Simulation of rotation and scaling algorithm for numerically modelled structures

S K Ruhit*, A Vijaya and Sunil Singh Kotia

1,3PG Student, Department of Mechanical Engineering, SRM Institute of Science and Technology, India.
2Assistant Professor, Department of Mechanical Engineering, SRM Institute of Science and Technology, India.

*Corresponding Author: ruhit_abdulkhyuam@srmuniv.edu.in,

Abstract. ANSYS (APDL) has become one of the important solver tools of Finite element analysis. Numerical analysis is carried out for different structures in ANSYS. In few instances, experiments should be conducted repeatedly by changing the orientation or scale of the model to validate their algorithm or experimental techniques. The experimental results should be verified with numerical analysis in ANSYS for different modelling and orientation. Hence, for solving the same structure for different scaling and orientation, it requires the repeated time consuming procedure in ANSYS. This problem can be overcome by importing the results obtained at the nodes of any one of the model in MATLAB and simulating those results for different orientations and change in size of the model with the help of simple mathematical formulas of rotation and scaling. The simulation of the solved results has been carried out in MATLAB. The case studies of identical centrally loaded corner supported square plate as well as triangular plate are considered and they are modelled for different orientation and scaling respectively, and the simulated results are compared with the results obtained in ANSYS.

Keywords. Rotation; Scaling; ANSYS; Centrally loaded Square and Triangular plate; Partial slope;

1. Introduction

Finite element analysis has nowadays become an integral part of Computer Aided Engineering (CAE) analysis and is being extensively used in the design and analysis of many complex engineering problems. The field of finite element analysis has matured to such an extent that it now rests on rigorous mathematical foundation. Many commercial softwares have been developed overtime to explore the vast field of FEA. One such powerful software that is widely being utilized in industry and academic research is ANSYS (APDL). Though ANSYS has developed itself into most user friendly solver system related to solving numerical analysis problems, few drawbacks still remain, which needs to be tapped in order to morph it into a favourable user interfaced solver system. One such problem faced in ANSYS is regarding the rotation and scaling of the developed solved model. Martelli [1] carried out simulations for coupling problems for a model related to CFD in ANSYS (FLUENT), but didn't address the problems faced by users for structural analysis.

Developing a model in ANSYS is the most time consuming and cumbersome process that involves extensive input of parameters [2][3]. In most of the practical cases, it may become a
necessity to rotate the model while keeping the same boundary conditions or to scale the model with the same boundary conditions. This rotation and scaling of the model can be carried out by remodelling the structure in ANSYS either by changing the dimensions in terms of trigonometric functions or else by multiplying the dimensions with suitable scaling factor respectively. As most of the practical structures have complex shapes with many material and loading parameters being involved to model them, it becomes a daunting task to re-model the structure in ANSYS with varying rotation and scaling. Vijaya [4] simulated the ANSYS nodal values along the desired path for different loading and positioning. Bianchi [5] developed customised grid methodology which aids in using nodal values by generating interpolated range values.

In this present work, a MATLAB coding has been developed in such a way that by importing ANSYS nodal results along with its co-ordinates for any solved model from different domains, is sufficient for simulating results in different orientations or scaling. The existing available algorithms deal only with change in the geometrical co-ordinates in X & Y axis whereas, this simulation is concerned with changing the Z value appropriately based on the changes in geometrical co-ordinates. The objective of this study is to present and compare the simulated partial slope values for centrally loaded corner supported square and triangular plate with ANSYS solution.

2. Rotation and Scaling

2.1. Basic principal of Rotation

Rotation involves re-positioning of the object along x-y plane in the circular path. Parameters that are required for the two-dimensional rotation are the rotation angle (θ) and two rotation points called pivot points, (x,y) as shown in figure 1a.

From Pauline Baker [6], based on below transformation equation (1) and (2), rotation of the pivot points is performed.

\[ x^1 = x \cos(\theta - y \sin \theta) \]
\[ y^1 = x \cos(\theta + y \sin \theta) \]

The above two equations form the basis for simulating rotation. Here \( x^1 \) and \( y^1 \) represent the co-ordinate of new rotated dimension. The algorithm is developed in a way where it utilizes the principal of these rotation transformation equations.

The nodal cloud obtained after importing ANSYS values into MATLAB too are scaled with constant \( C \), which in turn leads to expanded or shrinked slope values depending on the scaling factor.

2.2. Basic principal of Scaling

Dimensional scaling process involves either expanding or shrinking the size of the model. Scaling operation can be performed by multiplying a suitable scaling factor with the co-ordinates to produce scaled transformed co-ordinates as shown in figure 1b.

\[ \begin{bmatrix} M \\ N \end{bmatrix} = \begin{bmatrix} C & 0 \\ 0 & C \end{bmatrix} \begin{bmatrix} X \\ Y \end{bmatrix} \]

Where M and N are scaled co-ordinates, C is scaling constant and X & Y are original co-ordinates.

Scaling constant ‘C’ is obtained from below equation (4)

\[ C = \frac{M}{X} \]
The nodal cloud obtained after importing ANSYS values into MATLAB too are scaled with constant C, which in turn leads to expanded or shrinked slope values depending on the scaling factor.

(a) Figure 1. Representation of Rotation (a) and Scaling (b)

3. Methodology

In this present study, a 2-D model of thin plate is structurally analysed in ANSYS (APDL). A plate is modelled by taking its length parallel to X axis, solved and post-processed to get slope values in X and Y direction. The nodal co-ordinates along with its results are exported to MATLAB and results are simulated based on the desired angle of rotation and scaling factor. The simulated results are verified by modelling and solving the same plate in different orientations or by scaling its size in ANSYS. The square plate of same dimensions and equiangular triangular plate is modelled for verification of rotation and scaling respectively. Below flowchart gives the cycle of simulation undertaken in this work.

Figure 2. Flow Chart of Simulation.

4. Numerical Analysis of Square plate for different orientations

A square plate of dimension 29*29*2mm has been modelled with centrally loaded in terms of displacement and corner supported on four of its corners. The same plate is modelled with same boundary and loading condition by rotating its center at 45 degrees about Z axis orientation (Rhombus). By applying suitable parameters and solving the model, post processed results of slope values are
obtained. The input parameters for the ANSYS [7] is given below in Table 1:

| Table 1. ANSYS Input Parameters. |
|----------------------------------|
| **Element Type** | **Shell 4 Node 181** |
| Elastic Modulus | 2500 N/mm² |
| Poisson's Ratio | 0.3 |
| Uₓ, Uᵧ, Uz, ROTz | 0 |
| Known Displacement (At Centre) | 0.01mm |

Both the models are solved and the nodal results along with its co-ordinates are exported to MATLAB. In MATLAB, a coding is generated using Scattered Interpolant for simulating the cloud points.

**Figure 3.** Schematic representation of Rotation.
In order to get the results in matrix form, a regular grid is generated and the values are interpolated from the mathematical fitted function (Scattered Interpolant Function) [4]. The generated grid is used to simulate the results for different orientations using the rotate function in MATLAB [8]. This function sets the axis of rotation normal to X & Y direction and rotates the co-ordinates using transformation equations described in Eq. 1 & 2, while simultaneously calculating the nodal cloud shift in Z direction which gives the required result. The generated co-ordinates are again interpolated in a new grid as shown in figure 3c.

In order to verify the viability of the simulated rotation, the slope values along the diagonal of the square is used for comparison purpose. In figure 3a, let diagonal AB of square be called as principal diagonal along which slope values can be compared. The principal diagonal AB in square when rotated by 45 becomes CD in rhombus as in figure 3c, which means that the diagonal of square should be equal to the horizontal axis of rhombus CD. The slope values obtained by simulated rotation along principal diagonal CD should be equal to the slope value obtained from ANSYS for rhombus along CD.

5. Numerical Analysis and Application of Triangular plate

An equiangular triangle of 100*80mm and 120*100mm has been modelled with centrally loaded in terms of displacement and corner supported on three of its corners, Figure 4a & 4c. The height is considered as principal height and the variation of slope is measured along this principal height. The simulation flowchart shown in figure 2 is followed for scaling. By multiplying the co-ordinates with the required scaling constant, C from Eq.4, the scaled co-ordinates is obtained. From Timoshenko [9], the slope is inversely proportional to the constant, C. Based on this, scaled slope values are obtained and principal height is compared for simulated scaled model and ANSYS model.

Figure 4. Schematic representation of Scaling.
6. Results and Discussions

6.1. Rotation

From figure 5, blue curve represents the slope values along principal diagonal AB of square as shown in figure 3a, which was modelled in ANSYS while black curve represents the slope values along principal diagonal of rhombus as shown in figure 3d that was obtained from ANSYS. The red dots represent slope values obtained by simulating rotation in MATLAB. It is evident from the above results, the slope values of the rotated model (rhombus) obtained from algorithm completely matches to the slope values obtained from ANSYS rhombus model.

6.2. Scaling

From figure 6, red curve represents the slope value along principal height of initial triangle modelled in ANSYS as shown in figure 4a, while blue curve represents the slope values along principal height of scaled simulated triangle in MATLAB as shown in figure 4d. The green curve represents the slope values obtained from scaled model of ANSYS. From the curves, the slope values obtained by simulating scaling vary slightly from the slope values of scaled model in ANSYS with error being 6.25%. This error can be minimized by using double precision nodal values.
7. Conclusion

The simulated present study helps the researchers who want to repeat the experiment for structures of same loading and boundary conditions but in different orientations and scaling, where the nodal results and coordinates once exported to MATLAB is sufficient for getting the results in different orientations and sizes. However, the simulated results obtained for different orientations for the structured model is more accurate than the simulated scaled results, this is due to numerical round-off errors. This can be improved by increasing double precision for the nodal values in MATLAB. Using this simulation, one can reduce the time consumed for numerical analysis. The same program can be modified and extended for solving other problems involving structural, thermal, CFD, magnetic field analysis etc.,

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