INTERNATIONAL JOURNAL OF INNOVATION IN MECHANICAL CONSTRUCTION AND ENERGY
Vol. 1 No. 3 (2024), 173-180

IJIMCE
https://ijimce.ppj.unp.ac.id/index.php/ijimce
University of Negeri Padang

International Journal of Innovation in Mechanical Construction and Energy

ISSN: 3046-9112 e-ISSN: 3046-9104

Load Testing Analysis On Marapi Politeknik Negeri Padang Electric Car Design

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Received 22 November 2024; Accepted 22 November 2024; Available online 28 November 2024

Abstract

In electric vehicle design, the chassis presents its own challenges as it must meet two primary requirements: a lightweight structure to enhance energy efficiency and a robust construction to withstand vehicle loads. This study aims to design and analyze an urban electric car chassis using Aluminium Hollow 6061-T6, known for its high strength and lightweight properties. The chassis design employs the Ladder Frame type to distribute loads evenly. Testing was conducted using Ansys 15.0 software to analyze stress and strain under various loads. Simulation results showed that the maximum load the chassis could withstand is 95 kg or 932 Newton, with a maximum allowable stress of 35.09 MPa. At a load of 95 kg, the stress experienced was 34.13 MPa, which is within the safe limits of the material ($34.13 \leq 35.09$ MPa). This data provides critical initial information for determining the maximum load capacity of the electric vehicle before it is used in real-world conditions. The study demonstrates that the resulting chassis design is capable of enhancing the safety and efficiency of the electric vehicle while significantly extending the service life of the chassis.

Keywords: Load test analysis, electric car, Ansys, Shear stress

INTRODUCTION

The Indonesian government, through the Ministry of Education, Culture, Research, and Technology (Kemendikbudristek), continues to support the development of environmentally friendly and energy-efficient vehicle technologies as part of efforts to reduce carbon emissions and dependency on fossil fuels. One strategic initiative undertaken is the Energy-Saving Car Contest (Kontes Mobil Hemat Energi, KMHE), a national competition involving universities across Indonesia. This competition aims to encourage technological innovation among students while preparing skilled human resources in the fields of automotive technology and renewable energy [1],[2]. One category of vehicles included in the KMHE competition is urban electric cars. These vehicles are designed to meet urban mobility needs, focusing on energy efficiency, comfort, and zero emissions. The trend of urban electric cars aligns with global developments, where major automotive manufacturers such as Tesla, Nissan, and Hyundai are increasingly introducing energy-efficient electric vehicles for urban markets. According to the International Energy Agency (IEA), global use of electric vehicles has significantly increased in recent years, with projections indicating that 30% of total vehicles will be electric by 2030 [3]. This trend is also reflected in Indonesia, particularly following the issuance of Presidential Regulation No. 55 of 2019 on the Acceleration of Battery-Based Electric Vehicle Programs. In line with this effort, Politeknik Negeri Padang (PNP) sees participation in KMHE as a strategic opportunity to apply knowledge and technology in real-world projects, further contributing to innovation and technological advancement in energy-efficient vehicles.

Both conventional and electric vehicles rely heavily on the chassis as a primary structural component. In the context of electric vehicles, chassis design poses unique challenges, as it must meet two critical requirements: a lightweight structure to enhance energy efficiency and a sturdy construction to withstand vehicle loads. According to research [4], reducing vehicle weight by up to 10% can improve fuel or energy efficiency by 6-8%, which is particularly relevant for electric vehicles that rely on battery efficiency. Additionally, the chassis serves as the main structure bearing all loads within the vehicle, including the weight of passengers, the engine, steering systems, and comfort equipment. Research [5] has shown that evenly distributing loads across the chassis can improve vehicle stability and reduce the risk of structural deformation, particularly under dynamic loading conditions. Therefore, chassis design must consider not only functional aspects but also factors such as structural shape, material selection, and manufacturing processes. The material used in chassis production plays a critical role in achieving an optimal balance between strength and weight. For example, Aluminum 6061-T6 alloy, as frequently highlighted in prior studies [6][7], has demonstrated high strength-to-weight ratios, excellent corrosion resistance, and good manufacturability. However, material selection must also account for operational conditions, such as static and dynamic loads, as well as the vehicle's operating environment. The manufacturing process of the chassis is equally crucial in determining its final quality. Modern manufacturing techniques, such as hydroforming and laser welding, enable the production of chassis structures with high precision and material efficiency [8]. Furthermore, simulation-based tools such as ANSYS and SolidWorks allow virtual testing of chassis designs before production, significantly reducing the risk of structural failures in real-world applications. By integrating these considerations, designing and constructing an electric vehicle chassis requires a well-rounded technical approach and collaboration among design, material selection, and manufacturing technology. Prior studies provide a vital reference point in developing chassis structures that meet the demands of modern electric vehicles in terms of efficiency, safety, and durability.

The chassis type designed and utilized for the Marapi PNP electric vehicle is the Ladder Frame chassis, which is known for its primary characteristic of evenly distributing loads across the entire frame structure. This type of chassis has been widely adopted in various types of vehicles due to its strength and stability, particularly in supporting heavy loads. For the Marapi PNP electric vehicle, the choice of this chassis type aims to ensure safety and performance under diverse operational conditions. In this study, an initial load analysis was conducted using ANSYS software, a finite element analysis tool that enables in-depth examination of stress, strain, and deformation distributions in the chassis structure. This analysis was applied to the design of the Marapi PNP electric vehicle chassis prior to real-world testing. The loading method included simulations of static and dynamic loads to represent various operational scenarios, such as the weight of the driver, passengers, and additional equipment installed in the vehicle. The development of electric vehicles through initiatives like the Energy-Saving Car Contest (KMHE) has the potential to positively impact Indonesia's automotive industry as it transitions toward environmentally friendly vehicles. This competition not only fosters a culture of innovation but also helps build a research ecosystem that supports the development of locally produced electric vehicles. With the support of the government, educational institutions, and industry, Indonesia is expected to become a key player in the global electric vehicle industry in the future.

RESEARCH METHODS

This study falls into the category of experimental research based on simulation, where the performance of the electric vehicle chassis design is tested through simulations to analyze its structural behavior under various loading conditions. The analysis is conducted computationally using finite element analysis (FEA)-based simulation software. These simulations replicate real-world conditions for the vehicle, including static and dynamic loads. Experimental testing is performed virtually using ANSYS 15.0, which facilitates the analysis of stress, strain, and deformation without requiring physical testing.

The research begins with the design of the electric vehicle chassis using SolidWorks software. The design adheres to the actual shape and dimensions of the electric vehicle, ensuring that the simulation results accurately represent real-world conditions. **Figure 1** illustrates the 3D geometry of the Marapi electric vehicle chassis with an isometric view and a top-down perspective. The key specifications of the chassis design are as follows: (1) Chassis length: 252 cm, (2) Chassis width: 108 cm, (3) Chassis height: 101.5 cm, (4) Chassis weight: 16.6 kg. This methodology allows for a thorough evaluation of the chassis design, ensuring that the structural integrity of the chassis meets operational requirements before real-world implementation. The use of SolidWorks for modeling and ANSYS 15.0 for simulation provides a robust approach for identifying potential structural issues and optimizing the design.

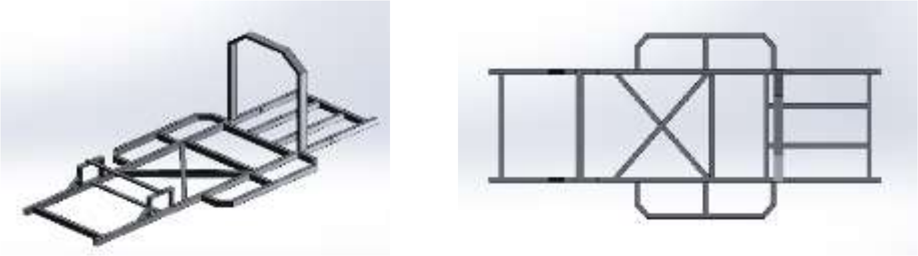

Fig 1. Geometry 3D of Marapi electric car (a) isometric (b) top view.

The material used for the chassis construction is Aluminium 6061-T6, which has a density of 2.7 g/cm³. This material was selected due to its optimal combination of high strength, lightweight properties, and excellent corrosion resistance, which are crucial for electric vehicles. According to a study [9], Aluminium 6061-T6 has a tensile strength of 310 MPa and a yield strength of 276 MPa, making it ideal for structural applications that require high strength while minimizing weight. Additionally, research [10] indicates that using Aluminium 6061-T6 for chassis construction can reduce vehicle weight by up to 20%, directly contributing to improved energy efficiency in electric vehicles. The structural design of the chassis, which incorporates Aluminium 6061-T6, offers significant advantages for lightweight electric vehicles without compromising on durability or safety. This design can be viewed in **Figure 2**, illustrating the thoughtful integration of material properties into the chassis layout.

Fig 2. (a) chassis made (b). The Chassis fits its seat.

After completing the chassis design, load simulations were conducted using ANSYS 15.0 software. The primary goal of these simulations was to analyze the structural strength of the chassis under various loads representing the driver's weight and the vehicle's operational load. The first step in the simulation process involved creating a domain meshing for the chassis design, as illustrated in **Figure 3**. This process divides the chassis structure into small finite elements, enabling a more precise analysis of stress and strain distribution across the chassis. By discretizing the structure, the simulation can accurately identify critical stress points and areas prone to deformation. The simulation process was conducted using a range of loading scenarios that reflect the weight of the driver and the operational conditions of the vehicle. These scenarios were designed to replicate real-world conditions as closely as possible. The simulation results provided crucial data on the chassis, including maximum stress, strain, and deformation. This information is essential for evaluating the structural integrity and ensuring the chassis can withstand operational loads safely and efficiently.

Fig 3. Computational mesh (a) mesh isometric view (b) mesh side view.

RESULTS AND DISCUSSION.

In this study, load simulations were conducted using ANSYS software to analyze the strength and structural behavior of the Marapi PNP electric vehicle chassis. This paper discusses the impact of varying loads on electric vehicles. Using ANSYS, the predefined conditions from the pre-processing stage were processed iteratively by applying loads of 50 kg, 55 kg, 60 kg, 65 kg, 70 kg, 75 kg, 80 kg, 85 kg, 90 kg, 95 kg, and 100 kg. The applied loads were based on the weight variations of the driver combined with the weight of other vehicle components. The primary objective of this simulation was to evaluate how the chassis design responds to varying loads, particularly those associated with the driver's weight and other vehicle components. The simulation covered a range of loads from 50 kg to 100 kg, representing the typical weight range encountered in urban electric vehicles. Each load scenario included the combined weight of the driver and additional components applied to the chassis.

The first simulation results were obtained for a 50 kg load, represented in **Figure 4**. This analysis provided critical data on the distribution of stress (Von Mises Stress) and deformation (Displacement) in the Marapi PNP electric vehicle chassis. For the 50 kg load, the highest stress was concentrated in specific areas, such as the lower frame joints, which are points of concentrated load due to the distribution of the driver's weight and other components. The simulation results indicated that red areas represented the maximum stress locations, while blue areas showed regions of minimal stress. The maximum stress observed on the chassis for the 50 kg load was 18.29 MPa, significantly below the allowable maximum stress for Aluminium 6061-T6, which is 35.09 MPa. This finding demonstrates that under a 50 kg load, the chassis remains in a safe condition with sufficient capacity to accommodate additional stress. Moreover, the results highlight that Aluminium 6061-T6 effectively distributes the load evenly through the Ladder Frame design, ensuring structural stability. According to research [11], such a design is ideal for vehicle applications as it promotes efficient load distribution and reduces the risk of permanent deformation. These findings reinforce the suitability of the Marapi PNP chassis design for urban electric vehicles, validating its capacity to handle standard operational loads safely and efficiently.

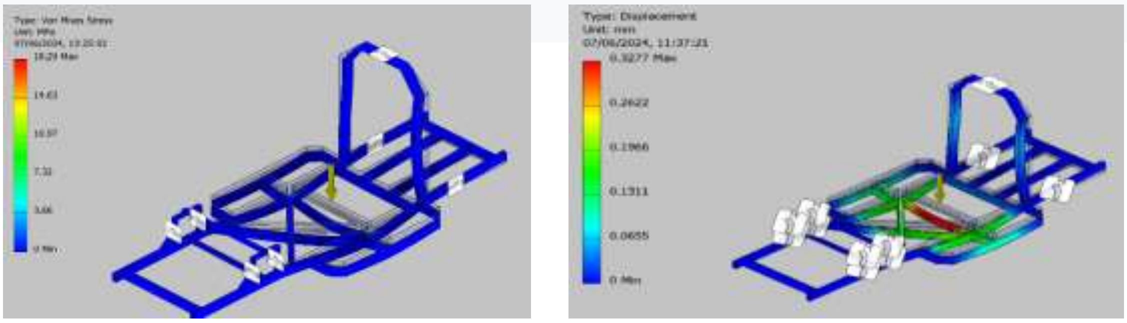

Fig 4. Computational Ansys (a) Tensile for 50 kg (b) Strain for load 50 kg.

The simulation results for a maximum load of 100 kg illustrate the distribution of stress (Von Mises Stress) and deformation (Displacement) on the electric vehicle chassis. This analysis provides a comprehensive overview of the structural response under high-load conditions. **Figure 5** presents the simulation outcomes, showing the stress and strain experienced by the chassis, offering critical insights into areas of maximum stress concentration and deformation. These results are crucial for evaluating the chassis's performance under extreme load scenarios and ensuring its structural integrity under real-world operational conditions.

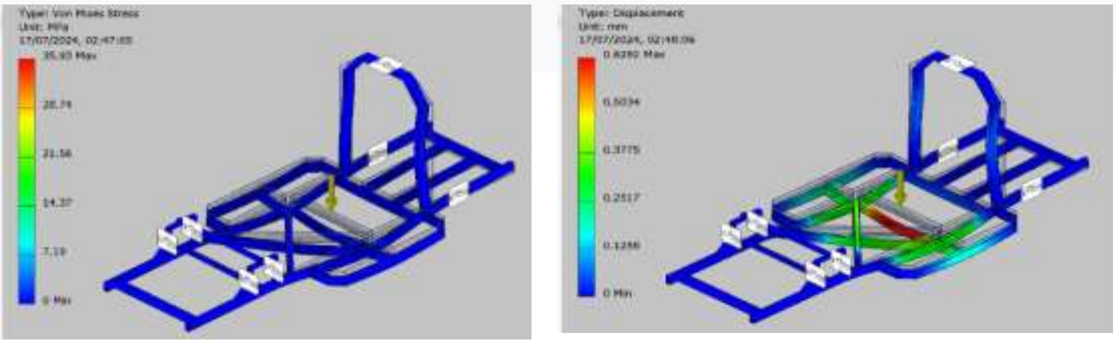

Fig 5. Computational Ansys (a) Tensile for 100 kg (b) Strain for load 100 kg.

The maximum stress detected on the chassis was 35.93 MPa, which closely approaches the allowable maximum stress for the material, 35.09 MPa. This result indicates that the chassis is in a critical state under a 100 kg load, with stress distribution concentrated in specific areas such as joints or primary support points. The highest stress zones, marked in red in the simulation results, highlight the potential risk of material failure if loads exceeding 100 kg are applied. The maximum deformation detected was 0.6292 mm, occurring at the center of the chassis. Although this value remains within the design tolerance, higher deformation could affect the overall stability and performance of the vehicle, especially under dynamic conditions. Compared to the simulation results for a 50 kg load, the stress and strain distribution for a 100 kg load showed a significant increase. This finding aligns with the principles of material mechanics, where higher loads lead to greater stress and strain. These simulation results are consistent with previous studies [12],[13], which state that aluminum-based chassis designs have reliable elastic limits up to a certain load. However, stress concentration at critical points, such as joints, could lead to permanent deformation if not addressed.

The relationship between stress and various load variations is illustrated in **Figure 6**, while the correlation between strain and load variations is presented in **Figure 7**. These graphs provide additional insights into how the chassis responds to different load scenarios, reinforcing the need for careful design considerations to ensure structural integrity under operational conditions.

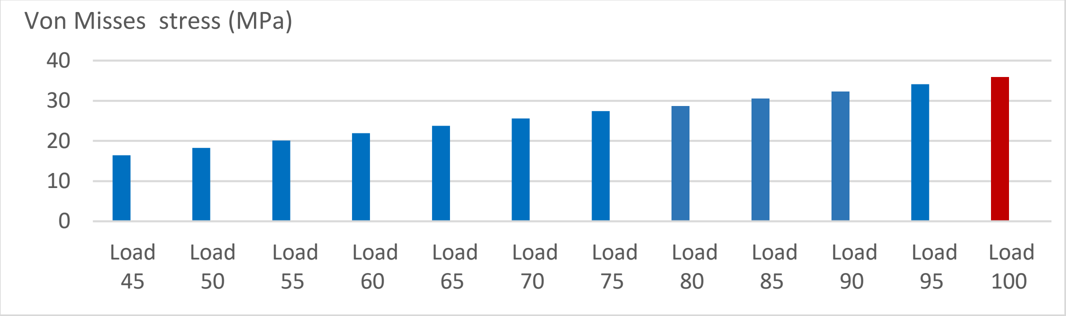

Fig 6. Diagram of influence Load on Von Misses stress.

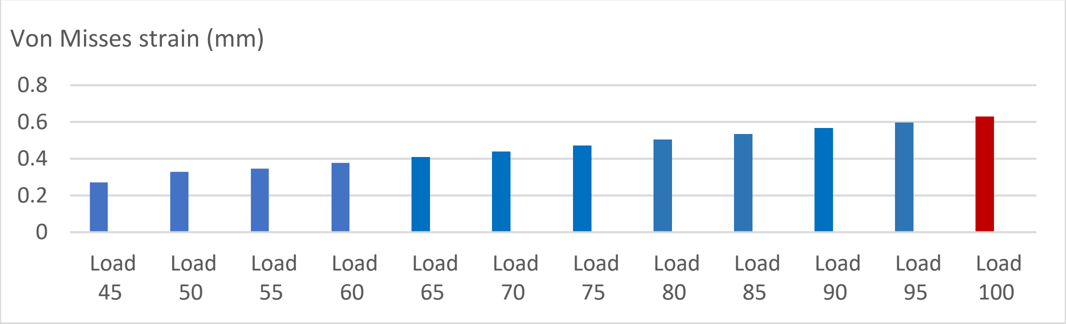

Fig 7. Diagram of influence Load on Von misses strain.

Based on the simulation results shown in Figure 6 and Figure 7, a linear relationship can be observed between increasing loads and the stress and strain experienced by the chassis. The detected stress increased from 16.46 MPa at a 45 kg load to 35.93 MPa at a 100 kg load. At a load of 95 kg, the stress reached 34.13 MPa, which remains within the safe limit for Aluminium T6061-T6 (35.09 MPa). However, at a load of 100 kg, the stress exceeded the safe limit, indicating that the chassis design is approaching a critical state. This increase in stress aligns with the theory of material elasticity, where stress increases proportionally with load as long as the material remains within its elastic limit. However, the detected concentration of stress at specific frame joints indicates that load distribution is not entirely uniform, suggesting the need for design optimization to enhance structural durability. The strain analysis, meanwhile, shows an increase in deformation from 0.22 mm at a 45 kg load to 0.63 mm at a 100 kg load. The strain remains within the elastic limit of Aluminium T6061-T6, meaning the chassis can return to its original shape after the load is removed, up to a load of 95 kg. This indicates that the chassis design is sufficiently rigid for light to moderate loads. According to studies [14],[15], minor deformations of this magnitude do not affect structural integrity as long as stress remains within the material's elastic range.

To determine the allowable shear stress for the material, Equation 1 was used. Given that the maximum shear stress for Aluminium T6061-T6 is 85 MPa and a safety factor of 2.5 was applied, the calculated allowable shear stress is 34.4 MPa. This value confirms that the chassis is safe to handle loads up to 95 kg, as the simulated shear stress was 34.13 MPa. However, at 100 kg, the stress exceeded the safe limit, posing a risk of material failure under dynamic operational conditions. This analysis demonstrates that the current chassis design is suitable for handling loads up to 95 kg, with stress and strain distribution remaining within safe limits. However, for higher loads or dynamic conditions, design optimization is required. Potential improvements include adding reinforcements to areas with high stress concentrations or increasing the material thickness in critical regions. Validating these simulation results through physical testing on a prototype is also strongly recommended to ensure the chassis performs safely under real-world conditions. These findings align with previous studies [9], which highlighted Aluminium T6061-T6 as an ideal material for electric vehicle chassis applications due to its lightweight, high strength, and efficiency in supporting vehicle structures. The results underscore the importance of balancing material properties and design strategies to achieve optimal performance in electric vehicle chassis. In this research, to determine the allowable shear stress, the following equation 1 can be used:

$$\tau = \frac{\tau\, max}{v} \tag{1}$$

Known :

τ : Shear Stress
$\tau\, max$: Shear maximum (taken 86 MPa)
V : Safety Factor (Taken 2,5)

The material used in this chassis is Aluminum T6061-T6, with a maximum shear stress ranging from 70 - 102 MPa. Meanwhile, the safety factor based on **Table 1** is taken as 2.5 (median value) because in reality the car receives the maximum load in dynamic conditions.

Table 1. Safety Factor Values for static and dinamics loads.

No	Load type	Safety Factor
1	Static Load	1.25 - 2
2	Dinamic Load	2 - 3
3	shock load	3 - 5

Can be determinated:

$$\tau = \frac{86\ Mpa}{2} = 34,4\ MPa$$

The theoretical allowable shear stress is 34.4 MPa. Based on data from testing using Ansys software and comparing the theoretically allowable shear stress, the following table can be created:

Table 2. Comparison Shear tress allowable of Shear tress Software Ansys

No	Load (Kg)	Shear stress Allowable (Mpa)	Shear stress Von Misses Software (Mpa)	Safe/unsafe
1	45	34,40	16.46	Safe
2	50	34,40	18.29	Safe
3	55	34,40	20.12	Safe
4	60	34,40	21.95	Safe
5	65	34,40	23.78	Safe
6	70	34,40	25.61	Safe
7	75	34,40	27.44	Safe
8	80	34,40	28,74	Safe

9	85	34,40	30,54	Safe
10	90	34,40	32,33	Safe
11	95	34,40	34,13	Safe
12	100	34,40	35,93	Unsafe

The results from the ANSYS simulation indicate that stress increases proportionally with added load, with simulated stress values ranging from 16.46 MPa at a 45 kg load to 35.93 MPa at a 100 kg load. The simulation results show that the chassis remains safe under loads up to 95 kg, where the maximum stress observed is 34.13 MPa, still within the safe limit for Aluminium 6061-T6. However, at a load of 100 kg, the stress reaches 35.93 MPa, exceeding the allowable shear stress of 34.4 MPa. This finding suggests that at this load, the chassis begins to enter a critical state and may experience material failure if operated under real-world conditions. This trend aligns with the mechanical properties of materials, where stress increases linearly with the load as long as the material remains within its elastic range [16].

Based on these findings, it can be concluded that the chassis design is safe for loads up to 95 kg. However, for higher loads, such as 100 kg, design optimization is necessary to prevent potential structural damage. Adding reinforcements to areas with high stress concentrations, such as frame joints or support points, can improve the structure’s durability. Furthermore, validating the simulation results through physical testing on a chassis prototype is strongly recommended to ensure the structure's performance under real-world conditions, particularly under dynamic loads. These findings also confirm that Aluminium 6061-T6 is an effective material for electric vehicle chassis designs. This conclusion is consistent with previous research, which highlighted this material's high strength-to-weight ratio, contributing to improved energy efficiency in vehicles. Thus, this study provides a robust foundation for further development in both chassis design and material selection to ensure enhanced safety and performance for electric vehicle applications in the future.

CONCLUSIONS.

Based on the load test conducted on the Marapi PNP electric vehicle chassis, analysis using ANSYS software with the Von Mises Stress method successfully provided insights into the structural capability of the chassis before its use in real-world conditions. The chassis was designed using Aluminium 6061-T6, which has a maximum shear stress of 85 MPa, and employed a Ladder Frame design. The test results showed that the chassis could withstand a maximum load of 95 kg or 932 N, with an allowable shear stress of 34.4 MPa. The shear stress observed in the ANSYS simulation was 34.13 MPa, which falls within the material's safe limits. Additionally, the maximum strain detected was 0.5977 mm, indicating that the chassis remained within its elastic range under the maximum load. To enhance safety, usage efficiency, and the durability of the Marapi PNP electric vehicle chassis, it is recommended that the maximum load at the driver's point not exceed 95 kg. This study provides a critical foundation for further development, including design optimization and validation through physical testing, to ensure the chassis performs reliably under real-world operational conditions, particularly under dynamic loads.

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