INNOVATIVE WORLD

ISSN: 3030-3079

ORIENTAL JOURNAL OF ACADEMIC AND MULTIDISCIPLINARY RESEARCH

SHARQ AKADEMIK VA KO'P TARMOQLI TADQIQOTLAR JURNALI

Scientific Journal

2026/6

www.innoworld.net

+998 33 5668868

ORIENTAL JOURNAL OF ACADEMIC AND MULTIDISCIPLINARY RESEARCH

Volume 4, Issue 6
2026

Journal has been listed in different indexings

Google Scholar, digital object identifier, ResearchGate, zenodo, ADVANCED SCIENCE INDEX, OpenAIRE, Academic Resource Index ResearchBib, DRJI Directory of Research Journals Indexing

The offical website of the journal:
www.innoworld.net

Uzbekistan-2026

Advanced Technologies for Lifetime Prediction of Automotive Plastic Components

Almataev Nozimbek
DSc candidate of Andijan state technical institute
E-mail: nozimalmataev@gmail.com

Annotatsion. The precise durability prognostics of automotive plastic details (bumpers, interior/exterior panels, and engine compartment polymer components) is highly complex due to material aging and wear under coupled thermal and dynamic stresses. This paper reviews the state-of-the-art technologies and advanced techniques currently employed to address these challenges.

Keywords: predicting, plastic, composite, Loadings, Degradation, technology.

Introduction: The use of polymer composite materials in automotive vehicles to reduce weight and improve fuel efficiency is increasing year by year. Accurately predicting the service life of plastic components (bumpers, panels, polymer parts around the engine) under aging, thermal, and dynamic loading is more complex than for metals and is critically important from both safety and economic perspectives, requiring specialized modern approaches. Unlike metals, plastic materials age over time and lose their properties under the influence of temperature and ultraviolet (UV) radiation.

Nowadays, a number of modern technologies and methods are widely used to predict the lifespan of these components. How are automotive composite parts tested for fatigue using Abaqus or ANSYS?

Fatigue testing and life prediction of automotive composite and plastic components using **ANSYS (nCode DesignLife) or Abaqus (Fe-Safe / Direct Cyclic) differ fundamentally from the testing of conventional metallic parts.** The reason is that composites possess an **anisotropic structure**, meaning that their mechanical properties vary depending on the direction.

The stages and algorithm of this process in modern digital engineering technologies are as follows:

1. Geometry and Fiber Orientation Characterization (Micro-/Micromechanics).

When a plastic or composite component (for example, an intake manifold or a bumper bracket) is manufactured through injection molding, the glass or carbon fibers inside the material become oriented in different directions. The fiber orientation largely determines where and how the component is likely to fail.

- **Technology:** The internal fiber orientation is calculated using **Moldex3D** or **Autodesk Moldflow** software.
- **Integration:** The obtained fiber-orientation data are then transferred into the **Abaqus** or **ANSYS** environment through material-modeling tools such as

Digimat or **Material Designer**. Without this information, accurate fatigue-life prediction is not possible.

2. Static and Dynamic Stress Analysis (FEA – Finite Element Analysis). The real-life loading conditions acting on the component, such as vehicle vibrations, road irregularities, and temperature effects, are applied to the numerical model.

- In **Abaqus/Standard** or **ANSYS Mechanical**, the stress and strain fields (E and σ) within the component are determined.
- For composite materials, critical regions are identified not only by evaluating stresses but also by applying composite failure criteria such as **Tsai–Wu** or **Hashin Failure Criteria** to locate the most vulnerable areas.

3. Selection and Simulation of the Fatigue Model.

This is the most important stage of the analysis, where specialized fatigue algorithms are employed within the software environment.

A. In the ANSYS nCode DesignLife Environment

- **Material Properties (S-N Curve):** Fatigue curves (S–N curves) are defined for each composite layer and fiber orientation.
- **Load History (Load Provider):** Real vibration data obtained from automotive proving-ground tests (time-series data) are imported into the software.
- **Calculation:** Based on the **Palmgren–Miner linear damage rule**, the software determines the location where microcracks are most likely to initiate and predicts the number of load cycles the component can withstand before failure (Life Cycle).

B. In the Abaqus (Direct Cyclic & Fe-Safe) Environment

- **Direct Cyclic Approach:** Abaqus employs a specialized algorithm to efficiently analyze high-cycle loading conditions. Instead of calculating each cycle individually, it evaluates material degradation using **Fourier series-based methods**.
- **Plasticity and Creep:** For plastic components located near the engine, the combined effects of temperature-induced creep and fatigue (**creep–fatigue interaction**) are taken into account.

4. Post-Processing and Results Evaluation

After the simulation is completed, the software displays the following results in the form of color contour maps:

- **Fatigue Life:** The number of cycles (**N**) that the component can endure before failure. For example, 106 cycles.
- **Fatigue Damage:** A damage index indicating the level of accumulated fatigue damage. When this value reaches **1.0**, failure is predicted to occur at that location.
- **Factor of Safety:** The safety margin of the component with respect to the applied loads and stresses.

Unlike metallic materials, special attention should be paid to the factors presented in **Table 1**.

Table 1

Criterion	**Metal Components**	**Plastic/Composite Components**
Temperature Sensitivity	Properties change significantly only at very high temperatures	Even at temperatures of **40–60°C**, the matrix may soften, resulting in a significant reduction in fatigue life
Loading Frequency	Loading frequency has a relatively minor effect on fatigue behavior.	Under high-frequency vibrations, the material may heat up due to internal energy dissipation (**hysteretic heating**), leading to accelerated degradation and reduced fatigue life.
Anisotropy	Generally exhibit uniform mechanical properties in all directions (**isotropic behavior**)	Mechanical properties depend strongly on fiber orientation; the material is significantly stronger along the fiber direction and considerably weaker in the transverse direction

Summary: In modern technology, testing plastic components in Abaqus or ANSYS requires not only their geometry but also integration of manufacturing process data (such as the casting stage) and environmental temperature into the software.

References:

1. Kojic, M., & Bathe, K. J. (2024). "Inelastic Analysis of Solids and Structures: Metals and Polymers in Automotive Design." Elsevier.

2. Laurence W. McKeen. (2016)Fatigue and Tribological Properties of Plastics and Elastomers (3 rd edition). England.

3. www.google.com