

Source: RAMMIT Analysis of TAMMS Data, 1970-77.

FIGURE 2

FIELD DEMAND DATA FOR MAIN ROTOR BLADES - CURRENT SYSTEMS

ACFT SYSTEM	NO. BLADES	REPORTING PERIOD	NO. ACFT IN FLEET	TOTAL FLIGHT HRS	TOTAL DEMANDS	MTBD[1/]
AH-1G	2	Oct 77-Sep 78 (12 Mo.)	441	41,458	149	556 hrs
CH-47C	6	Oct 77-Sep 78 (12 Mo.)	210	31,229	373	502
OH-58A	2	Oct 77-Oct 78 (13 Mo.)	2,025	318,320	535	1,190
UH-1H	2	Nov 76-Oct 78 (24 Mo.)	3,566	1,405,658	2,019	1,392

1/ Mean Time Between Demands (MTBD) = Total Flight Hours/Total Demands.

Source: Item Managers, Directorate for Materiel Management, TSARCOM.

FIGURE 3

RAM PROJECTIONS FOR MAIN ROTOR BLADES - DEVELOPMENTAL/PIP SYSTEMS

ACFT SYSTEM	MTBR INHERENT/ ALL CAUSES	MTBR - ALL CAUSES		MTTR		MMH/FH			RETIREMENT LIFE
		REPLACE	REPAIR	REPLACE	REPAIR	AVUM	AVIM	DEPOT	
AH-1S	3,401/737 hrs	3877 hrs	910 hrs	2.5 hrs	1.6 hrs	.0853	.0006	--	10,000 + hrs
AH-64	11,000/1,996	--	--	--	--	.0047	.00125	.0053	4,500
CH-47D	1,426/885	2750	885	--	2.7	.2351	.1289	--	10,000 +
UH-60A	1,910/770	858	7548	0.2	0.4	.020	.166	.443	20,000

Source: PM development estimates, reliability growth estimates, and program requirements.

growth projections for the UH-60A were chosen for display in order to equalize its figures with those of the other systems.

c. Comparison of Current and Developmental Systems - A meaningful comparison between current and developmental rotor blades is not possible, since both data sources are suspect. However, observation of the figures shown for the corresponding RAM parameters indicates a logical progression from current to developmental systems. The most dramatic improvement is expected in the area of blade retirement life, which should be practically unrestricted on the new blades.

6. <u>FUTURE EFFORT</u>: As indicated in paragraph 5a above, an attempt is being made to isolate more recent data on the current blades. Specifically, the data being sought would cover the 1974-78 time period, which would eliminate nearly all of the Vietnam-era bias while still providing a large enough base for a meaningful assessment. This data should be available in the near future, as soon as existing computer programming problems are resolved. In regard to the developmental blades, it is anticipated that actual data, as well as improved projections, will eventually be available as more RAM/LOG data comes in from both test sites and operational field environments. When new data becomes available on current and/or developmental rotor blades, the changes will be included in a future revision to this report.

APPENDIX A

ADVANTAGES OF FIBERGLASS ROTOR BLADES

OVER METAL BLADES

ADVANTAGES OF FIBERGLASS ROTOR BLADES OVER METAL BLADES

*Improved Safety
*Improved Performance
*Increased Reliability and Maintainability
*Improved Survivability
*Increased Fatigue Life
*Reduced Radar and Aural Detectability

Improved Safety - For equal weight, the spar material of a fiberglass blade is four times thicker than a steel blade and has five times greater static strength. This higher strength-to-weight ratio of fiberglass provides a "strength bonus" which enhances the structural reliability, and hence safety, of the blade. Even more important is the characteristic "soft" failure mode of fiberglass blades. This refers to the fact that when fiberglass blades are stressed beyond their design values, they will gradually lose stiffness and provide vibratory or other warning, but they will not rupture abruptly as will metal blades. If fiberglass blades are damaged by mishandling, tree strikes, or combat, the damaged area will not grow rapidly under repeated flight loads. Similar damage in metal blades causes stress concentrations and fatigue cracking which rapidly leads to blade failure.

Improved Performance - The precision molding processes used to produce fiberglass blades allow almost unlimited variations in airfoil section, taper, and twist along the span of the blade. This gives the designer the ability to optimize blade aerodynamic characteristics in an economical manner not possible with metal blades. In addition, the mass and stiffness distributions of fiberglass blades can be controlled more easily than with metal blades resulting in better dynamic characteristics for the composite blade. Performance improvements (usually measured in terms of increased hover gross weight or reduced horsepower required to hover at a given weight) in the range of 2% to 6% can be reasonably expected to result from fiberglass blades.

It is important to note that it may not be possible to take full advantage of these performance improvements when replacing metal blades on existing helicopters. This is because the existing rotor head, drive system, and supporting structure may not be able to absorb increased lifting loads generated by the new fiberglass blade.

Increased Reliability and Maintainability - A major problem of metal blades which contributes to their low reliability is corrosion of metal spars and aluminum honeycomb structure. Fiberglass blades are corrosion-free. The characteristic of high strength without high stiffness allows fiberglass blades to be bent, without damage, by ground winds, snow loads, and mishandling. Also, fiberglass blades are relatively insensitive to small defects and notches which in metal blades would result in ever growing stress patterns radiating from the defect until catastrophic failure of the structure results. All of the factors combine to give the fiberglass blade much better reliability than metal blades. Another plus for fiberglass blades is the ability to field repair virtually all damage not requiring complete replacement of major blade components.

Improved Survivability - The ability of a blade to survive after ballistic damage is related to the failure mechanism of the material. There is considerable difference between the failure mechanisms of metal and fiberglass blades. Metal blades "tear" when hit resulting in extended damage beyond the hit area and providing crack starters which accelerate damage propagation. Depending upon the severity of the hit, catastrophic failure usually results anywhere from instantaneously to within a few flight hours. Fiberglass blades, on the other hand, confine damage to the area of the hit and the crack propagation rate is much slower than in metal blades. In one test performed by Boeing Vertol, a hit by a 20mm HEI caused 50% loss of spar area, but no damage growth was evident after 6 hours of flight loads. Under similar conditions, a hit by a 20mm HEI on a metal spar resulted in catastrophic failure (separation) after 3 minutes of flight load.

Fiberglass blades are also more survivable against tree strikes and similar FOD damage. On an equal weight basis, fiberglass can withstand 12 times greater compression load (such as occurs in tree strikes) than an equal weight steel spar.

Increased Fatigue Life - Fiberglass blades exhibit almost unlimited fatigue life. Associated with this characteristic is the option of establishing "on-condition" removal rather than a specific finite life. This will result in longer service life and reduced life cycle cost.

Reduced Radar and Aural Detectability - All composite blades (those without metal erosion strips) offer reduced radar signature over metal blades. In addition, the aerodynamic refinements possible with composite blades have resulted in significant noise reductions associated with helicopter blades. These factors combine to increase the survivability of the helicopter operating in a hostile environment.

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