Mainstream CAE Tools: Technical Considerations and Informative Comparisons

January, 1999

Revised – March, 1999

"In this report, ANSYS, Inc. is trying to show the importance of the fundamental characteristics of design analysis software and to educate prospective buyers. The process by which they've done this has been explained to me, and I've been given the chance to review and comment on this report.

I believe that ANSYS, Inc. has made every effort to make this report fair, comprehensive, and accurate. Although I did review the testing procedures and preliminary results I can not vouch for the reliability of results. The report does, however, illuminate key issues which perspective buyers of this class of software should be aware of."

Robert Mills
Editor
Computer-Aided ENGINEERING magazine

Table of Contents:

1.0. Introduction:

ANSYS, Inc. performed an evaluation of mainstream engineering design packages over a three-month period. This document provides information on the evaluation procedures and results of the tests. This report can be viewed online at:

1. Go to: http://www.designspace.com
2. Select: "Mainstream CAE Tools: Technical Considerations and Informative Comparisons"

The goals of this evaluation were many. First was to bring to the forefront, the critical issues in evaluating mainstream CAE tools. The ease of use and speed of some of today's engineering tools makes it easy to overlook the core building blocks necessary for a quality tool. Secondly was to help educate as to the dangers of "check box" software evaluation. What is meant by "check box", is comparing feature lists. When evaluating CAE tools the devil truly is in the details. Without the fundamental building blocks, subsequent functionality is suspect. Lastly the evaluation was used to gain insight into possible DesignSpace weaknesses.

Linear stress, steady state thermal and thermal stress were the scope of the testing during this evaluation. These areas were chosen because they are the targeted areas of application for mainstream engineering tools

The following packages were used in the evaluation process:

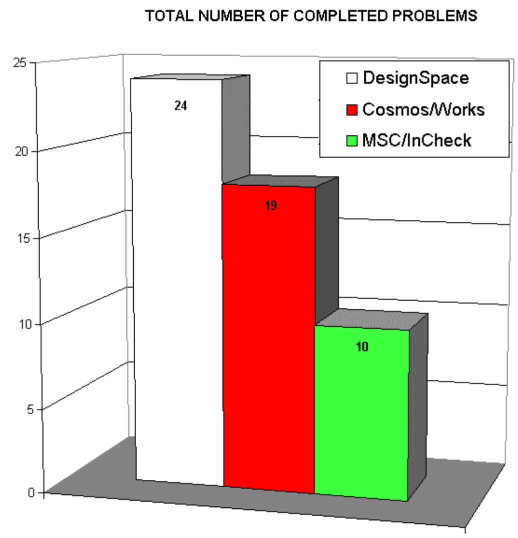
1) COSMOS/Works version 4.0 – 98/150 R_1
2) MSC/InCheck version 2
3) DesignSpace version 4.1

Test Models

The models used for meshing and solving comparisons were obtained from public CAD models, from SolidWorks, and proprietary customer models. The nonproprietary parts used for the evaluation can be viewed in appendix B. The accuracy problems were taken directly from theoretical engineering cases such as a plate with a hole. These problems have results that can be calculated by hand using standard engineering equations. Four of these cases were chosen for the accuracy comparisons.

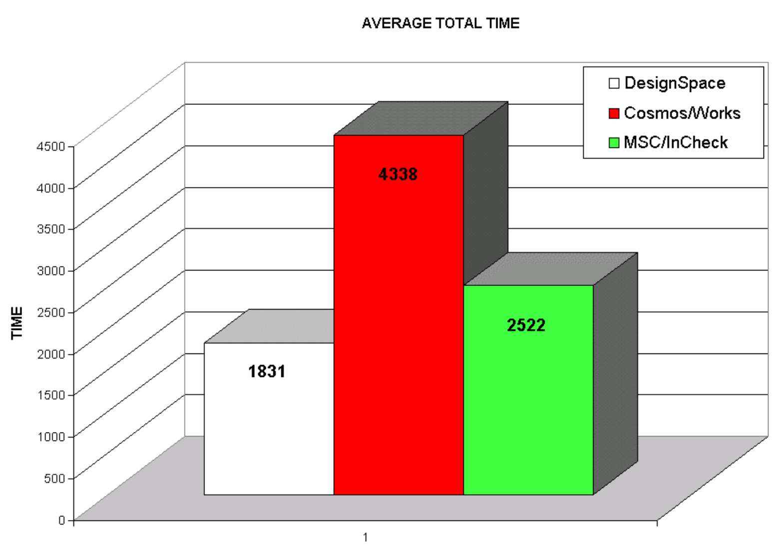
2.0. Summary of results:

This section will give a general summary of the results compiled from the evaluations. The explanations of the results and testing procedures are described in section three of this report.



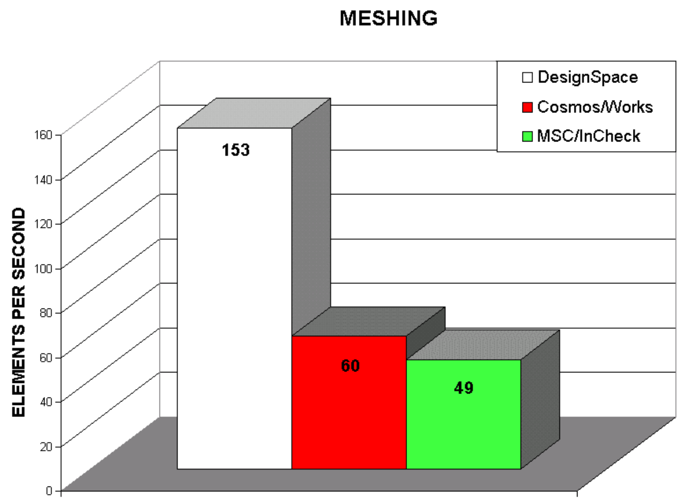
SUCCESS RATE:

DesignSpace successfully meshed and solved 100% of the test cases (24 models) Cosmos/Works meshed and solved 80% of the test cases and MSC/InCheck meshed and solved 42% of the problems.



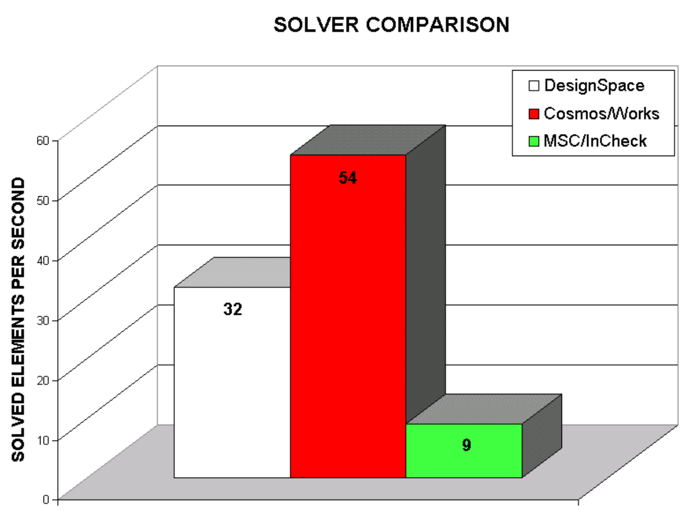
OVERALL SPEED:

On average problem speed, which is the combination of the mesh and solve. DesignSpace was 2.4 times faster than Cosmos and 1.4 times faster than MSC/InCheck. These numbers reflect the average time per part.



MESHING SPEED:

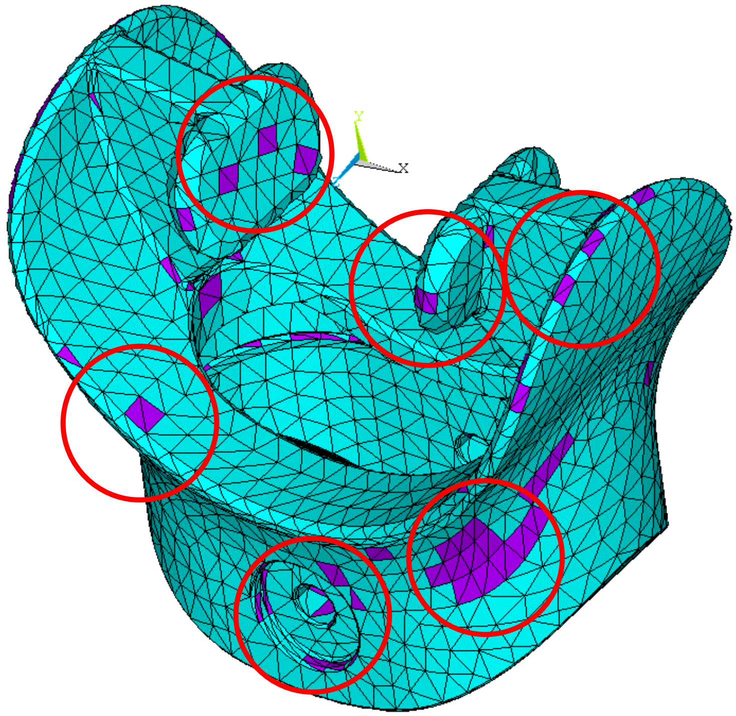
Meshing speed results in elements per second: DesignSpace was over 2.5 times faster than Cosmos and over 3.1 times faster than MSC/InCheck.



SOLVING SPEED:

Solving speeds measured in solved elements per second: Cosmos/Works was 1.6 times faster than DesignSpace. DesignSpace was 3.5 times faster than the MSC/InCheck.

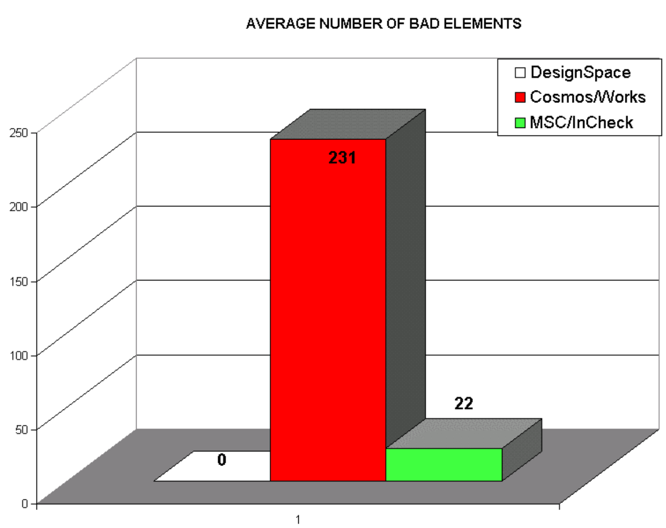
**** Note: DesignSpace solves twice during the Automatic adaptive solution.**



<u>MESH QUALITY EXAMPLE</u>:

Actual picture of SolidWorks model meshed in Cosmos/Works. The dark areas are bad elements** that produce invalid results. (See section 3.3., accuracy test - case 077)

**** The definition of a bad element is explained in section 3.1.**



<u>MESH QUALITY:</u>

When looking at mesh quality DesignSpace created no bad elements. Cosmos/Works had an average of 231 bad elements per part. MSC/InCheck had 22 bad elements per part.

Accuracy Considerations

Accuracy was measured in percent error from the theoretical result. Below is a chart that conveys the general results. Each engineering case looked for different results. Some cases had only one result while others may have had many. There were a total of 14 different results for the four engineering cases evaluated.

DesignSpace produced consistently more accurate results than COSMOS/Works or MSC/InCheck. COSMOS/Works had several results well over 100% off of the theoretical result (see section 3.3 case 077) MSC/InCheck had mesh and solve failures on these simple models.

The following charts represent the number of results that fall within a particular range of the theoretical answer. Each problem was run on the default mesh setting and the most accurate setting available in each program.

Chart 1 describes the results that tended to be **LESS accurate** or more than 20% from the theoretical answer.

Chart 1: Number of less accurate results: R_4

Mesh Setting	Default	High	
	# of results greater than 20% from theoretical	# of results greater than 20% from theoretical	# of failures
DesignSpace	0	0	0
COSMOS/Works	1	2	1
MSC/InCheck	0	0	2

Chart 2 describes the results that tended to be **MORE accurate** or less than 5% of the theoretical answer.

Chart 2: Number of accurate results:

Mesh Setting	Default	High
	# of results under 5% of theoretical	# of results under 5% of theoretical
DesignSpace	12	11
COSMOS/Works	5	3
MSC/InCheck	2	4

Note: Because some problems have more answers associated with them, failures can dramatically affect the results.

3.0. Detailed Procedures and Results

3.0. Detailed procedures and results:

This section outlines what areas of the software were evaluated, a description of testing methods, documentation of any system settings, and evaluation results. Each section starts with an area abstract that will describe why that particular area of testing is deemed important to the quality of the analysis results and to the completeness of an engineering package. There will be a procedure section that explains, in detail, the method used to evaluate each area. Evaluations and comparisons were done in the following areas:

- Meshing
  - Number of parts successfully meshed
  - Average number of elements
  - Average time
  - Number of elements per second
  - Number of bad elements

- Solving
  - Number of parts successfully solved
  - Average solve time
  - Average number of elements per second

- Accuracy
  - 077 - Radial flow in a copper disk
    - FIND: disc temperatures and heat fluxes
  - 013 - Plate with a hole
    - FIND: peak stress near hole
  - 021 - Grooved bar
    - FIND: peak stress in X direction
  - 078 - Thermal stresses in a long thick cylinder
    - FIND: MAX/MIN hoop stress, axial stress, thermal strain

- Functionality breadth (check list)

These tests were all run on the same Intergraph TDZ-400 NT workstation.

Workstation configuration:

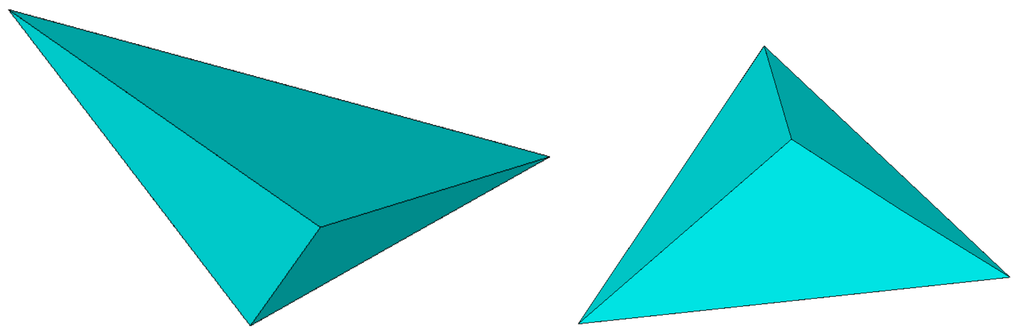
- Dual Pentium II 300Mhz processor
- 128 MB RAM
- 350-650MB virtual memory

3.1. Meshing

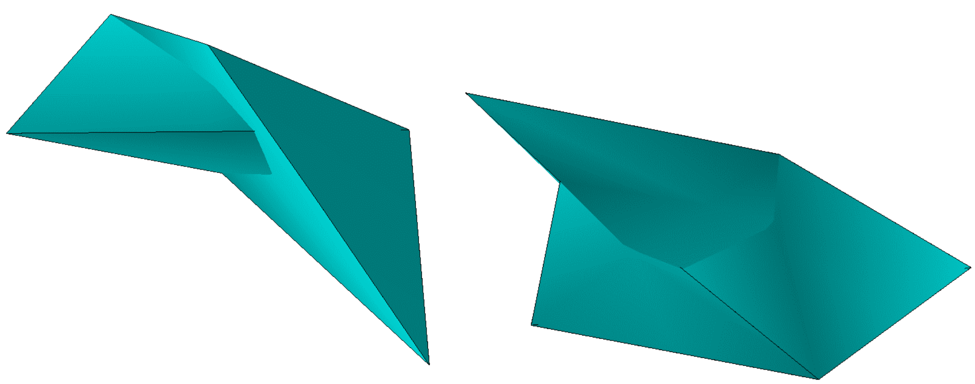
<u>3.1. Meshing:</u>

Abstract

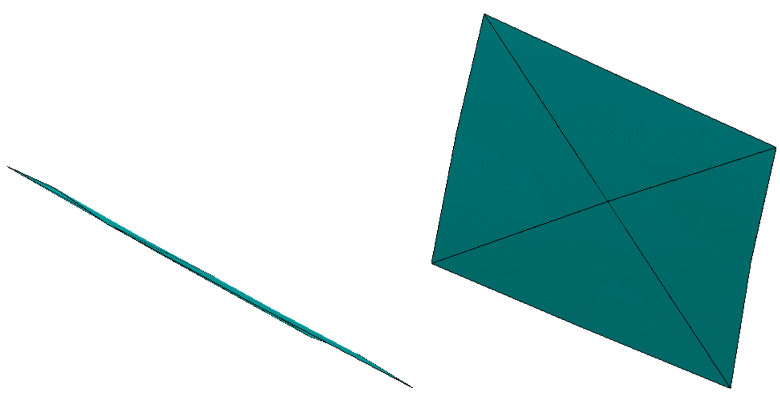
A good finite element mesh is fundamental to getting realistic results from an analysis. It comes down to one word, QUALITY. The result of an analysis of a model with "bad" elements is that the answers become completely unreliable and misleading regardless of the correctness of the boundary conditions (see accuracy results section 3.3). When looking at a finite element mesh there are many measures of quality. After extensive research ANSYS, Inc. has found the Jacobian ratio to be the best overall measure of an element's shape and performance ability. Jacobian ratio is a measure of volumetric distortion. The pictures below show the differences between good and bad elements. The number of elements, and speed were also topics for investigation.



Nearly perfect tetrahedral element



Element with negative Jacobian ratio



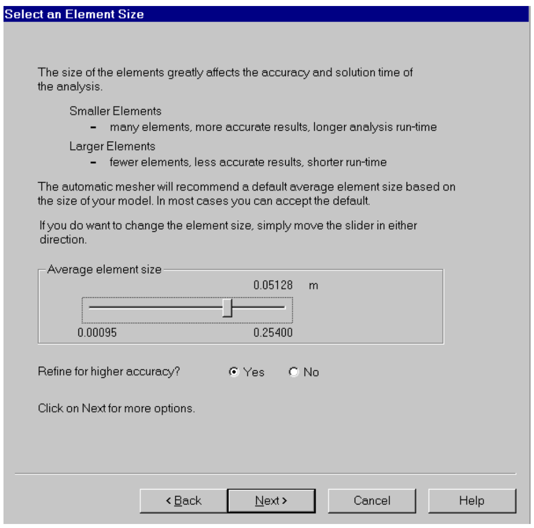
Flat element with nearly zero Jacobian

NOTE: Actual elements from testing procedures.

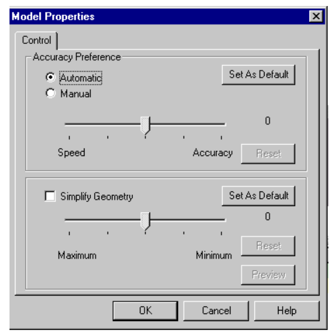
Procedure

The meshing tests were performed on 24 models of varying complexity. The models were meshed on the system default settings unless otherwise indicated. If models failed to mesh, the smallest (most accurate) mesh size was used. If any one system took orders of magnitude longer to mesh than the others, it was considered failed and documented on the meshing data spreadsheets (see appendix A). The default mesh settings for each package are as follows:

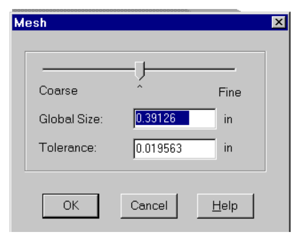
- DesignSpace uses an automatic adaptive mesh and solve as the default.
- COSMOS/Works sets a global mesh size for each part by default.
- MSC/InCheck sets a global mesh size for each part by default.



MSC/InCheck default meshing dialog box



DesignSpace default meshing dialog box



COSMOS/Works default meshing dialog box

The speed was recorded and the element shape, and quality were checked by taking the database of element information into ANSYS. Element shape checking tools were used to look at shape quality and check Jacobian ratios. Because element quality is important, most high end finite element packages have tools to identify elements that do not fit a users criteria for a "good element". The purpose for this is so that the user can manually fix the regions of poor quality. These tools are not available in mainstream CAE tools. In some cases the format of the ASCII file was modified in order to facilitate transferring the information. This modification does not affect the mesh data or the results of the shape checking and is merely formatting.

<u>Meshing Results</u>

Program	Number of parts meshed from 24	Average number of elements per part	Average time to mesh (seconds)	Number of elements per second	Number of bad elements per part
DesignSpace	24	14027	108	153	0
COSMOS/Works	20	15863	311	60	231
MSC In/Check	14	21750	1370	49	22

3.2. Solving Studies

3.2. Solving Studies

Abstract

Solvers are the brains behind the programs that assemble and solve the massive system of equations that are associated with finite element models. There are different solvers for different types of analysis problems. In this evaluation there was no attempts made to change or “tweak” which solver was being used. Each system used the defaults. Some of the programs, such as DesignSpace, may automatically choose the appropriate solver for a given problem while others may stick with one type of solver. Either way the thrust of the evaluation was “hands off” speed, robustness, and accuracy.

Procedure

The procedure to test the solvers was straightforward. Each system solved the problems using the default mesh settings. Obviously, if the part did not mesh, then the solver routine could not be tested. The times were measured using a stopwatch or system clock. Problems that took orders of magnitude longer to solve in comparison to the other programs were considered failed. These situations were documented in the Detailed Results spreadsheet in appendix A.

Solver Results

Program	Number of parts solved from 24	Average solve time (seconds)	Elements solved per second
DesignSpace	24	1724	32
COSMOS/Works	19	4011	54
MSC In/Check	10	1917	9

3.3. Accuracy

3.3. Accuracy

Abstract

Accuracy of a finite element answer can be a hard thing to quantify. The easiest way to evaluate accuracy between different design packages is to use simple problems with known answers, such as a plate with a hole or a bar in tension. In this section we have taken a subset of typical theoretical engineering problems. These problems are used to validate the accuracy of finite element solutions. The purpose of this section was to evaluate accuracy with respect to ease of use. In other words, "how easy is it to get accurate answers?" These results point to the trend of a package to get accurate answers.

Procedure

Each problem was set up according to the problem specification defined in this document. Each test case was run using the default mesh settings and then at high accuracy, or the most dense, mesh settings. The results were recorded and the percentage of error from the theoretical answer was documented.

In most cases the automatic setting is considered the most accurate setting for DesignSpace. Setting the global mesh size slider bar to most accurate increases the accuracy of COSMOS/Works. MSC/InCheck uses a global mesh size slider bar to increase accuracy also. Using manual intervention, MSC/InCheck has the option of decreasing the mesh size in user selected areas. A user may use this method to manually increase the accuracy of a result in a specific area.

Any results that were found to be significantly different than the theoretical answer, more than 20%, will be highlighted in red and explained if possible.

Accuracy Test Case Problems

Test Case Name - Engineering 077 - Radial flow in a Copper disk

Other Files Required for this Test Case

Test Case File:
Drawing File: disk.sat

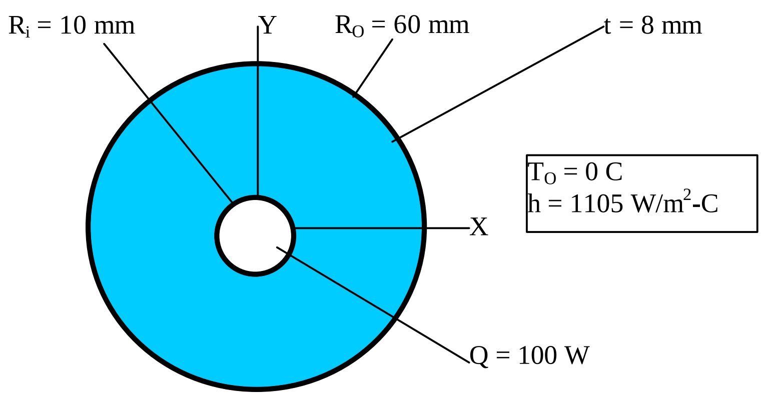
Known

A copper disk (thickness t, radius R_O) is insulated on the flat faces has a heat generating coaxial cable (of radius R_i) passing through its center. The cable delivers a total heat flow of Q to the disk. The surrounding air is at a temperature of T_a and the convective film coefficient is h.

Find

The disk temperatures and heat fluxes at inner and outer radius.

Schematic and Given Data



Material Properties

K = 401.0 W/m-C (thermal conductivity)
This material corresponds to Copper Alloy in the default.idx material file.

Analysis

The resulting temperature distribution is given by: T(r) = -4.9612 ln r + 16.042

T_{MAX} = 38.9
T_{MIN} = 30.0
Maximum Total Heat flux = 198943 W/m^2
Minimum Total Heat flux = 33157 W/m^2

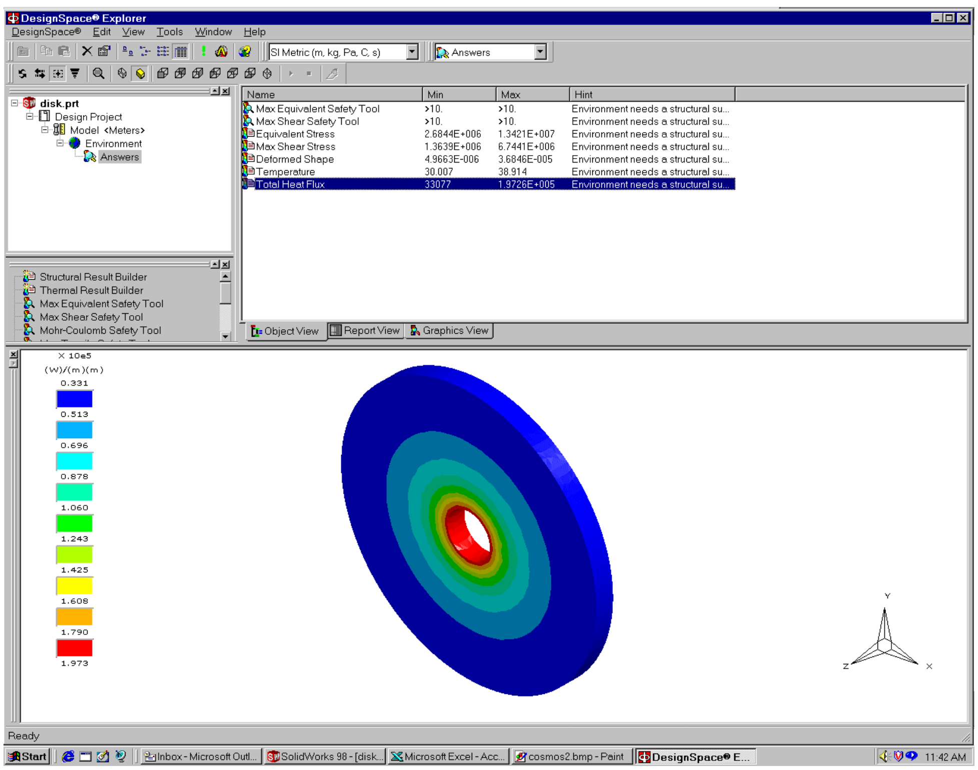
Validation Considerations

Drawing units: mm
Validation Units: m, kg, s, PA

Engineering 077 - Radial flow in a Copper disk Results

DesignSpace results

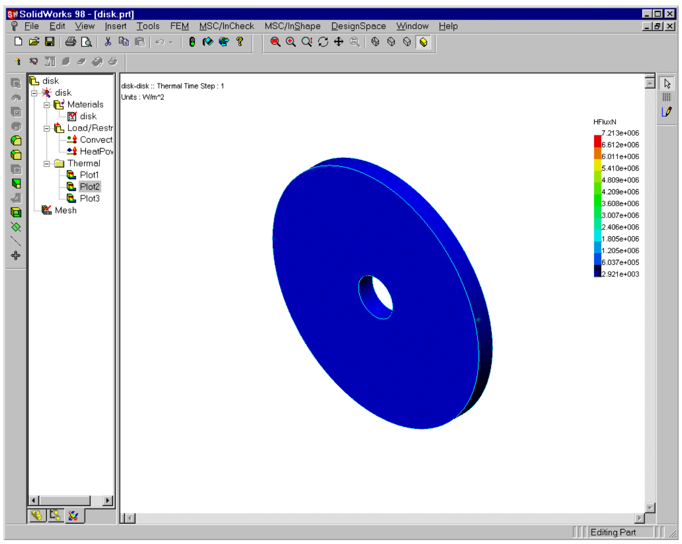
		Expected	DesignSpace	
TestCase	**Accuracy**	**result**	**result**	**% error**
077-	**Default**			
Radial flow	Tmax	38.9	38.903	0.0077115
in a	Tmin	30.0	30.005	0.0166639
Copper disk	Max Total Heat Flux	198943	190340	4.5198067
	Min Total Heat Flux	33157	32636	1.5963966
	High			
	Tmax	38.9	38.914	0.0359768
	Tmin	30.0	30.007	0.0233279
	Max Total Heat Flux	198943	197030	0.9709181
	Min Total Heat Flux	33157	33076	0.2448906



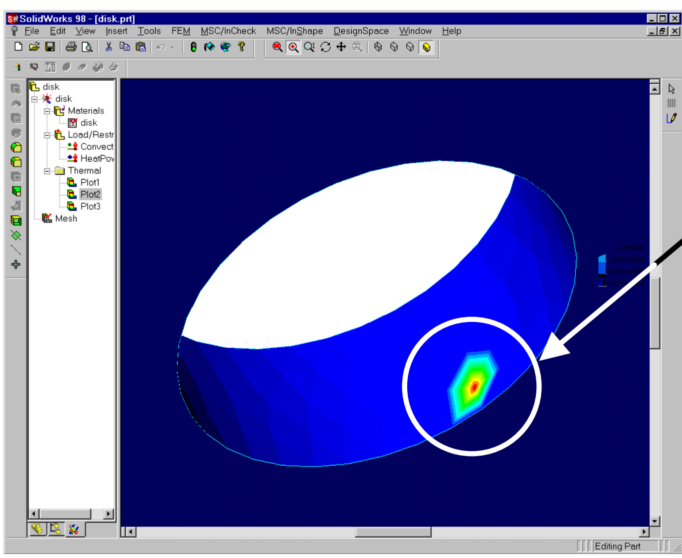
Correct Total Heat Flux distribution

COSMOS/Works Results

		Expected	COSMOS/Works	
TestCase	**Accuracy**	**result**	**result**	**% error**
077-	**Default**			
Radial flow	Tmax	38.9	38.97	0.1799
in a	Tmin	30.0	30.06	0.2
Copper disk	Max Total Heat Flux	198943	202500	1.7879
	Min Total Heat Flux	33157	118400	**257.09**
	High			
	Tmax	38.9	38.94	0.1028
	Tmin	30.0	30.02	0.0667
	Max Total Heat Flux	198943	2949000	**1382.3**
	Min Total Heat Flux	33157	1822	**94.505**



Incorrect total heat flux distribution with COSMOS/Works.



Bad element in COSMOS/Works cause *grossly inaccurate* answers.

MSC/InCheck results

		Expected		**MSC/InCheck**	
TestCase	**Accuracy**	**result**		**result**	**%error**
077-	**Default**				
Radial flow	Tmax	38.9		38.396	1.29563
in a	Tmin	30.0		28.3725	5.425
Copper disk	Max Total Heat Flux	198943		186995.421	6.00553
	Min Total Heat Flux	33157		34253.9691	3.30841
	High				
	Tmax	38.9		38.8979	0.0054
	Tmin	30.0		30.0064	0.02133
	Max Total Heat Flux	198943		191882	3.54926
	Min Total Heat Flux	33157		33250	0.28048

NOTES:

For this test, one of the loads is heat flow through a surface. This is not an option in MSC/Incheck.

With MSC/Incheck, you can only add a heat flow load to a vertex or edge. Instead, a heat flux of .198943 W/mm^2-C was applied to the surface.

Test Case Name: 013 - Plate with hole with tensile loading

Other Files Required for this Test Case

Test Case File

013 - Plate with hole with tensile loading
Drawing File: PlateWHole.dwg

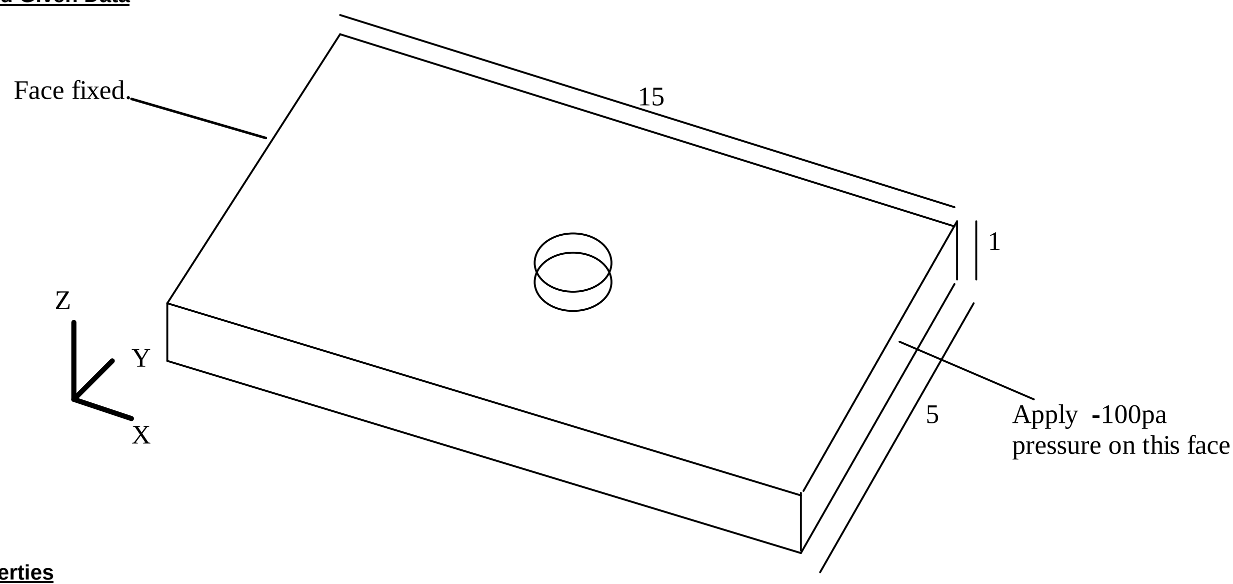
Known

Plate in tension with a transverse hole. Plate dimensions are 1x5x15 meters and hole diameter is 1 meter. Plane stress behavior is simulated in the plate by ignoring poisson effect. One end of the plate is fixed and the other end is loaded with a uniform tensile stress (pressure) of 100 pascals.

Find

Peak stress near the hole.

Schematic and Given Data



Material Properties

E = 1000 pa
nu = 0.0
This material corresponds to material T5 of the test.idx material file (SI Units).

Analysis

Shigley, Mechanical Engineering Design, McGraw-Hill, 2nd Ed., 1972, Table A-20, p723.
Using d/w = 1/5 =.2, A = (w-d)h = (5-1)1 = 4,

σ_0 = P/A = 500/4 = 125 pa
K_t = 2.5 (approx.)

peak $\sigma_x = K_t \sigma_0$ = 2.5x125 = 312.5 pa

Validation Considerations

Drawing Units: m
System of Units: SI Metric (m, kg, s)

013 - Plate with hole with tensile loading - Results

DesignSpace results

		Expected		DesignSpace	
TestCase	**Accuracy**	**result**		**result**	**% error**
013-	**Default**				
Plate with	peak Sx	312.5		304	2.72
hole with					
tensile	**High**				
loading	peak Sx	312.5		270.22	13.5296

COSMOS/Works results

		Expected		COSMOS/Works	
TestCase	**Accuracy**	**result**		**result**	**% error**
013-	**Default**				
Plate with	peak Sx	312.5		273.5	12.48
hole with					
tensile	**High**				
loading	peak Sx	312.5		313.7	0.384

MSC/InCheck results

		Expected		MSC/InCheck	
TestCase	**Accuracy**	**result**		**result**	**%error**
013-	**Default**				
Plate with	peak Sx	312.5		292.931	6.2621
hole with					
tensile	**High**				
loading	peak Sx	312.5		****mesh fails**	n/a

****** Meshing this part with MSC/Incheck at the highest accuracy caused the machine run out of virtual memory.

Test Case Name - 021 - Grooved Bar with Tensile Loading

Other Files Required for this Test Case

Test Case File: 021 - Grooved Bar with Tensile Loading.mst
Drawing File: GroovedBar

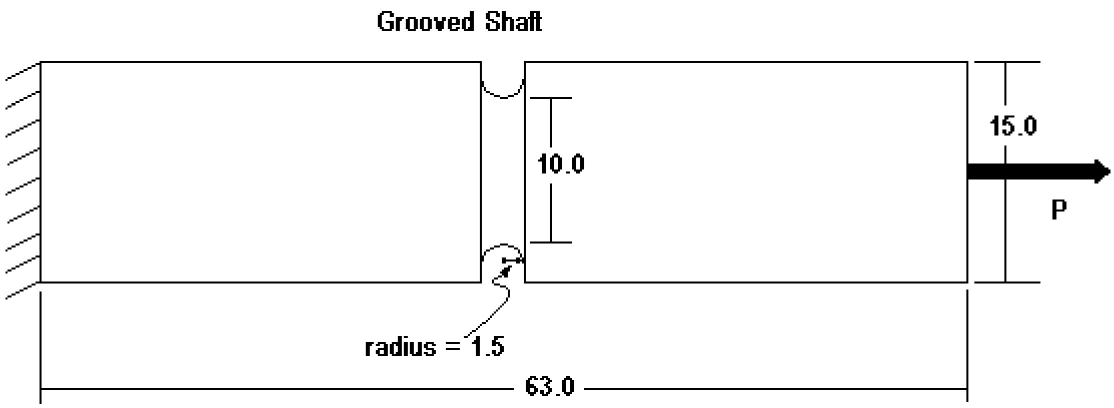
Known

A shaft (diameter(D) = 15m) with a groove (depth(h) = 2.5m, radius(r) = 1.5m, inner diameter(d) = D-2h = 10m) around the circumference is loaded in tension. One end of the shaft is fixed while the other end is subjected to a uniform tensile stress of -10 N. The material properties are such that there are no end effects at the fixed end of the shaft.

Find

The peak stress in the X-direction for the shaft.

Schematic and Given Data



Material Properties

E = 1000 Pa
ν = 0.0
This material corresponds to material T5 of the test.idx material file.

Analysis

$$s_o = \frac{P}{A} = \frac{\dfrac{10(p)(D^2)}{4}}{\dfrac{p(d^2)}{4}} = 22.5$$

Reference - Roark and Young, Formulas for Stress and Strain, 5th Ed., Table 37, case 15a, p599

$$\frac{h}{r} = 1.667 \qquad \frac{2h}{D} = 0.333 \qquad K_t \approx 2.19$$

Therefore $\text{Peak } s_x = K_t s_o \approx 2.19x22.5 = 49.275$

021 - Grooved Bar with Tensile Loading - Results

DesignSpace results

		Expected		**DesignSpace**	
TestCase	**Accuracy**	**result**		**result**	**% error**
021-	**Default**				
Grooved bar	peak Sx	49.275		53.673	8.9254186
with tensile					
loading	**High**				
	peak Sx	49.275		52.393	6.3277524

COSMOS/Works results

		Expected		**COSMOS/Works**	
TestCase	**Accuracy**	**result**		**result**	**% error**
021-	**Default**				
Grooved bar	peak Sx	49.275		47.43	3.7443
with tensile					
loading	**High**				
	peak Sx	49.275		53.72	9.0208

MS/InCheck results

		Expected		**MSC/InCheck**	
TestCase	**Accuracy**	**result**		**result**	**%error**
021-	**Default**				
Grooved bar	peak Sx	49.275		43.644	11.428
with tensile					
loading	**High**				
	peak Sx	49.275		solve failed	n/a

Test Case Name - 078-Thermal stresses in a Long Thick Cylinder

Other Files Required for this Test Case

Test Case File:
Drawing File: thickcyl

Known

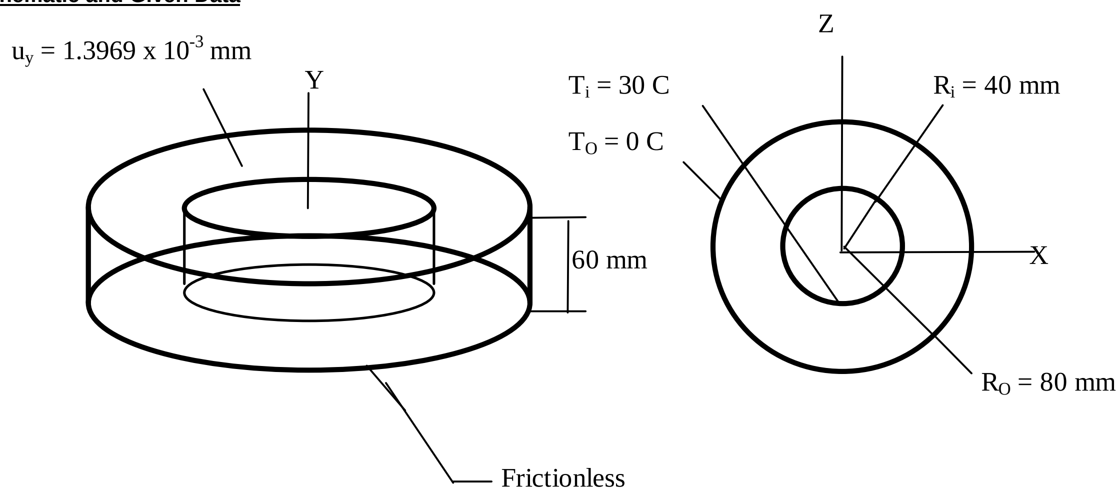
A long thick-walled cylinder is maintained at a temperature T_i on the inner surface and T_O on the outer surface. The inner and outer radii are R_i and R_O respectively.

> NOTE: The long cylinder implies a plain strain condition in the axial direction. This problem is modeled using a short cylinder instead, with an imposed displacement of U_y on the top surface.

Find

The minimum and maximum hoop stress, axial stress, and thermal strain.

Schematic and Given Data



Material Properties

k = 60.5 W/m-C (thermal conductivity)
E = 2 x 10^{11} Pa (Young's Modulus)
v = 0.3 (Poisson's ratio)
alpha = 1.2 x 10^{-5} /C (Coefficient. of thermal expansion)
This material corresponds to Structural Steel in the default.idx material file.

Analysis

The resulting stresses and strains are given by Timoshenko (see Comments):
Minimum: $S_{HOOP} = S_{AXIAL} =$ -62.95 MPa (must correspond to min World X, Y, Z stress components)
Maximum: $S_{HOOP} = S_{AXIAL} =$ 39.91 MPa (must correspond to max World X, Y, Z stress components)
Minimum: $e_{THERMAL} = 0$
Maximum $e_{THERMAL} = 3.6 \times 10^{-4}$

Validation Considerations

Drawing units: mm
Validation Units: mm, kg, s, MPa

Comments

The closed form solution can be obtained from: "Theory of Elasticity", S.p. Timoshenko; J.N. Goodier, McGraw-Hill Book Company, 3rd Edition. Pg 448, Eqns. 257 through 259. The equivalent plane strain applied on the top face of the cylinder section is given by:

> e_Z = (alpha)(T) + (1/E) [S_{AXIAL} - v ($S_{RADIAL} + S_{HOOP}$)] = constant
> where T = T_i ln(R_O/r) / ln(R_O/R_I

078- Thermal Stresses in a Long Thick Cylinder - Results

DesignSpace results

		Expected		**DesignSpace**	
TestCase	**Accuracy**	**result**		**result**	**% error**
078-	**Default**				
Thermal	Max Sx	39.91		40.28	0.9270859
stresses in a	Max Sy	39.91		40.411	1.2553245
long thick	Max Sz	39.91		40.63	1.8040591
cylinder	Min Sx	-62.95		-63.483	0.8467037
	Min Sy	-62.95		-64.416	2.3288324
	Min Sz	-62.95		-63.684	1.1660048
	Max Thermal Strain	0.00036		0.00036214	0.5944444
	Min Thermal Strain	0		-1.79E-06	
	High				
	Max Sx	39.91		40.166	0.6414432
	Max Sy	39.91		40.678	1.9243297
	Max Sz	39.91		40.346	1.092458
	Min Sx	-62.95		-63.701	1.1930103
	Min Sy	-62.95		-63.868	1.4583002
	Min Sz	-62.95		-63.619	1.0627482
	Max Thermal Strain	0.00036		0.00036062	0.1722222
	Min Thermal Strain	0.00E+00		-5.76E-07	

NOTES: Thermal loads in stress analysis are not an option in MSC/InCheck, so there is no way to do any part of this test. R_2

COSMOS/Works results

		Expected		**COSMOS/Works**	
TestCase	**Accuracy**	**result**		**result**	**% error**
078-					
Thermal	**Default**				
stresses in a	Max Sx	39.91		41.4	3.7334
long thick	Max Sy	39.91		37.33	6.4645
cylinder	Max Sz	39.91		43.41	8.7697
	Min Sx	-62.95		-97.95	**55.6**
	Min Sy	-62.95		-106.6	**69.341**

RESULTS OBSOLETE (See note on page39)

	High				
	Max Sx	39.91		72.72	**82.21**
	Max Sy	39.91		52.19	**30.769**
	Max Sz	39.91		62.1	**55.6**
	Min Sx	-62.95		-114.9	**82.526**
	Min Sy	-62.95		-109.7	**74.265**
	Min Sz	-62.95		-113	**79.508**
	Max Thermal Strain	0.00036		n/a	n/a
	Min Thermal Strain	0.00E+00		n/a	

078- Thermal Stresses in a Long Thick Cylinder - Results

COSMOS/Works results- R_3

Note: Due to the support conditions of this problem causing rigid body motion, an extra support was added to the frictionless surface in order to achieve the results on page 38 for Cosmos/Works. In order to more accurately simulate the theoretical support conditions of the 078 problem, the Cosmos direct solver with the spring option was used. This should allow a problem to solve that has rigid body motion by supporting the part, with weak springs, in the direction of rigid body motion.

This problem was manually stopped after 3 hours of run time.

3.4. Functionality Breadth

3.4. Functionality Breadth

Abstract

The breadth, or features, of a product is something that is most easily captured in a checklist of capabilities. The checklist is not meant to be all inclusive or to explain the depth of functionality for each feature but to come up with a list of features and critical points internal to each feature that companies will look for during an evaluation. This is something that most, if not all prospects of any type of software package will do. The problem with checklists is that they do not take into consideration fundamentals or the critical building blocks of a program (e.g. sections 3.1-3.3.) This information is based only on commercial released products.

	DesignSpace	**MSC In/Check**	**COSMOS/Works**
Structural			
Stress	X	X	X
Deflection	X	X	X
Factor of safety tools	X	X	X
Thermal			
Thermal stress	X	-	X
Temperature on a surf	X	X	X
Convection	X	X	X
Heat flux	X	X	X
Heat flow	X	X	X
Non linear materials	-	-	-
Buckling	-	X	X
Modal			
First 6 frequencies	X	X	X
More that first 6	-	-	-
Specified Modal range	-	-	-
Optimization			
Closed loop parameters	-	X	-
Topological	X	-	-
Assemblies			
Multiple materials	-	-	X
Engineering Report			
Automatic generation	X	X	X
Embedded JPEG support	X	-	-
HTML based	X	X	X
"live" Intranet publish.	X	-	-
continued			

Procedure

The necessary element here is a fair and knowledgeable evaluation of what features are available with each program. The content of this checklist was gathered by; using the programs, reading the documentation, and talking to users. This may not be a complete list of features or functionality but covers the key aspects of many customer evaluations.

	DesignSpace	MSC In/Check	COSMOS/Works
Meshing			
Element type	H	H	H
4 node Tetrahedral (optional)	-	X	X
10 node Tetrahedral (default)	X	X	X
Manual control	X	X	X
Local refinement	-	X	-
Automatic refinement	X	-	-
Shell elements	-	-	X
Solving			
Automatic solver selection	X	-	-
Auto adaptive solutions	X	-	-
CAD system support			
Mechanical Desktop	X	X	-
SolidWorks	X	X	X
Pro/Engineer	X	-	X
Unigraphics	X	-	-
SolidEdge	-	-	X
Helix	-	-	X
Microstation	-	-	X
Eureka	-	-	X
Parasolids support	X	-	-
ACIS SAT support	X	-	X
Design Tree	X	X	X
Copy Paste "what ifs"	X	-	-
Save multiple part versions	X	-	-
Multiple load cases	X	-	X
Copy Paste Load / Supports	X	-	X
Loads and Supports			
Traditional 6 dofs	-	X	X
Non-linear pinned support	X	-	-
Bolt loads	X	-	-
User defined CSO	-	X	X
Knowledge based/Intuitive	X	-	-
Misc.			
Customizable Alerts	X	-	-
Results probe	X	-	-
Dynamic 3D rotation	X	-	X
Analysis shortcuts	X	-	-

Appendix A

Appendix A

Detailed results spreadsheet DesignSpace

	DesignSpaceV4.1 Standalone					
	# Elements	**Time to Mesh**	**Time to Solve**	**Total time**	**Elnts/sec**	**Solved Es/sec**
diaphram	6812	18	170	188	378.44	40.07
diaphramCover	10466	65	297	362	161.02	35.24
diaphramRetainer	3341	61	79	140	54.77	42.29
exhaustCap	6812	43	126	169	158.42	54.06
gearOilPumpDrive	8517	39	133	172	218.38	64.04
housing	35023	165	1672	1837	212.26	20.95
innerBasket	15826	107	789	896	147.91	20.06
mouthPiece	23672	107	885	992	221.23	26.75
newFrontE	15772	135	1036	1171	116.83	15.22
oralButtonBezel	4524	27	89	116	167.56	50.83
outerBasket	23233	375	1016	1391	61.95	22.87
pressurePlate	18278	104	620	724	175.75	29.48
QDPlug	7157	75	170	245	95.43	42.10
antbase2	3904	23	100	123	169.74	39.04
id	10214	110	441	551	92.85	23.16
jama31	11011	76	266	342	144.88	41.39
kones	11310	90	786	876	125.67	14.39
mmplatfo	44869	383	29952	30335	117.15	1.50
nec	10438	56	262	318	186.39	39.84
od	17300	202	826	1028	85.64	20.94
saw	8858	85	313	398	104.21	28.30
sept26mod	20637	96	620	716	214.97	33.29
tobiseal	12230	81	542	623	150.99	22.56
ug_mcm	6441	57	181	238	113.00	35.59
			Averages:	1831.2917	153.14	31.83

Appendix A (continued)

Detailed results spreadsheet MSC/InCheck

MSCInCheck					
# Elements	**Time to Mesh (s)**	**Time to Solve (s)**	**Total time(s)**	**Elnts/sec**	**Slv Es/sec**
634	38	41	79	16.68421053	15.46341463
n/a	mesh failed	n/a	n/a	n/a	0
n/a	mesh failed	n/a	n/a	n/a	0
n/a	mesh failed	n/a	n/a	n/a	0
17652	166	2117	2283	106.3373494	8.338214454
14722	215	1457	1672	68.4744186	10.10432395
29685	370	solve is unsuccessful	n/a	80.22972973	0
n/a	mesh failed	n/a	n/a	n/a	0
32213	3694	solve is unsuccessful	n/a	8.720357336	0
n/a	mesh failed	n/a	n/a	n/a	0
n/a	mesh failed	n/a	n/a	n/a	0
9703	181	1094	1275	53.60773481	8.86928702
28305	2571	solve is unsuccessful		11.00933489	0
13259	111	1178	1289	119.4504505	11.25551783
22732	1565	3905	5470	14.52523962	5.821254802
n/a	mesh failed	n/a	n/a	n/a	0
14260	362	2063	2425	39.39226519	6.912263694
70719	1016	solve is unsuccessful	n/a	69.60531496	0
n/a	mesh failed	n/a	n/a	n/a	0
n/a	mesh failed	n/a	n/a	n/a	0
15843	258	1453	1711	61.40697674	10.90364763
14433	447	2907	3354	32.2885906	4.964912281
n/a	mesh failed	n/a	n/a	n/a	0
20342	2706	2954	5660	7.51736881	6.886255924
		Averages:	2521.8	49.23209583	8.951909221

Appendix A (continued)

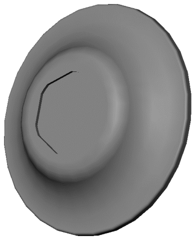
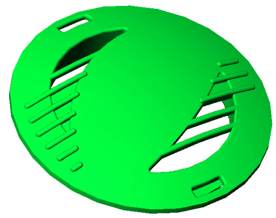
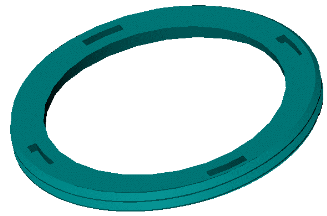
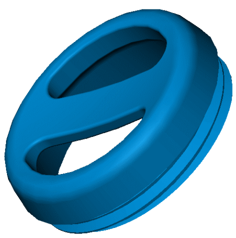
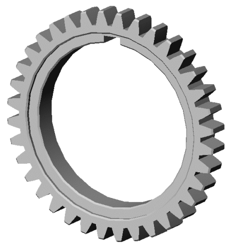
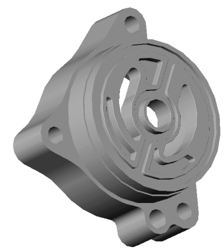
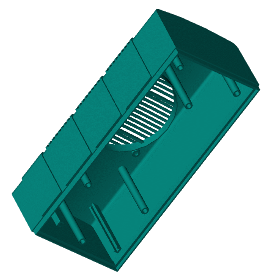
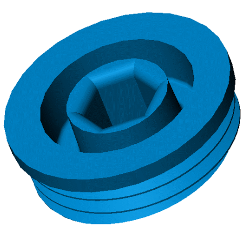
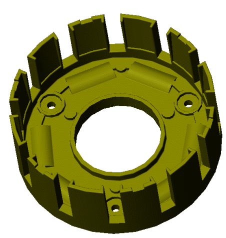
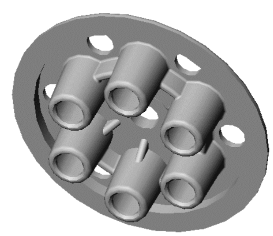
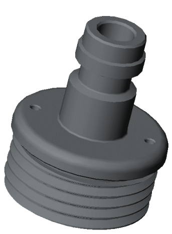
Detailed results spreadsheet Cosmos/Works

COSMOS/Works					
# Elements	**Time to Mesh (s)**	**Time to Solve (s)**	**Total time(s)**	**Elnts/sec**	**Slv Es/sec**
11571	91	738	829	127.1538462	15.67886179
10808	238	305	543	45.41176471	35.43606557
8324	195	70	265	42.68717949	118.9142857
8531	168	90	258	50.7797619	94.78888889
8383	151	63	214	55.51655629	133.0634921
9627	166	104	270	57.9939759	92.56730769
15184	375	317	692	40.49066667	47.89905363
10770	351	794	1145	30.68376068	13.56423174
59703	848	54922	55770	70.40448113	1.087050726
7541	127	93	220	59.37795276	81.08602151
n/a	mesh failed	n/a	n/a	n/a	0
13301	240	321	561	55.42083333	41.43613707
8970	214	116	330	41.91588785	77.32758621
12420	101	140	241	122.970297	88.71428571
n/a	mesh failed	n/a	n/a	n/a	0
9824	259	125	384	37.93050193	78.592
n/a	mesh failed	n/a	n/a	n/a	0
54209	812	10304	11116	66.75985222	5.260966615
9113	64	172	236	142.390625	52.98255814
17006	990	5830	6820	17.17777778	2.916981132
n/a	mesh failed	n/a	n/a	n/a	0
9462	472	331	803	20.04661017	28.58610272
16645	351	1373	1724	47.42165242	12.12308813
n/a	mesh failed	n/a	n/a	n/a	0
		Averages:	4337.947368	59.60705176	53.79078763

Appendix B

<u>Appendix B</u>

Non-Proprietary Models

Diaphragm 	Diaphragm Cover 	Diaphragm Retainer 
Exhaust Cap 	Gear Oil Pump Drive 	Housing 
Inner Basket 	Mouth Piece 	New Front End 
Oral Button Bezel 	Outer Basket 	Pressure Plate 
QD Plug 	This space should be blank.	Unable to show Proprietary Customer Geometry.

NOTES:

For more information

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1-800-WE-R-FEA1 ext. 3185
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1-724-514-1990

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