POLITECNICO
MILANO 1863

Application 1 – Part 1

Safe-life and damage tolerance analysis of TP400 propeller shaft

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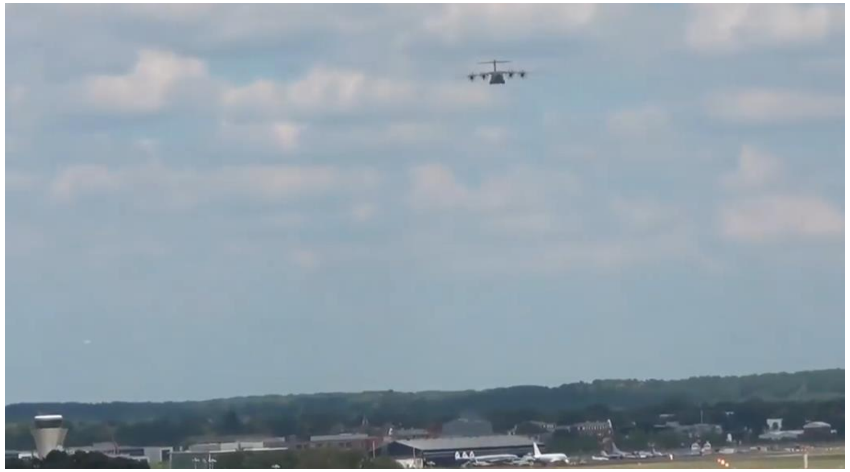
Avio Aero
A GE Aviation Business

Introduction (1)

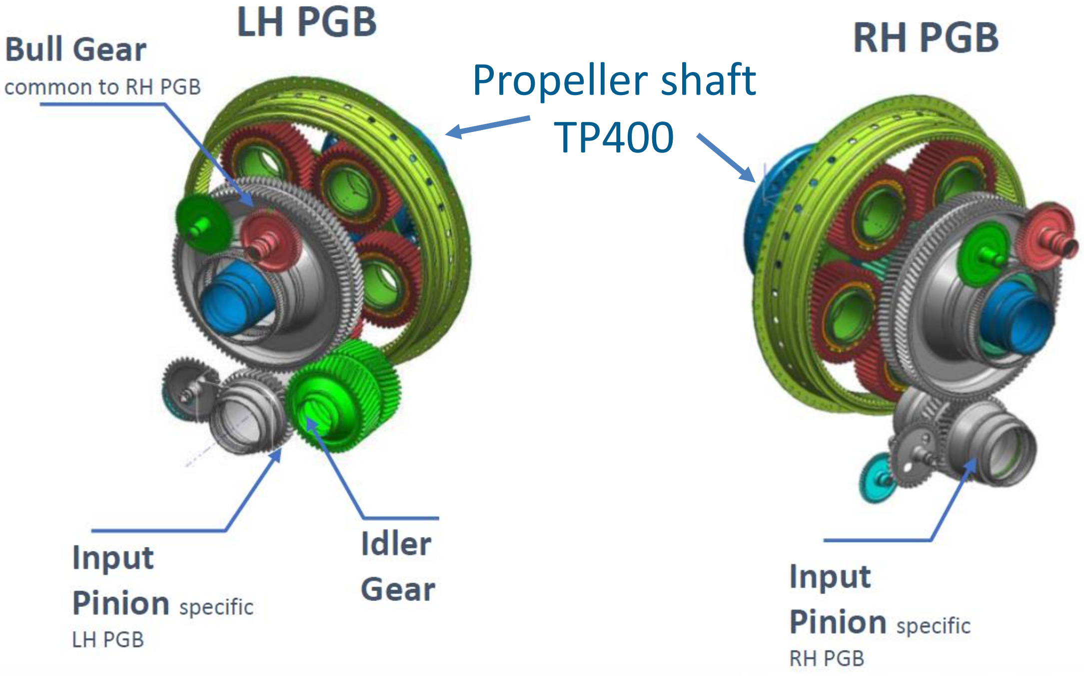


Airbus A400M

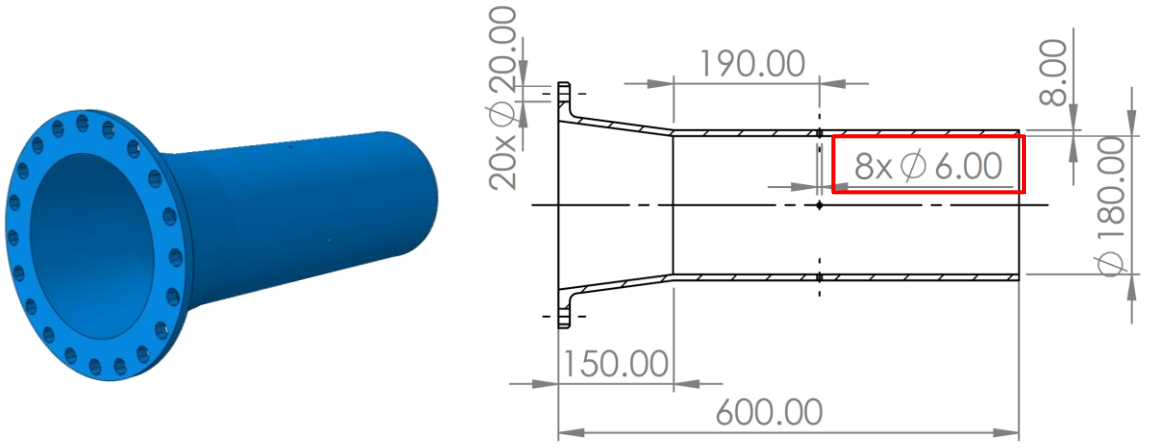
Military airlifter

Four-engine turboprop

Gear transmission

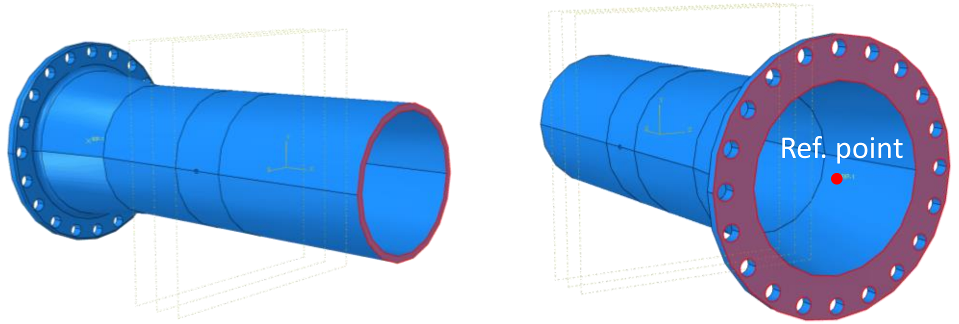


Introduction (2)



Shaft geometry

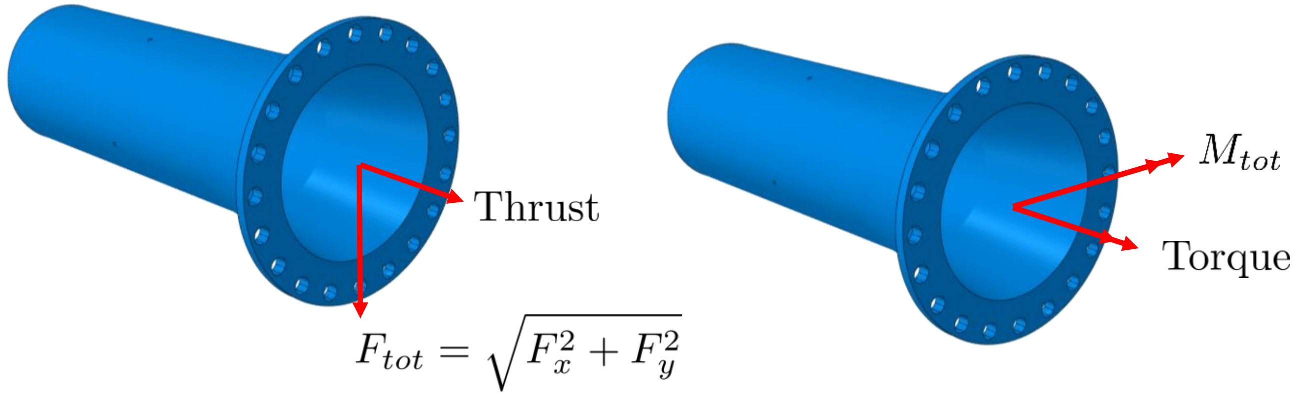
Numerical model for local stress identification



One end is encastered

The other is coupled with a ref. point for load application

Loads acting on the shaft



For simplicity, we assume that radial forces generate a moment in phase with the bending moment (conservative assumption)

During operation, the shaft rotates:

→ Torque and thrust generate a costant state of stress (**mean stress**) in the section

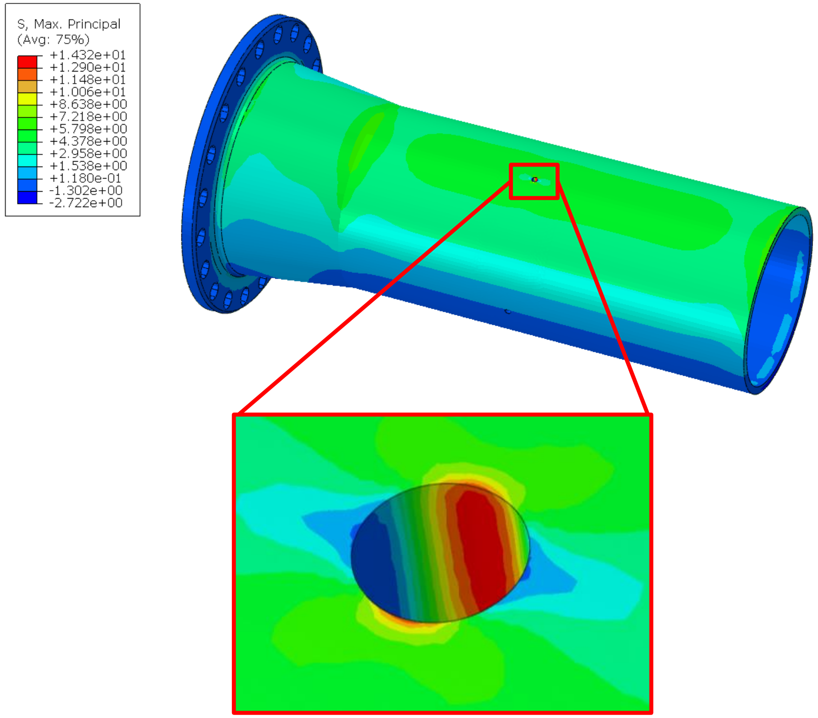
→ Bending moment and radial force generate an **alternate stress** state in the section

Stress history data (1)

We have the measurements of the loads acting on the shaft for 3 different mission profiles:

- Profile 1: approximately 3 hours of flight
- Profile 2: approximately 1 hours of flight
- Profile 3: extreme flight mission (to be used for maximum admissible crack)

→ A standard mission is composed by profile 1 + profile 2 (4 hours of flight)

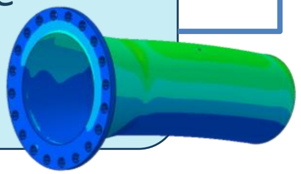


Most critical point is the drain hole

Time history of load components

$M_{tot}(t),\ F_{tot}(t),\ \ldots$

FE model of the component



Time history of equivalent amplitude and mean stress

$\sigma_a(t),\ \sigma_m(t)$

Stress history data (2)

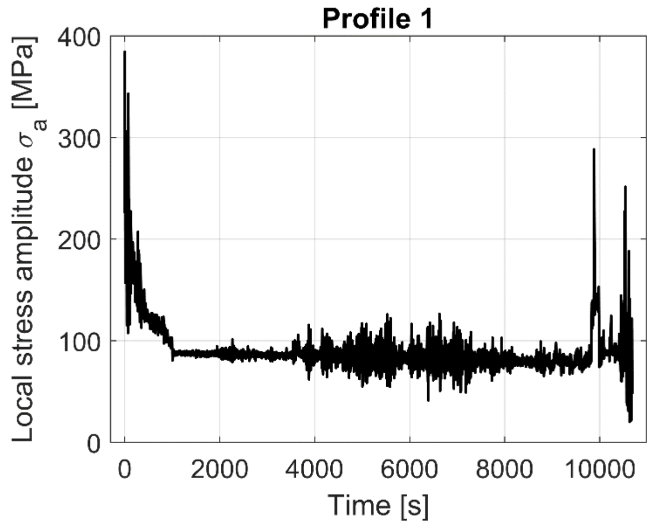
- For each profile, you have an excel file with three columns: time, alternate stress and mean stress (maximum value during the sampling time)
- The shaft rotates with a constant rotational speed ω of 900 rpm
- The stresses are given as local values, i.e. they already embed the concentration factor given by the hole (K_t = 3)

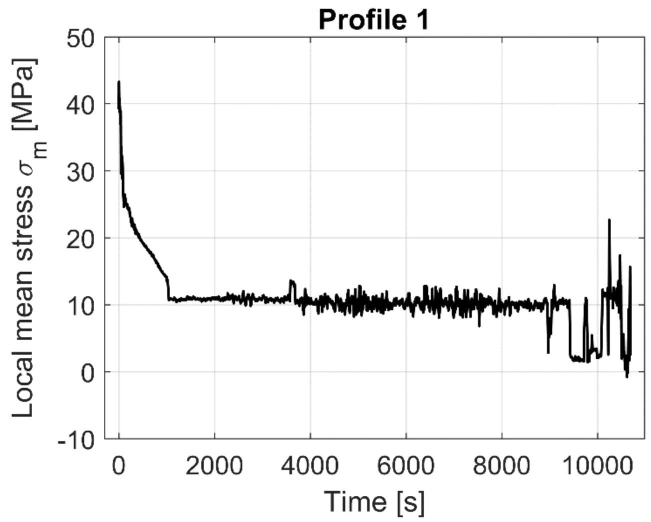
t [s]	σ_a [MPa]	σ_m [MPa]
0	225.707	39.179
0.156	259.589	40.100
0.313	272.900	40.566
0.469	295.062	40.900
0.625	340.689	41.814
0.781	364.744	42.269
0.938	360.365	42.503
1.094	370.745	42.809
1.25	384.434	43.201
1.406	380.566	43.282
1.563	376.857	43.148
…	…	…

Each line correspond to a number or cycles:

$$n_i = \omega(t_{i+1} - t_i)$$

!! ω in round per seconds !!





Material data

Material: AISI430 steel

Elastic modulus [MPa]	210000
Poisson’s ratio	0.3
Yielding stress [MPa]	972.2
UTS [MPa]	1103
KIc [MPa m^1/2]	112.1

Fatigue data from the excel files fatigue_dataX.xlsx, where X is your data code

S [MPa]	N [cycles]	Run-out?
750	20924	0
750	19515	0
750	20012	0
750	31092	0
750	26412	0
650	83565	0
650	65788	0
650	67308	0
650	58303	0
650	110779	0
550	391092	0
550	356807	0
550	308519	0
550	276038	0
550	370768	0
450	2000000	1
450	1582332	0
450	1696395	0
450	1855152	0
450	1412137	0

Data for SN fitting

Staircase (X failure, O run-out)					
480					
470					
460				X	
450	X		O		X
440		O			
430					

Modified staircase results for fatigue limit identification

Part 1 – Task 1

Safe-life assessment 3rd parameter is σ_logN (constant scatter)

1.1) Fit the SN diagram with a 3 parameters model, considering also run-outs.

1.2) Calculate the damage associated to a mission composed only by profile 1. Assume constant scatter for the SN diagram, use the μ-3σ curve. Lump the stress history in blocks of approx. 15 MPa. Assume a CV of 5% for the loads and use the μ+3σ load percentile.

1.3) Calculate the damage associated to a standard mission (profile 1 + profile 2) Simple summation

1.4) Which is the maximum number of hours of flight for standard missions?

1.5) Probabilistic question: Plot a curve of failure probability Pf against life. Normal and 3 parameter model