

SUMMARY ABOUT PANDA2

The purpose of PANDA2 is to find the minimum weight design of a stiffened panel made of laminated composite material. Of course, simple isotropic panels can also be designed. The panel can be loaded by up to 5 independent sets of loads, (N_x , N_y , N_{xy} , M_x , M_y , and p), in which N_x is the load in the axial direction (negative for compression) and p is the normal pressure. M_x and M_y are axial and hoop moment resultants. The panel may also be "loaded" by temperatures, which can be different in each segment of a panel module. Temperatures are uniform in all segments except for the web(s), in which temperature is assumed to vary linearly from the root of the web to the tip. Included with each of the 5 load sets are:

(a) a local imperfection, assumed to be in the form of the local buckling mode;

(b) a global imperfection, assumed to be in the shape of the general buckling mode;

(c) a global out-of-roundness, assumed to be prismatic (uniform in the axial direction) and vary as $\cos(2\theta)$ in the circumferential direction;

(d) an inter-ring imperfections, assumed to be in the shape of the inter-ring buckling mode.

PANDA2 represents a more detailed treatment of certain behavior not handled by the original PANDA [1]. In particular, optimum designs can be obtained for both perfect and imperfect panels with locally post-buckled skin and for panels with hat stiffeners and panels with isogrid-stiffened or truss-core sandwich construction or other sandwich wall construction; stresses induced by uniform normal pressure are included in the analysis. Thermal loading and loading by edge moments are also handled. The effects of further bending of the panel as it is loaded by axial and/or hoop compression are of course included. Residual stresses from curing the panel and stiffeners are accounted for.

Optimization is carried out based on several independently treated structural models of the panel, as follows:

1. PANDA-type models [1] for general, local, and panel buckling, buckling of stiffener parts, and rolling of stiffeners with and without participation of the panel skin are included. These models are described in detail in [1]. (See Table 1 and Figs. 1-4 of [1].)

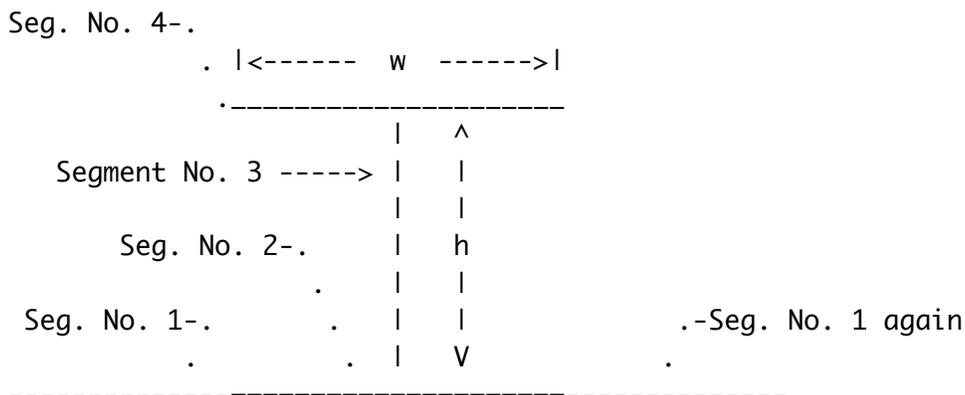
2. Buckling load factors and post-local buckling behavior are calculated for what is termed in PANDA2 a "panel module". Such a module is depicted in Figs. 1 and 2. A module includes the cross section of a stiffener plus the panel skin of width equal to the spacing between stiffeners. In this model the panel module cross section is divided into segments, each of which is discretized and analyzed via the finite difference energy method. Variation of deflection in the axial direction is assumed to be harmonic [$\sin(n*\theta)$ or $\cos(n*\theta)$]. This one-dimensional discretization is similar to that used in the BOSOR programs for the analysis of shells of revolution. In fact, many of the subroutines for buckling and vibration analysis are taken from BOSOR4 and modified slightly. The modification is necessary to handle prismatic structures instead of shells of revolution. Both local and wide-column instability can be handled with the same structural model.

3. A discretized model of the entire width of the panel, treated in this case with stringers smeared out. This model is used only if there exists normal pressure or if the axial load varies across the width of the panel.

4. A discretized module model analogous to that described in Paragraph 2 just above but this time involving one ring and the skin with smeared stringers between rings. This model is described in detail in ITEM 463 of the file ...panda2/doc/panda2.news.

In the panels designed by PANDA2 the skin between stringers may buckle well before failure of the panel. The maximum stress components and therefore stress constraints in the optimization analysis are computed including growth and modification of the local skin buckling mode as predicted in a theory similar to that formulated by Koiter in 1943 [4].

A typical panel module is shown in Fig. 1.



are produced by the optimizer ADS, written by Gary Vanderplaats. In CHOOSEPLOT/DIPILOT you can select quantities to be plotted.

SCOPE OF PANDA2

1. GEOMETRY
 - a. flat or cylindrical panels
 - b. complete cylindrical shell (modelled as 180-deg. panel)
 - c. unstiffened or stiffened by either stringers or rings or both
2. TYPES OF STIFFENERS
 - a. T-shaped
 - b. J-shaped
 - c. Z-shaped
 - d. Rectangular
 - e. Hat-shaped
 - f. Truss-core sandwich
 - g. Isogrid
 - h. sandwich face sheet buckling, core shear crimping, etc.
 - i. rectangular substiffeners between major stiffeners
3. BOUNDARY CONDITIONS
 - a. Curved edges: simply supported or clamped
 - b. Generators: simply supported
4. MATERIAL
 - a. linear elastic laminated composite material
 - b. temperature-dependent material properties
5. LOADING
 - a. up to 5 sets of combined loads N_x , N_y , N_{xy} , p , temperature
6. IMPERFECTIONS
 - a. Local: in the form of the local buckling mode
 - b. Global: axial bowing or in the form of general buckling mode
 - c. for cyl. panels: out-of-roundness + general buckling modal
+ inter-ring buckling modal + local buckling modal
7. TYPES OF ANALYSIS
 - a. optimization
 - b. fixed design
 - c. test simulation (fixed design under increasing load)
 - d. design sensitivity (margins vs selected decision variable)
 - e. load interaction curves for fixed design.

LIMITATIONS OF PANDA2

1. Panel is uniform, that is:
 - a. constant thickness (with thickened regions near stiffeners)
 - b. uniformly spaced identical stringers. You cannot analyze a panel with only one stiffener. Stiffener spacing is constant over the surface of the panel.
 - c. uniformly spaced identical rings. You cannot analyze a panel with only one ring.
 - d. panel is either flat or cylindrical.
 - e. projected shape of panel on flat surface is rectangular.
2. Only certain types of stiffener cross sections are included.
(blades, jays, zees, tees, hats, truss-core-sandwich, simple sandwich)
3. Material is linear and elastic.
4. Temperature distribution limited as follows:
 - a. must be uniform through thicknesses of web and flange.
 - b. must be uniform along the length of the panel.
 - c. distribution must be the same in each panel module.
 - d. must be uniform over surface of panel skin and outstanding stiffener flanges. (Can be different in skin and flange).
 - e. varies linearly across height of the stiffener webs.
 - f. varies linearly through thickness of panel skin.
5. With discretized module model, local buckling and postbuckling behaviors are generated with the assumption that the panel skin is flat.
6. Loading is uniform over the panel.
7. Boundary conditions are restricted as noted in SCOPE OF PANDA2.

PANDA2 COMMANDS

bush-> panda2log

PANDA2 commands have been activated.

PANDA2 commands are:

begin - you provide a starting design, material properties, boundary conditions

choosetemp - choose temperature dependence

setup - PANDA2 generates BOSOR4-type matrix skylines for use by PANDA2
decide - you choose decision variables, lower and upper bounds, linking relationships
mainsetup - you provide loading, imperfection amplitudes, fact.of safety, analysis type, strategy
pandaopt - launch run of mainprocessor for a single set of design iterations
superopt - launch run for multiple sets of design iterations (obtain a global optimum design)
change - assign new values to parameters (or save an optimum design)
autochange - assign new vector of decision variables randomly (used in the superopt process)
chooseplot - choose which variables/margins to plot
diplot - generate & print PostScript file containing plots
panel - generate BOSOR4 input for a skin-stringer multi-module model
panel2 - generate BOSOR4 input for a skin-ring multi-module model
panel3 - generate BOSOR4 input for a skin-stringer + weld land multi-module model
stagsmodel - generate STAGS input for panel (element unit, no rings)
stagsunit - generate STAGS input for panel (shell units, both rings and stringers permitted)
cleanpan - delete temporary case-specific files

A typical PANDA2 runstream is:

```
begin
  setup
  decide
  mainsetup
  superopt (or pandaopt)
  (several more pandaopts if the previous command is not superopt)
  chooseplot
  diplot
  change
  superopt or pandaopt
  etc.
  cleanpan
```

Please consult the files in ../panda2/doc for more information about PANDA2.

Also review the sample cases in ../panda2/case.

Also read the published papers listed in the file ../panda2/doc/panda2.ref.

The file, ../panda2/doc/panda2.news contains updates and comments since 1987.

Useful annotation appears in the *.OPM file when NPRINT = 2 in the *.OPT file.

USEFUL HINT PERTAINING TO THE INTERACTIVE INPUT YOU SHOULD PROVIDE DURING 'mainsetup':

After you type the command, 'mainsetup', try just hitting ENTER to obtain the default value

of any data entry that you are unsure about. PANDA2 will provide what its developer

usually chooses. Generally use 5 iterations/pandaopt; Generally use NPRINT = 0;

Generally use 'superopt'; Generally choose 5 pandaopts per autochange for superopt runs.

USEFUL HINT FOR SAVING OPTIMUM DESIGNS FOR FUTURE RUNS:

Once you have obtained a global optimum design that you are happy with, execute the

process called 'change' in order to save this global optimum design in a file called *.CHG

Then the global optimum design will be preserved in the *.CHG file after execution of 'cleanpan'.

You can then execute 'change' immediately following 'begin' in order to re-establish

that same global optimum design at any time in the future.

FILES THAT ARE PRESERVED FOLLOWING EXECUTION OF THE COMMAND, 'cleanpan':

*.BEG (from 'begin'), *.DEC (from 'decide'), *.OPT (from 'mainsetup'), *.CHG (from 'change')

*.CPL (from 'chooseplot'), *.PAN (from 'panel' or 'panel2'), *.STG (from 'stagsunit'

or from 'stagsmodel'). These preserved files are valid input for the interactive processors,

begin, decide, mainsetup, change, chooseplot, panel or panel2, stagsunit or stagsmodel,

respectively.