L05 Panel pressures

Introduction

In example L04, we demonstrated how sectional multibody analysis can be used to evaluate the distribution of wave-induced loads acting on a single structure. Example L03 employed classical multibody analysis to similar effect when dealing with a platform constructed from several distinct volumes. We anticipate both approaches will typically be used to evaluate the load distribution on a platform or vessel at relatively coarse resolution.

OrcaWave is also capable of reporting panel pressures, which offer the user an opportunity to disaggregate the load at much finer resolution. Using model files based on those built in example L04, we will demonstrate how the OrcaFlex interface to Python can be used to report panel pressures.

OrcaWave panel pressures

Panel pressure

OrcaWave has been capable of reporting panel pressure via the API since v11.0. Panel pressures will be stored in the .owr file provided the *Output option* 'Panel pressures' is ticked on the *Calculation & output* page. The OrcFxAPI `panelPressure` method reports the first order complex pressure per panel, per wave period, per wave direction. Just like RAOs, this panel pressure is proportional to wave amplitude. The results represent the pressure at the panel centroid as the body undergoes motion in accordance with the respective displacement RAOs.

```
import OrcFxAPI
diff = OrcFxAPI.Diffraction('L05 Panel pressures.owr')
panelPress = diff.panelPressure
```

Decomposed panel pressures

In v11.2, decomposed panel pressure results were introduced, dividing the panel pressure into diffraction and radiation parts. Decomposed pressure results will be stored in the .owr file provided the *Output option* 'Intermediate results' is ticked.

The OrcFxAPI `panelPressureDiffraction` method reports the diffraction component of panel pressure per panel, per wave period, per wave direction. The diffraction component of pressure represents the pressure due to the incoming and diffracted wave field when the body is stationary i.e. it is the pressure that generates a load RAO.

The `panelPressureRadiation` method reports the radiation component of pressure per panel, per wave period, per degree of freedom. The radiation component of pressure represents the pressure on a panel due to forced oscillation of the body in still water i.e. it is the pressure that generates an added mass and damping matrix.

```
import OrcFxAPI
diff = OrcFxAPI.Diffraction('L05 Panel pressures.owr')
panelPressDiff = diff.panelPressureDiffraction
panelPressRad = diff.panelPressureRadiation
```

Working with panel pressure results

All three types of panel pressure result return a complex pressure that can be converted into amplitude and phase components. By multiplying the total and/or diffraction pressure amplitude by the respective panel area, you will return a force per metre wave amplitude. The radiation component of pressure is more complicated. The panel results help page shows that radiation pressure must be combined with the amplitude of the body motion before it can be considered a pressure.

The force derived from pressure will act at the panel centroid in the direction of the panel normal. Note this is the pressure due to first-order wave loading and does not include hydrostatic water pressure.

Panel pressure time history

The OrcFxAPI `panelPressure` method reports the pressure from a frequency domain diffraction analysis in which the body is moving with motion described by displacement RAOs. The additional information contained in decomposed panel pressure results make it possible to calculate panel pressure for a body moving with a given time history of motion. The wave components present in an OrcaFlex simulation determine the appropriate components of diffraction pressure. Selecting the appropriate components of radiation pressure is more challenging, since a computation over the history of body motion is required. Recognising this challenge, OrcaFlex v11.5 includes features to perform the calculation of panel pressure time history.

We will use the OrcaWave and OrcaFlex files built for example L04 to demonstrate this capability.

Preparation

The OrcaFlex panel pressure time history feature is made available via OrcFxAPI. The feature makes use of the decomposed panel pressure results provided by an OrcaWave results (.owr) file. Therefore, as discussed earlier, you must tick the *Output option* 'Intermediate results' on the *Calculation & output* page before initiating the diffraction analysis. Furthermore, the diffraction analysis must be run in OrcaWave v11.5 or later.

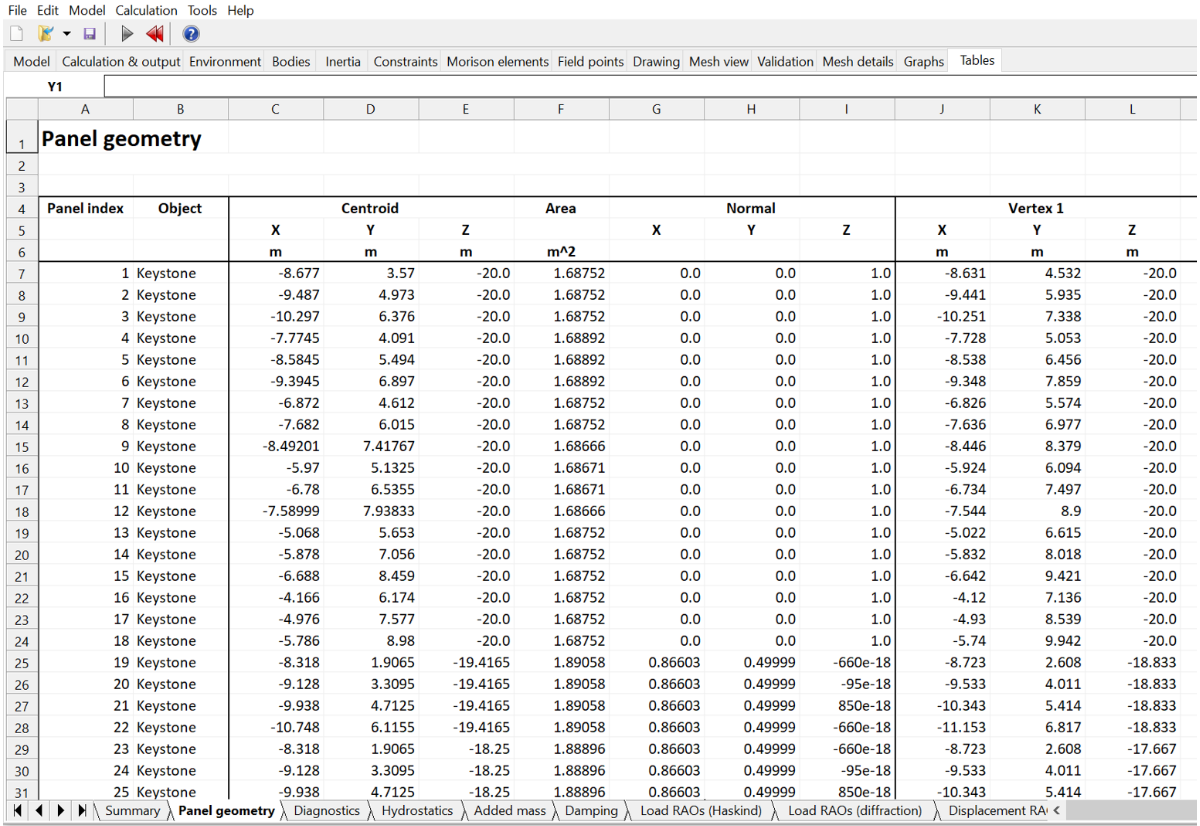
OrcaFlex also relies upon a time history of motion for a vessel object, stored in an OrcaFlex simulation (.sim) file.

Reporting panel pressure time history

The following demonstration references model files from a sectional multibody analysis where a semi sub floating wind platform is constructed from seven sectional bodies.

Please note, panel pressure time histories can be reported for any diffraction body. In this case we have results from a sectional multibody analysis. In some cases, it may be preferable to reference a conventional single body analysis.

Calculating a time history of panel pressure can be computationally intensive. In some applications, it may be appropriate to calculate the pressure at every body panel. In other cases, computational time can be saved by restricting the calculation to a subset of panels. For this reason, the user must nominate one or more panel indices to be included in the calculation. To identify the relevant panels, users should make use of OrcaWave's 'Panel geometry' results. Panel geometry results are available in both the OrcaWave user interface, via the *Tables* page, and in OrcFxAPI, via the `panelGeometry` method.



Panel geometry

Panel index	Object	Centroid X (m)	Centroid Y (m)	Centroid Z (m)	Area (m^2)	Normal X	Normal Y	Normal Z	Vertex 1 X (m)	Vertex 1 Y (m)	Vertex 1 Z (m)
1	Keystone	-8.677	3.57	-20.0	1.68752	0.0	0.0	1.0	-8.631	4.532	-20.0
2	Keystone	-9.487	4.973	-20.0	1.68752	0.0	0.0	1.0	-9.441	5.935	-20.0
3	Keystone	-10.297	6.376	-20.0	1.68752	0.0	0.0	1.0	-10.251	7.338	-20.0
4	Keystone	-7.7745	4.091	-20.0	1.68892	0.0	0.0	1.0	-7.728	5.053	-20.0
5	Keystone	-8.5845	5.494	-20.0	1.68892	0.0	0.0	1.0	-8.538	6.456	-20.0
6	Keystone	-9.3945	6.897	-20.0	1.68892	0.0	0.0	1.0	-9.348	7.859	-20.0
7	Keystone	-6.872	4.612	-20.0	1.68752	0.0	0.0	1.0	-6.826	5.574	-20.0
8	Keystone	-7.682	6.015	-20.0	1.68752	0.0	0.0	1.0	-7.636	6.977	-20.0
9	Keystone	-8.49201	7.41767	-20.0	1.68666	0.0	0.0	1.0	-8.446	8.379	-20.0
10	Keystone	-5.97	5.1325	-20.0	1.68671	0.0	0.0	1.0	-5.924	6.094	-20.0
11	Keystone	-6.78	6.5355	-20.0	1.68671	0.0	0.0	1.0	-6.734	7.497	-20.0
12	Keystone	-7.58999	7.93833	-20.0	1.68666	0.0	0.0	1.0	-7.544	8.9	-20.0
13	Keystone	-5.068	5.653	-20.0	1.68752	0.0	0.0	1.0	-5.022	6.615	-20.0
14	Keystone	-5.878	7.056	-20.0	1.68752	0.0	0.0	1.0	-5.832	8.018	-20.0
15	Keystone	-6.688	8.459	-20.0	1.68752	0.0	0.0	1.0	-6.642	9.421	-20.0
16	Keystone	-4.166	6.174	-20.0	1.68752	0.0	0.0	1.0	-4.12	7.136	-20.0
17	Keystone	-4.976	7.577	-20.0	1.68752	0.0	0.0	1.0	-4.93	8.539	-20.0
18	Keystone	-5.786	8.98	-20.0	1.68752	0.0	0.0	1.0	-5.74	9.942	-20.0
19	Keystone	-8.318	1.9065	-19.4165	1.89058	0.86603	0.49999	-660e-18	-8.723	2.608	-18.833
20	Keystone	-9.128	3.3095	-19.4165	1.89058	0.86603	0.49999	-95e-18	-9.533	4.011	-18.833
21	Keystone	-9.938	4.7125	-19.4165	1.89058	0.86603	0.49999	850e-18	-10.343	5.414	-18.833
22	Keystone	-10.748	6.1155	-19.4165	1.89058	0.86603	0.49999	-660e-18	-11.153	6.817	-18.833
23	Keystone	-8.318	1.9065	-18.25	1.88896	0.86603	0.49999	-660e-18	-8.723	2.608	-17.667
24	Keystone	-9.128	3.3095	-18.25	1.88896	0.86603	0.49999	-95e-18	-9.533	4.011	-17.667
25	Keystone	-9.938	4.7125	-18.25	1.88896	0.86603	0.49999	850e-18	-10.343	5.414	-17.667

Figure 1 – Panel geometry results table, OrcaWave results file.

Note that the panel indices found in the panel geometry results may be different from the panel indices found in the *Mesh details* page and the *Mesh view*. This is because the *Mesh details* page and the *Mesh view* include interior surface panels, which are not included in the panel geometry results. The relevant source of panel index for calculating panel pressure time history is the panel geometry results, as stated above.

In this first example we will report a time history of pressure for a single panel. Note Python indices are zero based, so index 0 corresponds with panel index 1 shown in the panel geometry results table in OrcaWave. Just like any other OrcaFlex time history result, the user must define the period over which the time history is to be reported. Furthermore, the user can choose to include/exclude the hydrostatic, diffraction and radiation components of pressure by supplying true and false statements.

```
import OrcFxAPI
import matplotlib.pyplot as plt

#Reference OrcaFlex simulation and OrcaWave results
model = OrcFxAPI.Model('L05 Panel pressures.sim')
diff = OrcFxAPI.Diffraction('L05 Panel pressures.owr')

#Assemble list of panel indices
panel_IDs = [0]

#Define period and pressure parameters
period = OrcFxAPI.SpecifiedPeriod(0, 20)
parameters = OrcFxAPI.PanelPressureParameters(True, True, True) #Components of
water pressure to be included (Hydrostatic, Diffraction, Radiation)
```

```
#Report time histories
PPTH = model['Keystone'].PanelPressureTimeHistory(diff, panel_IDs, period,
parameters)
time = model.SampleTimes(period)

#Plot time history at panel
plt.plot(time, PPTH)
plt.title('Panel #{} pressure'.format(panel_IDs[0]+1))
plt.xlabel('Time (s)')
plt.ylabel('Pressure (kN/m^2)')
plt.show()
```

In this first example, we report all three components of pressure by setting the three panel pressure parameters to 'True'. In addition, for the diffraction and radiation components of pressure to be included, OrcaFlex will check to confirm that the OrcaFlex vessel object referenced via the simulation file has the *included effects* 'Wave load (1st order)' and 'Added mass and damping' ticked.

The vessel object 'Keystone' is also a member of a multibody group. One of the features of a multibody group is an extended matrix of added mass and damping data describing the load on one body due to oscillation of other members of the group. OrcaFlex will include these effects during the calculation of pressure provided that the vessel is part of a multibody group in the OrcaFlex simulation file. Furthermore, that multibody group must include all the diffraction bodies from the referenced OrcaWave diffraction analysis, in the same order.

Notice that the panel pressure time history is called for a vessel object named 'Keystone'. Using the OrcaWave panel geometry results table, we know that panel 1 belongs to the Keystone. Furthermore, in example L04 the name Keystone was maintained in both OrcaWave and OrcaFlex models. However, OrcaFlex cannot rely on this naming consistency. Therefore, it is the user's responsibility to make sure that the panel indices belong to the appropriate vessel object.

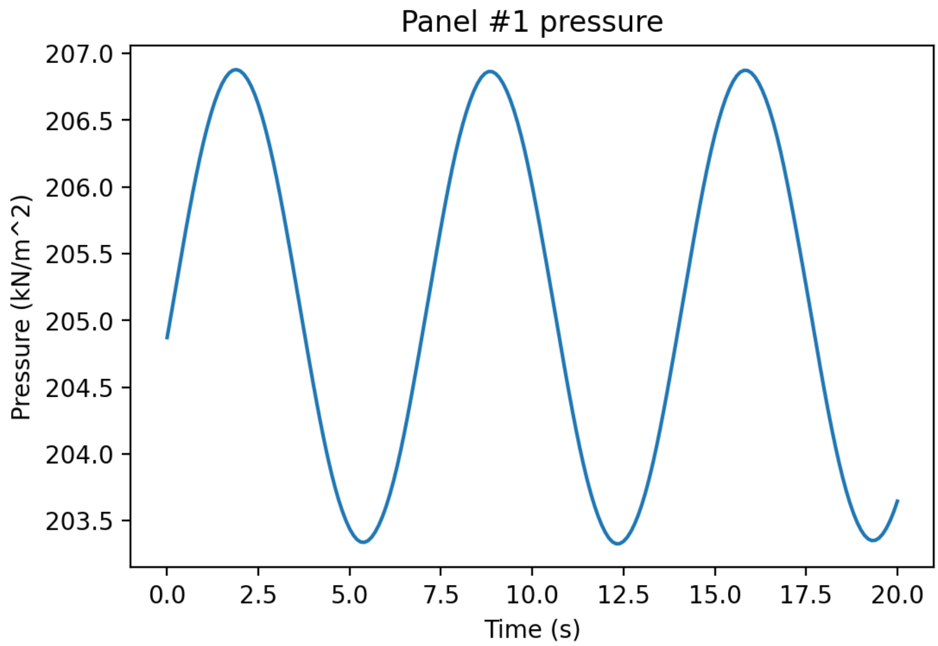


Figure 2 – Time history of panel pressure for panel index 1.

In this second example, we use panel geometry data to identify all the panels belonging to the body named ‘Keystone’. We then plot a 3D scatter plot, positioning a data point at the centroid of each panel. The colour of the data point is set to indicate the magnitude of the pressure at a simulation time of 5s.

```
import OrcFxAPI
import matplotlib.pyplot as plt

panel_IDs = []
x = []
y = []
z = []

#Reference OrcaFlex simulation and OrcaWave results
model = OrcFxAPI.Model('L05 Panel pressures.sim')
diff = OrcFxAPI.Diffraction('L05 Panel pressures.owr')

#Assemble list of panel indices
panelGeo = diff.panelGeometry

for i in range(len(panelGeo)):
    if panelGeo['objectName'][i] == 'Keystone':
        panel_IDs.append(i)
        x.append(panelGeo['centroid'][i][0])
        y.append(panelGeo['centroid'][i][1])
        z.append(panelGeo['centroid'][i][2])


#Define period and pressure parameters
period = OrcFxAPI.SpecifiedPeriod(5, 5) #FromTime, ToTime
parameters = OrcFxAPI.PanelPressureParameters(True, True, True) #Components of
water pressure to be included (Hydrostatic, Diffraction, Radiation)

#Report time histories
PPTH = model['Keystone'].PanelPressureTimeHistory(diff, panel_IDs, period,
parameters)

#3D scatter plot of pressure reported at a simulation time of 5s.
ax = plt.axes(projection='3d')
scatter = ax.scatter3D(x, y, z, c=PPTH[0], marker='.')
ax.set_aspect('equal')
ax.set_axis_off()
ax.set_title('Panel pressure at {}s'.format(period.FromTime))
plt.colorbar(scatter).ax.set_ylabel('Pressure kN/m^2')
plt.show()
```

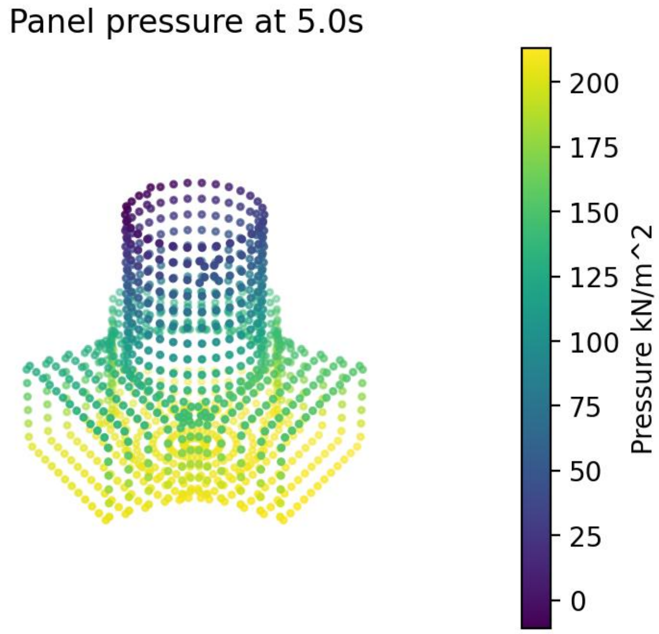


Figure 3 – 3D scatter plot of panel pressure at time = 5.0s

Limitations

The time history motion of a vessel can be influenced by many factors. When reporting a time history of panel pressure, OrcaFlex is able to include the hydrostatic pressure, plus the component of pressure due to wave diffraction and radiation. OrcaFlex cannot include the component of pressure experienced by the panel due to other environmental effects such as current or 2nd order wave loading.