

DOC. N. : **R-101-10-06**Issue : **B**Customer : **/****TITLE : MAIN ROTOR STRESS SUBSTANTIATION**Summary

This report presents the static and fatigue stress substantiation of the main rotor system for the ES101 helicopter kit.

All the calculated, static and fatigue Margins of Safety are positive.

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**MODIFICATIONS RECORD**

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## **1 Introduction**

This Aviotecnica Technical Report presents the static and fatigue stress substantiation of the main rotor for the ES101 helicopter kit.

In particular, the CRITICAL parts (whose structural failure can compromise flight safety) shall be considered by the analysis.

## **2 References**

### **2.1 CS-VLR**

Certification Specifications for Very Light Rotorcraft CS-VLR  
Amendment 1 - 17 November 2008  
EASA

### **2.2 CS27**

Certification Specifications for Small Rotorcraft CS27  
Amendment 2 - 17 November 2008  
EASA

### **2.3 Order 8110.9**

Handbook on Vibration and Fatigue Evaluation of Helicopter and Other Power Transmission System  
20 January 1975  
FAA

### **2.4 Manuale di Impiego per il Pilota**

25 August 2003  
Aviotecnica

### **2.5 DOT/FAA/AR-MMPDS-01**

Metallic Materials Properties Development and Standardization (MMPDS)  
January 2003  
FAA

**2.6 R-101-10-01**

BASIC DESIGN CRITERIA FOR THE ES101 HELICOPTER TRANSMISSION SYSTEM

May 2010

Aviotecnica

**2.7 PB.AT 22**

VALIDATION DES PALES ECA SC 1003-EC

September 2006

ECA

**2.8 SSM-1**

SIKORSKY STRUCTURES MANUAL

1992

United Technology Corporation

**2.9 R-101-10-02**

MAIN ROTOR MAST (P/N E1.63.039.202) STRUCTURAL STRESS ANALYSIS

June 2010

Aviotecnica

**2.10 Mechanical Engineering Design**

By J.E. Shigley / L.D. Mitchell

1983

Mc Graw-Hill

### 3 Acronyms and Abbreviations

|     |                          |
|-----|--------------------------|
| CG  | Center of Gravity        |
| FEA | Finite Element Analysis  |
| FEM | Finite Element Method    |
| FRP | Fiber Reinforced Plastic |
| g   | gravity acceleration     |
| GAG | Ground-Air-Ground        |
| LCF | Low Cycle Fatigue        |
| MCP | Maximum Continuous Power |
| MGB | Main Gearbox             |
| MR  | Main Rotor               |
| Nr  | Rotor RPM                |
| RPM | Revolutions Per Minute   |
| TOP | Take-Off Power           |
| TR  | Tail Rotor               |
| VM  | Von Mises                |

### 4 Basic Main Rotor Data (Ref. Fig. 1)

#### 4.1 Main Rotor Basic Data

|   |                                      |
|---|--------------------------------------|
| Type.....                               | : teetering (see-saw)                |
| Number of blades.....                   | : 2 (Ref. 2.4)                       |
| Sense of rotation.....                  | : counter clock-wise seen from above |
| Diameter.....                           | : 7680 mm (Ref. 2.6)                 |
| Radius.....                             | : 3840 mm                            |
| Pre-Cone.....                           | : 2.5°                               |
| Nominal rotational speed.....           | : 535 RPM (100%)                     |
| Rotational speed range (power on).....  | : 98 % – 102 % (Ref. 2.4)            |
| Rotational speed range (power off)..... | : 90 % – 110 % (Ref. 2.4)            |
| Flapping angle.....                     | : +/- 8°                             |
| Mass of hub and blades.....             | : 40 Kg                              |

#### 4.2 Blades Data (Ref. 2.7)

|  |                     |
|--|---------------------|
| Airfoil.....                             | : NACA 23015        |
| Length.....                              | : 3550 mm           |
| Cord.....                                | : 195 mm            |
| Thickness.....                           | : 28 mm             |
| Single Blade Mass .....                  | : 12.5 Kg           |
| Radius of CG (289.3+1800).....           | : 2089.3 mm         |
| Nominal Centrifugal Force (100% Nr)..... | : 81974 N = 8356 Kg |



Maximu Centrifugal Force (110% Nr).....: 99188 N = 10111 Kg

#### 4.3 Rotor Torques (Ref. 2.9)

Limit Torque.....: 203.6 Kgm  
Fatigue Torque (steady).....: 190.0 Kgm  
Fatigue Torque (alternating,  $\pm 15\%$ ).....:  $\pm 28.5$  Kgm  
Bearing Design Torque.....: 122.1 Kgm

### 5 Factors and Assumptions

The following safety factors shall be used in the substantiation of the design of the transmissions system.

Static factor of safety.....:  $K_S = 1.5$  (Ref. 2.1)

Static casting factor.....:  $K_C = 2$  (Ref. 2.1)

Limit torque factor.....:  $K_{TQ} = 1.25$  (Ref. 2.2)

Crash loads (Ref. 2.1):

- |              |      |
|--------------|------|
| (1) Upward   | 1.5g |
| (2) Forward  | 12g  |
| (3) Sideward | 6g   |
| (4) Downward | 12g  |
| (5) Rearward | 1.5g |

Fatigue factor of safety.....:  $K_F = 3$  (Ref. 2.3)

NOTES:

- 1) a fatigue factor of safety  $K_F = 2.5$  may be used for parts of simple geometry or where the calculation method is detailed enough to provide a more precise and reliable estimate of the calculated stresses (e.g. if detailed FEA models have been used)
- 2) for low cycle fatigue (limited life) the factor  $K_F$  may be taken as 1 provided that the a suitable life factor (see blow) is adopted

Torque modulation factor.....: 0.15 (+/- 15%)

Life factor.....:  $K_L = 10$

Number of start/stop cycles per flight hour.....:  $N_{S/S} = 4$