

Altair MotionView 2019 Tutorials

MV-2040: Load Estimation for a Fore Canard Actuator Mechanism under Aero-dynamic Loads

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MV-2040: Load Estimation for a Fore Canard Actuator Mechanism under Aero-dynamic Loads

In this tutorial, you will learn how to:

- Represent pressure/distributed loads as Modal Forces on a CMS flexible body.
- Scale Modal Forces to real world loads in MotionView/MotionSolve.

What is Modal Force?

Forces acting on a flexible body may be an aerodynamic load, liquid pressure, a thermal load, an electromagnetic force or any force generating mechanism that is spread out over the flexible body, such as non-uniform damping or visco-elasticity. It may be even a contact force between two bodies. These distributed loads can be conveniently transformed from Nodal to Modal domain and represent as Modal Forces.

If we define $[\Phi]$ as the mode shapes of the flexible body, and $\{F\}$ as the Nodal load acting on the flexible body, the equivalent Modal load on the flexible body $\{f\}$ is defined as:

 $\{f\} \triangleq \left[\Phi\right]^T \{F\}$

Exercise:

In this exercise, you will create a flexible body of a Fore Canard of an aircraft with aerodynamic loads using Optistruct. Aero-dynamic loads for three operating positions of the fore canard, namely -10 deg, 0 deg, and 10deg, considering an air speed of 200m/sec at 1 atm pressure are available from a CFD simulation using AcuSolve. A later section of the exercise involves embedding this flexible body in the actuator mechanism model in MotionSolve to estimate actuator loads required for the operation of fore canard.

Copy all of the files located in the mbd_modeling\flexbodies\modalforce folder to the <working directory>.





Fore Canard of an Aircraft

Step 1: Creating a Fore Canard flexible body.

- 1. Review the HyperMesh model:
 - Open ForeCanard.hm in Hypermesh with **Optistruct** selected as the user profile.



Fore Canard meshed model

 The HM file contains a meshed model of Fore Canard with material properties and control cards defined.

	Entities	ID 🕥
	🕀 💫 Assembly Hierarchy	
	🖨 🔞 Card (2)	Specifies Model Units .
	- CTI_UNITS	2
	GLOBAL_CASE_CONTROL	
Fore Canard component	😑 🛜 Component (2)	Control card for CMSMETH.
	Fore Canard	1 🗖
RBE2 elements component	📂 🎛 Rigids	2
	🕀 🚱 Load Collector (2)	CMSMETH load collector
	- 📁 🎛 CMS	1
	- 🗾 🎛 ASET	2 ASET Constraints
	🖨 🙀 Material (1)	
	- 😰 Steel	1 Material Property
	🖶 😂 Property (1)	
	Shell	1 Element property
	i ⊕- 🧊 Title (1)	

HyperMesh model browser

Note Please note model units are Newton-Meter-KG-Sec, therefore all properties defined are consistent with this unit system.



2. Create aerodynamic loads from CSV files:

Average pressure distribution over the surface of canard is exported as text file from AcuFieldView. This file contains the location and value of the pressure. The AerodynamicLoad_Odeg.csv, AerodynamicLoad_Negative10deg.csv, and AerodynamicLoad_Positive10deg.csv files contain the pressure distribution information for Odeg, -10 deg, and 10 deg of canard orientation respectively.

- Add load collectors for three cases:

- Left click on the *Load Collector* icon from toolbar.
- Verify that the **create** radio button is selected and specify a new load collector name as <code>AerodynamicLoad_Odeg</code>.
- With drop-down menu for card image set as **no card image**, click on the *create* button.

<mark>1</mark> #• 😹 🖏 🐂 🖗	Left Club	+ (>+ @+ @ 皇h:Coop - + @+ @+ /+ + + + # 型 ★	Left Clus
P create C update	loadcol name +	AerodynamicLoad_0deg nocendimege	Create create/edit

- Follow steps above to create the other two load collectors with names as AerodynamicLoad_Negative10deg and AerodynamicLoad_Positive10deg.
- Click *return*.
- 3. Browse to the **Pressure load** panel:
 - Select the *Analysis* radio button to go to the **Analysis** page.
 - Click on **Pressures** button to open the **pressure** panel.

vectors	load types		interfaces	control cards	J C	Geom
systems	constraints		rigid wells	ovtput block	c	1D
preserve node	equations	temperatures	entity sets	loadsteps] c	2D
	forces	Buc	blocks		1.0	30
	moments	load an geam	contectauts	optimization	10	Analysis
	pressures		bodies		. c	Teel
	<u> </u>		nun	OptStuct	C	Post

Analysis page

- 4. Set the pressure load type to linear interpolation:
 - Verify that the **create** radio button is selected.

ø	create	•	faces H		label loads	magnitude % =	25.000	create
	•	maanitude =	1.000	- "	10000			reject
	0	lamon]			break angle -	30.000	
						load types =	PLOAD4	return

Pressures panel

- Click on the drop-down arrow next to **faces** button.



Surface type set as faces by default





Specifying entity type as elems from list

from faces to elems.

- Click on drop-down menu button next to **magnitude**.

•	magnitude =	1	0	0	0
		-			

- Select *entities* from the drop-down menu to switch the surface selection type

Magnitude type is a constant vector by default

- Select **linear interpolation** from the list.

constant vector	equation
constant components	linear interpolation
curve, vector	field loads
curve, components	

Specifying magnitude as linear interpolation from list

 Upon selection of the above settings, you can select elements on which pressure loads are applied and a CSV file for pressure load info.

e C	create update	v v gierrs H		0 0 create
		lineer interpolation	nodes on face: sodes breek.angle = 3	14 Noview
		verification and a search radius - 10.0	loadtypes = PLOAD4	



5. Create pressure loads on canard surface:

Pressure loads for each position are created under their respective load collectors so that you can scale them in MotionSolve with respect to the canard position. Create a pressure load for 0deg by following the steps below.

- Make AerodynamicLoad_Odeg as the current load collector by following below steps:
 - Left click on the **Set Current Load Collector** button located at the bottom.



Information bar at the bottom with current model, component, and load collector information



• Select AerodynamicLoad_Odeg from the load collector list.

CMS AerodynamicLoad_0deg AerodynamicLoad_Negative10deg AerodynamicLoad_Positive10deg	▼ all	1 > >>
	▼ name	return
Load collectors list		I

- Specify the elements from the Fore Canard collector by following the steps below:
 - Left click on the *elems* button.

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я.	create				et	errs	н	J	0		mognitude % -	5	25.000		create
C	update								1	label loads					creeke/edit
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	٥		169+								break angle +		30.00	0	
		N.	filgep												
				search rai	diss =			10.000			load types =		PLOAD4	_	return

Left click on elems button to display different element selection options

• Select *by collector* from the list.

				and a second sec		
	by window	on plone	bywidth	bygeoms	by domains	by laninate
	displayed	retrieve	by group	by adjacent	by handles	by path
	al .	seve	duplicete	by effected	by nogh vols	by include
	18/18/18	byid	by config	bytece	by block.	
	by collector	by essents	by sets	by sulpublock	by ply	
_						

Element selection options dialog

• Select the *Fore Canard* collector from the component collector list and activate the *select* button to return back to **pressures** panel.



Component collectors list

- Select the 0 deg pressure info CSV file by following below steps:
 - Click on the *ellipsis* button ... to browse for the file.

♦ file=				
➡ IIIE=			file-	
			ille=	—
	_			



• The **Open** dialog box is displayed. Browse to your <working directory> to select the AerodynamicLoad Odeg.csv file and click **Open**.

5	(Open				×
Look in:	MForce	•	+ 🗈 💣 📰 ◄			
Recent places Desktop Libraries This PC Overwork	Name		Type Microsoft Excel C Microsoft Excel C Altair HyperWorks	Size 792 KB 790 KB 792 KB 190 KB		
	File name:				*	Open Cancel Explore

 The selection of surface elements and the pressure info file is now complete. Click on the *create* button to create pressure loads for the 0deg position.



Completed pressure panel



Pressure loads on canard surface



- **Note** The pressure load on each element is obtained by a linear interpolation of pressure values with respect to its location.
- Follow the above steps to create pressure loads for -10deg and +10deg under the respective load collectors AerodynamicLoad_Negative10deg and AerodynamicLoad_Positive10deg.
- 6. Specify load sets for CMS method:

Three load cases modeled in previous step represent nodal forces. These nodal forces are transformed as modal forces using CMS method. In this step you modify the existing CMSMETH card image to include three load sets.

- Open an existing **CMS** card image by following the steps below:
 - Browse to the CMS load collector from Entities browser.
 - Right click on **CMS** load collector.



Opening CMS load collector card image from browser context menu







CMS load collector card image dialog with method specified as Craig-Bampton (CB) and the number of modes as 25

- 7. Specify load sets for CMSMETH by following below steps:
 - In Card Image dialog, activate the **LOADSET** check box.
 - Specify the CMSMETH_LOADSET_LSID_NUM value as 3.

4	Card Image	×
СМЅМЕТН	CMSD METHOD [UB_PRE0] [NMODES] [SPID] [SOLVER] [AMPPFACT] 1 CB 2 5 5 5 5	
	[USETYPE] LSD(1) LSD(2) LSD(3) L 0 A D S E T BOTH 0 0 0	
Type	Shuclane Only	reject default
	DSET 2 CMSMETH_LOADSET_LSID_NUM * 3	abort refer

Specifying LOADSET option for CMSMETH

Observe that the Card Image shows an option to specify three load sets.

- Specify load collectors for three load sets by following the steps below:
 - Double click on the **LSID(1)** button to open load collectors list.



Browsing to load collector's list from Card Image dialog



 Select AerodynamicLoad_Odeg from the list and click on return button to return back to CMS card image.

<i>C</i> s	Card Image ×
CMS AerodynamicLoad_0deg	
AerodynamicLoad_Negative10deg	$\langle \langle \rangle$ $\langle \rangle$ $\langle \rangle$ $\langle \rangle$ \rangle \rangle
AerodynamicLoad_Positive10deg	
	▼ nome return
_oad collectors list	



Card image with LSID(1) specified

- Similarly, specify the AerodynamicLoad_Negative10deg and AerodynamicLoad_Positive10deg load collectors for LSID(2) and LSID(3) respectively.
- Click *Return*.
- 8. Generate flexbody.

Your model is now ready for solving to generate a flexbody. The two control cards required to solve for flexbody creation are already specified in the model.

- Review the control cards:
 - Click on *control cards* button from the **Analysis** page.

vectors	load types		interfaces	control cards	C Geom
systems	constraints	1	rigid walls	output block	C 1D
preserve node	equations	temperatures	entity sets	loadsteps	C 2D
	forces	flux	blocks		C 3D
	moments	load on geom	contactsurfs	optimization	Analysi
	pressures	1	bodies	12 2	C Tool
		-	nsm	OptiStruct	C Post

 Click on the DTI_UNITS button from the first page to review flexible body units. Click *Return*.

DTI UNITS	1	MASS KG	FORCE	LENGTH M	TIME	
DTI_UNITS card image					-	



- Click on *GLOBAL_CASE_CONTROL* in the next card to see the CMS load collector specified for CMSMETH solution.
- Click *return* twice.

CMSMETH = 1 CMSLoad collector ID	
	reject default
CMETHOD CMSMETH CNTNLSUB DEFORM CDESVAR	abort return

GLOBAL_CASE_CONTROL card image

- Solve the model by following the steps below:
 - Click on the **Optistruct** button from **Analysis** page.

vectors	load types		interfaces	control cards	0	Geom
systems	constraints		rigid walls	output block.	C	1D
preserve node	equations	temperatures	entity sets	loedsteps	C	2D
	forces	flux	blocks		- c	3D
	moments	load on geom	contactsurfs	optimization	6	Analy
	pressures		bodies		c	Tool
		7.4	nsm	OptiStruct		Post

Analysis Page

- In the Optistruct analysis panel:
 - Set export options to all.
 - Set **run options** to **analysis**.
 - Browse to your working directory and specify input file name as flex ForeCanard.fem.
 - Click on the **Optistruct** button.

inputfil	ie: 🗸 <	< a n	d	Re	5	u I	t	s F	1	l e	5	/	M F	0	1	c	e /	F	0	r	e C	0.	n	a 1	d		f e	3	•	58/8	as		Optis	hud	4	
-	export options:	-1		1			_	run o	ptions			ah mi		2	2					iemo	y op	ions:		e - ded	a di								Нуре	Vaw		
-		81					•				en	ays	5			_		•					emo	ry ae	BUI								view	.out		
Г	include connectors							optio	ns:	ſ		0	p t	8	k	ī	P	_	_	_	_	_	_	_	_	_	_	_	_					105,01	fi -	

Completed Optistruct panel



9. Review flexbody modes.

On successful completion of solver run, open the flexbody flex_ForeCanard.h3d created from Optistruct run in ¹ HyperView to review the various mode shapes. Your flexbody contains 34 modes constituting normal modes, constraint modes, and Static modes.

Total number of modes = Normal modes + Static modes [Constraint modes (number of constraints * 6) + Loadset modes (number of load sets)]

CMS Mode	Frequency	Eigenvalue
1	3.201236E-04	4.045713E-06
2	6.147661E-04	1.492037E-05
3	8.204394E-04	2.657374E-05
4	8.496589E-04	2.850027E-05
5	9.269365E-04	3.392030E-05
6	1.001399E-03	3.958892E-05
7	7.523622E+01	2.234671E+05
8	8.995211E+01	3.194349E+05
9	1.055819E+02	4.400872E+05
10	1.131912E+02	5.058076E+05
11	1.313088E+02	6.806870E+05
12	1.403516E+02	7.776687E+05
13	1.462932E+02	8.449047E+05
14	1.681590E+02	1.116349E+06
15	1.762500E+02	1.226360E+06
16	1.806985E+02	1.289048E+06
17	1.949189E+02	1.499918E+06
18	1.977864E+02	1.544375E+06
19	1.988683E+02	1.561317E+06
20	2.035630E+02	1.635902E+06
21	2.048646E+02	1.656890E+06
22	2.076144E+02	1.701667E+06
23	2.175228E+02	1.867967E+06
24	2.198202E+02	1.907633E+06
25	2.230178E+02	1.963536E+06
26	2.276060E+02	2.045160E+06
27	2.321855E+02	2.128286E+06
28	2.365257E+02	2.208596E+06
29	2.398275E+02	2.270689E+06
30	2.461475E+02	2.391941E+06
31	3.254115E+02	4.180474E+06
32	3.586049E+02	5.076826E+06
33	4.039304E+02	6.441289E+06
34	6.987050E+02	1.927292E+07

= 25 + [1 * 6 + 3] = 34

Frequency and Eigen values read from flex_ForeCanard.out file





Three aero-dynamic loads represented as static modes

Step 2: Creating a MotionView model.

A MotionView model of the fore canard mechanism has been provided. In this model, the Fore Canard body is modeled as a rigid body. In this next step we will replace the rigid Fore Canard body with a flexible body created in the previous step and use ModalForce entities to scale the pressure loads with respect to canard position.

1. Review the MotionView model:

- Open the ForeCanard_Model.mdl in MotionView. The model contains:

- Four bodies namely Fore Canard, Torque Arm, Piston, and Cylinder.
- A motion on the Piston with an expression 0.025*SIN(2*PI*TIME) to extend and retract the piston by 25mm at 1 Hz. This piston motion varies the fore canard angular position between -9.619 deg to +9.984 deg.



MotionView model of Fore canard mechanism



- An **expression** type Output request to measure the "ForeCanard angular position" and "Piston force along its axis".
 - The Fore canard angular position is measured from the RevJnt_TorqueArm_Gnd joint rotation angle using the expression `RTOD({j 4.AZ})`.
 - The Piston force is measured from the Piston Motion using the expression `MOTION({mot_0.idstring}, {0}, {4}, {j_2.i.idstring})`.

Properties	Expressions	
	F2: RTOD(AZ(30102030, 30101030))	F6: 0
	F3: MOTION(301001,0,4,30103070)	F7: 0
	F4: 0	F8: 0

Output requests

- Solve the model with the rigid Canard to review piston forces without aerodynamic loads.
 - Invoke the **Run** panel by clicking the **Run Solver** button, 🕮, in the toolbar.
 - Specify the MotionSolve file name as *ForeCanard_withoutAeroloads.xml*.
 - Select the **Simulation type** as **Quasi-static**, the **End time** as **1** sec, and the **Print interval** as **0.01**.
 - Click on the *Run* button.
 - After the simulation is completed, click on the **Animate** button to view the animation in HyperView.



Initial position 0 deg (meshed) and rotated position 10deg at 0.25 sec of simulation

• Click on the *Plot* button from the MotionView **Run** panel to load the ForeCanard_withoutAeroloads.abf file in HyperGraph2D.



• Plot the Piston Force versus Fore Canard Angular Position by selecting the below data in HyperGraph.

Select the following for X-axis data:

Х Туре	Expression
X Request	REQ/70000000 Fore Canard Angular Position (deg)F2, Piston Force (N)F3
X Component	F2

Select the following for Y-axis data:

Ү Туре	Expression
Y Request	REQ/70000000 Fore Canard Angular Position (deg)F2, Piston Force (N)F3
Y Component	F3



Results without aero-dynamic loads

The piston forces in this case are due to the canard mass moment of inertia.

- 2. Return to MotionView and switch the rigid fore canard to a flexible body.
 - Browse and select the *Fore Canard* body from **Project** browser.
 - In the **Body** panel, activate the *Flex Body(CMS)* check box.

4 00 e		b_canard X	I fr
•	Properties CM Coordinates	Flex Body (CMS)	Get Properties from associated Graphic(s)
	Inertia Coordsys		Inertia properties:
	Body Coordsys		lxx: 167.4930 lxy: 8.9632
	Initial Conditions		lyy: 192.6200 lxz: -67.0089
		Mass: 19.7714	lzz: 31.1814 lyz: -22.1164

Body panel



and H3D files. Properties 1.0000 Flex Body (CMS) Animation scale: FEM Inertia Props Graphic file: E:WFORCE\ModelandResultsFiles\MForce\ForeCanard.h3d Locate. Body Coordsys Initial Conditions Invariants E:\MFORCE\ModelandResultsFiles\MForce\ForeCanard.h3d H3D Ber Nodes. Include geometric stiffening Rigidify Modes

- Browse to your working directory, specify *flex ForeCanard.h3d* for the **Graphic**

Specify flexbody h3d file for Fore Canard body

- Click on *Nodes* button and resolve the flexbody interface nodes.
- 3. Model Aero-dynamic loads through Modal Force entity:

The aero-dynamic loads are estimated at three distinct positions of canard namely -10 deg, 0deg, 10deg. We assume the each pressure load to linearly vary in interval ± 10 deg on a 0 to 1 scale. This variation of the aero-dynamic loads is achieved by scaling Modal Forces with respect to canard angle using an expression.

- Create a solver variable:

An explicit solver variable is created to measure the fore canard's position.

Right-click on the SolverVariable *X* icon from the toolbar.

The **Add SolverVariable** dialog is displayed.

Specify the **Label** as **Angle Measure** and the **Variable** name as **sv ang**.

🛆 Add SolverVariable 🛛 🔀			
Parent: System Model Label: Angle Measure Variable: sv_ang			
Type: Single Pair			
<u>O</u> K <u>Apply</u> <u>Cancel</u>			

Completed Add SolverVariable dialog

Click OK.

The SolverVariable panel is displayed.



• From the **Properties** tab, specify the **Type** as *Expression* and enter `RTOD({j 4.AZ})` for the **Expression**.

(-	sv_ang	🗙 🧹 fr				
X Properties Image: Construction of the second se	User-defined properties Initial Conditions: Specify Type as	0.0000	0.0000		Default	
	"Expression" Type: Expression Expression Total	m: Z(30102030, 30101030	Expression	Penalty1:	100.0000	1

Defining explicit solver variable

This creates an explicit variable that measures the Fore Canard angle.

– Add a ModalForce:

Add three modal forces each corresponding to one load set.

• Right-click on the *ModalForce* icon from the **Force Entity** toolbar.



MotionView Force Entity toolbar

The **Add Modal Force** dialog is displayed.

• Specify the **Label** as *AerodynamicLoad_Odeg* and the **Variable** name as *mfrc_Odeg*.

🛆 Add ModalForce
Parent: System Model Label: AerodynamicLoad_0deg
Variable: mfrc_0deg
Type: Single Pair
Comment (Optional):
<u>O</u> K <u>Apply</u> <u>Cancel</u>

Click OK.

The **ModalForce** panel is displayed.

p.16

• From the **Connectivity** tab, specify *Fore Canard* for the **FlexBody**.



Specifying flexbody

- From the **Properties** tab, specify the scaling type, expression, and load case ID as shown below:
 - Specify the **Scale type** as *Expression*.
 - Specify the **LoadCaseID** corresponding to **Odeg**, in other words **3**.
 - Specify Expression as `STEP(VARVAL({sv_ang.idstring}), -10,0,0,1)*STEP(VARVAL({sv_ang.idstring}),0,1,10,0)`.

	mfrc_0deg	🗙 🗸 fre
Connectivity Properties	Scale: Expression Linear Curve Spline3D Expression	Expression:

<		mfrc_0deg	🗙 🥑 fn	
	Connectivity Properties	Scale:	Expression:	
	2			
		Loadcase ID: 3		
		5		

~	mfrc_0deg X V fie
Connectivity Properties	Scale: Expression:
8 3	Expression STEP(VARVAL(),-10,0,0,1)*STEP(VARVAL(),0,1,10,0)
_	LoadCase ID: 3
`	

Steps of creating Modal Force for Odeg



The product of the two STEP functions evaluates to gradually increasing the value of the scale from 0 to 1 and then back to 0, while the canard angular position varies from -10deg to 10 deg as shown in the expression below:



 Follow the steps above to create the remaining Modal Forces as specified below:

S.No	Label	Variable name	Flexbody	Scale Type	Load Case ID	Expression
1	Aerodyna micLoad_ Negative 10deg	mfrc_ne g10deg	Fore Canard	Expression	4	<pre>`STEP(VARVAL({s v_ang.idstring}),-20,0,- 10,1)*STEP(VARV AL({sv_ang.idst ring}),- 10,1,0,0)`</pre>
2	Aerodyna micLoad_ Positive 10deg	mfrc_po s10deg	Fore Canard	Expression	5	<pre>`STEP(VARVAL({s v_ang.idstring}),0,0,10,1)*STE P(VARVAL({sv_an g.idstring}),10 ,1,20,0)`</pre>



Step3: Solving the model and post-processing.

- 1. Invoke the **Run** panel by clicking the **Run Solver** button, 🖤, in the toolbar.
- 2. Specify the MotionSolve file name as *ForeCanard_withAeroloads.xml*.
- 3. Select the **Simulation type** as *Quasi-static*, the **End time** as **1** sec, and the **Print interval** as **0.01**.
- 4. Click on the *Run* button.
- 5. After the simulation is completed, click on the *Animate* button to view the animation in HyperView.
- 6. Use the *Start/Pause Animation* button to play the animation.



- 7. Click on the **Contour** button μ to activate the **Contour** panel.
- 8. Under **Result type**, select **Stress (t)** and click **Apply** to view the stress contours.



Stress contour at 0.25 sec

9. Click on the *Plot* button from MotionView **Run** panel to load the ForeCanard withAeroloads.abf file in HyperGraph2D.



10. Plot the Piston Force versus Fore Canard Angular Position by selecting below data in HyperGraph2D.

Х Туре	Expression
X Request	REQ/70000000 Fore Canard Angular Position (deg)F2, Piston Force (N)F3
X Component	F2

Select following for X-axis data:

Select the following for Y-axis data:

Ү Туре	Expression
Y Request	REQ/70000000 Fore Canard Angular Position (deg)F2, Piston Force (N)F3
Y Component	F3



Results with aero-dynamic loads

You can overlay the plots to observe the difference in piston forces with and without aero-dynamic forces.



