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Replacement of Subway Car Shock Absorbers: From Metal-Rubber Type to Kaprolan Type

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Annotation: This manuscript explores the technical and operational rationale behind the transition from traditional metal-rubber shock absorbers to kaprolan-based alternatives in subway car bogies. It delves into the inherent limitations of metal-rubber components, such as susceptibility to aging, fatigue, and environmental degradation, which often lead to compromised damping performance and increased maintenance demands. In contrast, kaprolan (polyamide 6, cast nylon) offers superior mechanical properties, including high wear resistance, excellent elasticity, and chemical inertness, making it an attractive material for shock absorption applications. This paper details the advantages of kaprolan shock absorbers, including extended service life, improved vibration isolation, reduced noise levels, and enhanced operational safety.

Keywords: subway, metal, rubber, shock, composite.

Tashkent State Technical University named after Islam Karimov

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Introduction

Subway systems are critical components of urban infrastructure, facilitating mass transit for millions daily. The operational efficiency, safety, and passenger comfort of these systems heavily rely on the integrity and performance of their various components, particularly the suspension and damping mechanisms. Shock absorbers play a pivotal role in mitigating dynamic loads, vibrations, and impacts experienced by subway cars during acceleration, braking, and movement over tracks. Traditionally, metal-rubber composites have been the material of choice for these critical components dueishing to their combined elastic and damping properties. However, as technological advancements progress and demands for higher performance, reduced maintenance, and enhanced sustainability grow, the limitations of metal-rubber shock absorbers have become increasingly apparent. This has spurred research and development into alternative materials, with kaprolan emerging as a promising candidate. Metal-Rubber Shock Absorbers. Metal-rubber shock absorbers typically consist of a rubber elastomer bonded to metal plates or inserts. The rubber component provides elasticity and damping, while the metal parts provide structural integrity and facilitate attachment to the vehicle's bogie or chassis.

Characteristics:

- Damping Properties: Rubber exhibits good hysteretic damping, converting kinetic energy into heat.
- Elasticity: Provides flexibility and allows for deflection under load.
- Load Bearing: Capable of supporting significant static and dynamic loads.

Advantages:

- Proven Technology: Widely used and well-understood for decades.
- Cost-Effective (Initial): Relatively inexpensive to manufacture.
- Vibration Isolation: Effective in isolating high-frequency vibrations.

Disadvantages:

Despite their widespread use, metal-rubber shock absorbers suffer from several drawbacks:

- Aging and Degradation: Rubber is susceptible to aging due to exposure to UV radiation, ozone, temperature fluctuations, and chemicals, leading to hardening, cracking, and loss of elasticity.
- Fatigue: Repeated cyclic loading can cause fatigue failure in both the rubber and the metal-rubber bond.
- Temperature Sensitivity: Performance can significantly degrade at extreme temperatures, becoming brittle in cold and softening in heat.
- Limited Lifespan: Typically require frequent inspection and replacement, leading to higher maintenance costs and downtime.
- Noise Transmission: Can transmit structural noise due to their inherent stiffness at certain frequencies.
- Environmental Impact: Disposal of aged metal-rubber components can be environmentally challenging.

Kaprolan Shock Absorbers. Kaprolan, also known as cast nylon or polyamide 6 (PA6), is a high-performance engineering thermoplastic produced by the anionic polymerization of caprolactam. Its unique molecular structure and manufacturing process impart a combination of properties that make it highly suitable for demanding mechanical applications, including shock absorption.

Properties of Kaprolan:

- High Mechanical Strength: Possesses excellent tensile strength, compressive strength, and stiffness.
- Exceptional Wear Resistance: Exhibits superior abrasion resistance, making it ideal for components subjected to friction and wear.
- Good Elasticity and Resilience: While stiffer than rubber, kaprolan retains significant elasticity and can absorb impact energy effectively without permanent deformation.
- Low Coefficient of Friction: Reduces friction when in contact with other surfaces, contributing to smoother operation and less heat generation.
- Chemical Resistance: Resistant to a wide range of chemicals, oils, and greases, enhancing durability in harsh operating environments.
- Temperature Stability: Maintains its mechanical properties over a broader temperature range compared to rubber.
- Noise Reduction: Due to its inherent material properties, kaprolan can contribute to quieter operation by absorbing vibrations more effectively and reducing structural noise transmission.
- Lightweight: Significantly lighter than metal, contributing to reduced unsprung mass in bogies.

The decision to replace metal-rubber shock absorbers with kaprolan types is driven by a confluence of factors aimed at improving overall subway system performance and reducing operational expenditures. Kaprolan's superior mechanical properties translate directly into improved shock absorption performance and significantly extended service life. Its resistance to fatigue, wear, and environmental degradation means components can withstand the rigorous demands of continuous operation for longer periods, leading to higher reliability. The extended lifespan of kaprolan components drastically reduces the frequency of replacement, thereby lowering material costs, labor expenses associated with maintenance, and vehicle downtime. This contributes to a significant reduction in the total lifecycle cost of the shock absorber system. Better vibration isolation and noise reduction capabilities of kaprolan shock absorbers enhance passenger comfort by providing a smoother, quieter ride. Furthermore, the increased durability and reliability of these components contribute to overall operational safety by minimizing the risk of unexpected failures. Kaprolan is a recyclable material, and its longer lifespan reduces the volume of waste generated from component replacements. The manufacturing process for kaprolan can also be more energy-efficient than that for some metal-rubber composites, contributing to a smaller environmental footprint. The transition from metal-rubber to kaprolan shock absorbers requires careful technical consideration to ensure seamless integration and optimal performance. While kaprolan can often be used as a direct replacement in terms of form factor, minor design adjustments may be necessary to fully leverage its properties. This might involve optimizing the geometry of the shock absorber to account for kaprolan's specific elasticity and damping characteristics, ensuring proper load distribution, and designing for ease of installation and removal.

The specific grade of kaprolan must be carefully selected based on the required mechanical properties, operating temperature range, and chemical exposure. Advanced manufacturing techniques, such as precision casting or machining, are employed to produce components with tight tolerances and consistent quality. Installation procedures should be clearly defined, taking into account the material properties of kaprolan. Proper torque specifications for fasteners and alignment procedures are crucial to ensure correct functioning and prevent premature wear. Rigorous testing is essential to validate the performance of kaprolan shock absorbers under various operational conditions. This includes:

- Static and Dynamic Load Testing: To assess load-bearing capacity and deflection characteristics.
- Fatigue Testing: To determine the component's lifespan under cyclic loading.
- Vibration and Noise Analysis: To quantify damping efficiency and noise reduction capabilities.
- Environmental Testing: To evaluate performance under extreme temperatures, humidity, and exposure to contaminants.

Table 1. Performance Comparison: Metal-Rubber vs. Kaprolan

Feature	Metal-Rubber Shock Absorbers	Kaprolan Shock Absorbers
Damping Efficiency	Good, but degrades with age and temperature.	Excellent, consistent over time and temperature range.
Lifespan	Limited, susceptible to aging and fatigue.	Significantly extended due to high wear and fatigue resistance.
Wear Resistance	Moderate, can degrade due to friction and abrasion.	Superior, excellent resistance to wear.
Temperature Range	Performance degrades at extreme cold (brittle) or heat (soft).	Wider operational temperature range with stable properties.
Noise Reduction	Can transmit structural noise.	Better absorption of vibrations, leading to reduced noise.
Vibration	Effective, but can be	Highly effective and consistent

Isolation	compromised by material degradation.	over time.
Maintenance Needs	High, frequent inspection and replacement.	Low, reduced frequency of replacement.
Weight	Heavier due to metal components.	Lighter, contributing to reduced unsprung mass.
Chemical Resistance	Variable, susceptible to certain chemicals and oils.	Good resistance to most common chemicals and oils.

The initial investment in kaprolan shock absorbers might be slightly higher than traditional metal-rubber types. However, the long-term economic benefits are substantial:

- Reduced Total Cost of Ownership (TCO): Lower maintenance costs, less frequent replacements, and reduced vehicle downtime contribute to a significantly lower TCO over the lifespan of the subway car.
- Increased Operational Efficiency: Fewer unscheduled maintenance events mean higher availability of subway cars, leading to improved service reliability and capacity.

Environmental Benefits:

- Waste Reduction: The extended service life of kaprolan components directly translates to a reduction in the volume of scrap materials requiring disposal.
- Recyclability: Kaprolan is a thermoplastic and can often be recycled at the end of its service life, further reducing its environmental footprint.
- Resource Conservation: Reduced need for raw material extraction and processing due to longer component lifespans.

Conclusion

The replacement of metal-rubber shock absorbers with kaprolan types in subway cars represents a significant step forward in rail technology. Kaprolan's superior mechanical properties, including high wear resistance, excellent elasticity, and chemical stability, offer a compelling alternative to traditional materials. This transition promises substantial benefits, including extended component lifespan, reduced maintenance costs, improved passenger comfort and safety, and a positive environmental impact. While challenges related to initial investment and integration exist, these can be effectively managed through thorough planning, rigorous testing, and collaborative efforts across the industry. The widespread adoption of kaprolan technology is poised to enhance the efficiency, reliability, and sustainability of modern subway systems, paving the way for a new generation of high-performance urban transit.

References:

1. Liubarskyi, Borys & Kuznetsov, Valeriy & Kardas-Cinal, Ewa & Lukashova, Natalia & Petrenko, Oleksandr & Nikonov, Oleh & Nikonov, Dmytro. (2022). Evaluation of the effectiveness of using an electromechanical shock absorber in a subway car. Eksploatacja i Niezawodnosc - Maintenance and Reliability. 24. 603–611. 10.17531/ein.2022.4.1.
2. Liubarskyi, B., Lukashova, N., Petrenko, O., Yeritsyan, B., Kovalchuk, Y., & Overianova, L. (2019). Procedure for modeling dynamic processes of the electromechanical shock absorber in a subway car. *Eastern-European Journal of Enterprise Technologies*.
3. Dushchenko, V., Vorontsov, S., Masliyev, V., Agapov, O., Nanivskyi, R., Cherevko, Y., & Masliiev, A. (2021). Comparing the physical principles of action of suspension damping devices

based on their influence on the mobility of wheeled vehicles. *Eastern-European Journal of Enterprise Technologies*.

4. Alimbabaeva, Z.L., Bektemirov, B. Sh. Composite materials production technology for machining materials. Lityo i metallurgiya 2020: sbornik nauchnih rabot III Mejdunarodnoy nauchnoprakticheskoy internet konferenciy studentov i magistrantov, 18-19 noyabrya 2020 g./sost. AP Bejok.–Minsk: BNTU, 2021.–S. 92-93
5. Alimbabaeva ZL., et al. "Physical and technological basis for formation of coatings by electric contact sintering". Casting and metallurgy 2022: collection of scientific papers of the International Scientific and Practical Internet Conference of Students and Undergraduates. Minsk: BNTU (2022): 175-176.
6. Bektemirov, B. S. Advanced ceramic coating methods B. Sh. Bektemirov, R. Kh. Saydakhmedov, A. Kh. Alikulov Tashkent State Technical University named after Islam Karimov, Tashkent, Uzbekistan The article is dedicated to put together on data associated with researches.