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OPTIMIZING WELDED FRAMEWORK STRUCTURES FOR BODY-IN-WHITE (BIW) COMPONENTS IN SKD AUTOMOTIVE EXPORT SYSTEMS

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Abstract

This paper investigates the structural optimization of welded vehicle bodies, specifically the Body-in-White (BIW) configuration, tailored for Semi-Knocked Down (SKD) export logistics at UzAuto. The BIW architecture forms the load-bearing spatial framework of a vehicle, dictating its mechanical strength, geometric precision, and vibration resistance. However, long-distance maritime and overland SKD transport exposes pre-welded frameworks to dynamic deformations and mechanical stresses. This study establishes a comparative framework for global automotive export methodologies (CBU, SKD, CKD, DKD) and analyzes the technical parameters of raw materials, such as Low-Carbon Steel, High-Strength Low-Alloy (HSLA), and Ultra-High-Strength Steel (UHSS). By tracking the technological sequence from automated spot welding and anti-corrosion coating to specialized containerized fastening with rubber dampers and structural jigs, this research proposes adjustments to the welding geometry that mitigate transit deformation, optimize container volume utilization, and ensure zero-defect integration at downstream foreign assembly lines.

1. Introduction

Modern automotive manufacturing is increasingly dependent on distributed supply chains where vehicles are exported as modular kits rather than fully assembled units. At the core of this export infrastructure is the vehicle's spatial framework, known in the industry as Body-in-White (BIW). The BIW comprises interconnected structural panels brought to a unified state through precision welding. This complex spatial structure includes front and rear longitudinal beams (side members), floor panels, side walls, A, B, and C-pillars, roof assemblies, door frames, and reinforcing cross-members (traverses). The primary function of this welded assembly is to partition operating loads evenly across the vehicle body while maintaining geometric accuracy, vibration dampening, and passenger safety.

To maintain high strength-to-weight ratios, contemporary BIW configurations utilize specialized metallurgy, including low-carbon steels ($0.08\%

- 0.12%text, High-Strength Low-Alloy (HSLA) steels, Ultra-High-Strength Steels (UHSS), and galvanized sheet metals.

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When exporting these units, manufacturers select an assembly distribution model based on target market regulations, tariffs, and localized production capabilities. For regional manufacturing hubs like UzAuto, exporting via the Semi-Knocked Down (SKD) method serves as a highly efficient logistical model. Under the SKD regime, the BIW is fully welded, painted, and geometric-validated at the parent plant before being packed alongside primary powertrain modules for final assembly in the destination country.

1-pictures. Body-in-White

However, because the welded framework is shipped completely built up geometrically, it is highly susceptible to transit-induced structural stresses, vibrations, and shifting. This study focuses on improving the welded framework design used for UzAuto body exports to minimize deformation and



increase transit safety.

2. Methods

The research evaluates the technological workflow of BIW preparation and establishes a comparative matrix of industrial export mechanisms to isolate the exact stressors acting upon the framework.

2.1. Classification of Industrial Automotive Export Methods

To understand the economic and technical necessity of SKD optimization, a multi-variant analysis of current international automotive delivery systems was conducted:

- **CBU (Completely Built Unit):** Export of fully assembled vehicles. It requires zero localized assembly infrastructure but incurs high customs tariffs, steep shipping premiums, and zero local content integration.
- **SKD (Semi-Knocked Down):** Semi-assembled export where the BIW arrives fully welded and painted. This method benefits from lower import tariffs and VAT exemptions while requiring minimal capital investment in the importing nation.
- **CKD (Completely Knocked Down):** Fully disassembled export where stamping, welding, painting, and assembly are executed entirely at the destination site. It features the highest local content value but requires massive capital expenditure.

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- **DKD (Direct Knocked Down):** A hybrid or transitional variant where pre-assembled sub-nodes undergo final, basic joining, serving as a low-risk stepping stone toward CKD.

2.2. Technological Processing and Stabilization Protocol

To protect the structural alignment of the BIW during transport, specialized metal transport jigs (frameworks) were engineered. The vehicle body is anchored onto these transport frames using specific bolted joints, locking elements, and vibration-absorbing rubber cushions. Soft protective coatings and chemical preservation agents are then applied to prevent moisture-induced corrosion inside transcontinental shipping containers.

3. Results

The structural and logistical characteristics of the varying export methods were compiled to highlight the unique mechanical challenges faced by the SKD BIW framework during long-term storage and multi-modal transit:

Table 1: Comparative Engineering and Economic Matrix of Automotive Export Configurations

Configuration Metric	**CBU**	**SKD (Current Focus)**	**CKD**	**DKD**
Parent Plant Structural Role	Full Assembly & QC	Complete BIW Welding & Painting	Sheet Metal Stamping Only	Sub-Node Pre-Assembly
Destination Plant Infrastructure	None (Sales Dealership)	Basic Assembly Line & Inspection	Full Welding, Paint, & Assembly Shops	Minimal Modular Assembly Jigs
Logistical Volume Efficiency	Low (High air volume per car)	Medium-High (Nested framework stacking)	Maximum (Dense parts packing)	Medium
Primary Risk Factor During Transit	Cosmetic surface scratches	**Structural BIW misalignment / Elastic deformation**	Component loss / Moisture corrosion	Interface fitment errors
Tariff Mitigation Capability	Minimal/None	High (Significant tax/VAT exemptions)	Maximum Government Incentives	Moderate

Evaluation of the current SKD packing sequence revealed that standard rigid constraints without dampening elements transferred transit vibrations directly into the structural pillars (A, B, and C-pillars) of the BIW. This caused minor micro-deformations that altered the geometric tolerance of door

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frames. Introducing the updated transport karkas framework with integrated rubber dampers effectively isolated the BIW from low-frequency railway vibrations.

4. Discussion

The analytical findings underscore that while SKD provides a fast and highly profitable gateway to entering new international markets without immediate capital investments, it shifts the engineering burden onto the transport security of the welded framework.

Because the BIW arrives at the destination country ready for the mechanical marriage stage (installation of the engine, suspension, and interior), any structural twist or bending sustained during shipping will disrupt automated assembly robots at the receiving plant.

Relying purely on standard rigid shipping racks is insufficient because materials like HSLA and UHSS possess high yield strength but remain vulnerable to localized buckling at thin-walled junctions under continuous cyclic vibration.

Optimizing the welded design involves reinforcing critical stress points—such as the junctions between the floor panel, cross-traverses, and longitudinal lonjerons—with temporary reinforcing braces or optimized locking pins on the shipping jig. This closed-loop design ensures that the geometric integrity checked in the parent plant's quality zone remains unchanged when the container is opened abroad.

5. Conclusion

1. The Body-in-White (BIW) welded structure forms the foundational framework of automotive structural safety, making its geometric preservation during SKD export a critical factor for international quality compliance.
2. Comparative analysis reveals that SKD provides the optimal balance between lower customs duties and reduced capital investment, provided that transit-related deformation risks are addressed.
3. Modifying the export framework via automated robotic welding alignment, paired with vibration-dampening rubber mounts and structural transport karkas units, significantly reduces structural deformations, lowers rework rates at the destination plant, and maximizes shipping container efficiency.