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Rack Upright Protection with Impact History Indicator

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Abstract

An arrangement for protecting a storage rack upright incorporates a deformable element designed to absorb impact energy. This element integrates a passive indicator mechanism that records accumulated impact history without requiring external power. The mechanism provides a visual indication of past impacts, allowing for objective assessment of the upright's potential compromise. This system addresses the issue of latent damage in rack uprights, where seemingly minor impacts can reduce load-bearing capacity, leading to unexpected failure. It replaces subjective visual inspections with a quantifiable, non-powered assessment of impact severity and frequency.

1. Technical Field

[0001] The present disclosure relates to industrial storage systems, specifically to arrangements for protecting structural components such as uprights in pallet racking and shelving systems from impact damage. More particularly, it concerns methods and apparatus for monitoring and indicating the impact history sustained by such protective arrangements.

2. Technical Context

[0002] Industrial storage racks, such as pallet racking, are subject to impacts from material handling equipment like forklifts and pallet jacks. These impacts can occur at various heights and with varying energy levels. A significant problem in rack maintenance is the detection of damage, particularly sub-critical damage, to the vertical load-bearing members, known as uprights. An upright that has sustained an impact may appear visually undamaged or only superficially scratched, yet its structural integrity can be compromised. This latent damage can reduce the upright's capacity to bear vertical loads, potentially leading to a catastrophic collapse under loads it previously supported safely. Current inspection procedures often rely on visual assessment by trained personnel, which can be subjective and may miss hidden or subtle deformations. Moreover, the history of impacts to a particular upright is typically not recorded, making it difficult to assess cumulative damage. The absence of an objective, reliable, and easily interpretable indication of past impacts contributes to the risk of structural failure and necessitates conservative replacement criteria or frequent, extensive inspections.

3. System Overview

[0003] The disclosed system comprises a deformable element (12) mounted to a rack upright (10). This deformable element (12) is designed to absorb kinetic energy from impacts, thereby reducing the stress transmitted to the upright (10). Integrated within or associated with the deformable element (12) is a passive indicator mechanism (18). This mechanism (18) records the history of impacts sustained by the deformable element (12) without requiring any external power source. The indicator mechanism (18) provides a readily observable visual indication (22) of the accumulated impact energy or the number of impacts above a certain threshold. This visual indication (22) serves as an objective basis for determining when the deformable element (12) needs replacement, or when the underlying upright (10) requires closer inspection or replacement, even if the upright (10) itself shows no visible damage. The system aims to provide a clear, quantifiable metric for assessing the state of protection and the potential compromise of the rack structure.

4. Components

[0004] The system includes several key components, as depicted in FIG. 1 and FIG. 2. A **rack upright (10)** is the primary structural member of a storage rack that requires protection. It is typically a cold-formed steel section with perforations for beam attachment. A **deformable element (12)** is positioned to absorb energy from impacts before that energy is fully transmitted to the rack upright (10). This element (12) is constructed from a material engineered to deform plastically or elastically under impact. Examples include high-density polymers, elastomeric compounds, or engineered crushable metallic structures. The deformable element (12) may be enclosed within an **outer housing (14)**, which provides structural integrity, weather protection, and a mounting interface. The outer housing (14) is typically made from a durable plastic or metal. An **inner core (16)**, situated within the deformable element (12) or as part of its internal structure, interacts directly with the impact force and is designed to deform in a controlled manner. This inner core (16) directly influences the recording mechanism. The **indicator mechanism (18)** is a passive device integrated with the deformable element (12). This mechanism (18) translates the deformation of the deformable element (12) or inner core (16) into a persistent, observable record. It does not require electrical power for its function. **Impact markers (20)** are discrete sub-components within the indicator mechanism (18) that are irreversibly altered upon specific levels of deformation or impact energy. These can include frangible links designed to break sequentially, crushable cells that permanently deform, or shear pins that yield. A **visual indicator (22)** is a display feature, often a window or a color-changing component, that presents the state of the impact markers (20) to an observer. This might be a physical flag that appears, a color scale that changes, or a counter displaying a number. **Mounting brackets (24)** are used to securely attach the deformable element (12) assembly to the rack upright (10). These brackets (24) are typically metal, designed for easy installation and replacement. **Fasteners (26)**, such as bolts, screws, or clips, are used to secure the mounting brackets (24) to the upright (10) and the deformable element (12) to its housing or brackets.

5. Operation

[0005] The system operates as follows: **At start or installation:** A new deformable element (12) with its integrated indicator mechanism (18) is installed on a rack upright (10) using mounting brackets (24) and fasteners (26). The visual indicator (22) is in its initial, "no impact" state, signifying that the component has not yet experienced any significant impacts. This initial state might be a green color, a "0" on a counter, or an absent flag.

[0006] **During normal running:** The deformable element (12) remains in its passive state, providing physical protection to the upright (10) against incidental contact. The indicator mechanism (18) is quiescent, and the visual indicator (22) remains in its initial state.

[0007] **Upon impact:** When a material handling vehicle strikes the deformable element (12), the element (12) absorbs kinetic energy by deforming. The outer housing (14) may deflect, and the inner core (16) within the deformable element (12) undergoes controlled deformation. This deformation directly interacts with the impact markers (20) of the indicator mechanism (18). Depending on the design, a single significant impact or a series of lesser impacts will cause one or more impact markers (20) to trigger. For instance, a small impact might deform the inner core (16) sufficiently to break a first frangible link, while a larger impact might break multiple links or activate a different marker (20).

[0008] **Indicator update:** As impact markers (20) are triggered, the state of the visual indicator (22) changes permanently. For example, a series of windows might reveal different colored segments (e.g., green, yellow, red) as internal mechanisms shift, or a mechanical counter might increment. This change is irreversible for each triggered marker (20), thereby recording the impact history. The mechanism (18) is designed such that the indicator (22) retains its state even after the impact force is removed and the deformable element (12) may partially recover its shape (if it has elastic properties).

[0009] **Inspection procedure:** During routine safety inspections, personnel visually examine the visual indicator (22) on each installed deformable element (12). This replaces the need for subjective judgment about minor dents or scrapes on the upright (10) itself. The state of the indicator (22) provides an objective, immediately understandable assessment of the impact history.

[0010] **Replacement criterion:** A predefined threshold on the visual indicator (22) dictates when action is required. For example, if the indicator (22) displays a "yellow" state, it might trigger a closer inspection of the upright (10) and the protective element (12). If it displays a "red" state, it mandates immediate replacement of the deformable element (12) and a thorough inspection of the underlying upright (10) for potential latent damage, even if no visible damage is apparent on the upright (10). The replacement criterion is based on engineering calculations of the cumulative energy absorption or deformation limit of the protective element (12) before its protective capacity is significantly diminished or before the probability of upright damage becomes unacceptably high.

6. Example Embodiments

[0011] **Embodiment 1** This embodiment features a deformable element (12) constructed from a high-density polyethylene block, shaped to fit around the front face of a rack upright (10). The inner core (16) of this block contains a series of three shear pins (20) made from a material like aluminum alloy, each designed to shear at a successively higher force threshold. These shear pins (20) are arranged vertically. A spring-loaded plunger (part of 18) is positioned behind each pin (20). When a shear pin (20) fractures due to an impact exceeding its threshold, the plunger extends into a transparent window (22) on the outer housing (14), revealing a colored tip. The first pin's plunger might show a yellow tip, the second an orange tip, and the third a red tip. The presence of any colored tip indicates an impact event, and the number of visible tips indicates the severity or cumulative count of impacts. The element (12) is secured to the upright (10) via two steel mounting brackets (24) that clasp the upright (10) flanges and are fastened with bolts (26).

[0012] **Embodiment 2** In this configuration, the deformable element (12) is a multi-chambered structure fabricated from a thermoplastic elastomer. Each chamber contains a sealed, crushable cell (20) filled with a non-toxic pigment. These cells (20) are arranged in a linear array. Upon impact, the deformation of the elastomeric material compresses the cells (20) sequentially. When a cell (20) is crushed, its pigment is released into a transparent channel that acts as the visual indicator (22). The channel is marked with calibration lines. As more cells (20) are crushed, the pigment level rises, providing a clear visual scale of accumulated deformation. The first three cells might release a light blue pigment, the next three a darker blue, and the final three a dark red pigment, providing a graduated visual indication of impact history. The outer housing (14) protects the elastomer and contains the transparent channel. This assembly is designed to be floor-mounted around the upright (10) base, independent of direct attachment to the upright (10) itself, using anchor bolts (26) into the concrete floor.

[0013] **Embodiment 3** This embodiment utilizes a deformable element (12) made from a viscoelastic polymer foam encased in a durable, transparent outer housing (14). Embedded within the foam at specific locations are small, sealed capsules (20) containing a reagent that undergoes an irreversible color change upon reaching a critical pressure or shear deformation. For example, some capsules might change from clear to green, others from green to yellow, and a final set from yellow to red. The capsules (20) are positioned at varying depths or within areas of the foam engineered to deform at different impact energy levels. As impacts occur, the foam deforms, crushing specific capsules (20) and causing their color change. The transparent housing (14) allows direct observation of these color changes. The pattern and intensity of the colored capsules (20) visible through the housing (14) serve as the visual indicator (22), providing a permanent record of the impact profile. This system is attached to the upright (10) using an interlocking tongue-and-groove system with positive locking clips (26) that snap onto the upright's (10) perforations.

7. Alternative Configurations

[0014] The deformable element (12) could be constructed from a composite material, such as a fiberglass-reinforced polymer, designed for controlled fracture or delamination upon impact, with optical fibers embedded to show damage propagation through light transmission changes. The indicator mechanism (18) could employ a magnetic system, where deformation causes the irreversible displacement of a small magnetic flag, which then becomes visible through a window (22). Instead of direct impact, the deformable element (12) could be designed to compress a small air bladder, which then irreversibly actuates a mechanical counter (22). The mounting method could include a break-away design, where excessive impact causes the entire protector to detach without damaging the upright (10), with the detached state serving as the ultimate indicator.

8. Parameter Variations

Parameter	Realistic Range	Effect of Moving Within Range
Material Hardness/ Stiffness of Deformable Element (12)	Shore D 40-70 (polymers); 50-200 GPa (metals)	A softer material (lower Shore D, lower GPa) absorbs more energy through larger deformation at lower peak forces, potentially reducing stress on the upright (10) but increasing overall protector size. A harder material transmits more force to the upright (10) for a given deformation, but might be more compact and resistant to minor abrasions.
Trigger Thresholds for Impact Markers (20)	50 J to 500 J per discrete marker	Lower thresholds allow detection of minor impacts, providing a more detailed history but potentially leading to more frequent replacements. Higher thresholds focus on significant impacts that are more likely to compromise the upright (10), reducing

Parameter	Realistic Range	Effect of Moving Within Range
		nuisance indications but potentially missing cumulative effects of smaller impacts.
Thickness of Deformable Element (12)	20 mm to 100 mm	A thicker element (12) generally provides greater energy absorption capacity and a longer deformation stroke for the same material, reducing peak force transmitted. A thinner element (12) reduces aisle intrusion but may transfer more impact energy to the upright (10) or activate indicators more rapidly for a given impact.
Number of Impact Markers (20)	1 to 5 stages of indication	More stages provide finer granularity in impact history reporting, allowing for better tracking of cumulative damage and more nuanced replacement decisions. Fewer stages simplify the visual indicator (22) but offer less detail on the impact magnitude or frequency.
Mounting Height from Floor	100 mm to 500 mm	Lower mounting heights protect against pallet jack impacts and low forklift forks, which are common impact sources. Higher mounting heights can protect against impacts from raised forks or loads but may leave the lower section vulnerable. Multiple protectors at different heights can address a wider range of potential impact zones.
Recovery Characteristics of Element (12)	Elastic (full recovery) to Plastic (permanent deformation)	An element (12) with high elastic recovery can endure multiple minor impacts without permanent physical change, relying solely on the internal indicator (18) for history. A plastically deforming element (12) provides a clear visual sign of impact on its external surface in addition to the internal indicator (18), but its protective capacity may diminish more rapidly after a single significant event.

9. Additional Implementations

[0016] The disclosed system can be adapted for protecting other structural members in industrial environments, such as building columns, wall corners, or machinery bases, where impact damage is a concern and visual inspection is challenging or unreliable. The passive indicator mechanism (18) can be integrated into barrier systems, such as guard rails or bollards, to provide a record of impacts they sustain, informing maintenance schedules for these protective structures. Furthermore, while primarily passive, the concept of impact history recording could be extended to include materials with embedded micro-sensors that change electrical resistance upon deformation, which could then be read by a handheld, non-contact device for an automated, though still non-powered, assessment of the indicator state. This would enable faster data collection across a large installation without requiring direct visual access to each indicator. The deformable element (12) can also be designed as a retrofittable kit, allowing existing rack installations to be upgraded with impact history monitoring capabilities without requiring extensive structural modifications.

10. Figures

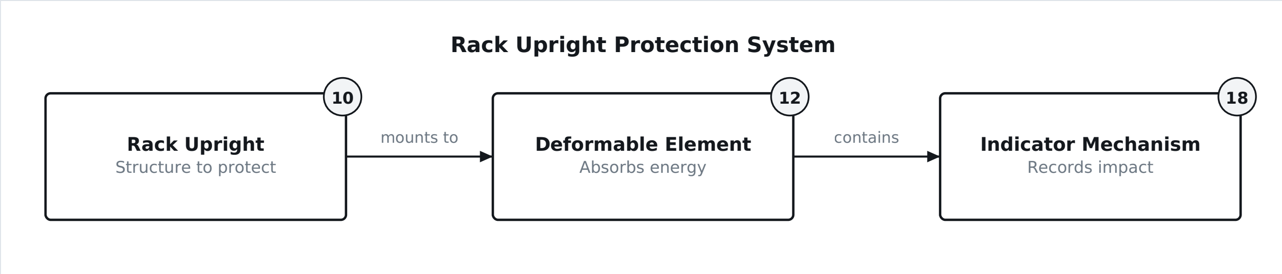

FIG. 1 Block diagram showing the interaction between the rack upright and the protection system. PNG

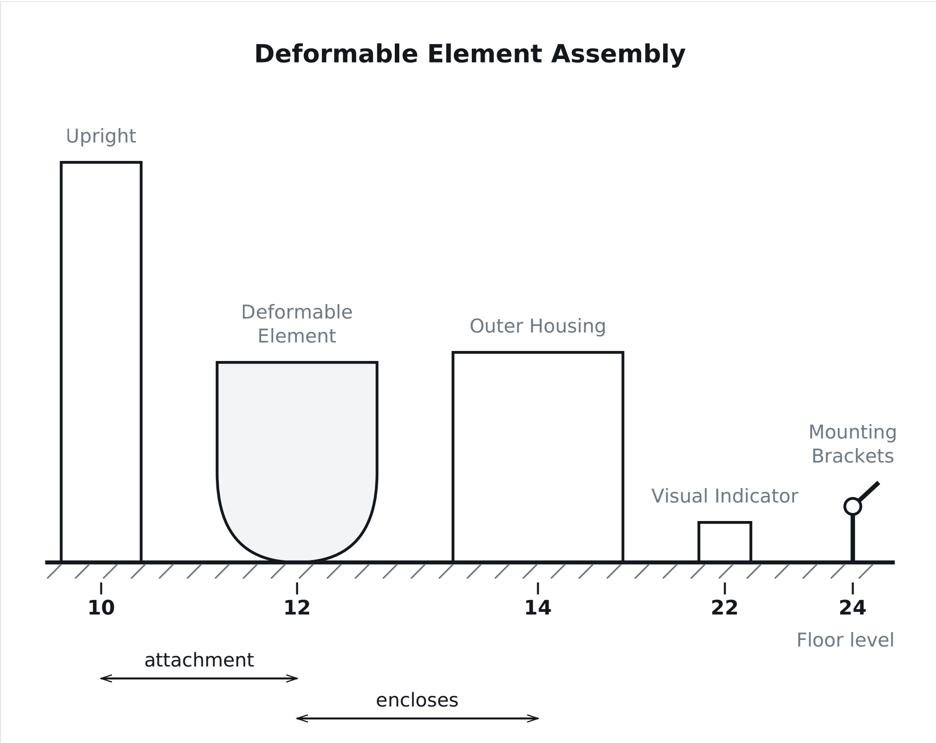

FIG. 2 Elevation view of the deformable element mounted to a rack upright. PNG

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