

INTRODUCING APDL MATH COMMANDS

A new set of commands in ANSYS Mechanical APDL provides access to powerful matrix manipulation features.

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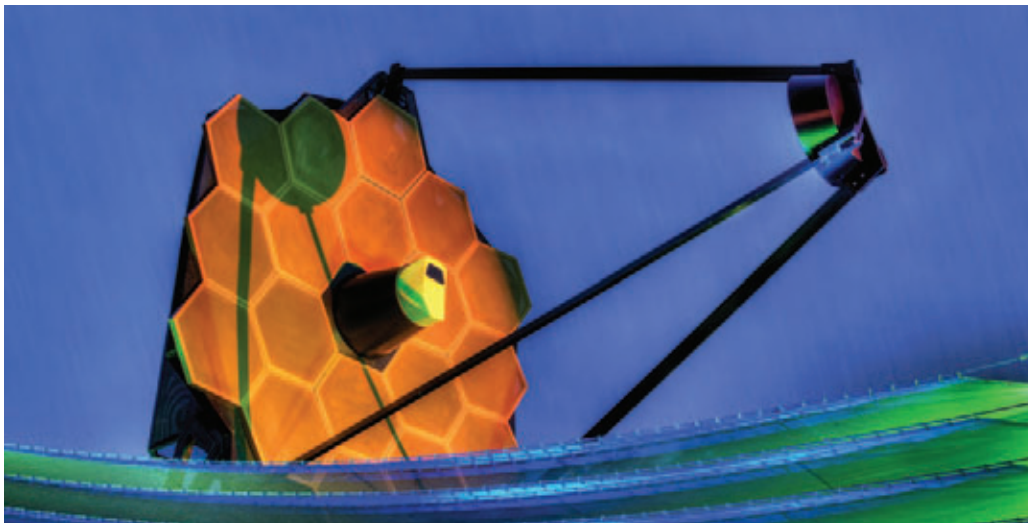
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The ANSYS Parametric Design Language (APDL) allows you to script and control the different steps of a solution process, from pre-processing to post-processing. A new set of commands called APDL Math provides the ability to access and manipulate the large sparse matrices involved in the solve step itself. Accessing this data delivers more possibilities than ever to customize the analysis process.

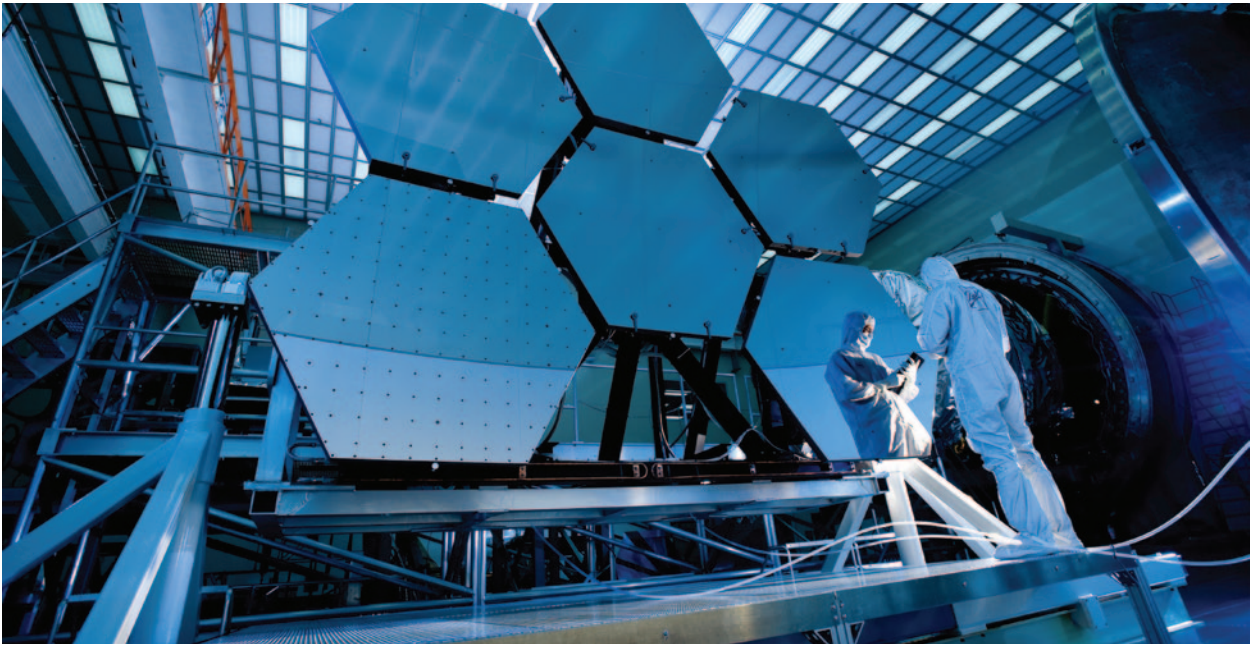
This command set is based on tools for manipulating large mathematical matrices and vectors that provide access to standard linear algebra operations, access to the powerful sparse linear solvers of ANSYS Mechanical APDL (MAPDL), and the ability to solve eigenproblems.

APDL Math allows you to access matrices and vectors on .FULL, .EMAT, .MODE and .SUB files, as well as other sources, so you can read them in,

manipulate them, and write them back out or solve them directly. This functionality augments vector and matrix operations (such as *VOPER and *MOPER) in the standard APDL scripting environment. Both dense matrices and sparse matrices can be manipulated using APDL Math. Prior to the implementation of APDL Math, you needed to use FORTRAN code to obtain access to the data in these files.



The James Webb space telescope



Six of the 18 mirror segments ready for optical test in a cryogenic environment at NASA Marshall Space Flight Center

On average, the ANSYS sensitivity capability has decreased by approximately six times the amount of time to perform work on the telescope.

PROGRAMMING ADVANCED ALGORITHMS

APDL Math commands open a new field of application: the ability to program complex algorithms directly in MAPDL input files so you can manipulate sparse and dense matrices to solve linear systems and eigenproblems, for example:

APDL Math Commands Examples

```
*SMAT,K,D,FULL,file.full,STIFF
```

! Obtain the stiffness matrix from an existing
! MAPDL full file

```
*LSENGINE,MySolver,BCS,K
```

! Factor this matrix using the BCS sparse solver

```
*LSFACTOR,MySolver
```

THE JAMES WEBB SPACE TELESCOPE: SENSITIVITY ANALYSIS USING APDL MATH

The James Webb Space Telescope (JWST) is an orbiting infrared observatory that will complement and extend the Hubble Space Telescope's discoveries. The Smithsonian Astrophysical

Observatory (SAO) is involved in research and development work on this next-generation telescope, which has a launch date of 2018.

Once the telescope is in orbit, it will observe distant objects in space for as long as two weeks at a time. During that period, the telescope's temperature may

change a small amount, and even this minute change will affect optical performance (wavefront error). To verify that performance is within specifications, the NASA Johnson Space Center (JSC) will test the JWST optical telescope element (the eye that gathers light for the instruments) and science instrument payload in a huge vacuum chamber that will bring the telescope temperature down to spaceflight conditions of approximately 30 K. During that test, JSC will make optical measurements of the telescope to compare them with numerical model predictions. To accurately make those measurements, researchers must install many thermal sensors on the telescope so that its temperature state can be understood. Those sensors need to be placed on the parts that have the highest wavefront error sensitivity to small temperature changes; therefore, to place the sensors

properly, researchers need to understand the part-by-part sensitivity.

One of the challenges researchers face is to understand the sensitivity of the mechanical behavior of this very complex, large assembly (more than 65 million equations) with respect to a very large number of input material parameters, each of which vary in a set of several different values.

The structure that supports the 18 mirror segments has more than 3,000 graphite-composite and pallet components. To determine the optical wavefront sensitivity of each of these parts

would take more than 3,000 CPU hours in excess of four calendar months using the normal brute-force method of changing the thermal strain behavior of each and every part separately.

Taking full benefit of the very local definition of all these parameters — less than 1 percent of the global number of elements are influenced by a variation of one parameter — and starting from a single complete solve on the whole model, researchers defined a set of APDL Math commands to accelerate this sensitivity analysis, using an iterative solve method.

With APDL Math commands, you can create specific customized processes in MAPDL that are adapted to your organization's real needs.

Overview of APDL Math Commands Sequence

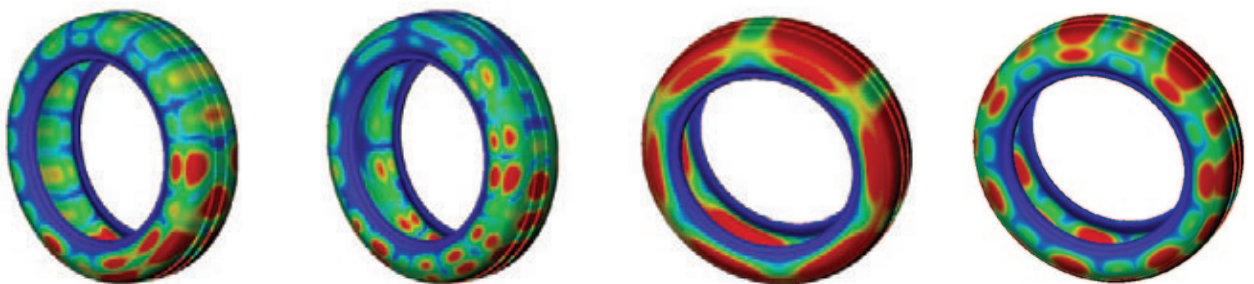
...	! Set up initial state: $K_0 U_0 = F_0$
WRFULL,1	! Create the full file but do not solve the
SOLVE	! equations
*SMAT,K0,D,IMPORT,FULL,file0.full,STIFF	! Get K_0, F_0 from the full file
*VEC,F0,D,IMPORT,FULL,file0.full,RHS	
...	
*LSENGINE,MyBcs,BCS,K0	! Solve the initial state: $K_0 U_0 = F_0$
*LSFACTOR,MyBcs	! using the BCS sparse solver
*LSBAC,MyBcs,F0,X0	
...	
! Parameter variation	! Introduce small variations in K and/or F:
	! $K_1 = K_0 + \Delta K, F_1 = F_0 + \Delta F$
...	
WRFULL,1	! Form the matrices K_1, F_1
SOLVE	
*SMAT,K1,D,IMPORT,FULL,file1.full,STIFF	! Import the new matrix and vector
*VEC,F1,D,IMPORT,FULL,file1.full,RHS	
*ITENGINE,PCG,MyPcg,MyBcs,K1,F1,X1	! Use a PCG algorithm, based on the
	! factorization of K_0 and the updated
	! matrices K_1, F_1 to quickly get the
	! updated solution U_1 .

On average the new ANSYS sensitivity capability has decreased by approximately six times the amount of time to perform this work. Using this customized process, it is possible to accomplish this analysis in a realistic amount of time.

With APDL Math commands, you can create very specific customized processes in MAPDL that are adapted to your organization's real needs.

OTHER APPLICATIONS

APDL Math allows the rapid implementation of a number of different algorithms, and the commands have been used in implementing specific algorithms.



Tire vibration

Michelin's teams of experts rely on APDL Math technology as part of its simulation effort.



- In rotordynamics, APDL Math was used to develop an algorithm to very quickly directly solve for the critical speeds by resolving a unique and customized eigenproblem. The algorithm replaced the classical loop needed to generate the Campbell diagram.
- In modal analyses, the derivatives of the eigenvalues with respect to a design parameter variation is an item of interest for sensitivity studies. The formula to compute this derivative is known, and is easy to implement with the APDL Math set of commands.
- To identify material properties from a set of experimental data to build an accurate model in MAPDL, APDL Math was employed to perform the interpolation of these quantities to automate this parameter identification step.
- By exporting MADPL substructures (SUB file) to NASTRAN DMIG files and vice versa, customers have been able to work in environments using both codes.

ENHANCE COMMUNICATION WITH THIRD-PARTY TOOLS

APDL Math commands deliver new ways to communicate with third-party tools, such as Matlab®, by offering the ability to import and export data in various sets of file formats (Matrix Market, Harwell Boeing, etc.).

MICHELIN REDUCES TIRE NOISE
Michelin®, a world leader in tires for all types of vehicles, is committed to conducting business in a sustainable and responsible manner, in accordance with its Michelin® Performance and Responsibility program. The program also guides the company's product strategy to satisfy market requirements by offering innovative, high-technology products that comply with standards, regulations and specific uses. To continue to reduce the environmental footprint of tires and to plan for future standards and different levels of labeling (tire classifications based on fuel consumption, wet grip and noise) around the globe, Michelin is redoubling its efforts to significantly reduce the noise that tires produce.

Simulation is the best means for achieving the noise-reduction objective. It can be used to identify and understand the mechanisms that cause noise, leading to development of increasingly innovative products. Michelin's teams of experts rely on APDL Math technology as part of this simulation effort. The technology couples generic digital analysis methods with Michelin's own internal expertise and systems. The combination makes it easier to obtain high-quality data rapidly and provides more accurate noise-reduction diagnostics.

COUPLING THE MICHELIN IN-HOUSE SOLVER WITH THE MAPDL SOLVER

Michelin has very specific, accurate knowledge of the numerical simulation

of tire models. The company needs to retain this sensitive, proprietary information, so the knowledge cannot be incorporated into a commercial code. On the other hand, Michelin engineers would like to use the power of the HPC solvers and algorithms developed inside MAPDL, since the MAPDL solver contains a highly optimized algorithm to perform harmonic analyses, allowing the solver to sweep over frequency ranges in a reduced amount of time.

To address these competing requirements, Michelin engineers set up a hybrid solve process that combines an FEM data provider (the Michelin in-house solver) to assemble the system of equations to solve along with the pure numerical solver contained in MAPDL. Communication between the two codes is based on APDL Math features and is performed in the same process. APDL Math commands also offer the ability for Michelin engineers to use the MAPDL eigensolvers on their own FEM problems.

This approach allows Michelin to focus on enhancing its knowledge of tire modeling and behavior, and it lets ANSYS technology solve the resulting equations.

SUMMARY

APDL Math extends the scripting language environment of ANSYS Mechanical APDL to give you access to powerful matrix manipulation routines, including fast and efficient solvers. ▲