



UNIVERSITÀ DEGLI STUDI DI TRENTO
DIPARTIMENTO DI INGEGNERIA INDUSTRIALE

Relazione

MECHANICAL VIBRATIONS

System identification of a 3 DOF system

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Chapter 1

Introduzione

1.1 Contesto applicativo

Ciao ragazzi :D questo è un template che potete utilizzare per scrivere la vostra tesi in L^AT_EX(sì, il nome di questo linguaggio è tutto un programma...)

Cos'è L^AT_EX? Cercatevelo su Wikipedia¹!

A parte gli scherzi... è un linguaggio che vi permette (in poche parole) di creare documenti accademici (e non) con uno stile molto professionale. Gran parte del lavoro sporco (creazione dei capitoli, delle sezioni, dell'indice, della bibliografia, gestione dei margini, ecc...) viene interamente gestito da L^AT_EX, le poche cose da configurare sono già state impostate in questo template... (quindi in poche parole avete già tutto pronto, stronzi!)

In questo pdf è spiegato un po' come far funzionare il tutto, ovvero:

- Dove scaricare l'IDE e come configurarlo
- Come scaricare il compilatore
- Come iniziare a personalizzare questo template

Cercherò di utilizzare più elementi L^AT_EX possibile nello scrivere questa guida (tabelle, elenchi puntati, footnote, immagini...) così quando andrete a leggere il codice vi imparate pure qualcosa, caproni (<3)

1.2 Motivazioni e obiettivi

Il principale motivo che mi spinge a creare questo pdf è quello di risparmiarvi gran parte delle rotture che si trovano quando ci si avvicina al mondo L^AT_EX... insomma mi auguro

¹<http://it.wikipedia.org/wiki/LaTeX>

che questa guida vi permetta di avere un buon punto d’inizio.

Come già spiegato nella sezione precedente, \LaTeX offre tantissimi servizi utili ed uno stile professionale unico, cose che su altri programmi (come Microsoft Word) potete anche sognarvi.

Insomma... con \LaTeX potete presentare una tesi fatta come si deve :)

1.3 Risultati raggiunti

Nella Figura 1.1 potete ammirare quanto \LaTeX sia più figo di Microsoft Word, ooooooh...

Figure 1.1: Oooooooh che figo \LaTeX , oooooooooh

1.4 Organizzazione della tesi

Vi spiego brevemente quali sono le parti di questo template:

Susanna.tex Questo è il file principale del template: contiene le impostazioni generali e la struttura della tesi. Ricordate di impostarlo come documento master ogni volta che iniziate a lavorare alla tesi (ovviamente potete rinominarlo, nabbazzi)

frontespizio.tex Sarebbe la copertina della tesi, nonché la prima pagina. Contiene nome dell’università, del dipartimento, nome della tesi bla bla bla... io ho scelto un argomento di Fisica molto importante <3

dedica.tex Una pagina dove scrivete a chi dedicate la tesi (Susanna <3)

introduzione.tex Il file che contiene questo capitolo introduttivo (vi consiglio di creare appunto un file .tex per ogni capitolo). Le 4 sezioni di questo capitolo (Contesto applicativo, Motivazioni e obiettivi, Risultati raggiunti e Organizzazione della tesi) sono le 4 sezioni standard da inserire nell’introduzione di una tesi, quindi vi consiglio di lasciarle così

start.tex Contiene l’unico capitolo utile di questo documento: spiega come scaricare l’occorrente e come configurare il tutto per lavorare con \LaTeX

conclusione.tex Contiene la conclusione (YOU DON’T SAY)

bibliografia.bib Contiene i dati relativi alle fonti che citerete nella tesi (ad esempio, ora sto citando un libro sugli algoritmi genetici [1], l’unico inserito nella bibliografia di questo template)

IEEEtran.bst È lo stile della bibliografia, non lo toccate

imgs Cartella contenente le immagini (YOU DON'T SAY AGAIN)

Chapter 2

Come fare le cose

In questo capitolo vediamo la roba smanettosa per iniziare a smanettare

2.1 Occorrente

Roba da scaricare e installare (Tabella 2.1).

Table 2.1: Tabella vergognosamente inutile

File	Piattaforma	Dimensioni
<i>TexMaker</i>	Windows	46.3 MB
<i>TexMaker</i>	Mac	40.7 MB
<i>MiKTeX</i>	Windows	154.1 MB
<i>MacTex</i>	Mac	2.3 GB
Template Susanna	Multiglobale-powa	4 MB (circa)

2.1.1 L'IDE

Allora... per prima cosa vi serve un IDE, ovvero un programma che vi funga da editor e compilatore (in realtà il compilatore si scarica a parte ma vabbè). Ce ne sono molti in giro ma io vi consiglio *TexMaker*¹ per due motivi:

1. È molto intuitivo è ben fatto
2. Esiste sia per Mac che per Windows

Non dovrete avere problemi con il download e l'installazione (vi state per laureare porca paletta, non devo spiegarvi pure questo).

2.1.2 Il compilatore

Per quanto riguarda il compilatore il discorso è un po' più complicato. Armatevi di pazienza e scaricate *MiKTeX*² se avete Windows oppure *MacTeX*³ se avete un Mac (mi dispiace ma non conosco un compilatore LaTeX per Linux... se lo trovate fatemelo sapere che aggiorno la guida). Entrambi questi programmi inglobano un ambiente di sviluppo L^AT_EX costituito da diversi compilatori che il nostro IDE riconoscerà automaticamente.

P.S. Prima che cominciate a strapparvi i capelli, sì, *MacTeX* occupa più di 2 GB... questo perchè comprende tutti i pacchetti necessari per L^AT_EX, mentre *MiKTeX* (che occupa solo 150 mb) li scarica volta per volta.

2.1.3 Il template

Trovate il sorgente di questo template ad un link dropbox non meglio specificato⁴

2.2 Configurazione dell'IDE

Oooh, ora che avete installato IDE e compilatore, lanciate l'IDE. Principalmente dovete fare tre cose una volta avviato:

1. Aprite il file *Susanna.tex* del template
2. Andate su Opzioni -> Definire il documento corrente come Master (questo serve per dire all'IDE che gli altri documenti sono inclusi in un documento master e che

¹<http://www.xmlmath.net/texmaker/>

²<http://miktex.org/download>

³<http://mirror.ctan.org/systems/mac/mactex/MacTeX.pkg>

⁴<https://www.dropbox.com/sh/1f06sd7eprongvl/dKsfd1Kwc>

quindi, al momento della compilazione, non devono essere trattati come documenti separati)

3. Andate nelle preferenze dell'IDE nella sezione Compilazione Rapida e personalizzate la compilazione tramite l'assistente-wizard. Essenzialmente dovete configurarla in modo da effettuare 3 compilazioni: PdfLatex, BibTex e di nuovo PdfLatex. Oltre a queste tre compilazioni aggiungete una quarta opzione ovvero la visualizzazione pdf.

Vi spiego meglio il punto 3... praticamente ci sono più compilatori diversi, che svolgono operazioni diverse... ma a noi interessano solo due compilatori, ovvero PdfLatex (che compila il codice \LaTeX in un documento pdf) e BibTex (che compila la bibliografia). Le compilazioni sono 3 e in quel preciso ordine perchè altrimenti la bibliografia non viene compilata bene (non chiedetemi perchè). Per evitare di dover eseguire manualmente le diverse compilazioni, *TexMaker* vi dà la possibilità di utilizzare la Compilazione Rapida che esegue automaticamente queste operazioni con un click. Configuratela come vi ho spiegato e non avrete problemi.

2.3 Siamo pronti

Abbiamo configurato l'IDE ed il (i) compilatore(i). Ora premendo sulla freccina della Compilazione Rapida (oppure premendo F1) potrete compilare il vostro codice \LaTeX in pdf. Fate una prova compilando il template (il pdf purtroppo, così come tutti gli scarti della compilazione, verranno generati nella stessa cartella del sorgente...).

E ora? Ora create i vostri capitoli copiando la struttura di *start.tex* e di *introduzione.tex* ed integrateli nel documento master :) se avete bisogno di ulteriori dettagli sulla sintassi \LaTeX vi consiglio di farvi un giro nella sezione Tex di *Stack Exchange*⁵: è tipo Yahoo Answers ma focalizzato ovviamente su \LaTeX .)

⁵<http://tex.stackexchange.com/>

Chapter 3

Eurocopter AS350

This chapter opens with an introduction to the helicopter named Eurocopter AS350, its development over the years and some technical features. In follow deals with the study of the tail in particular . . . , where the aeroelastic problem will be neglected and as a result all the aerodynamic components will be removed from the model.

3.1 Introduction

The **Eurocopter AS350 Écureuil** (*Squirrel*) is a single-engine light helicopter originally designed and manufactured in France by Aérospatiale, now Airbus Helicopters. In North America, the AS350 is marketed as the AStar. The AS355 Ecureuil 2 is a twin-engine variant, marketed in North America as the TwinStar. The Eurocopter EC130 is a derivative of the AS350 airframe and is considered by the manufacturer to be part of the Écureuil single-engine family. In the early 1970s, Aérospatiale decided to initiate a new development programme to produce a suitable replacement for the aging Aérospatiale Alouette II. While the Aérospatiale Gazelle, which had been developed in the 1960s and 1970s, had been met with numerous orders by military customers, commercial sales of the type had been less than anticipated, thus the need for a new civil-orientated development was identified. The development of the new rotorcraft, which was headed by Chief Engineer René Mouille, was focused on the production of an economic and cost-effective aerial vehicle, thus both Aérospatiale's Production and Procurement departments were heavily involved in the design process. One such measure was the use of a rolled sheet structure, a manufacturing technique adapted from the automotive industry; another innovation was the newly developed Starflex main rotor. It was also decided that both civil and military variants of the emergent helicopter would be developed to conform with established military requirements[2].



Figure 3.1: Helicopter takeoff
Di Fabien1309 - Own work

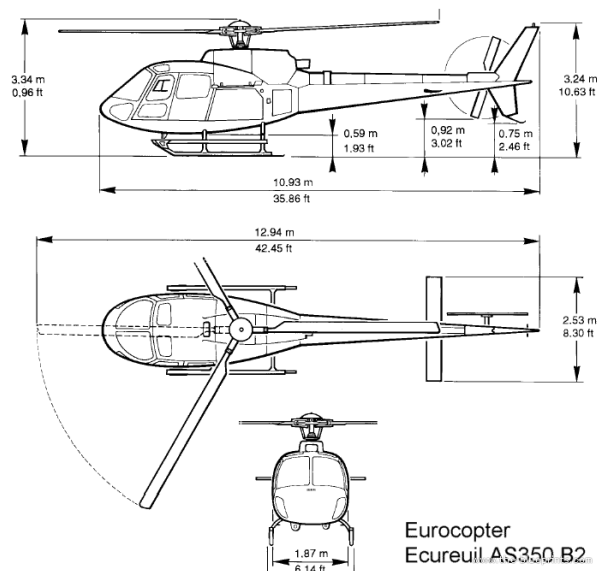


Figure 3.2: AS350 blueprints

General characteristics	
Length	12.94 m
Height	3.34 m
Main rotor diameter	10.69 m
Empty weight	1220 kg
Max takeoff weight	2250 kg
capability	2500 kg
Propulsion	
Powerplant	1 x Turbine Turbomeca Arriel 1D1
Power	546 kW
Performance	
Maximum speed	287 km/h
Range	476 km
service ceiling	6100 m

Table 3.1: Main characteristics AS350

3.2 Geometric model

The geometric model is shared among three different configuration where was enfatized a different approach to evalute the repsonce of structural elemtents in different condition of approximation. Infact the first case is an evaluation of the simple model where considering only tail like as a cantilever beam. While in the second case considering also the trasmission shaft rigidly linked at the tail and the presence of a lumped mass to simulate the persence of the block of rotor in the proximity the end of tail. Finally consider a third model where we considering the shaft's weight is distributed along the lenght of tail like as lumped mass, we consider as before another concentrated mass to represent the block of rotor at the tail's end. The model was obtained by the revolution of seven contiguous segments with respect to axis placed in the plane xz , thus obtaining a truncated cone having a radius 325 mm at the base and a radius 50 mm for the minor base, the whole extension is 5.2 m . The cone trunk was highlighted in twentyfour equal segments in order to obtain a bse for the reallization of components such as stringer, horizontal stabilizer attachment, stiffners and ribs. The result can be seen in the figure 3.3.

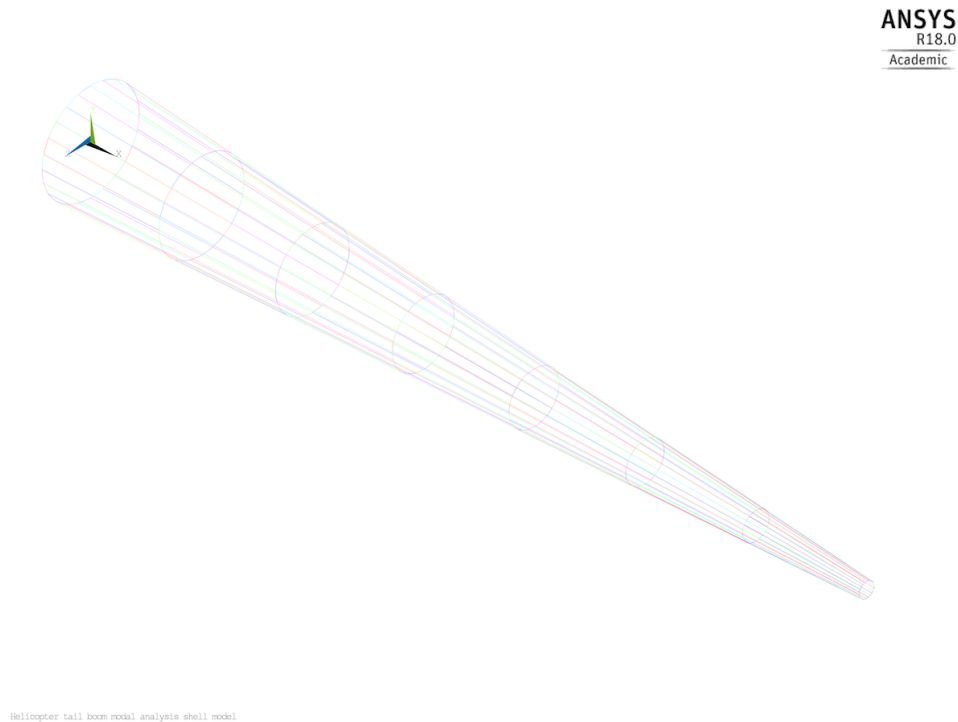


Figure 3.3: AS350 ansys model

3.3 Mesh model

After the geometric model has been realized, the finite element model has the same types of shared elements to ensure consistency between the models, as well as the texture of the matrices used to study the different models.

3.3.1 Simple model

For structural elements such as:

- stringer;
- horizontal stabilizer attachment;
- stiffeners;
- ribs.

Type elements have been used: BEAM189, this type of element has been assigned a rectangular section and a square as shown in 3.4. Specifically, the rectangular section, fig. 3.4a, is intended to form the stinger and longerons components, instead the square section, fig.3.4b, perform the ribs, then the structure skeleton are represented in fig. 3.5.

The material used is steel with the following properties:

- Young's modulus, 205 [GPa]
- Poisson's ratio, 0.29
- Density, 7850 [kg/m³]

On the other hand, to realize the mantle covering the support structure was used type element: SHELL181 with aluminum used as material with the following properties:

- Young's modulus: 64 [GPa];
- Poisson's ratio: 0.34;
- Density: 2700 [kg/m³].

Finally, you can see the full model in the figure 3.6.

3.3.2 Simple model with shaft

In this case, the geometric model has the same features as the previously described model, with the addition of a transmission shaft on top of the cone. the shaft has been modelled with type of elements BEAM189 with tube section, fig. 3.7, and realized in duralumin characterized by the following property:

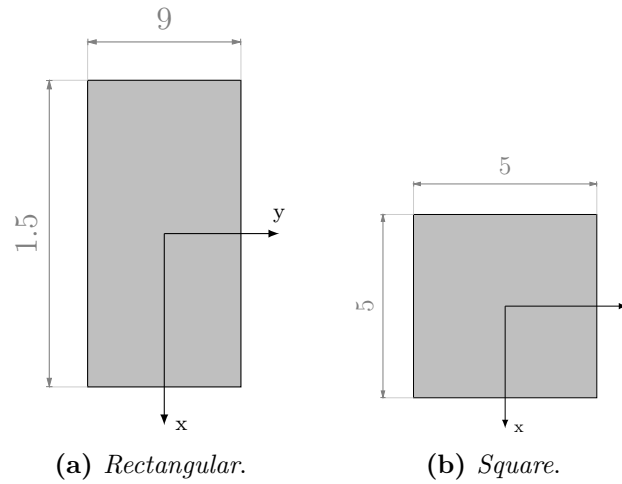
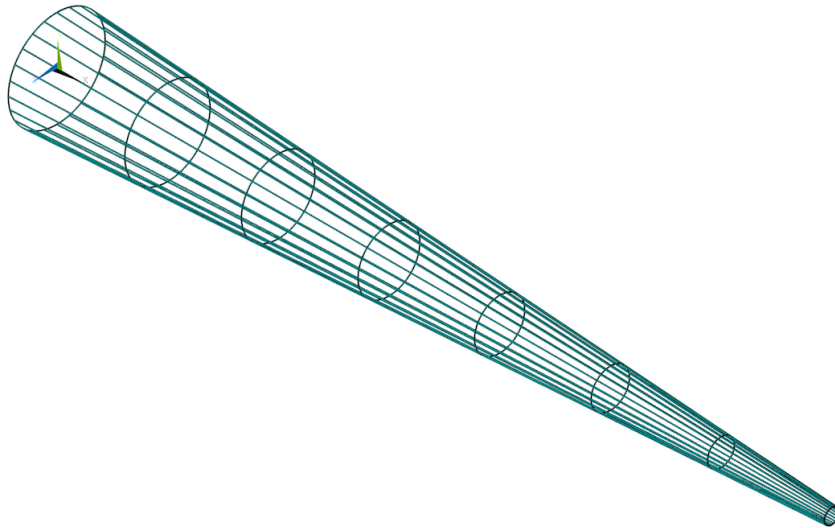


Figure 3.4: Section for element BEAM189

ANSYS
R18.0
Academic

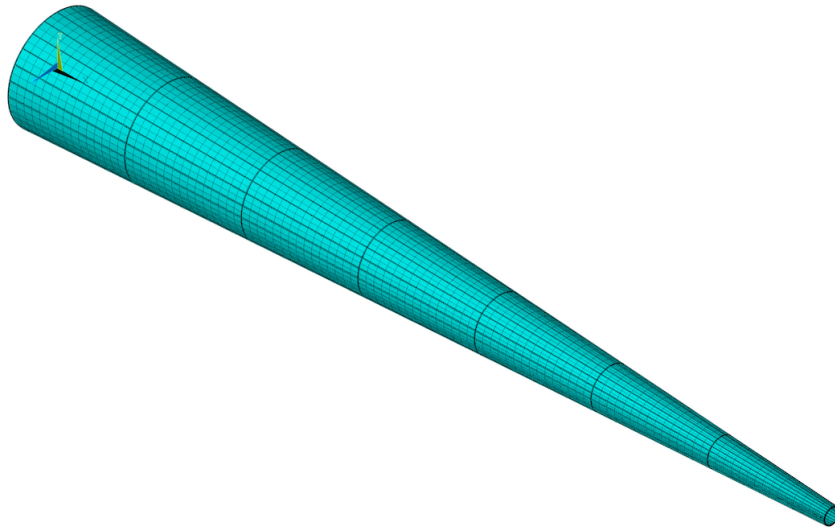


Helicopter tail boom model analysis shell model

Figure 3.5: Skeleton mesh model

- Young's modulus: $72 [GPa]$;
- Poisson's ratio: 0.33;
- Density: $2810 [kg/m^3]$.

To make rigid connections, elements of type: MPC184, with key option: 1, used to block six degrees of freedom. Moreover, they have resistance properties equal to those of the extruded steel for the beam elements. Note that they were used without densities be-



Helicopter tail boom modal analysis shell model

Figure 3.6: Complete mesh model

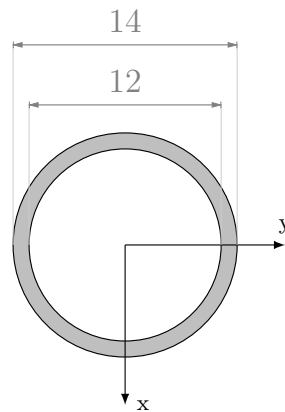


Figure 3.7: Shaft's tubular section

cause the default section in ANSYS is equal to 1 for default, this because they caused an overstimation in mass calculation and then in the derived natural frequencies of the modal analysis. Finally, we consider the mass concentrated near the end of the queue representing the tail rotor block, this simplification is static represented by elements of the type: MASS21, to which the following mass and inertia properties were assigned:

- concentrated mass: $30 [kg]$;
- concentrated inertia: $1 [kg * m^2]$.

The result is visible in fig. 3.8

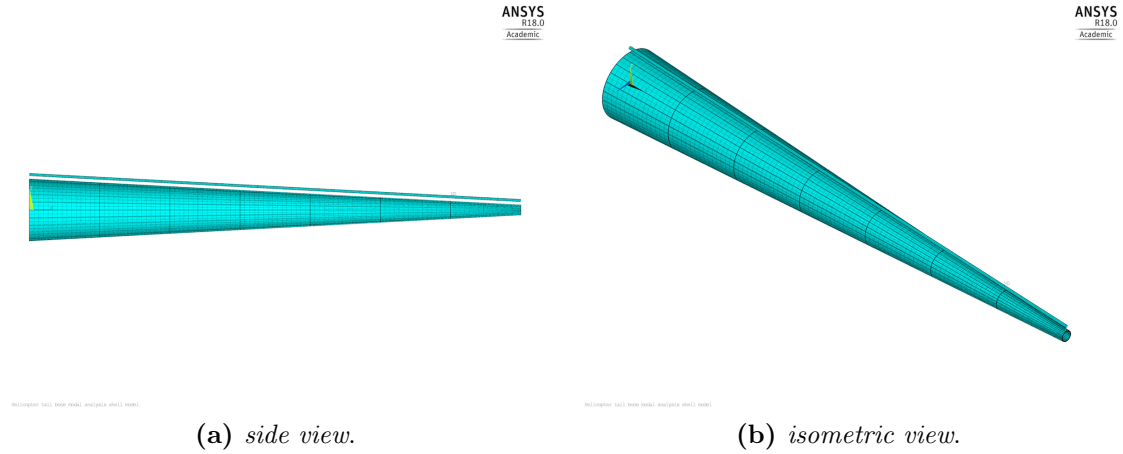


Figure 3.8: Shell model with shaft

3.3.3 Simple model with lumped mass

Starting with the simple model, in this case, the rigid links are added as done to the model with the shaft, but in this case in the connecting terminal part are added the concave mass portions representing the distributed shaft weight. In fact, these are modeled with MASS21 element type and have the property of having the mass equal to a fraction of the shaft. Also in this case consider the rotor block as near the tail as modeled in the previous case, the result is visible in fig.3.9.

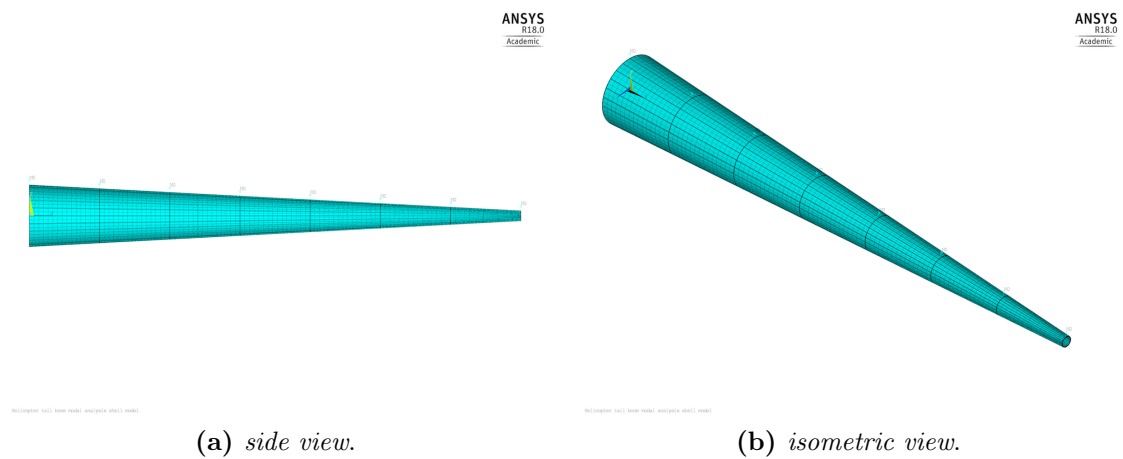


Figure 3.9: Simple model with lumped mass

3.4 Preliminary analysis

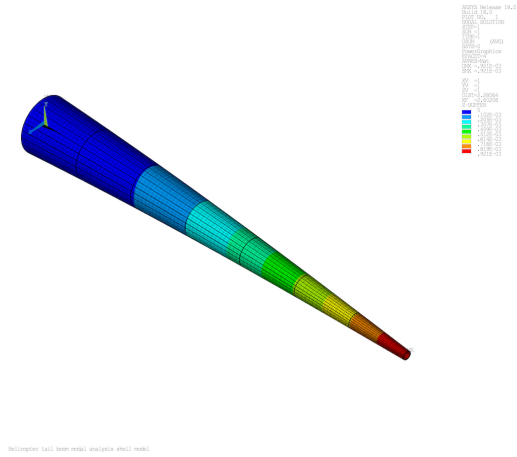
In the preliminary analysis we have investigated the deformations caused by the proper weight of the structure, in fact this is only subject to gravity acceleration, using an approximate value equal to $9.81 [m/s^2]$. Each model has been studied by making it a constraint with a cone at the base of the cone, so it is possible to make a parallelism with a cantilever beam. In the following, table 3.2, shows deflection and stress values while you can observe the effects of flexural tension distribution for structures and the effect due to the presence or not of the shaft, observable in figures 3.9–3.10.

Case	Displacement [m]
Simple model	0.00092
With shaft	0.00346
Lumped mass	0.00459

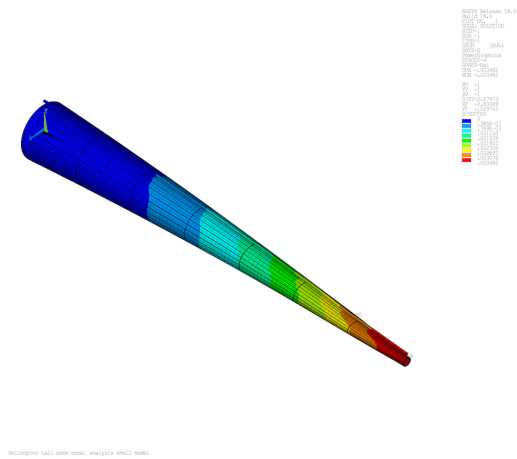
Table 3.2: Deformation values and stress of the models analyzed



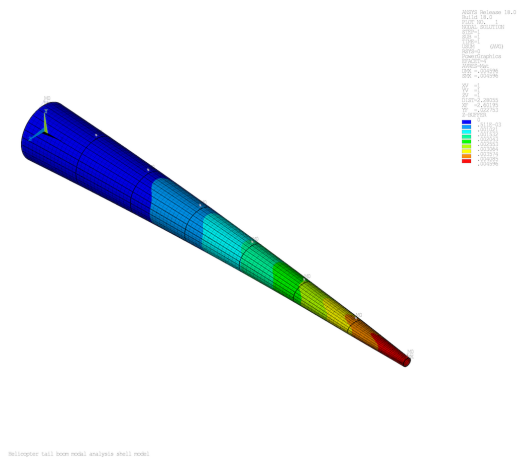
(a) *Simple model.*



(a) *Simple model.*



(b) *Model with Shaft.*



(c) *Model with lumped mass.*

Figure 3.10: Nodal solution

3.5 Modal Analysis

Mode	Frequency [Hz]
1	21.14089
2	21.15116
3	40.79259
4	40.80173
5	60.04059
6	60.05571
7	74.74651
8	74.76411
9	79.03090
10	79.08638

Table 3.3: Natural frequencies for the simple model

Mode	Frequency [Hz]
1	9.52497
2	19.89946
3	31.80325
4	42.65110
5	42.72723
6	57.92407
7	63.11685
8	63.51130
9	74.61297
10	78.93013

Table 3.4: Natural frequencies for the model with shaft

Mode	Frequency [Hz]
1	8.28224
2	9.64315
3	17.48365
4	37.98169
5	40.80936
6	51.66412
7	59.71804
8	59.95684
9	64.32600
10	65.32928

Table 3.5: Natural frequencies for the model with lumped mass

Chapter 4

Tail rotor

In this chapter we analyze the tail rotor in condition decoupled from rest of the structure because in this way it's possible observe in detail the behaviour when is performed a modal analisys and a transient analisys. In the following the tail rotor will be attached at the rest of the structure thanks to the macro realized both for the truss model and for the shell model.

Chapter 5

Complete Model

Now describe the procedure to attach the tail rotor to two structure: the truss model and shell model, respectively. In both base model we add a part that realize the nodes that represent rigid link between the tail structure and tail rotor. After call the macro to realize the component, realized connection by rigid elements between these and component previous realized, thus you can observe the result in figure.

Chapter 6

Conclusioni

Spero che la guida possa servirvi ragazzuoli!

Ringrazio di cuore Giordano Cardillo e Matteo Merola per avermi aiutato (e sopportato) a capire come funziona questo maledetto L^AT_EX! :P

Ringraziate Giordano anche per aver creato dei loghi vettoriali decenti da utilizzare :D (li trovate nella cartella delle immagini).

Vi voglio bene <3 (tranne a Rosangela u.u)

*Guida scritta da Lorenzo Valente*¹

¹<http://facebook.com/lorenzo.valente>

Chapter 7

Listing

Shell Model

Listing 7.1: ShellModel.txt

```
1 /COM, -----
2 /COM, PROBLEM: MODAL ANALYSIS of the helicopter's TAIL BOOM
3 /COM, -----
4 /COM, Natural frequencies and modal shapes of an helicopter's tail boom
5 /COM, -----
6
7 FINISH
8 /CLEAR, START, NEW
9 /FILNAM, Shellmodel
10 /TITLE, Helicopter tail boom modal analysis shell model
11 /UNIT, SI
12 /INQUIRE, StrJobname, JOBNAME
13 *USE, testperson.mac
14
15 ! >>>> MODEL PARAMETERS <<<<
16 *SET, Pi, ACOS(-1) !Pi constant
17 *AFUN, DEG !Specify units for angular measures [DEG], specify after
    function *AFUN
18 *SET, eps, 10e-3 !precision interval
19
20 ! >>>> MATERIAL PROPERTIES <<<<
21 !*** steel
22 *SET, SteelEyoungG, 205e9 ![Pa] Young's modulus
23 *SET, SteelNi, 0.29 !Poisson's ratio
24 *SET, SteelDensity, 7850 ![Kg/m^3]
25
26 !*** Aluminium
27 *SET, AluminiumEyoungG, 64e9 ![Pa] Young's modulus
28 *SET, AluminiumNi, 0.34 !Poisson's ratio
29 *SET, AluminiumDensity, 2700 ![Kg/m^3]
30
31 !*** Element size
32 *SET, E_length_ct, 50e-3 ![m]
33
```

```

34 !geometric parameter
35 *SET, Lt, 5.2 ! [m] total tail lenght
36 *SET, RadBaseTail, 0.65/2 ! [m]
37 *SET, RadEndTail, 0.10/2 ! [m]
38 *SET, alpha, atan((RadBaseTail-RadEndTail)/Lt) ! [deg]
39
40 !geometric parameters section stiffner
41 *SET, StiffnerBase, 5e-3
42 *SET, StiffnerHeight, 5e-3
43
44 !geometric parameters section Horizontal Stabilizer
45 *SET, HorizStabBase, 0.009
46 *SET, HorizStabHeigth, 0.0015
47
48 !geometric parameter mantle
49 *SET, ThichknessMantle, 5e-4 ! [m]
50
51 !other parameters
52 *SET, NumberDivisonSurface, 24 !division cone's area
53
54 /COM, -----
55 /COM, MODEL DEFINITION
56 /COM, -----
57 ! >>> DEFINE GEOMETRY <<<<
58 ! Reduced integration Timoshenko beam element, with quadratic shape functions
59 /PREP7
60 ! Define axis rotation
61 K, 1, 0, 0, 0
62 K, 2, 5, 0, 0
63
64 ! create keypoints
65 K, 3, 0, RadBaseTail, 0 !start keypoint tails
66 *GET, MaxKp, KP, 0, num, max !extract max keypoint
67 *SET, StartKpTail, MaxKp !store in variable
68 *DIM, SegmentRadius, ARRAY, 7, 1 !store in array radius
69 ! of segment distance between 0 - Y before rotating
70 *DO, i, 1, 7, 1
71     *GET, MaxKp, KP, 0, NUM, MAX !extract max keypoint
72     K, MaxKp+1, Lt/7*i, RadBaseTail-Lt/7*i*tan(alpha), 0 !create keypoint
73     SegmentRadius(i) = RadBaseTail-Lt/7*i*tan(alpha)
74 *ENDDO
75 *GET, MaxKp, KP, 0, num, max !extract max keypoint
76 *SET, EndKpTail, MaxKp !store in variable end's
77     tail
78
79 ! define keypoint mantle'tail
80 K, Maxkp+1, 0, RadBaseTail, 0
81 *GET, StartKpMantle, KP, 0, num, max
82 K, MaxKp+2, Lt/7*i, RadEndTail, 0
83 *GET, EndKpMantle, KP, 0, num, max
84
85 *DO, j, StartKpTail, EndKpTail-1, 1
86     L, j, j+1
87 *ENDDO
88 *GET, LenghtLineRference, LINE, 1, leng !extract lenght
89     segment line's cone generator

```



```

87
88 ! generate cone
89 *GET, NumberLine, line, 0, count !count lines
90 *GET, StartNumberLine, line, 0, num, min !extract first
    number line
91 *GET, NumberLine, line, 0, count !count lines
92 *GET, StartNumberLine, line, 0, num, min !extract first
    number line
93 LSEL, S, LOC, X, 0, Lt
94 AROTAT, ALL, , , , , 1, 2, 360, NumberDivisonSurface !generate cone
95
96 !divide line in array straight line and curved line
97 !to manage in next step meshing of elements
98 LSEL, S, LENGTH, , LenghtLineRference, LenghtLineRference
99 *VGET, StraighLine, LINE, , LLIST, , , 0
100 ALLSEL, ALL
101 LSEL, U, LENGTH, , LenghtLineRference, LenghtLineRference
102 *VGET, AcrLine, LINE, , LLIST, , , 0
103
104 *GET, StartNumberLine, line, 0, num, min
105 LSEL, ALL
106
107 /VIEW, 1, 1, 1, 1
108 /ANG, 1
109 /REP, FAST
110 LPLOT
111 *USE, generateimages.mac
112
113 ! >>>> MESH <<<<
114 /ESHAPE, 1
115 !set material properties and element
116 ET, 1, BEAM189
117 MP, EX, 1, SteelEyoungG
118 MP, NUXY, 1, SteelNi
119 MP, DENS, 1, SteelDensity
120
121 !***Horizontal Stabilizer
122 SECTYPE, 1, BEAM, RECT, HorizontalStabilizer, 0
123 SECOFFSET, CENT
124 SECDATA, HorizStabBase, HorizStabHeigth
125
126 *GET, LenghtStraighLine, 'PARM', StraighLine, DIM, X
127 LSEL, S, LINE, , StraighLine(1), StraighLine(LenghtStraighLine)
128 LESIZE, all, E_length_ct
129 LATT, 1, , 1, , , 1
130 LMESH, ALL
131 LSEL, NONE
132 /ESHAPE, 1
133 /REPLO
134
135 !***stiffners
136 SECTYPE, 2, BEAM, RECT, Stiffeners, 0
137 SECOFFSET, ORIG
138 SECDATA, StiffnerBase, StiffnerHeight
139
140 *GET, LenghtAcrLine, 'PARM', AcrLine, DIM, X

```

```

141 LSEL, S, LINE, , AcrLine(1), AcrLine(LenghtAcrLine)
142 LESIZE, ALL, , , , 3
143 LATT, 1, , 1, , , 2
144 LMESH, ALL
145 LSEL, NONE
146 /REPLO
147
148 /VIEW, 1, 1, 1, 1
149 /ANG, 1
150 /REP, FAST
151 EPLOT
152 *USE, generateimages.mac
153
154 !***Mantle
155 !set material properties and element
156 ET, 2, SHELL181
157 MP, EX, 2, AluminiumEyoungG
158 MP, NUXY, 2, AluminiumNi
159 MP, DENS, 2, AluminiumDensity
160 SECT, 3, SHELL, , mantle
161 SECDATA, ThichknessMantle, 2, 0.0, 3
162 SECOFFSET, top
163
164 TYPE, 2
165 SECNUM, 3
166 AESIZE, ALL, E_length_ct,
167 MSHAPE, 0, 2D
168 MSHKEY, 1
169 AMESH, ALL
170 SAVE
171
172 /VIEW, 1, 1, 1, 1
173 /ANG, 1
174 /REP, FAST
175 EPLOT
176 *USE, generateimages.mac
177
178 !***Boundary conditions at base of tail
179 ALLSEL, ALL
180 LSEL, S, LOC, Y, -(RadBaseTail*2)+eps, (RadBaseTail*2)+eps
181 LSEL, S, LOC, x, 0, 0
182 DL, ALL, , ALL, 0
183
184 *USE, calcmass.mac, StrJobname(1)
185 FINISH
186
187 /COM, -----
188 /COM, Preliminary static analysis - Prestress
189 /COM, -----
190 ! >>>> SOLUTION <<<<
191 /SOLU
192 ANTYPE, STATIC, NEW !Preliminary static analysis
193 PSTRES, ON !Includes prestress effects
194 Acel, , 9.81 !gravitational acceleration
195
196 SOLVE

```

```

197 FINISH
198
199 ! >>>> POSTPROCESSING <<<<
200 /POST1
201 PLDISP, 1
202 *USE, generateimages.mac
203 PLNSOL, U, SUM, 0, 1.0
204 *USE, generateimages.mac
205 PLNSOL, S, EQV, 0, 1.0
206 *USE, generateimages.mac
207
208
209 /COM, -----
210 /COM, Modal analysis
211 /COM, -----
212 ! >>>> SOLUTION <<<<
213 /SOLU
214 ANTYPE, MODAL, NEW
215 PSTRES, ON ! Includes prestress effects
216 MODOPT, LANB, 10 ! First 10 modes are extracted
217 LUMPM, OFF ! lumped/consistent mass matrix
218 MXPAND, 10, , , Yes ! First 10 modes are expanded, calculate element
    stress
219
220 SOLVE
221 FINISH
222
223 ! >>>> POSTPROCESSING <<<<
224 /POST1
225 SET, LIST !List natural frequencies
226 SET, 1, 1 !Loads first mode
227 PLDISP !Displays modal shape
228
229 *DIM, ModalFreq, ARRAY, 10, 1
230 *DO, i, 1, 10, 1
231   *GET, omega, MODE, i, FREQ
232     ModalFreq(i,1) = omega
233   *SET, omega,
234 *ENDDO
235
236 *SET, omega,
237 *CFOPEN, 'ModalFreq-%StrJobname(1)%', 'txt'
238   *VWRITE, 'Num', 'omega'
239     (8x, A8, 4X, A8,)
240   *VWRITE, sequ, ModalFreq(1,1)
241     (F12.0, F12.5)
242 *CFCLOS
243
244 FINISH
245 /EXIT, ALL

```

Listing 7.2: ShellModelShaft.txt

```

1 /COM, -----
2 /COM, PROBLEM: MODAL ANALYSIS of the helicopter's TAIL BOOM
3 /COM, -----

```

```

4 /COM, Natural frequencies and modal shapes of an helicopter's tail boom
5 /COM, -----
6
7 FINISH
8 /CLEAR, START, NEW
9 /FILNAM, ShellmodelShaft
10 /TITLE, Helicopter tail boom modal analysis shell model
11 /UNIT, SI
12 /INQUIRE, StrJobname, JOBNAME
13 *USE, testperson.mac
14
15 ! >>>> MODEL PARAMETERS <<<<
16 *SET, Pi, ACOS(-1) !Pi constant
17 *AFUN, DEG !Specify units for angular measures [DEG], specify after
    function *AFUN
18 *SET, eps, 10e-3 !precision interval
19
20 ! >>>> MATERIAL PROPERTIES <<<<
21 !*** steel
22 *SET, SteelEyoungG, 205e9 ![Pa] Young's modulus
23 *SET, SteelNi, 0.29 !Poisson's ratio
24 *SET, SteelDensity, 7850 ![Kg/m^3]
25
26 !*** Aluminium
27 *SET, AluminiumEyoungG, 64e9 ![Pa] Young's modulus
28 *SET, AluminiumNi, 0.34 !Poisson's ratio
29 *SET, AluminiumDensity, 2700 ![Kg/m^3]
30
31 !*** Duraluminium
32 *SET, DurAluminiumEyoungG, 72e9 ![Pa] Young's modulus
33 *SET, DurAluminiumNi, 0.33 !Poisson's ratio
34 *SET, DurAluminiumDensity, 2810 ![Kg/m^3]
35
36 !*** Element size
37 *SET, E_length_ct, 50e-3 ![m]
38
39 !geometric parameter
40 *SET, Lt, 5.2 ![m] total tail lenght
41 *SET, RadBaseTail, 0.65/2 ![m]
42 *SET, RadEndTail, 0.10/2 ![m]
43 *SET, alpha, atan((RadBaseTail-RadEndTail)/Lt) ![deg]
44
45 !geometric parameters section stiffner
46 *SET, StiffnerBase, 5e-3
47 *SET, StiffnerHeight, 5e-3
48
49 !geometric parameters section Horizzontal Stabilizer
50 *SET, HorizStabBase, 0.009
51 *SET, HorizStabHeigth, 0.0015
52
53 !geometric parameter mantle
54 *SET, ThichknessMantle, 5e-4 ![m]
55
56 !geometric parameter shaft
57 *SET, InternalRadius, 0.012
58 *SET, ExternalRadius, 0.014

```

```

59
60 !mass Lumped
61 *SET, MassRotor, 30                ![kg] concentrated mass motorblock
62 *SET, JO, 1                        ![kg*m^2] concentrated inertia
        motorblock
63
64 !other parameters
65 *SET, NumberDivisonSurface, 24  !division cone's area
66
67 /COM, -----
68 /COM,  MODEL DEFINITION
69 /COM, -----
70 ! >>>> DEFINE GEOMETRY <<<<
71 ! Reduced integration Timoshenko beam element, with quadratic shape functions
72 /PREP7
73 ! Define axis rotation
74 K, 1, 0, 0, 0
75 K, 2, 5, 0, 0
76
77 ! create keypoints
78 K, 3, 0, RadBaseTail, 0                !start keypoint tails
79 *GET, MaxKp, KP, 0, NUM, MAX            !extract max keypoint
80 *SET, StartKpTail, MaxKp                !store in variable
81 *DIM, SegmentRadius, ARRAY, 7, 1        !store in array radius
        of segment distance between 0 - Y before rotating
82 *DO, i, 1, 7, 1
83     *GET, MaxKp, KP, 0, NUM, MAX        !extract max keypoint
84     K, MaxKp+1, Lt/7*i, RadBaseTail-Lt/7*i*tan(alpha), 0  !create keypoint
85     SegmentRadius(i) = RadBaseTail-Lt/7*i*tan(alpha)
86 *ENDDO
87 *GET, MaxKp, KP, 0, NUM, MAX            !extract max keypoint
88 *SET, EndKpTail, MaxKp                  !store in variable end's
        tail
89 SAVE
90
91 ! define keypoint mantle'tail
92 K, Maxkp+1, 0, RadBaseTail, 0
93 *GET, StartKpMantle, KP, 0, NUM, MAX
94 K, MaxKp+2, Lt/7*i, RadEndTail, 0
95 *GET, EndKpMantle, KP, 0, NUM, MAX
96 SAVE
97 *DO, j, StartKpTail, EndKpTail-1, 1
98     L, j, j+1
99 *ENDDO
100 *GET, LenghtLineRference, LINE, 1, LENG        !extract lenght segment
        line's cone generator
101
102 ! generate cone
103 *GET, NumberLine, line, 0, COUNT            !count lines
104 *GET, StartNumberLine, LINE, 0, NUM, MIN      !extract first number
        line
105 LSEL, S, LOC, X, 0, Lt
106 AROTAT, ALL, , , , , 1, 2, 360, NumberDivisonSurface  !generate cone
107 SAVE
108
109 !divide line in array straight line and curved line

```

```

110 !to manage in next step meshing of elements
111 *GET, NumberLine, LINE, 0, COUNT !count lines
112 *DIM, StraighLine, ARRAY, NumberLine, 2
113 *DIM, ArchLine, ARRAY, NumberLine, 2
114 *DO, n, StartNumberLine, NumberLine, 1
115     *GET, LenghtLine, LINE, n, leng,
116     *IF, LenghtLineRference, EQ, LenghtLine, THEN
117         StraighLine(n, 1) = n
118         StraighLine(n, 2) = LenghtLine
119         *SET, LastStraightLine, n
120     *ELSE
121         ArchLine(n, 1)=n
122         ArchLine(n, 2)=LenghtLine
123         *SET, LastArchLine, n
124     *ENDIF
125 *ENDDO
126
127 *DIM, ConnectionKp, ARRAY, 8, 2
128 KSEL, S, LOC, X, 0, RadBaseTail
129 KSEL, S, LOC, Y, RadBaseTail*cos(360/NumberDivisonSurface), RadBaseTail*cos(360
    /NumberDivisonSurface)
130 KSEL, R, LOC, Z, -RadBaseTail, RadBaseTail
131 *GET, tmp1, KP, 0, NUM, MIN
132 *GET, tmp2, KP, 0, NUM, MAX
133 ConnectionKp(1, 1) =tmp1
134 ConnectionKp(1, 2) =tmp2
135 *DO, i, 1, 7, 1
136     KSEL, S, LOC, X, Lt/7*i
137     KSEL, R, LOC, Y, SegmentRadius(i)*cos(360/NumberDivisonSurface), SegmentRadius(i)
        *cos(360/NumberDivisonSurface)
138     KSEL, R, LOC, Z, -SegmentRadius(i)*sin(360/NumberDivisonSurface), SegmentRadius(i)
        *sin(360/NumberDivisonSurface)
139     *GET, tmp1, KP, 0, NUM, MIN
140     *GET, tmp2, KP, 0, NUM, MAX
141     ConnectionKp(i+1, 1) =tmp1
142     ConnectionKp(i+1, 2) =tmp2
143     !clear temp variable
144     *SET, tmp1,
145     *SET, tmp2,
146 *ENDDO
147 SAVE
148
149 /VIEW,1,1,1,1
150 /ANG,1
151 /REP,FAST
152 LPLOT
153 *USE, generateimages.mac
154
155 ! >>>> MESH <<<<
156 /ESHAPE, 1
157 ! set material properties and element
158 ET, 1, BEAM189
159 MP, EX, 1, SteelEyoungG
160 MP, NUXY, 1, SteelNi
161 MP, DENS, 1, SteelDensity
162

```

```

163 !***Horizontal Stabilizer
164 SECTYPE, 1, BEAM, RECT, HorizontalStabilizer, 0
165 SECOFFSET, CENT
166 SECDATA, HorizStabBase, HorizStabHeighth
167
168 LSEL, S, LINE, , 1, LastStraightLine
169 LESIZE, all, E_length_ct
170 LATT, 1, , 1, , , 1
171 LMESH, ALL
172 LSEL, NONE
173 /REPLO
174
175 !***stiffeners
176 SECTYPE, 2, BEAM, RECT, Stiffeners, 0
177 SECOFFSET, ORIG
178 SECDATA, StiffnerBase, StiffnerHeight
179
180 LSEL, S, LINE, , LastStraightLine+1, LastArchLine
181 LESIZE, ALL, , , 3
182 LATT, 1, , 1, , , 2
183 LMESH, ALL
184 LSEL, NONE
185 /REPLO
186
187 /VIEW, 1, 1, 1, 1
188 /ANG, 1
189 /REP, FAST
190 EPLOT
191 *USE, generateimages.mac
192
193 !***Mantle
194 ! set material properties and element
195 ET, 2, SHELL181
196 KEYOPT, 2, 3, 2
197 KEYOPT, 2, 8, 1
198
199 MP, EX, 2, AluminiumEyoungG
200 MP, NUXY, 2, AluminiumNi
201 MP, DENS, 2, AluminiumDensity
202 SECT, 3, SHELL, , mantle
203 SECDATA, ThichknessMantle, 2, 0.0, 3
204 SECOFFSET, TOP
205
206 TYPE, 2
207 SECNUM, 3
208 AESIZE, ALL, E_length_ct,
209 MSHAPE, 0, 2D
210 MSHKEY, 1
211 AMESH, ALL
212 SAVE
213
214 /VIEW, 1, 1, 1, 1
215 /ANG, 1
216 /REP, FAST
217 EPLOT
218 *USE, generateimages.mac

```

```

219
220 /COM, -----
221 /COM,  DEFINITION SHAFT AND SUPPORT
222 /COM, -----
223 *DIM, KpShaft, ARRAY, 8, 1
224 *GET, LastNode, KP, , num, max
225 K, LastNode+1, 0, RadBaseTail+50e-3, 0
226 *GET, LastNode, KP, , num, max
227 Kpshaft(1)=LastNode
228 *DO, i, 1, 7, 1
229     *GET, LastNode, KP, , num, max
230     K, LastNode+1, Lt/7*i, SegmentRadius(i)+50e-3, 0
231     *GET, LastNode, KP, , num, max
232     Kpshaft(i+1)=LastNode
233     *GET, LastLine, LINE, , num, max
234     L, LastNode-1, LastNode
235 *ENDDO
236
237 !***Shaft
238 MP, EX, 3, DurAluminiumEyoungG
239 MP, NUXY, 3, DurAluminiumNi
240 MP, DENS, 3, DurAluminiumDensity
241 SECTYPE, 4, BEAM, CTUBE, Shaft, 0
242 SECOFFSET, CENT
243 SECDATA, InternalRadius, ExternalRadius
244 LESIZE, ALL, E_length_ct
245 LATT, 3, , 1, , , 4
246 LMESH, ALL
247 SAVE
248
249 !***Support shaft - rigid connection
250 ET, 3, MPC184, 1
251 KEYOPT, 3, 1, 1
252 MP, EX, 4, SteelEyoungG
253 MP, NUXY, 4, SteelNi
254
255 SECNUM, 4
256 MAT, 4
257 TYPE, 3
258 *DIM, ConnectionShaftSupportNode, ARRAY, 8, 3
259 *DO, i, 1, 8, 1
260     KSEL, s, KP, , KpShaft(i)
261     NSLK, s
262     *GET, NodeShaft, node, , num, max
263     ConnectionShaftSupportNode(i, 1) = NodeShaft
264     *SET, NodeShaft,
265     KSEL, ALL
266     KSEL, s, KP, , ConnectionKp(i, 1)
267     NSLK, s
268     *GET, NodeSupport1, node, , num, max
269     ConnectionShaftSupportNode(i, 2) = NodeSupport1
270     *SET, NodeSupport1,
271     KSEL, ALL
272     KSEL, s, KP, , ConnectionKp(i, 2)
273     NSLK, s
274     *GET, NodeSupport2, node, , num, max

```



```

275         ConnectionShaftSupportNode(i, 3) = NodeSupport2
276         *SET, NodeSupport2,
277         E, ConnectionShaftSupportNode(i, 1), ConnectionShaftSupportNode(i, 2)
278         E, ConnectionShaftSupportNode(i, 1), ConnectionShaftSupportNode(i, 3)
279 *ENDDO
280
281 !***gearbox lumped
282 ET, 5, MASS21, , , 3          !2D mass with rotary inertia
283 R, 5, MassRotor, J0
284 TYPE, 5
285 REAL, 5
286 E, ConnectionShaftSupportNode(7, 1)
287
288 EPlot
289 /VIEW,1,,1
290 /ANG,1
291 /REP,FAST
292 *USE, generateimages.mac
293 /VIEW,1,1,1,1
294 /ANG,1
295 /REP,FAST
296 *USE, generateimages.mac
297
298 !***Boundary conditions at base of tail
299 ALLSEL, ALL
300 LSEL, S, LOC, Y, -(RadBaseTail*2)+eps, (RadBaseTail*2)+eps
301 LSEL, S, LOC, x, 0, 0
302 *GET, MinBaseTailLine, line, 0, num, min
303 *GET, MaxBaseTailLine, line, 0, num, max
304 *DO, i, MinBaseTailLine, MaxBaseTailLine, 8
305     DL, i, , ALL, 0
306 *ENDDO
307
308 *USE, calcmass.mac, StrJobname(1)
309 FINISH
310 SAVE
311
312 /COM, -----
313 /COM, Preliminary static analysis - Prestress
314 /COM, -----
315 ! >>>> SOLUTION <<<<
316 /SOLU
317 ANTYPE, STATIC, NEW          !Preliminary static analysis
318 PSTRES, ON                   !Includes prestress effects
319 Acel, , 9.81                 !gravitational acceleration
320
321 SOLVE
322 FINISH
323
324 ! >>>> POSTPROCESSING <<<<
325 /POST1
326 PLDISP, 1
327 *use, generateimages.mac
328 PLNSOL, U, SUM, 0, 1.0
329 *use, generateimages.mac
330 PLNSOL, S, EQV, 0, 1.0

```

```

331 *use, generateimages.mac
332
333 /COM, -----
334 /COM,  Modal analysis
335 /COM, -----
336 ! >>>> SOLUTION <<<<
337 /SOLU
338 ANTYPE, MODAL, NEW
339 PSTRES, ON                      ! Includes prestress effects
340 MODOPT, LANB, 10                ! First 10 modes are extracted
341 LUMPM, OFF                      ! lumped/consistent mass matrix
342 MXPAND, 10, , , Yes            ! First 10 modes are expanded, calculate element
    stress
343
344 SOLVE
345 FINISH
346
347 ! >>>> POSTPROCESSING <<<<
348 /POST1
349 SET, LIST                      !List natural frequencies
350 SET, 1, 1                      !Loads first mode
351 PLDISP                         !Displays modal shape
352
353 *DIM,ModalFreq,ARRAY,10,1
354 *DO, i, 1, 10, 1
355   *GET, omega, MODE, i, FREQ
356     ModalFreq(i,1) = omega
357   *SET, omega,
358 *ENDDO
359
360 *SET, omega,
361 *CFOPEN, 'ModalFreq-%StrJobname(1)%', 'txt'
362   *VWRITE, 'Num', 'omega'
363   (8x, A8, 4X, A8,)
364   *VWRITE, sequ, ModalFreq(1,1)
365   (F12.0, F12.5)
366 *CFCLOS
367
368 FINISH
369 /EXIT, ALL

```

Listing 7.3: ShellModelShaftLumped.txt

```

1 /COM, -----
2 /COM,  PROBLEM: MODAL ANALYSIS of the helicopter's TAIL BOOM
3 /COM, -----
4 /COM,  Natural frequencies and modal shapes of an helicopter's tail boom
5 /COM, -----
6
7 FINISH
8 /CLEAR, START, NEW
9 /FILNAM, ShellmodelShaftLumped
10 /TITLE, Helicopter tail boom modal analysis shell model
11 /UNIT, SI
12 /INQUIRE, StrJobname, JOBNAME
13 *USE, testperson.mac

```

```

14
15 ! >>>> MODEL PARAMETERS <<<<
16 *SET, Pi, ACOS(-1) !Pi constant
17 *AFUN, DEG !Specify units for angular measures [DEG], specify after
    function *AFUN
18 *SET, eps, 10e-3 !precision interval
19
20 ! >>>> MATERIAL PROPERTIES <<<<
21 *** steel
22 *SET, SteelEyoung, 205e9 ![Pa] Young's modulus
23 *SET, SteelNi, 0.29 !Poisson's ratio
24 *SET, SteelDensity, 7850 ![Kg/m^3]
25
26 *** Aluminium
27 *SET, AluminiumEyoung, 64e9 ![Pa] Young's modulus
28 *SET, AluminiumNi, 0.34 !Poisson's ratio
29 *SET, AluminiumDensity, 2700 ![Kg/m^3]
30
31 *** Element size
32 *SET, E_length_ct, 50e-3 ![m]
33
34 !geometric parameter
35 *SET, Lt, 5.2 ![m] total tail length
36 *SET, RadBaseTail, 0.65/2 ![m]
37 *SET, RadEndTail, 0.10/2 ![m]
38 *SET, alpha, atan((RadBaseTail-RadEndTail)/Lt) ![deg]
39
40 !geometric parameters section stiffner
41 *SET, StiffnerBase, 5e-3
42 *SET, StiffnerHeight, 5e-3
43
44 !geometric parameters section Horizontal Stabilizer
45 *SET, HorizStabBase, 0.009
46 *SET, HorizStabHeight, 0.0015
47
48 !geometric parameter mantle
49 *SET, ThichknessMantle, 5e-4 ![m]
50
51 !mass Lumped
52 *SET, MassShaft, 7 ![kg] concentrated mass shaft
53 *SET, MassRotor, 30 ![kg] concentrated mass motorblock
54 *SET, J0, 1 ![kg*m^2] concentrated inertia
    motorblock
55
56 !other parameters
57 *SET, NumberDivisonSurface, 24 !division cone's area
58
59 /COM, -----
60 /COM, MODEL DEFINITION
61 /COM, -----
62 ! >>>> DEFINE GEOMETRY <<<<
63 ! Reduced integration Timoshenko beam element, with quadratic shape functions
64 /PREP7
65 ! Define axis rotation
66 K, 1, 0, 0, 0
67 K, 2, 5, 0, 0

```

```

68
69 ! create keypoints
70 K, 3, 0, RadBaseTail, 0 !start keypoint tails
71 *GET, MaxKp, KP, 0, num, max !extract max keypoint
72 *SET, StartKpTail, MaxKp !store in variable
73 *DIM, SegmentRadius, ARRAY, 7, 1 !store in array radius
    of segment distance between 0 - Y before rotating
74 *DO, i, 1, 7, 1
75     *GET, MaxKp, KP, 0, num, max !extract max keypoint
76     K, MaxKp+1, Lt/7*i, RadBaseTail-Lt/7*i*tan(alpha), 0 !create keypoint
77     SegmentRadius(i) = RadBaseTail-Lt/7*i*tan(alpha)
78 *ENDDO
79 *GET, MaxKp, KP, 0, num, max !extract max keypoint
80 *SET, EndKpTail, MaxKp !store in variable end's
    tail
81 SAVE
82
83 ! define keypoint mantle'tail
84 K, Maxkp+1, 0, RadBaseTail, 0
85 *GET, StartKpMantle, KP, 0, num, max
86 K, MaxKp+2, Lt/7*i, RadEndTail, 0
87 *GET, EndKpMantle, KP, 0, num, max
88 SAVE
89 *DO, j, StartKpTail, EndKpTail-1, 1
90     L, j, j+1
91 *ENDDO
92 *GET, LenghtLineRference, LINE, 1, leng !extract lenght segment
    line's cone generator
93
94 ! generate cone
95 *GET, NumberLine, line, 0, count !count lines
96 *GET, StartNumberLine, line, 0, num, min !extract first number
    line
97 LSEL, S, LOC, X, 0, Lt
98 AROTAT, ALL, , , , , 1, 2, 360, NumberDivisonSurface !generate cone
99 SAVE
100
101 !divide line in array straight line and curved line
102 !to manage in next step meshing of elements
103 *GET, NumberLine, line, 0, count !count lines
104 *DIM, StraighLine, ARRAY, NumberLine, 2
105 *DIM, ArchLine, ARRAY, NumberLine, 2
106 *DO, n, StartNumberLine, NumberLine, 1
107     *GET, LenghtLine, LINE, n, leng,
108     *IF, LenghtLineRference, EQ, LenghtLine, THEN
109         StraighLine(n, 1) = n
110         StraighLine(n, 2) = LenghtLine
111         *SET, LastStraightLine, n
112     *ELSE
113         ArchLine(n, 1)=n
114         ArchLine(n, 2)=LenghtLine
115         *SET, LastArchLine, n
116     *ENDIF
117 *ENDDO
118
119 *DIM, ConnectionKp, ARRAY, 8, 2

```

```

120 ksel, s, loc, x, 0, RadBaseTail
121 ksel, s, loc, y, RadBaseTail*cos(360/NumberDivisonSurface), RadBaseTail*cos(360
    /NumberDivisonSurface)
122 ksel, r, loc, z, -RadBaseTail, RadBaseTail
123 *GET, tmp1, KP, 0, num, min
124 *GET, tmp2, KP, 0, num, max
125 ConnectionKp(1, 1) =tmp1
126 ConnectionKp(1, 2) =tmp2
127 *DO, i, 1, 7, 1
128     ksel, s, loc, x, Lt/7*i
129     ksel, r, loc, y, SegmentRadius(i)*cos(360/NumberDivisonSurface), SegmentRadius(i)
        *cos(360/NumberDivisonSurface)
130     ksel, r, loc, z, -SegmentRadius(i)*sin(360/NumberDivisonSurface), SegmentRadius(i)
        *sin(360/NumberDivisonSurface)
131     *GET, tmp1, KP, 0, num, min
132     *GET, tmp2, KP, 0, num, max
133     ConnectionKp(i+1, 1) =tmp1
134     ConnectionKp(i+1, 2) =tmp2
135     !clear temp variable
136     *SET, tmp1,
137     *SET, tmp2,
138 *ENDDO
139 SAVE
140
141 /VIEW,1,1,1,1
142 /ANG,1
143 /REP,FAST
144 LPLOT
145 *USE, generateimages.mac
146
147 ! >>>> MESH <<<<
148 /ESHAPE, 1
149 ! set material properties and element
150 ET, 1, BEAM189
151 MP, EX, 1, SteelEyoungG
152 MP, NUXY, 1, SteelNi
153 MP, DENS, 1, SteelDensity
154
155 !***Horizontal Stabilizer
156 SECTYPE, 1, BEAM, RECT, HorizontalStabilizer, 0
157 SECOFFSET, CENT
158 SECDATA, HorizStabBase, HorizStabHeigth
159
160 LSEL, S, LINE, , 1, LastStraightLine
161 LESIZE, all, E_length_ct
162 LATT, 1, , 1, , , 1
163 LMESH, ALL
164 LSEL, NONE
165 /REPLO
166
167 !***stiffeners
168 SECTYPE, 2, BEAM, RECT, Stiffeners, 0
169 SECOFFSET, ORIG
170 SECDATA, StiffnerBase, StiffnerHeight
171
172 LSEL, S, LINE, , LastStraightLine+1, LastArchLine

```

```

173 LESIZE, ALL, , , , 3
174 LATT, 1, , 1, , , 2
175 LMESH, ALL
176 LSEL, NONE
177 /REPLO
178
179 /VIEW, 1, 1, 1, 1
180 /ANG, 1
181 /REP, FAST
182 EPLOT
183 *USE, generateimages.mac, StrJobname(1)
184
185 !***Mantle
186 ! set material properties and element
187 ET, 2, SHELL181
188 KEYOPT, 2, 3, 2
189 KEYOPT, 2, 8, 1
190
191 MP, EX, 2, AluminiumEyoungG
192 MP, NUXY, 2, AluminiumNi
193 MP, DENS, 2, AluminiumDensity
194 SECT, 3, SHELL, , mantle
195 SECDATA, ThichknessMantle, 2, 0.0, 3
196 SECOFFSET, TOP
197
198 TYPE, 2
199 SECNUM, 3
200 AESIZE, ALL, E_length_ct,
201 MSHAPE, 0, 2D
202 MSHKEY, 1
203 AMESH, ALL
204 SAVE
205
206 /VIEW, 1, 1, 1, 1
207 /ANG, 1
208 /REP, FAST
209 EPLOT
210 *USE, generateimages.mac
211
212 !define shaft and support
213 *DIM, KpShaft, ARRAY, 8, 1
214 *GET, LastNode, KP, , num, max
215 K, LastNode+1, 0, RadBaseTail+50e-3, 0
216 *GET, LastNode, KP, , num, max
217 Kpshaft(1)=LastNode
218 *DO, i, 1, 7, 1
219     *GET, LastNode, KP, , num, max
220     K, LastNode+1, Lt/7*i, SegmentRadius(i)+50e-3, 0
221     *GET, LastNode, KP, , num, max
222     Kpshaft(i+1)=LastNode
223     *GET, LastLine, LINE, , num, max
224     L, LastNode-1, LastNode
225 *ENDDO
226 SAVE
227
228 !***Shaft lumped mass

```

```

229 *DIM, ConnectionShaftSupportNode, ARRAY, 8, 3
230 *GET, KpShaftDimension, 'PARM', KPSHAFT, DIM, X
231 ET, 4, MASS21, , , 2
232 R, 4, MassShaft/8
233 TYPE, 4
234 REAL, 4
235 *DO, i, 1, KpShaftDimension, 1
236     *GET, LastNode, NODE, , NUM, MAX
237     N, LastNode+1, KX(Kpshaft(i)), KY(Kpshaft(i)), KZ(Kpshaft(i))
238     *GET, node_num, NODE, , NUM, MAX
239     ConnectionShaftSupportNode(i, 1) = node_num
240     E, node_num
241 *ENDDO
242 SAVE
243
244 !***gearbox lumped
245 ET, 5, MASS21, , , 3          !2D mass with rotary inertia
246 R, 5, MassRotor, J0
247 TYPE, 5
248 REAL, 5
249 E, ConnectionShaftSupportNode(7, 1)
250
251 !***Support shaft - rigid connection
252 ET, 3, MPC184, 1
253 KEYOPT, 3, 1, 1
254 MP, EX, 3, SteelEyoungG
255 MP, NUXY, 3, SteelNi
256
257 SECNUM, 4
258 MAT, 3
259 TYPE, 3
260 *DO, i, 1, 8, 1
261     KSEL, s, KP, , KpShaft(i)
262     NSLK, s
263     *GET, NodeShaft, node, , num, max
264     *SET, NodeShaft,
265     KSEL, ALL
266     KSEL, s, KP, , ConnectionKp(i, 1)
267     NSLK, s
268     *GET, NodeSupport1, node, , num, max
269     ConnectionShaftSupportNode(i, 2) = NodeSupport1
270     *SET, NodeSupport1,
271     KSEL, ALL
272     KSEL, s, KP, , ConnectionKp(i, 2)
273     NSLK, s
274     *GET, NodeSupport2, node, , num, max
275     ConnectionShaftSupportNode(i, 3) = NodeSupport2
276     *SET, NodeSupport2,
277     E, ConnectionShaftSupportNode(i, 1), ConnectionShaftSupportNode(i, 2)
278     E, ConnectionShaftSupportNode(i, 1), ConnectionShaftSupportNode(i, 3)
279 *ENDDO
280 SAVE
281
282 EPLOT
283 /VIEW, 1, , , 1
284 /ANG, 1

```

```

285 /REP, FAST
286 *USE, generateimages.mac
287 /VIEW, 1, 1, 1, 1
288 /ANG, 1
289 /REP, FAST
290 *USE, generateimages.mac
291
292 !***Boundary conditions at base of tail
293 ALLSEL, ALL
294 LSEL, S, LOC, Y, -(RadBaseTail*2)+eps, (RadBaseTail*2)+eps
295 LSEL, S, LOC, x, 0, 0
296 *GET, MinBaseTailLine, line, 0, num, min
297 *GET, MaxBaseTailLine, line, 0, num, max
298 *DO, i, MinBaseTailLine, MaxBaseTailLine, 8
299     DL, i, , ALL, 0
300 *ENDDO
301
302 *USE, calcmass.mac, StrJobname(1)
303 FINISH
304
305 /COM, -----
306 /COM, Preliminary static analysis - Prestress
307 /COM, -----
308 ! >>>> SOLUTION <<<<
309 /SOLU
310 ANTYPE, STATIC, NEW      !Preliminary static analysis
311 PSTRES, ON               !Includes prestress effects
312 LUMPM, ON
313 Acel, , 9.81             !gravitational acceleration
314
315 SOLVE
316 FINISH
317
318 ! >>>> POSTPROCESSING <<<<
319 /POST1
320 PLDISP, 1
321 *use, generateimages.mac
322 PLNSOL, U, SUM, 0, 1.0
323 *use, generateimages.mac
324 PLNSOL, S, EQV, 0, 1.0
325 *use, generateimages.mac
326
327 /COM, -----
328 /COM, Modal analysis
329 /COM, -----
330 ! >>>> SOLUTION <<<<
331 /SOLU
332 ANTYPE, MODAL, NEW
333 PSTRES, ON               ! Includes prestress effects
334 MODOPT, LANB, 10         ! First 10 modes are extracted
335 LUMPM, ON               ! lumped/consistent mass matrix
336 MXPAND, 10, , , Yes     ! First 10 modes are expanded, calculate element
    stress
337
338 SOLVE
339 FINISH

```



```

340
341 ! >>>> POSTPROCESSING <<<<
342 /POST1
343 SET, LIST                      !List natural frequencies
344 SET, 1, 1                      !Loads first mode
345 PLDISP                         !Displays modal shape
346
347 *DIM,ModalFreq,ARRAY,10,1
348 *DO, i, 1, 10, 1
349   *GET, omega, MODE, i, FREQ
350     ModalFreq(i,1) = omega
351   *SET, omega,
352 *ENDDO
353
354 *SET, omega,
355 *CFOPEN, 'ModalFreq-%StrJobname(1)%', 'txt'
356   *VWRITE, 'Num', 'omega'
357     (8x, A8, 4X, A8,)
358   *VWRITE, sequ, ModalFreq(1,1)
359     (F12.0, F12.5)
360 *CFCLOS
361
362 FINISH
363 /EXIT, ALL

```

Listing 7.4: ShellModelRotor.txt

```

1 /COM, -----
2 /COM, PROBLEM: MODAL ANALYSIS of the helicopter's TAIL BOOM
3 /COM, -----
4 /COM, Natural frequencies and modal shapes of an helicopter's tail boom
5 /COM, -----
6
7 FINISH
8 /CLEAR, START, NEW
9 /FILNAM, ShellmodelRotor
10 /TITLE, Helicopter tail boom modal analysis shell model
11 /UNIT, SI
12 /INQUIRE, StrJobname, JOBNAME
13 *USE, testperson.mac
14
15 ! >>>> MODEL PARAMETERS <<<<
16 *SET, Pi, ACOS(-1)           !Pi constant
17 *AFUN, DEG                   !Specify units for angular measures [DEG], specify after
    function *AFUN
18 *SET, eps, 10e-3             !precision interval
19
20 ! >>>> MATERIAL PROPERTIES <<<<
21 *** steel
22 *SET, SteelEyoungG, 205e9     ![Pa] Young's modulus
23 *SET, SteelNi, 0.29          !Poisson's ratio
24 *SET, SteelDensity, 7850     ![Kg/m^3]
25
26 *** Aluminium
27 *SET, AluminiumEyoungG, 64e9 ![Pa] Young's modulus
28 *SET, AluminiumNi, 0.34     !Poisson's ratio

```

```

29 *SET, AluminiumDensity, 2700 ! [Kg/m^3]
30
31 *** Element size
32 *SET, E_length_ct, 50e-3 ! [m]
33
34 !geometric parameter
35 *SET, Lt, 5.2 ! [m] total tail lenght
36 *SET, RadBaseTail, 0.65/2 ! [m]
37 *SET, RadEndTail, 0.10/2 ! [m]
38 *SET, alpha, atan((RadBaseTail-RadEndTail)/Lt) ! [deg]
39
40 !geometric parameters section stiffner
41 *SET, StiffnerBase, 5e-3
42 *SET, StiffnerHeight, 5e-3
43
44 !geometric parameters section Horizizontal Stabilizer
45 *SET, HorizStabBase, 0.009
46 *SET, HorizStabHeigth, 0.0015
47
48 !geometric parameter mantle
49 *SET, ThichknessMantle, 5e-4 ! [m]
50
51 !other parameters
52 *SET, NumberDivisonSurface, 24 !division cone's area
53
54 !change view - isometric
55 /VIEW,1,1,1,1
56 /ANG,1
57 /REP,FAST
58
59 /COM, -----
60 /COM, MODEL DEFINITION
61 /COM, -----
62 ! >>>> DEFINE GEOMETRY <<<<
63 ! Reduced integration Timoshenko beam element, with quadratic shape functions
64 /PREP7
65 ! Define axis rotation
66 K, 1, 0, 0, 0
67 K, 2, 5, 0, 0
68
69 ! create keypoints
70 K, 3, 0, RadBaseTail, 0 !start keypoint
71 !tails
72 *GET, MaxKp, KP, 0, num, max !extract max
73 keypoint
74 *SET, StartKpTail, MaxKp !store in
75 variable
76 *DIM, SegmentRadius, ARRAY, 7, 1 !store in array radius
77 of segment distance between 0 - Y before rotating
78 *DO, i, 1, 7, 1
79 *GET, MaxKp, KP, 0, NUM, MAX !extract max keypoint
80 K, MaxKp+1, Lt/7*i, RadBaseTail-Lt/7*i*tan(alpha), 0 !create keypoint
81 SegmentRadius(i) = RadBaseTail-Lt/7*i*tan(alpha)
82 *ENDDO
83 *GET, MaxKp, KP, 0, num, max !extract max
84 keypoint

```

```

80 *SET, EndKpTail, MaxKp                                !store in
    variable end's tail
81
82 !define keypoint mantle'tail
83 K, Maxkp+1, 0, RadBaseTail, 0
84 *GET, StartKpMantle, KP, 0, num, max
85 K, MaxKp+2, Lt/7*i, RadEndTail, 0
86 *GET, EndKpMantle, KP, 0, num, max
87
88 *DO, j, StartKpTail, EndKpTail-1, 1
89     L, j, j+1
90 *ENDDO
91 *GET, LenghtLineRference, LINE, 1, leng                !extract lenght
    segment line's cone generator
92
93 ! generate cone
94 *GET, NumberLine, line, 0, count                        !count lines
95 *GET, StartNumberLine, line, 0, num, min                !extract first
    number line
96 *GET, NumberLine, line, 0, count                        !count lines
97 *GET, StartNumberLine, line, 0, num, min                !extract first
    number line
98 LSEL, S, LOC, X, 0, Lt
99 AROTAT, ALL, , , , , 1, 2, 360, NumberDivisonSurface !generate cone
100
101 !divide line in array straight line and curved line
102 !to manage in next step meshing of elements
103 LSEL, S, LENGTH, , LenghtLineRference, LenghtLineRference
104 *VGET, StraighLine, LINE, , LLIST, , , 0
105 ALLSEL, ALL
106 LSEL, U, LENGTH, , LenghtLineRference, LenghtLineRference
107 *VGET, AcrLine, LINE, , LLIST, , , 0
108
109 *GET, StartNumberLine, line, 0, num, min
110 LSEL, ALL
111
112 ! >>>> MESH <<<<
113 /ESHAPE, 1
114 !set material properties and element
115 ET, 1, BEAM189
116 KEYOPT, 1, 1, 1
117 KEYOPT, 1, 15, 1
118 MP, EX, 1, SteelEyoungG
119 MP, NUXY, 1, SteelNi
120 MP, DENS, 1, SteelDensity
121
122 !***Horizzontal Stabilizer
123 SECTYPE, 1, BEAM, RECT, HorizzontalStabilizer, 0
124 SECOFFSET, CENT
125 SECDATA, HorizStabBase, HorizStabHeigth
126
127 *GET, LenghtStraighLine, 'PARM', StraighLine, DIM, X
128 LSEL, S, LINE, , StraighLine(1), StraighLine(LenghtStraighLine)
129 LESIZE, all, E_length_ct
130 LATT, 1, , 1, , , , 1
131 LMESH, ALL

```

```

132 LSEL, NONE
133 /ESHAPE, 1
134 /REPLO
135
136 !***stiffeners
137 SECTYPE, 2, BEAM, RECT, Stiffeners, 0
138 SECOFFSET, ORIG
139 SECDATA, StiffnerBase, StiffnerHeight
140
141 *GET, LenghtAcrLine, 'PARM', AcrLine, DIM, X
142 LSEL, S, LINE, , AcrLine(1), AcrLine(LenghtAcrLine)
143 LESIZE, ALL, , , , 3
144 LATT, 1, , 1, , , , 2
145 LMESH, ALL
146 LSEL, NONE
147 /REPLO
148
149 !***Mantle
150 !set material properties and element
151 ET, 2, SHELL181
152 KEYOPT, 2, 3, 2
153 KEYOPT, 2, 8, 2
154
155 MP, EX, 2, AluminiumEyoungG
156 MP, NUXY, 2, AluminiumNi
157 MP, DENS, 2, AluminiumDensity
158 SECT, 3, SHELL, , mantle
159 SECDATA, ThichknessMantle, 2, 0.0, 3
160 SECOFFSET, top
161
162 TYPE, 2
163 SECNUM, 3
164 AESIZE, ALL, E_length_ct,
165 MSHAPE, 0, 2D
166 MSHKEY, 1
167 AMESH, ALL
168 SAVE
169
170 /COM, -----
171 /COM, COMPLETE MODEL
172 /COM, -----
173
174 !Selct base keypoint and node
175 KSEL, S, LOC, X, 4.457143
176 KSEL, R, LOC, Y, 0.4464286E-01
177 KSEL, R, LOC, Z, -0.7732370E-01, 0.7732370E-01
178 *GET, BaseBearing1, KP, , NUM, MIN
179 *GET, BaseBearing2, KP, , NUM, MAX
180 ALLSEL, ALL
181
182 !create node for rigid link
183 *GET, LastNode, NODE, , NUM, MAX
184 N, LastNode + 1, kx(BaseBearing2), SegmentRadius(6)+50e-3, kz(BaseBearing2)
185 *GET, NodeBearing2, NODE, , NUM, MAX
186 *GET, LastNode, NODE, , NUM, MAX
187 N, LastNode + 1, kx(BaseBearing1), SegmentRadius(6)+50e-3, kz(BaseBearing1)

```

```

188 *GET, NodeBearing1, NODE, , NUM, MAX
189 *USE, distancenode.mac, NodeBearing1, NodeBearing2
190
191 !Set local systems
192 *USE, relativereferencesystem.mac, 1, 0, Lt/7*6, SegmentRadius(6)+50e-3, kz(BaseBearing1
    ), , , 90
193 *USE, relativereferencesystem.mac, 2, 0, Lt/7*6, SegmentRadius(6)+50e-3, kz(BaseBearing2
    ), , , 90
194
195 !Enter local system - z-positive
196 CSYS, LocalSystem_1
197
198 !create rotorblock
199 *USE, rotor.mac, NodeBearing1, NodeBearing2, DistancePoint, LocalSystem_1, LocalSystem_2
200
201 !return principal Reference system
202 CSYS, 0
203 SAVE
204
205 /COM, -----
206 /COM, RIGID LINK
207 /COM, create revolute joint to connect shfat and tail
208 /COM, -----
209 !define element rigid link
210 *GET, LastElementType, ETYP, , NUM, MAX
211 *SET, RigidLink, LastElementType + 1
212 ET, RigidLink, MPC184
213 !0 - rigid link block 3 d.o.f (x, y, z)
214 !1 - beam block 6 d.o.f (x, y, z, rx, ry, rz)
215 KEYOPT, RigidLink, 1, 1
216 KEYOPT, RigidLink, 2, 0
217
218 !material for rigid link
219 *GET, MaterialNum, MAT, , NUM, MAX
220 *SET, RigidLinkMaterial, MaterialNum + 1
221 !MP, EX, RigidLinkMaterial, SteelEyoungG
222 !MP, NUXY, RigidLinkMaterial, SteelNi
223 !MAT, RigidLinkMaterial
224
225 !create element
226 TYPE, RigidLink
227 KSEL,S,KP,,BaseBearing1
228 NSLK,S
229 *GET, LastNode, NODE, , NUM, MAX
230 E, LastNode, NodeStart
231 ALLSEL,ALL
232 KSEL,S,KP,,BaseBearing2
233 NSLK,S
234 *GET, LastNode, NODE, , NUM, MAX
235 E, LastNode, NodeEnd
236
237 !clear parmeters
238 *SET, BaseBearing1,
239 *SET, BaseBearing2,
240 *SET, NodeBearing1,
241 *SET, NodeBearing2,

```

```

242 *SET, LastNode,
243 *SET, i,
244
245 !change view - isometric
246 EPLOT
247 /VIEW,1,1,1,1
248 /ANG,1
249 /REP,FAST
250
251 /COM, -----
252 /COM, BOUNDARY CONDITION
253 /COM, -----
254 ALLSEL, ALL
255 LSEL, S, LOC, Y, -(RadBaseTail*2)+eps, (RadBaseTail*2)+eps
256 LSEL, S, LOC, x, 0, 0
257 *GET, MinBaseTailLine, line, 0, num, min
258 *GET, MaxBaseTailLine, line, 0, num, max
259 *DO, i, MinBaseTailLine, MaxBaseTailLine, 8
260     DL, i, , ALL, 0
261 *ENDDO
262 SAVE
263
264 !calc mass
265 *USE, calcmass.mac, StrJobname(1)
266 FINISH
267 SAVE
268
269 /COM, -----
270 /COM, PRELIMINARY STATIC ANALYSIS - PRESTRESS
271 /COM, -----
272 ! >>>> SOLUTION <<<<
273 /SOLU
274 ANTYPE, STATIC, NEW      !Preliminary static analysis
275 PSTRES, ON               !Includes prestress effects
276 Acel, , 9.81             !gravitational acceleration
277
278 SOLVE
279 FINISH
280
281 /COM, -----
282 /COM, Modal analysis
283 /COM, -----
284 ! >>>> SOLUTION <<<<
285 /SOLU
286 ANTYPE, MODAL, NEW
287 PSTRES, ON               ! Includes prestress effects
288 MODOPT, LANB, 10         ! First 10 modes are extracted
289 LUMPM, OFF               ! lumped/consistent mass matrix
290 MXPAND, 10, , , Yes      ! First 10 modes are expanded, calculate element
    stress
291
292 SOLVE
293 FINISH
294
295 ! >>>> POSTPROCESSING <<<<
296 /POST1

```

```

297 SET, LIST                                !List natural frequencies
298 SET, 1, 1                                !Loads first mode
299 PLDISP                                    !Displays modal shape
300
301 *DIM,ModalFreq,ARRAY,10,1
302 *DO, i, 1, 10, 1
303   *GET, omega, MODE, i, FREQ
304     ModalFreq(i,1) = omega
305   *SET, omega,
306 *ENDDO
307
308 *SET, omega,
309 *CFOPEN, 'ModalFreq-%StrJobname(1)%', 'txt'
310   *VWRITE, 'Num', 'omega'
311     (8x, A8, 4X, A8,)
312   *VWRITE, sequ, ModalFreq(1,1)
313     (F12.0, F12.5)
314 *CFCLOS
315
316 FINISH
317 /EXIT, ALL

```

Listing 7.5: ShellModeldiskRun.txt

```

1 /COM, -----
2 /COM, PROBLEM: MODAL ANALYSIS of the helicopter's TAIL BOOM
3 /COM, -----
4 /COM, Natural frequencies and modal shapes of an helicopter's tail boom
5 /COM, -----
6
7 FINISH
8 /CLEAR, START, NEW
9 /FILNAM, ShellmodelRotor
10 /TITLE, Helicopter tail boom modal analysis shell model
11 /UNIT, SI
12 /INQUIRE, StrJobname, JOBNAME
13 *USE, testperson.mac
14
15 ! >>>> MODEL PARAMETERS <<<<
16 *SET, Pi, ACOS(-1)                        !Pi constant
17 *AFUN, DEG                                !Specify units for angular measures [DEG], specify after
    function *AFUN
18 *SET, eps, 10e-3                          !precision interval
19
20 ! >>>> MATERIAL PROPERTIES <<<<
21 *** steel
22 *SET, SteelEyoungG, 205e9                  ![Pa] Young's modulus
23 *SET, SteelNi, 0.29                       !Poisson's ratio
24 *SET, SteelDensity, 7850                  ![Kg/m^3]
25
26 *** Aluminium
27 *SET, AluminiumEyoungG, 64e9              ![Pa] Young's modulus
28 *SET, AluminiumNi, 0.34                  !Poisson's ratio
29 *SET, AluminiumDensity, 2700             ![Kg/m^3]
30
31 *** Element size

```

```

32 *SET, E_length_ct, 50e-3                                ![m]
33
34 !geometric parameter
35 *SET, Lt, 5.2                                            ![m] total tail lenght
36 *SET, RadBaseTail, 0.65/2                               ![m]
37 *SET, RadEndTail, 0.10/2                                ![m]
38 *SET, alpha, atan((RadBaseTail-RadEndTail)/Lt)         ![deg]
39
40 !geometric parameters section stiffner
41 *SET, StiffnerBase, 5e-3
42 *SET, StiffnerHeight, 5e-3
43
44 !geometric parameters section Horizzontal Stabilizer
45 *SET, HorizStabBase, 0.009
46 *SET, HorizStabHeighth, 0.0015
47
48 !geometric parameter mantle
49 *SET, ThichknessMantle, 5e-4                            ![m]
50
51 !other parameters
52 *SET, NumberDivisonSurface, 24 !division cone's area
53
54 !change view - isometric
55 /VIEW,1,1,1,1
56 /ANG,1
57 /REP,FAST
58
59 /COM, -----
60 /COM, MODEL DEFINITION
61 /COM, -----
62 ! >>>> DEFINE GEOMETRY <<<<
63 ! Reduced integration Timoshenko beam element, with quadratic shape functions
64 /PREP7
65 ! Define axis rotation
66 K, 1, 0, 0, 0
67 K, 2, 5, 0, 0
68
69 ! create keypoints
70 K, 3, 0, RadBaseTail, 0                                !start keypoint
71                                     tails
72 *GET, MaxKp, KP, 0, num, max                             !extract max
73                                     keypoint
74 *SET, StartKpTail, MaxKp                                 !store in
75                                     variable
76 *DIM, SegmentRadius, ARRAY, 7, 1                        !store in array radius
77                                     of segment distance between 0 - Y before rotating
78 *DO, i, 1, 7, 1
79     *GET, MaxKp, KP, 0, NUM, MAX                         !extract max keypoint
80     K, MaxKp+1, Lt/7*i, RadBaseTail-Lt/7*i*tan(alpha), 0 !create keypoint
81     SegmentRadius(i) = RadBaseTail-Lt/7*i*tan(alpha)
82 *ENDDO
83 *GET, MaxKp, KP, 0, num, max                             !extract max
84                                     keypoint
85 *SET, EndKpTail, MaxKp                                   !store in
86                                     variable end's tail

```



```

82 !define keypoint mantle'tail
83 K, Maxkp+1, 0, RadBaseTail, 0
84 *GET, StartKpMantle, KP, 0, num, max
85 K, MaxKp+2, Lt/7*i, RadEndTail, 0
86 *GET, EndKpMantle, KP, 0, num, max
87
88 *DO, j, StartKpTail, EndKpTail-1, 1
89     L, j, j+1
90 *ENDDO
91 *GET, LenghtLineRference, LINE, 1, leng           !extract lenght
92     segment line's cone generator
93
94 ! generate cone
95 *GET, NumberLine, line, 0, count                 !count lines
96 *GET, StartNumberLine, line, 0, num, min          !extract first
97     number line
98 *GET, NumberLine, line, 0, count                 !count lines
99 *GET, StartNumberLine, line, 0, num, min          !extract first
100     number line
101 LSEL, S, LOC, X, 0, Lt
102 AROTAT, ALL, , , , , 1, 2, 360, NumberDivisonSurface !generate cone
103
104 !divide line in array straight line and curved line
105 !to manage in next step meshing of elements
106 LSEL, S, LENGTH, , LenghtLineRference, LenghtLineRference
107 *VGET, StraighLine, LINE, , LLIST, , , 0
108 ALLSEL, ALL
109 LSEL, U, LENGTH, , LenghtLineRference, LenghtLineRference
110 *VGET, AcrLine, LINE, , LLIST, , , 0
111
112 *GET, StartNumberLine, line, 0, num, min
113 LSEL, ALL
114
115 ! >>>> MESH <<<<
116 /ESHAPE, 1
117 !set material properties and element
118 ET, 1, BEAM189
119 KEYOPT, 1, 1, 1
120 KEYOPT, 1, 15, 1
121 MP, EX, 1, SteelEyoungG
122 MP, NUXY, 1, SteelNi
123 MP, DENS, 1, SteelDensity
124
125 !***Horizontal Stabilizer
126 SECTYPE, 1, BEAM, RECT, HorizontalStabilizer, 0
127 SECOFFSET, CENT
128 SECDATA, HorizStabBase, HorizStabHeigth
129
130 *GET, LenghtStraighLine, 'PARM', StraighLine, DIM, X
131 LSEL, S, LINE, , StraighLine(1), StraighLine(LenghtStraighLine)
132 LESIZE, all, E_length_ct
133 LATT, 1, , 1, , , , 1
134 LMESH, ALL
135 LSEL, NONE
136 /ESHAPE, 1
137 /REPLO

```

```

135
136 !***stiffners
137 SECTYPE, 2, BEAM, RECT, Stiffeners, 0
138 SECOFFSET, ORIG
139 SECDATA, StiffnerBase, StiffnerHeight
140
141 *GET, LenghtAcrLine, 'PARM', AcrLine, DIM, X
142 LSEL, S, LINE, , AcrLine(1), AcrLine(LenghtAcrLine)
143 LESIZE, ALL, , , , 3
144 LATT, 1, , 1, , , 2
145 LMESH, ALL
146 LSEL, NONE
147 /REPLO
148
149 !***Mantle
150 !set material properties and element
151 ET, 2, SHELL181
152 KEYOPT, 2, 3, 2
153 KEYOPT, 2, 8, 2
154
155 MP, EX, 2, AluminiumEyoungG
156 MP, NUXY, 2, AluminiumNi
157 MP, DENS, 2, AluminiumDensity
158 SECT, 3, SHELL, , mantle
159 SECDATA, ThichknessMantle, 2, 0.0, 3
160 SECOFFSET, top
161
162 TYPE, 2
163 SECNUM, 3
164 AESIZE, ALL, E_length_ct,
165 MSHAPE, 0, 2D
166 MSHKEY, 1
167 AMESH, ALL
168 SAVE
169
170 /COM, -----
171 /COM, COMPLETE MODEL
172 /COM, -----
173
174 !Selct base keypoint and node
175 KSEL, S, LOC, X, 4.457143
176 KSEL, R, LOC, Y, 0.4464286E-01
177 KSEL, R, LOC, Z, -0.7732370E-01, 0.7732370E-01
178 *GET, BaseBearing1, KP, , NUM, MIN
179 *GET, BaseBearing2, KP, , NUM, MAX
180 ALLSEL, ALL
181
182 !create node for rigid link
183 *GET, LastNode, NODE, , NUM, MAX
184 N, LastNode + 1, kx(BaseBearing2), SegmentRadius(6)+50e-3, kz(BaseBearing2)
185 *GET, NodeBearing2, NODE, , NUM, MAX
186 *GET, LastNode, NODE, , NUM, MAX
187 N, LastNode + 1, kx(BaseBearing1), SegmentRadius(6)+50e-3, kz(BaseBearing1)
188 *GET, NodeBearing1, NODE, , NUM, MAX
189 *USE, distancenode.mac, NodeBearing1, NodeBearing2
190

```

```

191 !Set local systems
192 *USE, relativereferencesystem.mac, 1, 0, Lt/7*6, SegmentRadius(6)+50e-3, kz(BaseBearing1
    ), , , 90
193 *USE, relativereferencesystem.mac, 2, 0, Lt/7*6, SegmentRadius(6)+50e-3, kz(BaseBearing2
    ), , , 90
194
195 !Enter local system - z-positive
196 CSYS, LocalSystem_1
197
198 !create rotorblock
199 *USE, rotor.mac, NodeBearing1, NodeBearing2, DistancePoint, LocalSystem_1, LocalSystem_2
200
201 !return principal Reference system
202 CSYS, 0
203 SAVE
204
205 /COM, -----
206 /COM, RIGID LINK
207 /COM, create revolute joint to connect shfat and tail
208 /COM, -----
209 !define element rigid link
210 *GET, LastElementType, ETYP, , NUM, MAX
211 *SET, RigidLink, LastElementType + 1
212 ET, RigidLink, MPC184
213 !0 - rigid link block 3 d.o.f (x, y, z)
214 !1 - beam block 6 d.o.f (x, y, z, rx, ry, rz)
215 KEYOPT, RigidLink, 1, 1
216 KEYOPT, RigidLink, 2, 0
217
218 !material for rigid link
219 *GET, MaterialNum, MAT, , NUM, MAX
220 *SET, RigidLinkMaterial, MaterialNum + 1
221 !MP, EX, RigidLinkMaterial, SteelEyoungG
222 !MP, NUXY, RigidLinkMaterial, SteelNi
223 !MAT, RigidLinkMaterial
224
225 !create element
226 TYPE, RigidLink
227 KSEL,S,KP,,BaseBearing1
228 NSLK,S
229 *GET, LastNode, NODE, , NUM, MAX
230 E, LastNode, NodeStart
231 ALLSEL,ALL
232 KSEL,S,KP,,BaseBearing2
233 NSLK,S
234 *GET, LastNode, NODE, , NUM, MAX
235 E, LastNode, NodeEnd
236
237 !clear parmeters
238 *SET, BaseBearing1,
239 *SET, BaseBearing2,
240 *SET, NodeBearing1,
241 *SET, NodeBearing2,
242 *SET, LastNode,
243 *SET, i,
244

```

```

245 !change view - isometric
246 EPLOT
247 /VIEW,1,1,1,1
248 /ANG,1
249 /REP,FAST
250
251 /COM, -----
252 /COM, BOUNDARY CONDITION
253 /COM, -----
254 ALLSEL, ALL
255 LSEL, S, LOC, Y, -(RadBaseTail*2)+eps, (RadBaseTail*2)+eps
256 LSEL, S, LOC, x, 0, 0
257 *GET, MinBaseTailLine, line, 0, num, min
258 *GET, MaxBaseTailLine, line, 0, num, max
259 *DO, i, MinBaseTailLine, MaxBaseTailLine, 8
260     DL, i, , ALL, 0
261 *ENDDO
262 SAVE
263
264 !calc mass
265 *USE, calcmass.mac, StrJobname(1)
266 FINISH
267 SAVE
268
269 /COM, -----
270 /COM, PRELIMINARY STATIC ANALYSIS - PRESTRESS
271 /COM, -----
272 ! >>>> SOLUTION <<<<
273 /SOLU
274 ANTYPE, STATIC, NEW      !Preliminary static analysis
275 PSTRES, ON              !Includes prestress effects
276 Acel, , 9.81            !gravitational acceleration
277
278 SOLVE
279 FINISH
280
281 ! >>>>> ANALISYS PARAMETERS <<<<<
282 *SET, nmd, 10            ! Number of modes
283 *SET, nmospn, 8          ! Number of speeds
284 *SET, mxspn, 4000        ! Max Omega (rpm)
285
286 !get element component about a user-defined rotational
287 !in this case there is only one component
288 *GET, NumberComponet, 'COMP', , NCOMP
289 *GET, RotorBlock, 'COMP', NumberComponet, NAME
290
291 !get value for axis X1, Y1, Z1 <-> X2, Y2, Z2
292 *USE, getextremeaxis.mac
293
294 /SOLU
295 !Setup modal run
296 ANTYPE, MODAL
297 CORIOLIS, ON, , , ON
298 MODOPT, QRDAMP, nmd, , , ON
299
300 *ABSET, "Loop On Speed - progress: 0%", Bar

```

```

301 ! Loop on speeds
302 *DO, i, 1, nmspn
303     *SET, progress, i/nmspn*100
304     spn = (i-1)*(mxspn/(nmspn-1))
305     *SET, OMEGAX, spn
306     *SET, OMEGAY, 0
307     *SET, OMEGAZ, 0
308     !CMOMEGA, CM_NAME, OMEGAX, OMEGAY, OMEGAZ, X1, Y1, Z1, X2, Y2, Z2
309     /COM,=====
310     /COM, CMOMEGA, %CM_Name%, %OMEGAX%, %OMEGAY%, %OMEGAZ%,
311     /COM, %Node1CoorX%, %Node1CoorY%, %Node1CoorZ%,
312     /COM, %Node2CoorX%, %Node2CoorY%, %Node2CoorZ%
313     /COM,=====
314     CMOMEGA, %CM_Name%, OMEGAX, OMEGAY, OMEGAZ, Node1CoorX, Node1CoorY, Node1CoorZ,
315         Node2CoorX, Node2CoorY, Node2CoorZ
316     MXPAND, nmd, , , YES
317     SOLVE
318     *ABCHECK, "progress, Loop On Speed - progress: %progress% %"
319 *ENDDO
320 *ABFINI
321 FINISH
322
323 /post1
324 ! Plot/List Campbell Diagrams
325 /gropts,view,2
326 /yrange,0,100
327 /xrange,0,4000
328 plcamp,,1,rpm
329 prcamp,,1,rpm
330
331 ! Plot orbit
332 set,1,2
333 plorb
334 ! Animate whirl
335 set,3,1
336 plnsol,u,sum
337 anharm
338 finish

```

Macro

Listing 7.6: testperson.mac

```

1  !!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
2  !
3  !           WINDOW PERSONAZATION STYLE MACRO           !
4  !           Author: Francesco Argentieri               !
5  !
6  ! NO PARAMETERS INPUT
7  !
8  !
9  !!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
10

```

```

11 WPSTYLE, , , , , , , 0
12 /PLOPTS, INFO, 2
13 /PLOPTS, LEG1, 1
14 /PLOPTS, LEG2, 1
15 /PLOPTS, LEG3, 1
16 /PLOPTS, FRAME, 0
17 /PLOPTS, TITLE, 1
18 /PLOPTS, MINM, 1
19 /PLOPTS, FILE, 0
20 /PLOPTS, SPNO, 0
21 /PLOPTS, WINS, 1
22 /PLOPTS, WP, 0
23 /PLOPTS, DATE, 0
24 /TRIAD, ORIG
25 /REPLOT

```

Listing 7.7: generateimages.mac

```

1  !!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
2  !
3  !          IMAGE GENERATOR MACRO          !
4  !          Author: Francesco Argentieri    !
5  !
6  ! NO PARAMETERS INPUT                     !
7  !
8  !
9  !!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
10
11 /EFACET, 4
12 /RGB, INDEX, 100, 100, 100, 0
13 /RGB, INDEX, 80, 80, 80, 13
14 /RGB, INDEX, 60, 60, 60, 14
15 /RGB, INDEX, 0, 0, 0, 15
16 /REPLOT
17 /SHOW, PNG, , 0
18 PNGR, COMP, 0, -1
19 PNGR, ORIENT, HORIZ
20 PNGR, COLOR, 2
21 PNGR, TMOD, 1
22 /GFILE, 2400,
23 !*
24 /REPLOT
25 /SHOW, CLOSE
26 /DEVICE, VECTOR, 0
27 !*
28 /RGB, INDEX, 0, 0, 0, 0
29 /RGB, INDEX, 60, 60, 60, 13
30 /RGB, INDEX, 80, 80, 80, 14
31 /RGB, INDEX, 100, 100, 100, 15
32 /REPLOT
33 /EOF

```

Listing 7.8: rotor.mac

```

1  !!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
2  !

```

```

3  !           TAIL ROTOR GENERATOR MACRO           !
4  !                                           !
5  !                                           !
6  !PARAMETERS INPUT:                           !
7  !           ARG1: 1st node value             !
8  !           ARG2: 2nd node value             !
9  !           ARG3: pass distance between      !
10 !               previous nodes                !
11 !           ARG4: Local reference frame       !
12 !           ARG5: Local reference frame       !
13 !!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
14
15 ! >>>> MODEL PARAMETERS SHAFT AND DISK <<<<
16 *SET, shftlen, 0.50
17 *SET, shftdia, 0.03
18 *SET, dskoff, shftlen
19 *SET, brngoff, 0.12
20 *SET, dskdia, 1.912
21 *SET, d_i, 1.75
22 *SET, dskthk, 0.02
23 *SET, bstf, 378E+7      ! Brng Stiffness
24
25 /COM, -----
26 /COM,  MODEL DEFINITION -SHAFT
27 /COM, -----
28 ! 1st part
29 *GET, NodeMax, NODE, , NUM, MAX
30 *SET, NodeStart, NodeMax + 1
31 N, NodeStart,
32 N, NodeStart + 8, ARG3 $ /COM, %NodeStart + 8%, %ARG3%
33 *GET, NodeEnd, NODE, , NUM, MAX
34 FILL, NodeStart, NodeEnd
35 ! 2nd part
36 *GET, NodeMax, NODE, , NUM, MAX
37 N, NodeMax+19, dskoff
38 *GET, LastNode, NODE, , NUM, MAX
39 FILL, LastNode, NodeEnd
40 N, LastNode, nx(LastNode) + 0.02
41 *GET, LastNode, NODE, , NUM, MAX
42 SAVE
43
44 /COM, -----
45 /COM,  MESH - SHAFT
46 /COM, -----
47
48 ! >>>> MATERIAL PROPERTIES <<<<
49 *GET, MaterialNum, MAT, , NUM, MAX
50
51 ! Aluminum 7075
52 *SET, Aluminum7075, MaterialNum + 1
53 MP, EX, Aluminum7075, 71.7e+9
54 MP, DENS, Aluminum7075, 2810
55 MP, NUXY, Aluminum7075, 0.33
56
57 /COM, DEFINE BEAM188 for SHAFT
58 *GET, LastElementType, ETYP, , NUM, MAX

```

```

59 *SET, BeamShaft, LastElementType + 1
60 ! Use 188 elements, solid
61 ET, BeamShaft, 188
62 KEYOPT, BeamShaft, 1, 1
63 KEYOPT, BeamShaft, 3, 2
64 KEYOPT, BeamShaft, 15, 0
65
66 *GET, LastElementType, ETYP, , NUM, MAX
67 /COM, BEAM188 for SHAFT have number %BeamShaft%
68 *GET, LastSectionType, SECP, , NUM, MAX
69 *SET, SectionBeamShaft, LastSectionType + 1
70 SECTYPE, SectionBeamShaft, BEAM, CSOLID
71 SECDATA, shftdia/2
72 !cm, BeamOmega, elem
73
74 ! Make elements
75 SECNUM, SectionBeamShaft
76 TYPE, BeamShaft
77 MAT, Aluminum7075
78 NSEL, S, NODE, , NodeStart, LastNode, 1
79 *GET, NodeNumShaft, NODE, , COUNT
80 *GET, NodeStartShaft, NODE, , NUM, MIN
81 *GET, NodeEndShaft, NODE, , NUM, MAX
82 *DO, i, NodeStartShaft, NodeEndShaft-1, 1
83     E, i, i+1
84 *ENDDO
85 SAVE
86
87 /COM, -----
88 /COM, MODEL DEFINITION - DISK
89 /COM, -----
90
91 ! >>>> DEFINE GEOMETRY <<<<
92 WPCSYS, -1
93 WPOFFS, nx(LastNode), ny(LastNode), nz(LastNode)
94 WPROTA, , , 90
95 CYL4, 0, 0, d_i/2, 0, dskdia/2, 360
96
97 /COM, -----
98 /COM, MESH - DISK
99 /COM, -----
100 /COM, DEFINE SHELL181 for DISK
101 *GET, LastElementType, ETYP, , NUM, MAX
102 *SET, ShellDisk, LastElementType + 1
103 ET, ShellDisk, SHELL181
104 KEYOPT, ShellDisk, 3, 2
105 KEYOPT, ShellDisk, 8, 2
106
107 *GET, LastElementType, ETYP, , NUM, MAX
108 /COM, SHELL181 for Disk have number %ShellDisk%
109 *GET, LastSectionType, SECP, , NUM, MAX
110 *SET, SectionShellDisk, LastSectionType + 1
111 SECTYPE, SectionShellDisk, SHELL
112 SECD, dskthk
113 TYPE, ShellDisk
114 SECNUM, SectionShellDisk

```



```

115 MAT, Aluminum7075
116 !cm, DiscOmega, elem
117 MSHKEY, 0
118 !MSHAPE, 1, 2D
119 ESIZE, 0.02
120 AMESH, ALL
121 SAVE
122
123 !*** clamp between disk and spindle
124
125 /COM, *** CLAMP BETWEEN DISK AND SPINDLE
126 /COM, DEFINE MASS21 for CLAMP BETWEEN DISK AND SPINDLE
127 *GET, LastElementType, ETYP, , NUM, MAX
128 *SET, ClampDiskSplinde, LastElementType + 1
129 ET, ClampDiskSplinde, MASS21
130 KEYOPT, ClampDiskSplinde, 2, 0
131 *GET, ClampDiskSplinde, ETYP, , NUM, MAX
132 /COM, MASS21 for clamp between disk and spindle have number %ClampDiskSplinde%
133 R, ClampDiskSplinde, 10, 10, 10, 8.59e-2, 4.295e-2, 4.295e-2
134 TYPE, ClampDiskSplinde
135 REAL, ClampDiskSplinde
136 MAT, Aluminum7075
137 E, LastNode
138 SAVE
139
140 CERIG, LastNode, LastNode-1, ALL
141 ALLSEL, ALL
142 LSEL, S, LOC, X, nx(LastNode)
143 LSEL, R, RADIUS, , d_i/2
144 NSLL, S, 1
145 NSEL, A, NODE, , LastNode
146 CERIG, LastNode, ALL, ALL
147 /REP, FAST
148 SAVE
149
150 /COM, -----
151 /COM, MESH - BEARINGS
152 /COM, -----
153 !*** define bearings
154 *GET, LastElementType, ETYP, , NUM, MAX
155 *SET, SpringDamper, LastElementType+1
156 ET, SpringDamper, COMBIN14
157 *GET, RealConstant, RCON, , NUM, MAX
158 *SET, SpringDumperRealConst, RealConstant + 1
159 R, SpringDumperRealConst, bstf
160
161 !1-D longitudinal spring-damper (UY degree of freedom)
162 TYPE, SpringDamper
163 KEYOPT, SpringDamper, 2, 2
164 REAL, SpringDumperRealConst
165 E, ARG1, NodeStart
166 E, ARG2, NodeEnd
167 /COM, 1-D longitudinal spring-damper (UY degree of freedom):
168 /COM, Node1: %ARG1% (ARG1); Node2: %NodeStart% (NodeStart)
169 /COM, Node1: %ARG2% (ARG2); Node2: %NodeEnd% (NodeEnd)
170

```

```

171 !***longitudinal spring-damper (UZ degree of freedom)
172 TYPE, SpringDamper
173 KEYOPT, SpringDamper, 2, 3
174 E, ARG1, NodeStart
175 E, ARG2, NodeEnd
176 /COM, 1-D longitudinal spring-damper (UZ degree of freedom):
177 /COM, Node1: %ARG1% (ARG1); Node2: %NodeStart% (NodeStart)
178 /COM, Node1: %ARG2% (ARG2); Node2: %NodeEnd% (NodeEnd)
179
180 /COM, -----
181 /COM, REVOLUTE JOINT
182 /COM, create revolute joint to block d.o.f shaft
183 /COM, -----
184 !MPC184 Revolute Joint Geometry shows the geometry and node locations for this element.
185 !Two nodes (I and J) define the element. The two nodes are expected to have identical
186 spatial
187 !coordinates initially.
188 *GET, LastElementType, ETYP, , NUM, MAX
189 *SET, RevoluteJoint, LastElementType+1
190 ET, RevoluteJoint, MPC184
191 KEYOPT, RevoluteJoint, 1, 6
192
193 !If KEYOPT(4) = 0, then element is an x-axis revolute joint with the local e1 axis as
194 the revolute axis.
195 !If KEYOPT(4) = 1, then element is a z-axis revolute joint with the local e3 axis as the
196 revolute axis.
197 KEYOPT, RevoluteJoint, 4, 0
198
199 !***define revolute joint
200 TYPE, RevoluteJoint
201 SECTYPE, , JOINT, REVO, RevoJoint_1
202 SECJOINT, , ARG4, ARG4
203 *GET, LastSectionType, SECP, , NUM, MAX
204 SECNUM, LastSectionType
205 E, ARG1, NodeStart
206 SECTYPE, , JOINT, REVO, RevoJoint_2
207 SECJOINT, , ARG5, ARG5
208 *GET, LastSectionType, SECP, , NUM, MAX
209 SECNUM, LastSectionType
210 E, ARG2, NodeEnd
211 SAVE
212
213 !select element to
214 ESEL, S, TYPE, , BeamShaft
215 ESEL, A, TYPE, , ShellDisk
216 ESEL, A, TYPE, , ClampDiskSplinde
217 EPLOT
218
219 !create a component
220 CM, RotorBlock, ELEM
221
222 !in this case there is only one component
223 *GET, NumberComponet, 'COMP', , NCOMP
224 *GET, CM_Name, 'COMP', NumberComponet, NAME
225 *MSG, UI, NumberComponet, CM_Name
226 "Created: (%I) component, Named: (%S)"

```

```

224
225 !clear parameters
226 *SET, NodeMax,
227 *SET, LastElementType,
228 *SET, RevoluteJoint,
229 *SET, LastNode,
230 *SET, LastElementType,
231 *SET, SpringDamper
232 *SET, SpringDumperRealConst
233 *SET, ClampDiskSplinde,
234 *SET, ShellDisk,
235 *SET, NodeNumShaft,
236 *SET, NodeStartShaft,
237 *SET, NodeEndShaft,
238 *SET, BeamShaft,
239 !Exit Macro
240 /EOF

```

Listing 7.9: relativereferencesystem.mac

```

1  !!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
2  !                                                                                      !
3  !              CREATE NEW LOCAL REFERENCE SYSTEM                                !
4  !                                                                                      !
5  !                                                                                      !
6  !PARAMETERS INPUT:                                                                !
7  !              ARG1: Number new reference system RF                            !
8  !              ARG2: KCS - Coordinate system type                                !
9  !              ARG3: x - Location (in the active coordinate
10 !              system) !
11 !              ARG4: y - Location (in the active coordinate
12 !              system) !
13 !              ARG5: z - Location (in the active coordinate
14 !              system) !
15 !              ARG6: First rotation about local Z
16 !              (positive X toward Y)
17 !              ARG7: Second rotation about local X
18 !              (positive Y toward Z)
19 !              ARG8: Third rotation about local Y
20 !              (positive Z toward X)
21 !!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
22
23 !CLOCAL, KCN, KCS, XL, YL, ZL, THXY, THYZ, THZX
24 !Defines a local coordinate system relative to the active coordinate system.
25
26 !KCN
27 !Arbitrary reference number assigned to this coordinate system. Must be greater than 10.
28 !A coordinate system previously defined with this number will be redefined.
29
30 !KCS - Coordinate system type:
31 !0 or CART - Cartesian

```

```

32 !1 or CYLIN - Cylindrical (circular or elliptical)
33 !2 or SPHE - Spherical (or spheroidal)
34 !3 or TORO - Toroidal
35
36 !XL, YL, ZL - Location (in the active coordinate system) of the origin of the
37 !new coordinate system (R,  $\theta$ , Z for cylindrical, R,  $\theta$ ,  $\Phi$  for spherical or toroidal).
38
39 !THXY - First rotation about local Z (positive X toward Y)
40 !THYZ - Second rotation about local X (positive Y toward Z)
41 !THZX - Third rotation about local Y (positive Z toward X).
42
43 ! define local variable
44 *SET, i, ARG1
45 *SET, KCS, ARG2
46 *SET, XL, ARG3
47 *SET, YL, ARG4
48 *SET, ZL, ARG5
49 *SET, THXY, ARG6
50 *SET, THYZ, ARG7
51 *SET, THZX, ARG8
52
53 !Set new local reference system
54 *GET, LastLocalSystem, CDSY, , NUM, MAX
55 *SET, LocalSystem_%i%, LastLocalSystem + 100
56 !CLOCAL, KCN, KCS, XL, YL, ZL, THXY, THYZ, THZX
57 CLOCAL, LocalSystem_%i%, KCS, XL, YL, ZL, THXY, THYZ, THZX
58 /COM, New local system generated, return: LocalSystem_%i%
59
60 !clear local variable
61 *SET, i,
62 *SET, KCS,
63 *SET, XL,
64 *SET, YL,
65 *SET, ZL,
66 *SET, THXY,
67 *SET, THYZ,
68 *SET, THZX,
69 *SET, LastLocalSystem
70
71 !reset to roiginal system reference
72 CSYS, 0
73 /EOF

```

Listing 7.10: distancenode.mac

```

1 !!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
2 !                                                                 !
3 !           NODE DISTANCE CALCULATOR                          !
4 !                                                                 !
5 !PARAMETERS INPUT:                                             !
6 !           ARG1: 1st Node value                               !
7 !           ARG2: 2nd Node value                               !
8 !RETURN:                                                       !
9 !           DistancePoint                                       !
10 !!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
11

```

```

12 !define local variable
13 *GET, Node1CoorX, NODE, ARG1, LOC, X
14 *GET, Node1CoorY, NODE, ARG1, LOC, Y
15 *GET, Node1CoorZ, NODE, ARG1, LOC, Z
16 *GET, Node2CoorX, NODE, ARG2, LOC, X
17 *GET, Node2CoorY, NODE, ARG2, LOC, Y
18 *GET, Node2CoorZ, NODE, ARG2, LOC, Z
19
20 *SET, x_1, Node1CoorX
21 *SET, y_1, Node1CoorY
22 *SET, z_1, Node1CoorZ
23 *SET, x_2, Node2CoorX
24 *SET, y_2, Node2CoorY
25 *SET, z_2, Node2CoorZ
26
27 !calculates the distance between your nodes according to the formula
28 !dist^2=(x_1-x_2)^2+(y_1-y_2)^2+(z_1-z_2)^2
29 !Return value DistancePoint
30 *SET, DistancePoint, ((x_1-x_2)**2+(y_1-y_2)**2+(z_1-z_2)**2)**(1/2)
31
32 !clear local variable
33 *SET, Node1CoorX,
34 *SET, Node1CoorY,
35 *SET, Node1CoorZ,
36 *SET, Node2CoorX,
37 *SET, Node2CoorY,
38 *SET, Node2CoorZ,
39 *SET, x_1,
40 *SET, y_1,
41 *SET, z_1,
42 *SET, x_2,
43 *SET, y_2,
44 *SET, z_2,
45 /EOF

```

Listing 7.11: calcmass.mac

```

1 !!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
2 !                                                                 !
3 !           WINDOW PERSONAZATION STYLE MACRO                    !
4 !           Author: Francesco Argentieri                         !
5 !                                                                 !
6 ! PARAMETERS INPUT:                                             !
7 !           ARG1: JOBNAME string                                !
8 !                                                                 !
9 !!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
10
11 /SOLVE
12 OUTPR, BASIC, ALL
13 /OUTPUT, mass_output-%ARG1%, txt
14 PSOLVE, ELFORM
15 PSOLVE, ELPREP
16 /OUT
17 FINISH
18 /EOF

```

Listing 7.12: getextremeaxis.mac

```

1  !CMGRP, RotorBlockGrouped, BeamOmega, DiscOmega, HubOmega
2
3  !CMOMEGA, CM_NAME, OMEGAX, OMEGAY, OMEGAZ, X1, Y1, Z1, X2, Y2, Z2
4  !Specifies the rotational velocity of an element component about a user-defined
   rotational axis.
5  !SOLUTION: Inertia
6
7  !CM_NAME
8  !The name of the element component.
9
10 !OMEGAX, OMEGAY, OMEGAZ
11 !If the X2, Y2, Z2 fields are not defined, OMEGAX, OMEGAY, and OMEGAZ specify the
   components of
12 !the rotational velocity vector in the global Cartesian X, Y, Z directions.
13
14 !If the X2, Y2, Z2 fields are defined, only OMEGAX is required. OMEGAX specifies the
   scalar
15 !rotational velocity about the rotational axis. The rotational direction of OMEGAX is
   designated
16 !either positive or negative, and is determined by the right hand rule.
17
18 !X1, Y1, Z1
19 !If the X2, Y2, Z2 fields are defined, X1, Y1, and Z1 define the coordinates of the
   beginning
20 !point of the rotational axis vector. Otherwise, X1, Y1, and Z1 are the coordinates of a
   point
21 !through which the rotational axis passes.
22
23 !X2, Y2, Z2
24 !The coordinates of the end point of the rotational axis vector.
25
26 !Change RF
27 CSYS, LocalSystem_1
28 WPCSYS, -1
29
30 !Select node
31 NSEL, S, LOC, Y, , 0, shftlen + dskthk
32 NSEL, R, LOC, z, , 0, 0
33 *GET, StartNode, NODE, , NUM, MIN
34 *GET, EndNode, NODE, , NUM, MAX
35 ALLSEL, ALL
36 CSYS, 0
37 WPCSYS, -1
38 !Plot nodes
39 NPLOT
40 *DO, j, StartNode, EndNode
41     /COM, %j%
42 *ENDDO
43
44 !define local variable
45 *GET, Node1CoorX, NODE, StartNode, LOC, X
46 *GET, Node1CoorY, NODE, StartNode, LOC, Y
47 *GET, Node1CoorZ, NODE, StartNode, LOC, Z
48 *GET, Node2CoorX, NODE, EndNode, LOC, X
49 *GET, Node2CoorY, NODE, EndNode, LOC, Y

```

```
50 *GET, Node2CoorZ, NODE, EndNode, LOC, Z
51 /COM,=====
52 /COM, CMOMEGA, ROTOR, OMEGAX, OMEGAY, OMEGAZ,
53 /COM, %Node1CoorX%, %Node1CoorY%, %Node1CoorZ%,
54 /COM, %Node2CoorX%, %Node2CoorY%, %Node2CoorZ%
55 /COM,=====
56 /EOF
```


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