

DIGITAL TECHNOLOGIES IN THE AUTOMOTIVE INDUSTRY: 3D MODELING AND VIRTUAL TESTING SYSTEMS

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Abstract. *This research examines the improved mechanism for adjusting the base of a variable-base tractor, which is essential for cultivating sloped, rainfed farmlands. The research determines the possible types and magnitudes of loads including compression, stress, shear, and safety factors as well as their directions under real field conditions. In addition, the influence of these loads on the variable-base tractor was evaluated through Finite Element Analysis (FEA).*

Keywords: *Additional loads, stress, displacement, compression, safety factor, variable base.*

Finite Element Analysis (FEA) is a highly effective computational method used to address complex engineering challenges that are difficult to solve using traditional analytical techniques. It enables engineers to determine stresses, deflections, and displacements within both simple and complex structures. FEA is widely applied in areas such as thermal, structural, and fluid flow analyses.

At its core, FEA works by breaking down a structure or component into smaller, more manageable parts through a process known as discretization. These parts, called *finite elements*, are assigned specific displacement functions and are connected at common points such as nodes, lines, and surfaces. Using the material properties of the structure, the response of each node is calculated based on the behavior of the surrounding elements. This process results in a system of equations for each node, which is solved using matrix operations to predict the structure's overall behavior.

Rather than relying on complex differential equations used in analytical methods, FEA employs numerical and matrix-based techniques that simplify computation. Although the results are approximations, accuracy can be enhanced by increasing the number of nodes—resulting in a finer mesh and a more precise solution.

Some of the most widely used and feature-rich industry packages include ADINA, ANSYS Mechanical, NEi/Nastran, SolidWorks, Pro/MECHANICA, COSMOS. Software such as Works, COMSOL, and Strand 7 are commonly used for Finite Element Analysis (FEA). Ultimately, the most suitable FEA package depends on the specific requirements of your application and your available budget. By utilizing computational power, FEA software efficiently solves complex mathematical

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equations, making it an indispensable tool for engineers seeking to understand and predict the performance of structures and components.

The accuracy of FEA results largely depends on the analyst's knowledge and expertise. When used properly, the software can yield precise and reliable outcomes. For instance, a study conducted by Leon O.N., Orta S.P., and Adaya (2000) revealed only a 5.17% deviation between experimental data and FEA predictions, demonstrating the method's high level of reliability. However, interpreting FEA outcomes requires careful consideration—particularly in applying correct loadings, boundary conditions, and constraints to a well-constructed model. As Toogood (2012) highlighted, the “garbage in, garbage out” (GIGO) principle applies: the quality of input data directly influences the accuracy of the results.

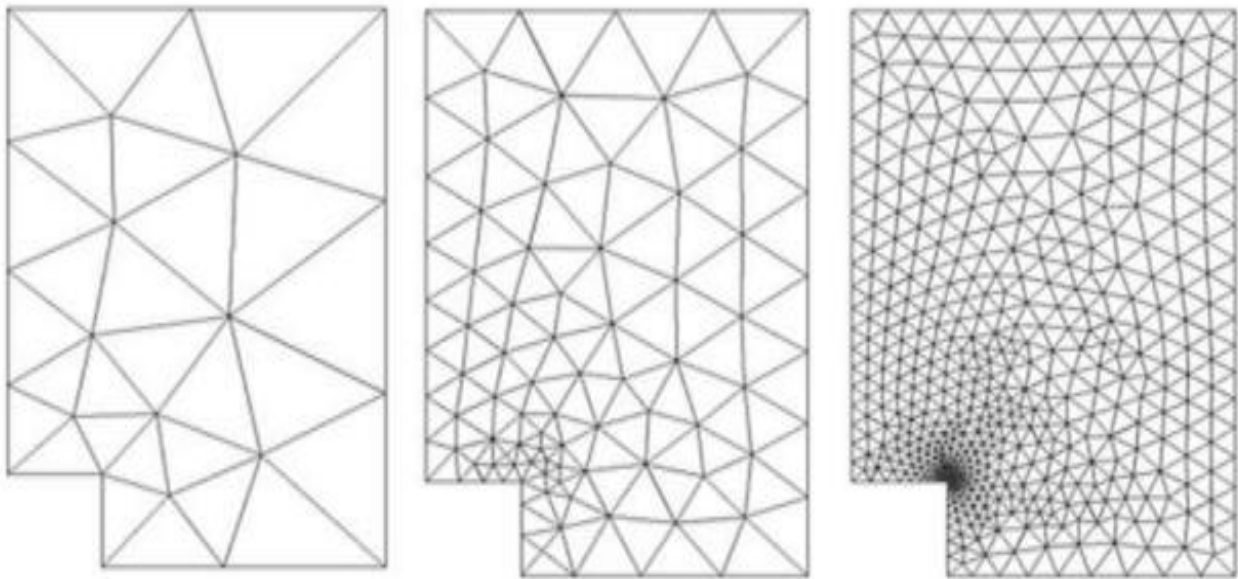
Why Use Finite Element Analysis?

1. FEA provides an economical method for validating the structural, thermal, or modal performance of new designs or modifications. Traditionally, engineers relied on physical prototypes and field testing, which were both costly and time-consuming. Any design flaw required expensive rework. FEA replaces this process with virtual simulations, allowing engineers to detect issues and make improvements early in the design phase—reducing costs and increasing efficiency.

2. FEA enables engineers to replicate real-world loads and constraints on components. By applying forces and boundary conditions such as fixed supports, planar surfaces, or pin joints, engineers can closely simulate how a part will behave under actual working conditions.

3. FEA facilitates rapid evaluation of a component's response to various load and constraint scenarios, depending on model complexity and computing resources. If results are unsatisfactory, the design can be easily modified and reanalyzed, enabling quick iteration and optimization during the development process.

4. Utilizing 3D parametric models in FEA provides the benefit of quick and flexible geometry modification. If the analysis results are unsatisfactory, the analyst can easily update the model by adjusting its defining parameters. This enables rapid design iteration and optimization without the need to recreate the model from scratch. An example of such refinements is illustrated in Figure 1.



(a)-Coarse mesh (b)-Intermediate mesh (c)-Fine mesh

Figure 1. Mesh refinements. (Source: <https://community.wvu.edu>).

Static and structural analysis of a component (or model) typically consists of three main stages: **pre-processing**, **processing**, and **post-processing**. In the **pre-processing** stage, the model is prepared for analysis by transforming it into a finite element model. During this step, the essential characteristics and parameters of the model are defined to ensure accurate simulation results.

The next step involves defining the material used in the new model along with its key mechanical properties (such as strength and stiffness). For the TTZ 80 10 universal tractor’s body and frame, the primary material selected is **Steel 35**. The characteristics of the Steel 35 grade are specified in accordance with **GOST 1050**, the national standard of the Republic of Uzbekistan[16].

In the FEA process, a metal type that is mechanically and technologically similar to **Steel 35** is selected from the materials available in the software database. The material most comparable to Steel 35 is **AISI 1035 Steel**. The mechanical properties of the AISI 1035 grade, as provided in the **SolidWorks** material library, are presented below in **Table 1**.

Elastic Modulus	$2.049999984 \times 10^{11}$	N/m ²
Poisson’s Ratio	0.29	N/A
Shear Modulus	$7.999999987 \times 10^{10}$	N/m ²
Mass Density	7849.999987	kg/m ³
Tensile Strength	585000002.9	N/m ²
Compressive Strength		N/m ²
Yield Strength	282685049	N/m ²
Thermal Expansion Coefficient	1.1×10^5	/K

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Thermal Conductivity	52	W/(m·K)
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Table-1. Mechanical properties of AISI 1035

Processing: During this stage, the axle model is prepared for computation by specifying the analysis type, convergence criteria, and output file directory within SolidWorks Simulation. A new static and structural analysis is initiated through the file drop-down menu, opening the Static Analysis window, where the constraints and loads defined in the pre-processing stage are applied for execution.

Post-Processing: Post-processing represents the final phase of the analysis, where the results generated during the processing stage are carefully examined and interpreted. Software such as SolidWorks, commonly used for this purpose, enables detailed evaluation through color-coded stress visualizations (such as von Mises stress plots). It also provides tools for sorting, printing, and graphing specific outputs from the finite element analysis.

Typical post-processing activities include:

- Sorting element stresses and displacements based on their magnitudes.
- Calculating the factor of safety.
- Generating convergence graphs.
- Producing plots and charts to visualize analysis results.

A key feature of post-processing software is its ability to animate the deformed shape of a component. This visual representation is particularly useful for verifying whether the applied constraints and boundary conditions were defined correctly.

Conclusion.

Overall, the results obtained from loading cases 1 to 3 were consistent and highlighted specific performance characteristics of the model. Based on these findings and the comprehensive analysis of the modified tractor base, it was concluded that the probability of failure under the applied loading conditions is minimal—even for the bracket identified as a potential weak point. Therefore, the applied loads in this analysis are deemed safe for the redesigned base.

It is important, however, that the tractor’s operational weight not exceed the recommended limit, as this serves as a guideline for maintaining a safe load capacity. From the outcomes of this study, it can be concluded that the modified front base design is structurally sound and acceptable.

This research primarily aimed to enhance the mechanism of the variable-base tractor. Through an evaluation of existing designs, both advantages and shortcomings were identified. To overcome these limitations, a new mechanism featuring a wider base (700 mm) an improvement over the current domestic standard of 673 mm was developed.

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