AvioTecnica®	Technical Report R-101-10-06/B

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.

FILE : R-101-10-06_B_Hub_and_blades_001.doc	**LINKS** : N.A.
NUMBER OF PAGES : 55	

Prepared by : Signature: Date:	Aviotecnica October, 16th 2010
Approved by : Signature: Date:	Aviotecnica October, 16th 2010

DISTRIBUTION

Customer (PDF file)

MODIFICATIONS RECORD

ISSUE	ISSUE DATE	AFFECTED PAGES	REASON OF CHANGE	AUTHOR
A	10/10/2010	ALL	FIRST ISSUE	Aviotecnica
B	16/10/2010	ALL	GENERAL UPDATE	Aviotecnica

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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, ±15%)……………………: ±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