# Designer Oriented Software - *Is it Accurate? Part 2*

**Ian Symington, NAFEMS**

This series takes a look at the tools currently available for designers aiming to develop their designs with an analysis capability. When selecting a particular software code, there are a range of criteria that need to be considered, such as cost, usability, speed and accuracy. In this series, we focus on performing an assessment of the accuracy of different designer oriented codes using eight benchmarks in the area of linear elastic, small displacement structural mechanics.

Part 1 features SimSolid by Altair and is available to download for free from the NAFEMS resource centre [1]. Here in part 2, the focus shifts to midas MeshFree [2] a software code developed by Midas IT.

Before taking a look at the tool, I wanted to recap what I'm looking for in a designer oriented tool. It is worth stressing that I'm not looking for a replacement for a general-purpose FEA package. I'm expecting that anyone needing reliable and robust results will already have access to one, or be able to outsource the analysis to an organisation with this capability. With the focus being on designer oriented software, I'm looking for a tool that can help inform design decisions. In particular I'm looking at tools that are:

1. Easy to use – require little specialist knowledge
2. Quick to run – this means the solution needs to run in the time it takes to grab a cup of coffee **AND** there should be no need for hours of preprocessing cleaning up the geometry so that it can be used in by the tool.
3. The accuracy must be sufficient to guide the direction that a design should take but doesn't need to be able to hit the level of precision that is achievable using a general-purpose analysis package.

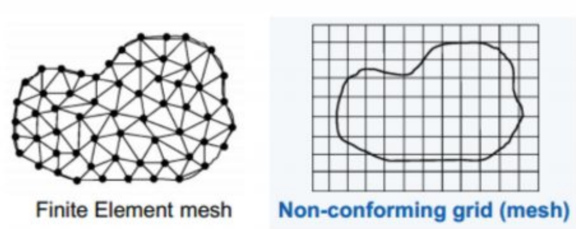


Figure 1: Comparison of discretisation using a traditional FEA approach (Left) and Non-conforming grid approach (Right).

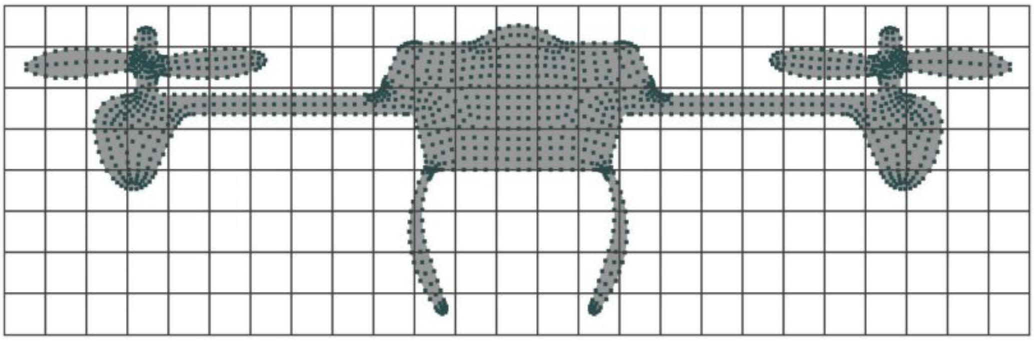

Figure 2: Computational Domain with an illustration of the adaptive integration scheme

## Unboxing midas MeshFree

Let's start by looking at how the midas MeshFree marketing team describe their product.

> *"MeshFree performs finite element analysis on the original CAD model without need for meshing or defeaturing. MeshFree frees you from all the difficulties of today's design and analysis software."*

midas MeshFree provides solution capabilities for analysing static and dynamic structural mechanics problems, steady-state and transient heat transfer problems and the ability to perform sequentially coupled thermal stress analysis.

The tool is marketed as *"Mesh Free"* and the user can perform the entire simulation process without defining or reviewing the discretised domain. MeshFree utilises concepts similar in principle to the Implicit Boundary Method using a non-conforming mesh [3].

This approach embeds the geometry of the part into a larger, regularly shaped computational domain which is discretised using a non-conforming grid (Figure 1). Putting it simply, MeshFree puts the model geometry inside a regularly shaped domain and then breaks this larger domain down into a 3D array of regular cells that do not align with the boundaries of the part that is being analysed. Cells which intersect with the boundary of the part are subject to a proprietary adaptive numerical integration scheme which optimises the number of quadrature points for an arbitrarily shaped domain of interest.

## The Simulation Process & Solution Accuracy

While the underlying numerical method may be new to most readers the basic workflow will be familiar and is shown in Figure 3 (note the absence of a mesh generation phase).

The accuracy of the solution is largely driven by the density of the non-conforming cells used in the initial discretisation phase. midas MeshFree contains controls allowing the user to manually specify the cell density for every part used in the analysis. This control allows the user to specify the number of non-conforming cells in three orthogonal directions however, for the purpose of this evaluation the automatic grid density settings have been utilised. The users are still able to influence the accuracy of the solution but this is done by setting the "reference memory" that the simulation process is able to utilise (Figure 4). Increasing the memory available to the simulation process increases the number of cells in the non-conforming grid.


Figure 3: midas MeshFree workflow

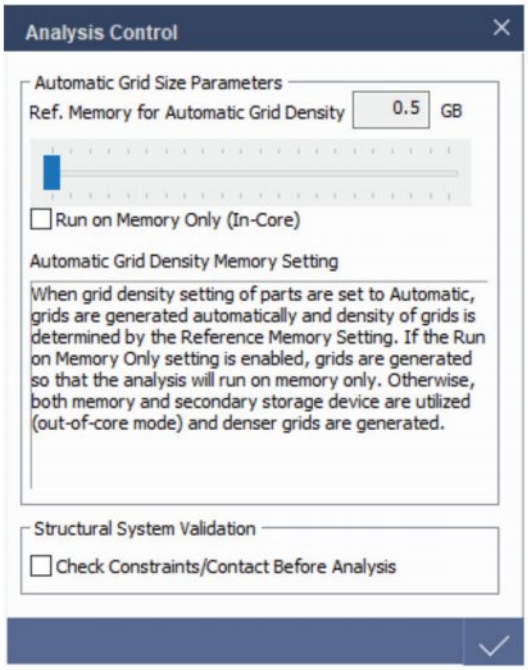


Figure 4: Analysis control dialogue box

The memory settings are available in the "Analysis Control" dialogue box in the form of a simple slider. Leaving the slider at the left-hand end of the scale will result in a quick solution but it should be less accurate than an analysis performed with the slider set at the right-hand position.

Users can see the effect that the Reference Memory setting has on the model size by opening up the log file that is generated as the solution progresses. The log file includes details of the density of the non-conforming grid and the resulting number of degrees of freedom. While I would not expect a designer to spend time parsing this file for information, the number of degrees of freedom have been provided in the table that accompanies each benchmark. This allows the rate at which the solution converges against the number of degrees of freedom to be observed. The density of the non-conforming grid can also be viewed graphically as shown in Figure 5.

During this evaluation, results were recalculated using 0.5, 2, 4, 6 and 8GB reference memory settings. All runs were performed in-house by NAFEMS.

Additional settings can be used to increase the solution accuracy under certain scenarios. It is not anticipated that a designer would modify these during a design exploration study. Unless otherwise stated, after discussion with MeshFree the modifiable solution parameters were set to:

- Automatic – Relative Grid Density = Medium
- Geometry Representation Details = 0.1
- Adapt Grid Orientation to Shape = Yes
- Enable Increased Integration Accuracy = Yes

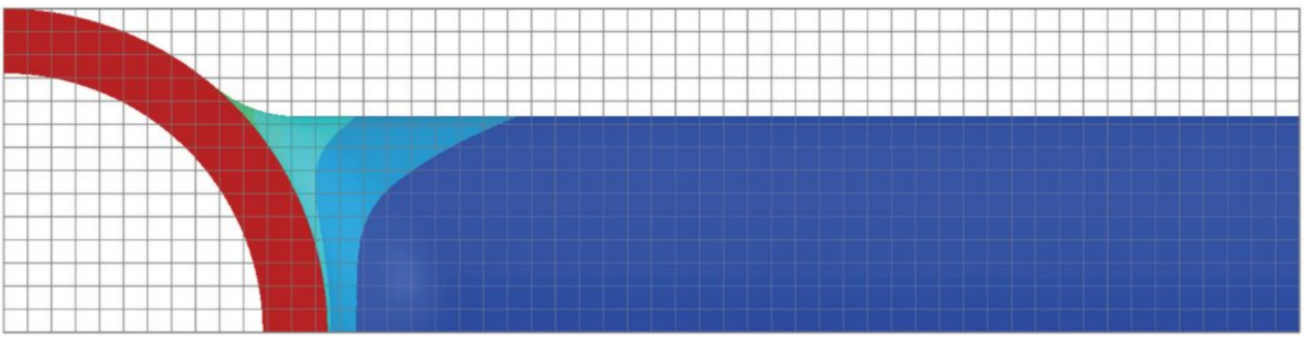

Figure 5: Benchmark 1 showing non-conforming background grid

| midas MeshFree | | | | | Target Solution (Mpa) |
|---|---|---|---|---|---|
| Iteration | Reference Memory (GB) | Number of Degrees of Freedom | Max VM Stress | Deviation | |
| 1 | 0.5 | 60285 | 537.5 | <1% | 534 |
| 2 | 2 | 171678 | 536.5 | <1% | |
| 3 | 4 | 271590 | 536.7 | <1% | |
| 4 | 6 | 380376 | 535.9 | <1% | |
| 5 | 8 | 480813 | 535.5 | <1% | |

Table 1: midas MeshFree - Benchmark 1 Details

## The Benchmark Problems

The benchmark problems are described more comprehensively (including links to download the benchmark geometry) in a white paper accompanying this initiative [5]. This paper is available to NAFEMS members and collates the results of the different codes that have been part of this evaluation.

Seven structural, static, linear elastic, small displacement benchmarks are considered where the target solutions are either a peak stress value (e.g. Maximum Von Mises Stress), peak displacement value, or a spring rate. Contour plots are supplied in order to allow the reader to see how the output in question is distributed throughout the component. One linear dynamic, modal benchmark is also considered where the target solution is the first 5 fundamental modes of vibration. All target solutions have been produced using a traditional finite element approach, with confidence in the target solution generated using mesh refinement studies.

## Benchmark 1 – Pressure Component

Benchmark 1 is a linear elastic stress analysis problem considering an internally pressurised pipe. The solution quantity of interest is the peak Von Mises stress on the inside surface of the main pipe. The details of the analysis settings, number of degrees of freedom in the model, predicted result and target solution are reported in Table 1.

Table 1 demonstrates that there is a linear relationship between the reference memory assigned to the problem and the number of degrees of freedom that are generated. Assuming that the degrees of freedom are being created in appropriate regions, it confirms that the reference memory can be considered as a simple control, allowing the user to transition from a quick and coarse solution to a more time consuming and accurate analysis. This relationship between reference memory and model size holds true for the rest of the problems considered in this study.

The coarsest solution setting produces a maximum Von Mises Stress distribution that is within 1% of the target solution. The contour plot of Von Mises shows a stepped variation that runs in the axial direction of the main pipe. This effect reduces as the reference memory assigned to the solution increases. The highly stressed regions of the inner surface of the pipe are easily identifiable.

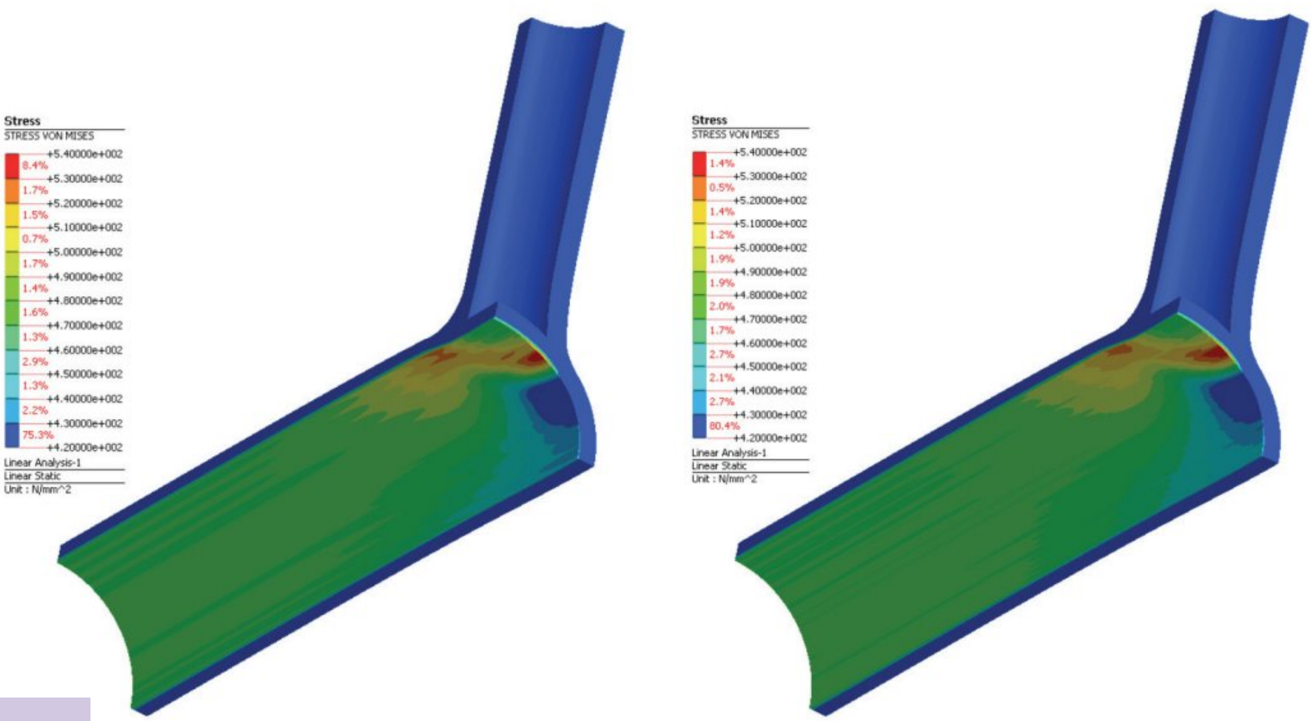


Figure 6: midas MeshFree – VonMises Stress -Contours scoped to 420-540MPa – Iteration 1 Left Hand Side, Iteration 5 Right Hand Side

| midas MeshFree | | | | | Target Solution (N/mm) |
|---|---|---|---|---|---|
| Iteration | Reference Memory (GB) | Number of Degrees of Freedom | Spring Rate (N/mm) | Deviation | |
| 1 | 0.5 | 129978 | 23.4 | 12.5% | 20.8 |
| 2 | 2 | 296292 | 22.1 | 6.3% | |
| 3 | 4 | 445008 | 22.1 | 6.3% | |
| 4 | 6 | 567504 | 20.9 | <1% | |
| 5 | 8 | 780936 | 21.9 | 5.3% | |
| 6 | Not Applicable | 10x10x50 background grids 31233 | 22.1 | 6.3% | |
| 7 | Not Applicable | 20x20x100 background grids 135285 | 21.1 | 1.4% | |
| 8 | Not Applicable | 40x40x200 background grids 682299 | 21.0 | 1.0% | |

Table 2: midas MeshFree - Benchmark 2 Details

## Benchmark 2 – Coil Spring

Benchmark 2 tests the ability of the designer-oriented package to predict the compliance of the coil spring shown in Figure 7. The details of the models and predicted results are shown in Table 2.

The spring rate is obtained by loading the top surface of the spring with a 1mm displacement applied in the axial direction and extracting the resulting reaction force. The reaction forces are calculated in midas MeshFree by graphically selecting the desired surface and hitting the calculate option (see Figure 8).

The coarsest solution setting resulted in a spring rate that deviated by 12.5% from the target solution. As the reference memory assigned to the solution was increased the deviation decreased. Interestingly iteration 4 with 6GB of reference memory provides a result that was almost identical to the target solution while the more computationally expensive 5th iteration was accurate to within 5.3%. This is a challenging benchmark and, understandably, automatically discretising the complex geometry is difficult. If the background grid density is manually set for each of the three primary directions then the solution quickly converges to the target value as shown in the results of iteration 6-8.

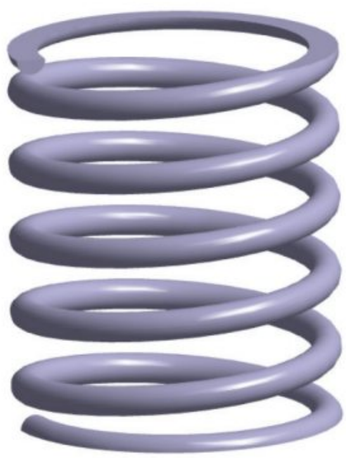

Figure 7: Geometry of the coil spring used in Benchmark 2


Figure 8: midas MeshFree – Iteration 4 - Contours showing deformation – Reaction force associated with extending the spring shown in dialogue box

## Benchmark 3 – Thin Skew Plate in Bending

The third benchmark considers a thin skewed plate (see Figure 9), restrained in a simply supported manner and loaded with a uniform pressure. The thin plate was selected to expose any deficiency in the numerical method's ability to appropriately capture bending behaviour of thin sections.

With the traditional FE approach, the geometry would be midsurfaced and then discretised using a shell element. This additional work is not required with midas MeshFree. The details and results of the midas MeshFree analysis runs are shown in Table 3, while the distribution of maximum principal stress in MeshFree analyses can be viewed in Figure 10.

The peak stress in the midas MeshFree model was extracted by generating a linear path between two corners of the lower surface of the plate. Under the coarsest solution setting the maximum principal stress in the plate centre was predicted with an error of less than 1%.

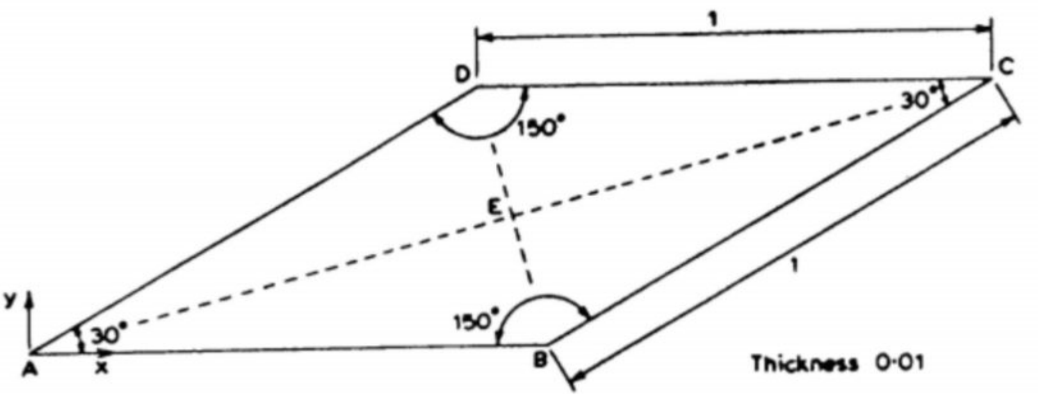


Figure 9: Benchmark 3 – Geometry

| midas MeshFree | | | | | Target Solution (Mpa) |
|---|---|---|---|---|---|
| Iteration | Reference Memory (GB) | Number of Degrees of Freedom | Principal Stress @ Plate Centre (MPa) | Deviation | |
| 1 | 0.5 | 93759 | 0.81 | 1% | 0.82 |
| 2 | 2 | 258345 | 0.82 | <1% | |
| 3 | 4 | 482037 | 0.82 | <1% | |
| As the solution has converged to < 1% of the target solution further runs were deemed unnecessary. | | | | | |

Table 3: midas MeshFree - Benchmark 3 Details

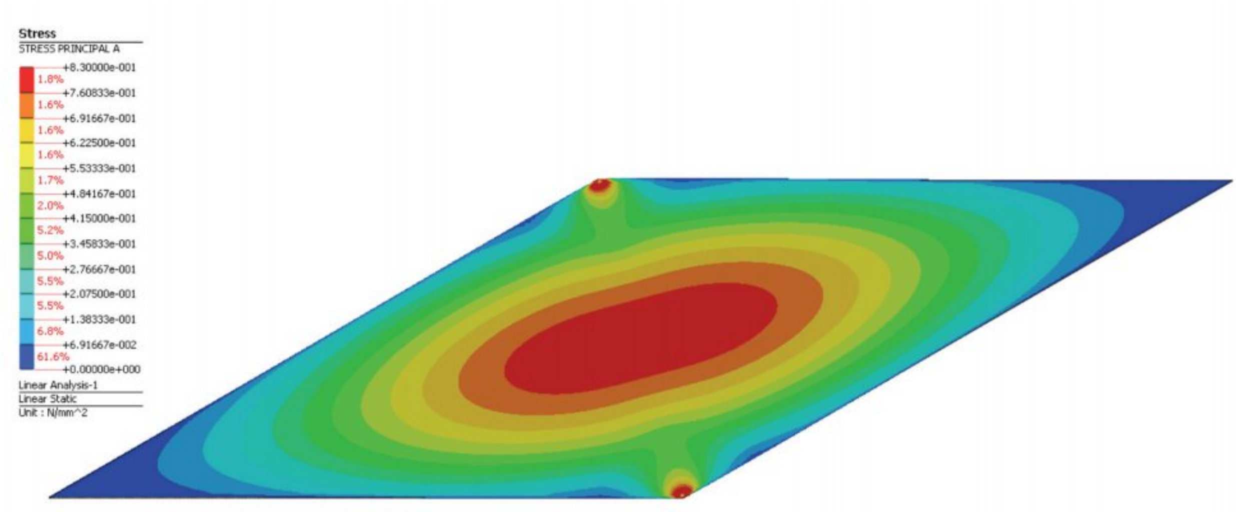


Figure 10: Benchmark 3 – midas MeshFree - Maximum principal stress on plate lower surface

## Benchmark 4 - Stress Concentration - Plate with Hole

The fourth benchmark tests the ability of the "designer oriented" code to capture a stress concentration in a plate containing a small hole. The benchmark has been designed so that the extent of the plate is large in comparison to the size of hole so as to pose a challenge when sizing the mesh in the vicinity of the stress concentration. The geometry used by benchmark 4 is shown in Figure 11 with the analysis details and calculated results available in Table 4. The target solution is the maximum and minimum principal stress in the vicinity of the hole. Many analytical solutions are available for this configuration but care is needed when interpreting the analytical solution as the traditional FEA approach takes the through thickness variation in stress into account.

There is significant solution to solution variation in the MeshFree results as the reference memory is increased. As the solution does not coverage with increased cell density confidence cannot be generated in the results although, from inspection of the 5 solution iterations, the predicted solution was within 14% for the maximum principal stress, and 27% for the minimum principal stress.

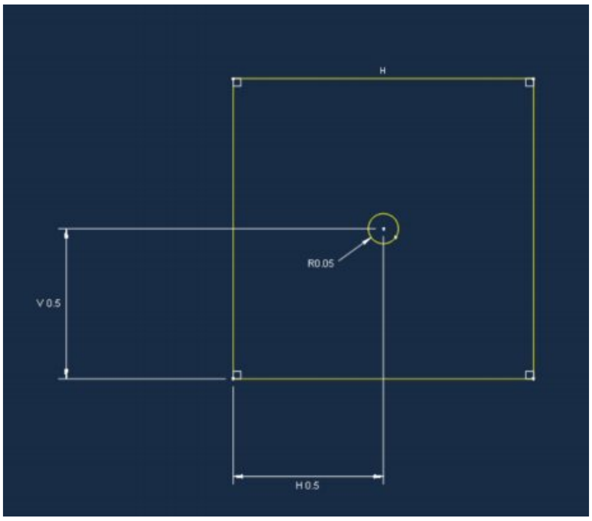


Figure 11: Geometry of the plate with hole benchmark

| midas MeshFree | | | | | | Target Solution (Mpa) |
|---|---|---|---|---|---|---|
| Iteration | Reference Memory (GB) | Number of Degrees of Freedom | Quantity | Stress (MPa) | Deviation | |
| 1 | 0.5 | 149988 | Max Principal Stress | 351.0 | 12% | 314 |
| | | | Min Principal Stress | -127.2 | 12% | -114 |
| 2 | 2 | 362340 | Max Principal Stress | 354.9 | 13% | 314 |
| | | | Min Principal Stress | -129.4 | 14% | -114 |
| 3 | 4 | 672252 | Max Principal Stress | 330.9 | 5% | 314 |
| | | | Min Principal Stress | -122.1 | 7% | -114 |
| 4 | 6 | 939756 | Max Principal Stress | 305.3 | 3% | 314 |
| | | | Min Principal Stress | -101.8 | 11% | -114 |
| 5 | 8 | 1141188 | Max Principal Stress | 359.2 | 14% | 314 |
| | | | Min Principal Stress | -145.1 | 27% | -114 |

Table 4: midas MeshFree - Benchmark 4 Details

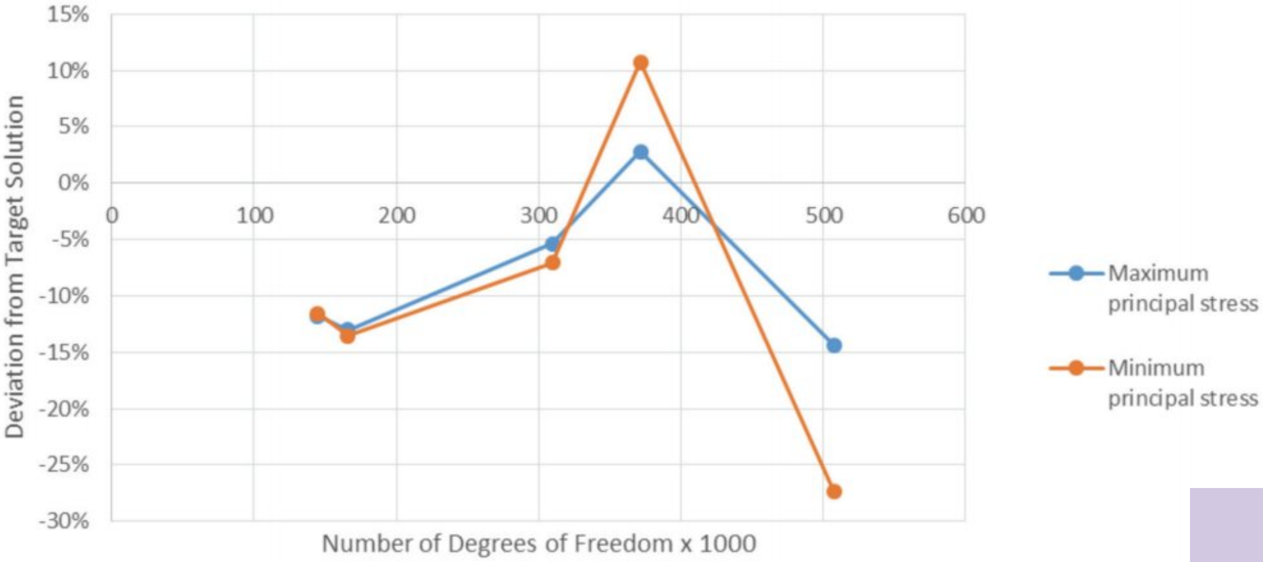


Figure 12: Deviation from target result against model size

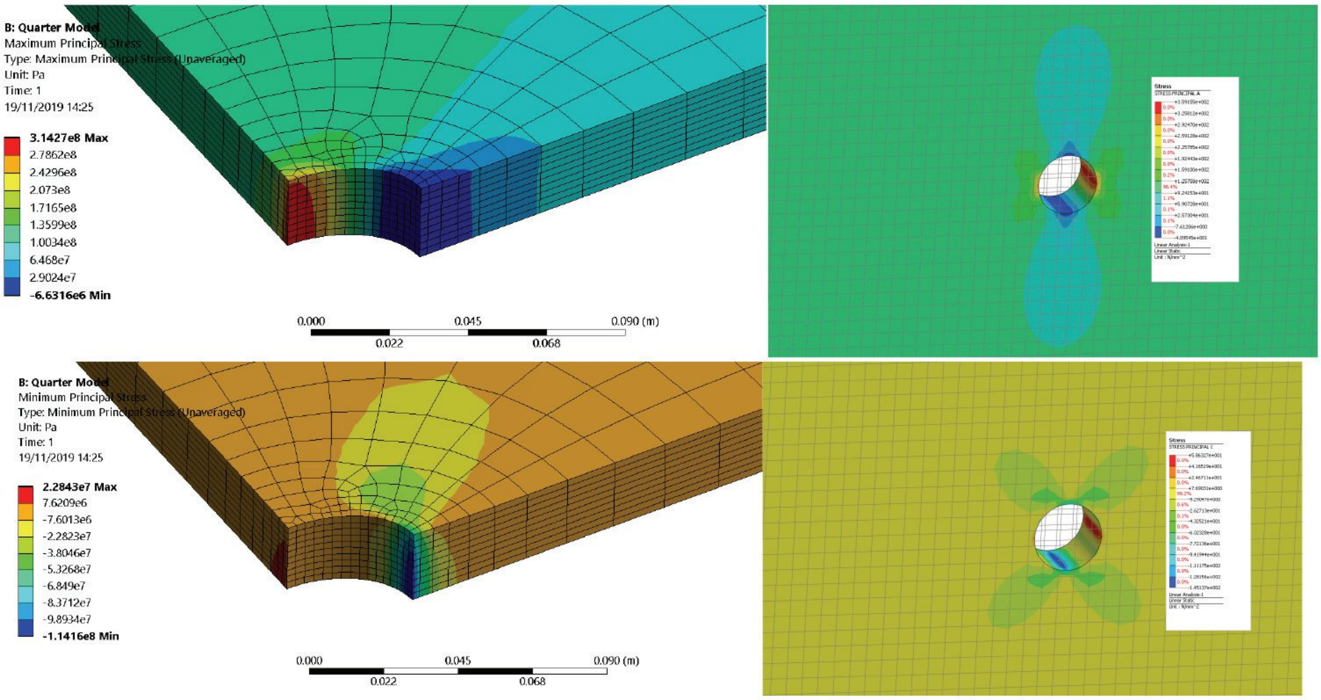


Figure 13: Principal stress results – Maximum (top), Minimum (bottom), Traditional FEA, Target Solutions (left), midas MeshFree (right)

## Benchmark 5 – Stress Concentration Notched Shaft

Benchmark 5 evaluates the ability of the designer oriented software to capture the stress concentration in a notched circular shaft loaded in uniaxial tension. The model details and predicted results are shown Table 5. The maximum principal stress produced by the target solution can be seen in Figure 14 with the midas MeshFree results shown in Figure 15 for Iteration 1 and Iteration 5.

The midas MeshFree solution overpredicts the peak principal stress by between 7% and 13% depending on the level of reference memory assigned to the solution process. Viewing the midas MeshFree principal stress distribution it can be seen that the stress at the centre of the notch has a degree of variation with circumferential position. If the stress at the base of the notch is averaged over the circumference of the shaft it is expected that the results would be a close approximation to the target solution. The variation in stress with circumferential position appears to present a challenge when predicted the stress distribution on curved surfaces. From Figure 15 it can be seen that the circumferential variation in stress reduces when increased reference memory is assigned to the solution i.e. when a denser array of cells is used.

| midas MeshFree | | | | | Target Solution (Mpa) |
|---|---|---|---|---|---|
| Iteration | Reference Memory (GB) | Number of Degrees of Freedom | Maximum Principal Stress (MPa) | Deviation | |
| 1 | 0.5 | 36756 | 56.2 | 13% | 48.2 |
| 2 | 2 | 104361 | 53.1 | 12% | |
| 3 | 4 | 174072 | 55.0 | 7% | |
| 4 | 6 | 225312 | 53.7 | 12% | |
| 5 | 8 | 260193 | 52.2 | 13% | |

Table 5: midas MeshFree - Benchmark 5 Details

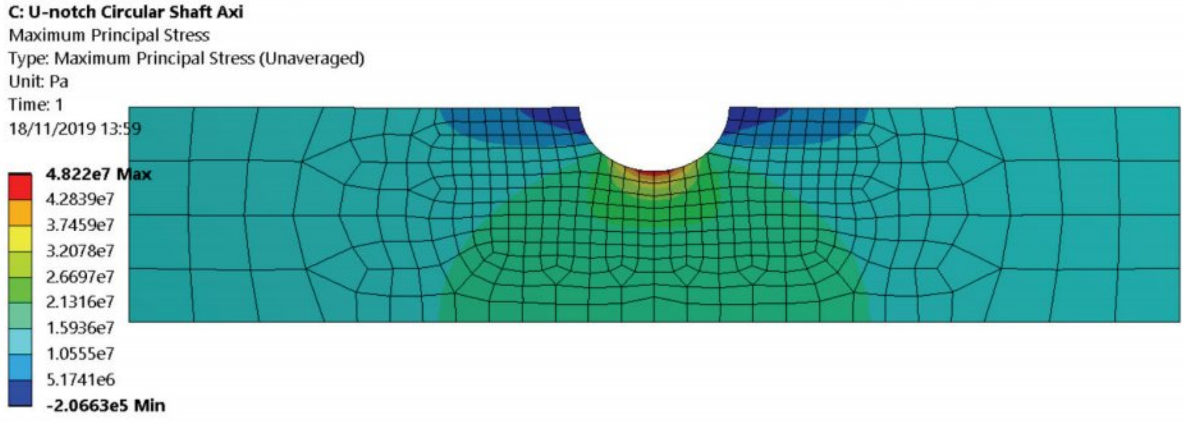


Figure 14: Target Solution – Maximum principal stress

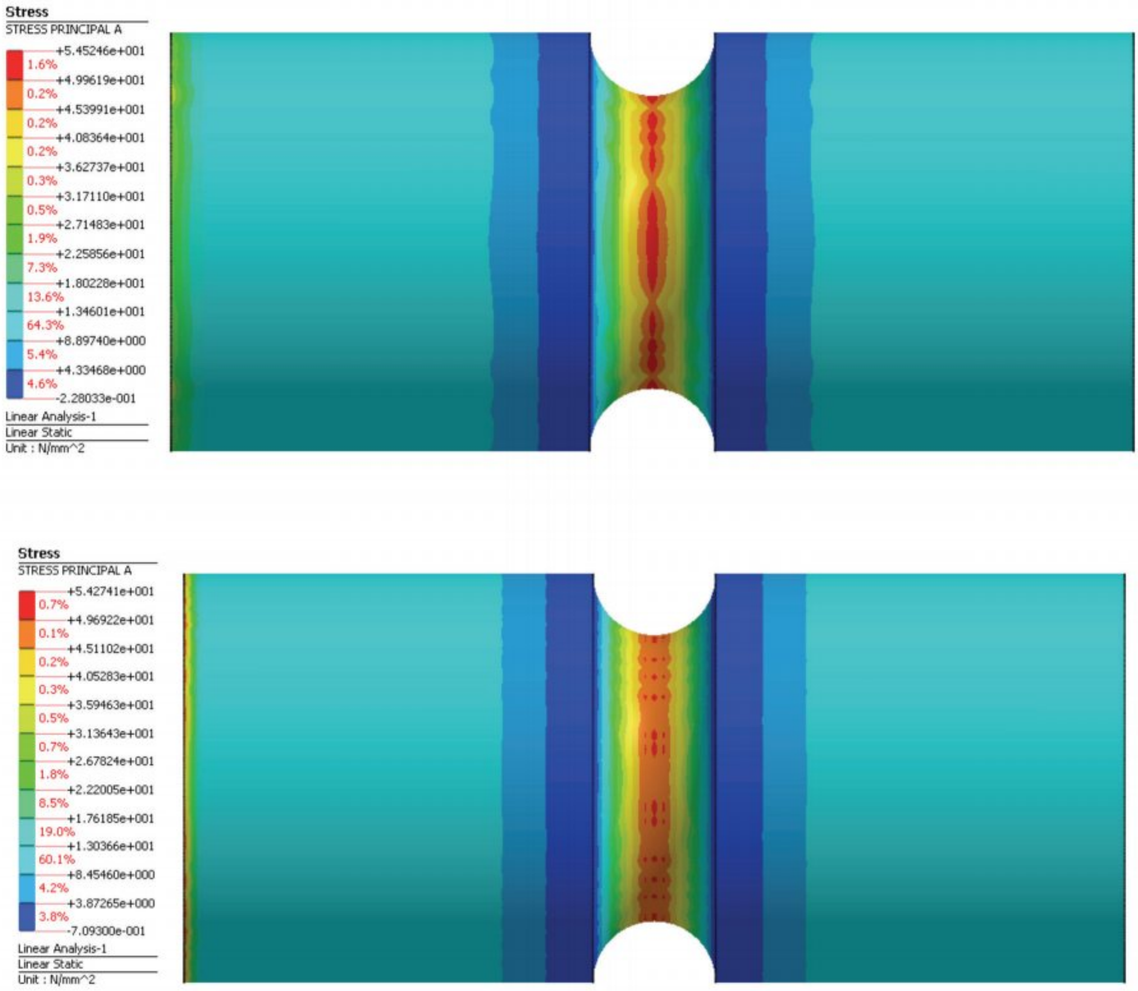


Figure 15: midas MeshFree – Maximum principal stress – 0.5GB Ref Memory Top, 8GB Reference Memory Bottom

## Benchmark 6 - Natural Frequency Thin Cantilevered Plate

The sixth benchmark is designed to test the ability of the software to accurately predict the first five modes of vibration of a thin square plate constrained to act as a cantilever. The solution details are provided in Table 6 with the mode shape associated with the 5th mode of vibration shown in Figure 16.

The results predicted by the coarsest solution setting are a good match to the target solution with a discrepancy of between 1.8% and 2.9%. Interestingly the predicted results do not vary significantly as increased reference memory is assigned to the solution although the analysis diagnostic information indicates that the number of degrees of freedom increase with the additional assigned memory.

| Iteration | Memory (GB) | Number of Degrees of Freedom | Natural Frequency (Hz) | Error | Target Solution (Hz) |
|---|---|---|---|---|---|
| 1 | 0.5 | 239145 | 0.43 | 2.1% | 0.42 |
| | | | 1.05 | 2.9% | 1.02 |
| | | | 2.63 | 1.9% | 2.58 |
| | | | 3.35 | 1.9% | 3.29 |
| | | | 3.82 | 1.8% | 3.75 |
| 2 | 2 | 701073 | 0.43 | 2.0% | 0.42 |
| | | | 1.05 | 2.8% | 1.02 |
| | | | 2.63 | 1.8% | 2.58 |
| | | | 3.35 | 1.9% | 3.29 |
| | | | 3.82 | 1.8% | 3.75 |
| 3 | 4 | 846009 | 0.43 | 2.0% | 0.42 |
| | | | 1.05 | 2.8% | 1.02 |
| | | | 2.63 | 1.8% | 2.58 |
| | | | 3.35 | 1.9% | 3.29 |
| | | | 3.82 | 1.7% | 3.75 |
| There is only minor variation in the results from the 4th and 5th solution iteration and so these results have been omitted. | | | | | |

Table 6: midas MeshFree - Benchmark 6 Details

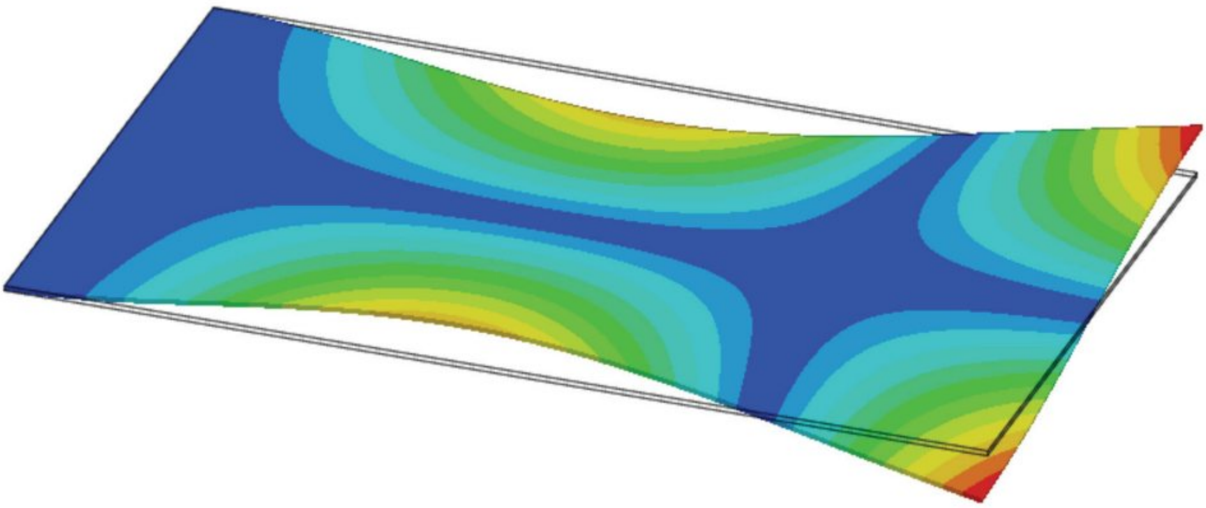

Figure 16: midas MeshFree –Mode Shape 5, Analysis Iteration 1- Contours showing normalised displacement

| midas MeshFree | | | | | | | Target Solution (Mpa) / (mm) |
|---|---|---|---|---|---|---|---|
| Iteration | Reference Memory (GB) | Number of Degrees of Freedom | Maximum Principal Stress (MPa) | Deviation | Maximum Displacement (mm) | Deviation | |
| 1 | 0.5 | 64836 | 221.8 | <1% | -24.7 | <1% | 221.8 / -24.7 |
| 2 | 2 | 220077 | 221.8 | <1% | -24.7 | <1% | |
| 3 | 4 | 337140 | 221.8 | <1% | -24.7 | <1% | |
| As the solution has converged to < 1% of the target solution further runs were deemed unnecessary. | | | | | | | |

Table 7: midas MeshFree - Benchmark 7 Details

## Benchmark 7 – Cantilever Under End Load

Benchmark 7 considers a cantilever beam, fully built in at one end with the other end loaded with a force acting perpendicularly to the beam axis. The target solution for benchmark 7 is the tensile stress found on the top surface, at the constrained end of the beam. While this appears to be a trivial problem and analytical solutions to this problem are readily available, a bending dominated problem has been included in this study as it can highlight deficiencies in both element formulation and the refinement of the automatically generated mesh.

As the midas MeshFree solution converges quickly and only marginal changes in the solution quantities are observed when additional reference memory is assigned to the problem only 3 solution iterations were run.

The simulation details for benchmark 7 can be found in Table 7. Directional stress is not currently an available output in midas MeshFree but fortunately in this case the maximum principal stress (Figure 17) and axial directional stress in this case should be equivalent. The predicted results for both stress and displacement are an excellent match to the target solution.

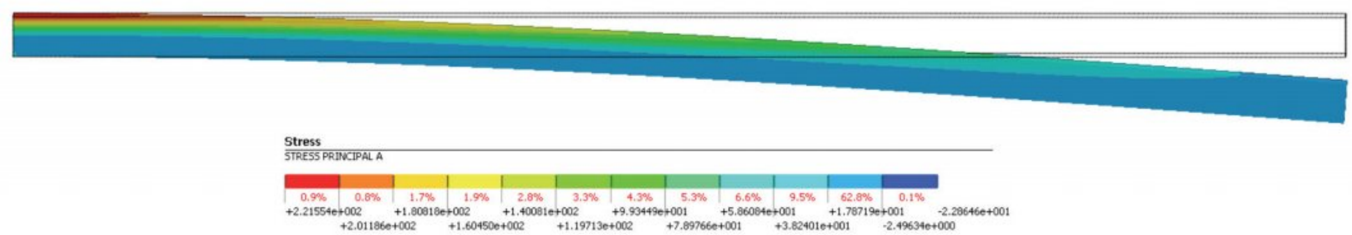


Figure 17: midas MeshFree – Benchmark 7 – Solution Iteration 1– Maximum principal stress.

## Benchmark 8 – Cantilever Under End Load – Stress Concentration

Benchmark 8 extends the geometry and loading used in the previous benchmark by building the geometry used in Benchmark 7 into a larger structure. A fillet radius of 5mm is used to smooth the transition between cantilever and the supporting structure. Benchmark 8 explores the ability of the designer-oriented software packages to capture the stress concentration near the constrained end of the cantilever. The length of the cantilever and the relatively small size of the fillet radius is expected to pose a challenge to an automatic discretisation process.

The target solution for this benchmark is the peak Von Mises stress in the model which should be found at the fillet transitioning between the cantilever and the supporting structure. The solution details and predicted results can be viewed in Table 8.

The convergence of the target solution as the reference memory assigned to the solution process is increased can be seen in Figure 18. Here we can see that there is considerable variation in the result quantity of interest under the first two solution iterations. The results range in accuracy from within 1% when a reference memory of 8GB is assigned to 18%. From Figure 18 it can be seen that there is a considerable variation in the quantity of interest between solution iterations. As the reference memory is increased, the results range in accuracy from within <1% when a reference memory of 8GB is assigned to 18%.

| Iteration | Reference Memory (GB) | Number of Degrees of Freedom | Maximum Von Mises Stress (MPa) | Deviation | Target Solution (MPa) |
|---|---|---|---|---|---|
| 1 | 0.5 | 67872 | 300.5 | 15.7% | 356.5 |
| 2 | 2 | 1437098 | 293.2 | 17.8% | |
| 3 | 4 | 3193381 | 306.4 | 14.1% | |
| 4 | 6 | 384783 | 304.4 | 14.6% | |
| 5 | 8 | 485445 | 355.7 | <1% | |

Table 8: midas MeshFree - Benchmark 8 Details

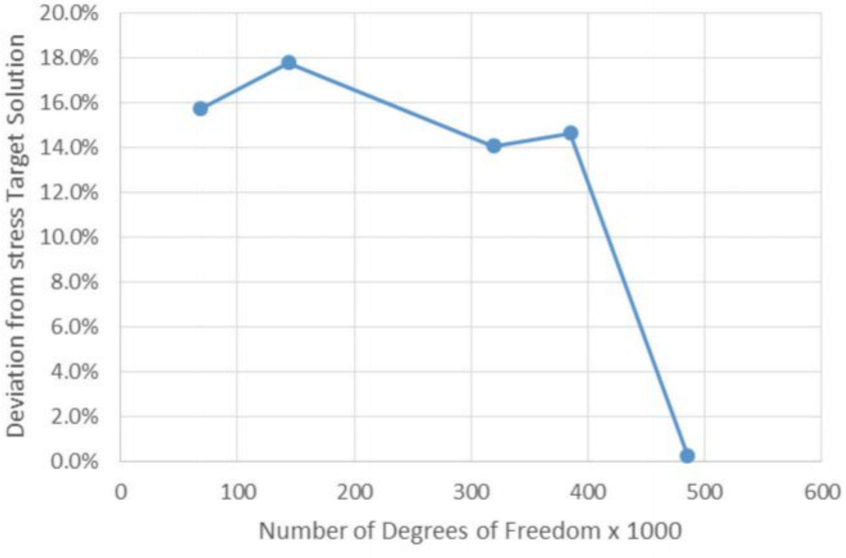


Figure 18: Deviation between peak Von Mises stress and target solution with increased degrees of freedom

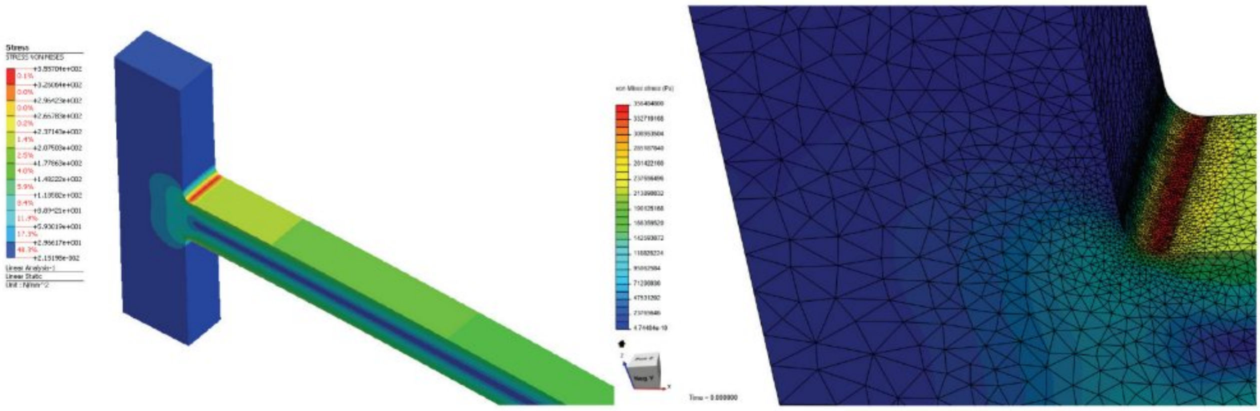

Figure 19: Benchmark 8 – Von Mises Stress – Traditional FEA (right), Midas MeshFree, Iteration 6 (left),

## Conclusion

A summary of the results from the eight benchmarks can be found in Table 9. One of the appealing features of the meshFree tool is the ability to perform a simple refinement study by increasing the reference memory assigned to the solution. Where this approach has allowed a converged solution to be demonstrated, a single value representing the converged results has been included in Table 9. Where it was not possible to demonstrate a converged solution, the range of results produced under different grid densities has been included. MeshFree produced results for benchmarks 1, 3, 6 and 7 that were an excellent match to the target solution even at the lowest accuracy setting (Reference memory set equal to 0.5GB).

While it was not possible to produce a converged solution when running benchmarks 2, 4, 5 and 8, it should be noted that these problems were deliberately selected to push the boundaries of a designer oriented software package.

The analyses run in support of this article have been produced using a maximum reference memory setting of 8GB. It should be noted that there is no limit for the maximum memory that can be assigned to midas MeshFree on a 64bit operating system and so the option of allocating more reference memory is available if your hardware is up to the task.

The analysis process is simple to use and requires no specialist knowledge. The results for thin, flexible components appeared to pose no problem for the numerical method and models can be turned around quickly as the midsurfacing preprocessing step is effectively removed from the method workflow.

NAFEMS members interested in further details of the benchmarks are encouraged to read the "Designer Oriented Software – Evaluation" white paper available at **nafe.ms/designer** and we hope to continue this series in following issues of Benchmark.

| Benchmark | Description | Quantity | Target Solution | midas MeshFree | |
|---|---|---|---|---|---|
| | | | | Result | Deviation |
| 1 | Pressure component | Von Mises Stress | 534MPa | 534.1MPa | <1% |
| 2 | Coil spring | Spring rate | 20.8N/mm | 20.9-23.4N/mm | <1-12.5% |
| 3 | Thin skew plate | Maximum principal stress | 0.82MPa | 0.82MPa | <1% |
| 4 | Plate with hole | Maximum principal stress | 314MPa | 305.2-359.2MPa | 3-14% |
| | | Minimum principal stress | -114MPa | -101.8->145.1MPa | 7%-27% |
| 5 | U-shaped notch | Maximum principal stress | 48.2MPa | 51.6-54.5MPa | 7-13% |
| 6 | Cantilevered plate | Mode 1 | 0.42Hz | 0.43 | 2.0% |
| | | Mode 2 | 1.02Hz | 1.05 | 2.8% |
| | | Mode 3 | 2.58Hz | 2.63 | 1.8% |
| | | Mode 4 | 3.29Hz | 3.35 | 1.9% |
| | | Mode 5 | 3.75Hz | 3.82 | 1.7% |
| 7 | Cantilever – bending dominated | Axial Stress | 221MPa | 221.6MPa | <1% |
| | | Displacement | 0.0247m | 0.0247m | <1% |
| 8 | Fillet Radius | Von Mises Stress | 356.5MPa | 293.2-355.7MPa | <1-17.8% |

**Table 9: A summary of the midas Mesh Free results for all the benchmarks**

## References


[1]. I. Symington, "Designer Oriented Software Is it Accurate?", 16 January 2020. [Online]. Available: **https://www.nafems.org/publications/resource_center/bm_jan_20_1/**. [Accessed 14 April 2020].

[2]. "MESH FREE makes you FREE," MIDASIT, [Online]. Available: **http://www.midasmeshfree.com/**. [Accessed 2020 April 14].

[3]. A. Kumar, S. Padmanabhan, Burla. R, "Implicit boundary method for finite element analysis using non-conforming mesh or grid", Int. J. Numer. Meth. Engng 2008; 74:1421-1447

[4]. A. Düster, J. Parvizian b, Z. Yang, E. Rank, "The finite cell method for three-dimensional problems of solid mechanics", Comput. Methods Appl. Mech. Engrg., vol. 197, pp 3768-3782 Aug 2008, 3768-3782

[5]. I. Symington, "Designer Orientated Software Evaluation – White Paper", 16 January 2020 [Online]. Available: **https://www.nafems.org/publications/resource_center/wp_jan_20/. [Accessed 14 April 2020].**


## About MidasIT

NAFEMS would like to thank **Piotr Stepien** and **Sungwoon Woo** for sharing their knowledge of the methods that underpin the meshFree tool.