Инженерный вестник Дона, №2 (2019)
ivdon.ru/ru/magazine/archive/n2y2019/5754

Sensitivity analysis as a tool for time consumption during simulation

I.A. Magomedov, H.A Murzaev

Chechen State University, Grozny

Annotation: The following work looked into sensitivity analysis. Sensitivity analysis is used to gather some data of analysed problem and further to reduce the time required to run a simulation. The work explains importance of the tool in field of mechanics engineering. The work briefly outlines applications of the tool in industries. Also, I-beam analysis was done to better understand influence of sensitivity analysis. The results illustrated that by reducing nodes in the geometry of the I-beam the output values stay the same, but too much reduction will lead to incorrect results. The comparison of the two methods also took a place in this work, to see the correlations and discrepancy of the problem.
Keywords: sensitive analysis, time reduction, finite element, I-beam, simulation

Introduction

Present day time values more than anything and can be a key point to the success. With a start of industrialization, where machineries were introduced to quicken production time, human resources were cut out, but few left to control and improve them. It is well known that companies spent a lot of money to reduce production time. Reduction not always mean a quality. Therefore, there should be a golden mean. Sensitivity analysis is used to balance time and quality. Hence it utilized in many industries. However, this article is focused on mechanics, thus sensitivity analysis will be used to reduce the time required to analysis 3D representations of real-world objects. In other words, sensitivity analysis in the context of engineering system design. Many software are able to calculate (simulate) enormous amount of data. It can be a complex analysis of fracture mechanics, simulations fluids flow, or composite analysis [1]. Software as Solidworks, Ansys or Abaqus are well used in industry as they are standards in those fields. In spite of this the amount of time required to calculate complex analysis is huge. Here can be introduces sensitivity analysis to deal with excessive time usage, where time and quality goes together.

Sensitive analysis

With the development of innovative technologies and methods of numerical analysis, mechanical engineering and other fields of science have vital demand of usage of complex models to investigate and navigate researchers' analyses . Many researchers utilize different models to predict behavior of such a system by using different methods [2]. A common use of input-output relationship can be represented as shown in the formula 1 below. Where X stands for the input values and Y for the output values, which signifies product/system performance. Relationship function between X and Y is indicated as f [3].

$$Y=f\,(X) \tag{1}$$

A representation of mathematical model, such as finite element or any related ones in a modern world can be extremely complex, therefore its relationships between input values and output values can be hard to comprehend. Decent knowledge in modeling process will lead to a better result [4]. Knowledge should consist of, first, evaluation of number of the uncertainty in results, and second, how much each input values contributed to the output values of uncertainty. Sensitivity analysis can be used to address the second of these problems, acting the role of ordering by importance the strength and relevance of the inputs in defining the distinction in the output [5].

To gather data for the sensitivity analysis requires model to be run various time. However, it's not always handy: firstly, a single model requires significant amount of time to be simulated and it can take hours depending on the complexity of the running model, second one is, that model could have numerous uncertainties as inputs. It is well known that with a growth of uncertain inputs sensitivity analysis time consumption will increase exponentially. Sensitivity analysis has several approaches when dealing with the analysis of the models :

1. Correlated inputs
2. Nonlinearity
3. Model interactions
4. Multiple outputs

5. Given data

The narrative of the work is to use numbers of iteration during simulation and to plot the graph of sensitive analysis, where by using different inputs (boundary conditions and segments or nodes number) to minimize time consumption and keep quality of the results constant. Sensitivity analysis helpful tool to recognize the influence of uncertainties in the system and afterward to reduce. For instance, sensitivity analysis can be utilized to investigate how "variation in the output of a model ... can be apportioned, qualitatively or quantitatively, to different sources of variation, and how the given model depends upon the information fed into it". Therefore, to answer the main questions: "What are the key factors that contribute to variability in model outputs?" and "On which factors should research aimed at reducing output variability focus?" [6].

Methodology

Manual calculation

Using data from table 1 the following results deflection and bending strain were calculated (table 2). To calculate these values formulas of bending strain and deflection were used (formula 1, 2 respectively). All values were calculated manually. To work out deflection and bending strain values force (F) was applied. Different values of forces were added: 9810, 5000 and 1000 N.

$$\sigma = \frac{My}{I} = \frac{Fxy}{\frac{bd^3}{12}} \qquad (2)$$

$$\delta = \frac{FL}{48EI} = \frac{FL}{48E\frac{bd^3}{12}} \qquad (3)$$

Table № 1

Properties of steel and I-beam dimensions

Properties of steel					
Density			7,850 kg/m³		
Modulus of elasticity (Young's modulus)			E = 200 * 10³ MPa		
Poisson's ratio			μ=0.30		
Shear modulus G = E / 2 (1+μ)			G = 77 * 10³ MPa		
Dimensions of I-beam					
Length (мм)	Breadth (мм)	Hight (мм)	Web thickness (мм)	Flange thickness (мм)	Position of centroid (мм)
5000.00	148.00	266.00	7.60	13.00	133.00

Numerical analysis

To understand the necessity of sensitivity analysis finite element model was built. Finite element consisted of a simple I-beam. A powerful tool Abaqus was used to investigate the problem. The following boundary conditions were added: model was constrained from both edges and force value were added at the mid of the construction. The same values were kept from the table 1 to represent the 3d model as in real environment.

Results

After simulation was run the necessary results were gathered with some number of nodes. Then the number of nodes were reduced by iteration to look at results, of both methods, to distinguish correlation/discrepancy. Its obvious that at some point of the reduction of nodes the final results of numerical analysis would be incorrect. Sensitivity analysis plot was plot (figure 1). The figure 1 illustrates that at approximately 150 and further increase of nodes are unnecessary. However, before the value 150 results are unstable. Table 2 represents values from manual calculations and numerical analysis. The similarity of the results of two methods are the same. Therefore, it can be said, that 150 nodes are enough for I-beam analysis with scoped problem.

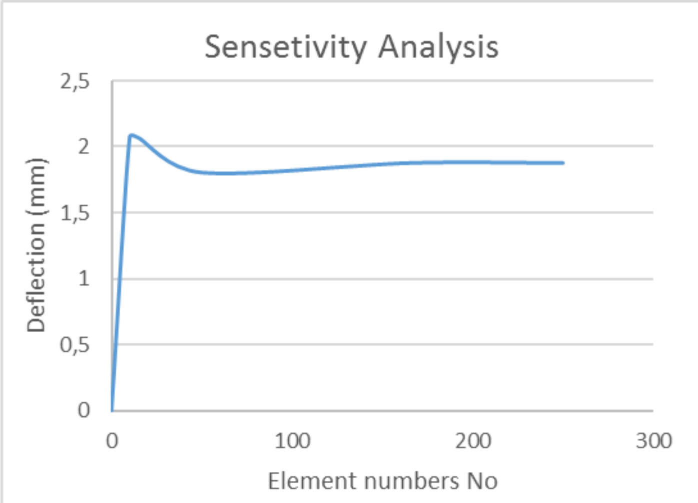

Fig. 1. Sensitivity Analysis

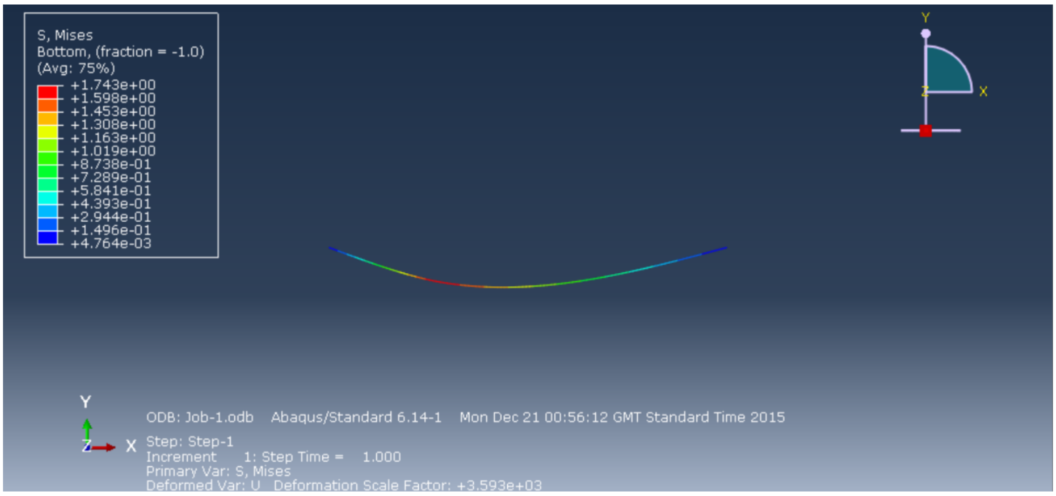

Fig. 2. Deformed I-beam

Table № 2

Gathered results of manual calculations of numerical analysis

Manual calculation		
Force (N)	Deflection (mm)	bending strain (MPa)
9810	1.8140	23.160
5000	0.9240	11.810
1000	0.1850	2.360
Numerical analysis		
9810	1.880	22.07
5000	0.958	11.21
1000	0.192	1.120

Conclusion

For the conclusion, the following work was done to illustrate the importance of the tool called sensitivity analysis. This work analyzed I-beam problem with some load to be hanged (applied) from the middle of it. Both manual calculation and numerical analysis was done to work out deflection and bending strain of the I-beam. The correlation of those two methods were almost exact with the use of calculated numbers of nodes. Sensitivity analysis showed that with its usage time required for the simulation for further calculation can be reduced.

References

1. Magomadov V.S. Quantum computing, quantum theory and artificial intelligence. Inženernyj vestnik Dona (Rus). 2018. №4. URL: ivdon.ru/ru/magazine/archive/n4y2018/5424.

2. Der Kiureghian, A.; Ditlevsen, O. (2009). "Aleatory or epistemic? Does it matter?". Structural Safety. 31 (2): pp. 105–112.

3. Agus S., Xiaoping Du. (2005). Probabilistic Sensitivity Analysis in Engineering Design using Uniform Sampling and Saddlepoint Approximation, pp.1-3.

4. Saltelli, A.; Ratto, M.; Andres, T.; Campolongo, F.; Cariboni, J.; Gatelli, D.; Saisana, M.; Tarantola, S. (2008). Global Sensitivity Analysis: The Primer. John Wiley & Sons. pp. 183-184

5. A. Saltelli, K. Chan, and E. M. Scott. Sensitivity Analysis. John Wiley & Sons, Inc., New York, NY, 2000. pp. 1-3.

6. D. L. Allaire. Uncertainty Assessment of Complex Models with Application to Aviation Environmental Systems. PhD thesis, Massachusetts Institute of Technology, Cambridge, MA, 2009. p. 19.

7. Cacuci, Dan G. (2003) Sensitivity and Uncertainty Analysis: Theory. I. Chapman & Hall. 28 p.

8. Yakovlev M. Y. Yakovleva M. Y. Inženernyj vestnik Dona (Rus). 2012. №2. URL: ivdon.ru/ru/magazine/archive/n2y2013/1639.

9. Bahremand, A.; De Smedt, F. (2008). "Distributed Hydrological Modeling and Sensitivity Analysis in Torysa Watershed, Slovakia". Water Resources Management. 22 (3): pp. 293–408.

10. Hill, M.; Tiedeman, C. (2007). Effective Groundwater Model Calibration, with Analysis of Data, Sensitivities, Predictions, and Uncertainty. John Wiley & Sons. pp. 26-40.