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Design & improvement in hydraulic Side broom to Pneumatic side broom used in Mechanical Sweeper machines

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Abstract

The transition from hydraulic to pneumatic side brooms in mechanical sweeper machines represents a significant advancement in street cleaning technology. Hydraulic side brooms, traditionally powered by hydraulic pumps and fluid systems, often face issues such as complexity, maintenance challenges, high energy consumption, and environmental concerns due to potential fluid leaks. This paper explores the design improvements and benefits of replacing hydraulic systems with pneumatic side brooms, which use compressed air for actuation and control. Pneumatic systems offer a simpler, more efficient alternative by reducing the number of components, lowering maintenance costs, and enhancing energy efficiency. Pneumatic side brooms also provide greater flexibility in adjusting broom height, angle, and rotation speed, improving overall performance. The design considerations for pneumatic systems include air compressor capacity, optimized air delivery systems, durable pneumatic cylinders, and enhanced safety features. Furthermore, integrating advanced control systems can further improve the precision and adaptability of pneumatic side brooms. The paper highlights the environmental advantages, reduced operational costs, and improved reliability of pneumatic systems, positioning them as a promising solution for modernizing mechanical sweepers. This transition not only enhances the operational capabilities of sweepers but also contributes to sustainability and operational efficiency in municipal and industrial street cleaning.

INTRODUCTION

A "sweeper machine" is a mechanical device used to clean floors, roads, or other surfaces by sweeping away debris and dirt using rotating brushes, often collecting the collected material in a hopper, essentially a motorized broom that can cover large areas efficiently; commonly used for cleaning sidewalks, parking lots, and industrial spaces. Sweepers have been cleaning roadways since 1914. Overall, mechanical sweepers are key equipment

for municipalities, construction sites, and large commercial properties, offering a powerful and efficient solution to maintaining clean and safe environments.

Key points about sweeper machines:

1. **Function:** The primary function of mechanical sweepers is to clean large outdoor areas such as streets, parking lots, roads, and industrial zones. They perform this task using a combination of different mechanisms designed to gather debris and dirt efficiently

2. **Types:**

Mechanical broom sweepers: Use rotating brushes to sweep debris into a hopper. They are fuel efficient and can handle rough street surfaces.

Vacuum sweepers: Similar to home vacuum cleaners, they suck up debris and work well in dusty environments.

Regenerative air sweepers: Use a combination of suction and high-velocity air to pick up debris.

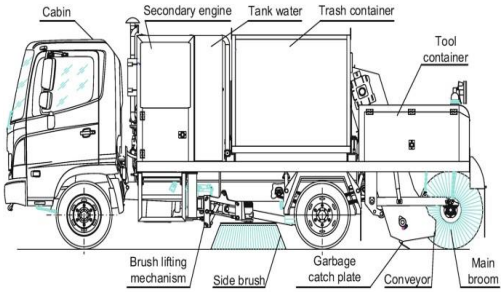

Fig.1 Sweeper Block Diagram.

SIDE BROOM WORKING AND SIGNIFICANCE

Working of a Side Broom:

The side broom is mounted on the side of the sweeper, usually near the front. It rotates at high speed, typically powered by the sweeper's hydraulic or mechanical system. As the broom rotates, it sweeps debris, dirt, leaves, and trash from the sides of the street toward the centre of the vehicle. The debris gathered by the side broom is directed into the main broom or vacuum system of the sweeper, which then collects it into the hopper for disposal.

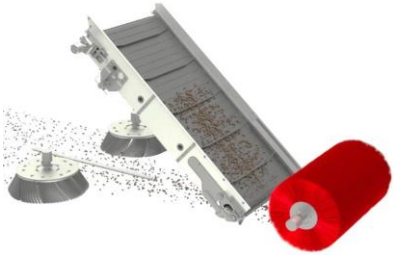

Fig.2 Side Broom working

Significance of the Side Broom:

Enhanced Cleaning Coverage: The side broom allows street sweepers to clean areas that the main broom might miss, especially along curbs, gutters, and edges of roads.

Efficiency: It helps cover a larger surface area in less time, especially for hard-to-reach areas. This reduces the need for manual cleaning, saving both time and labor.

Street Maintenance: Side brooms are essential for maintaining road cleanliness, which helps in reducing pollution and improving aesthetics. Clean streets also enhance safety by preventing debris that could cause accidents or block drainage systems.

Versatility: These brooms can be adjusted to different positions to clean various types of surfaces effectively, whether it's a narrow road, a wide highway, or a parking lot.

Environmental Impact: By removing dirt and trash from streets, side brooms contribute to reducing environmental contamination, preventing runoff, and improving air quality.

HYDRAULIC SIDE BROOM SYSTEM (TRADITIONAL)

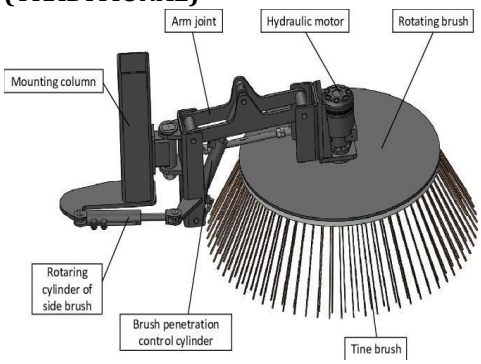

Fig.3 Side Broom Block Diagram

Design

Hydraulic side brooms are powered by hydraulic pumps, which are usually connected to the vehicle's engine. These brooms consist of rotating brushes that sweep debris to the side of the machine. The brooms' movement (height, angle, and rotation) is adjusted via hydraulic actuators controlled by the operator. Hydraulic hoses and components are used to transmit power and control the side broom.

Limitations

1. **Hydraulic System Complexity:**

The hydraulic system, including motors, cylinders, hoses, and pumps, requires regular maintenance to avoid leaks, pressure issues, or component failure. Hydraulic systems are prone to wear and tear, especially if not properly

maintained, which can lead to downtime and repair costs.

2. **Power Consumption:**
   High Energy Demand: Hydraulic systems generally require a considerable amount of power to operate efficiently. This can lead to increased fuel consumption, especially if the sweeper is working for long hours. The energy demand of the hydraulic motor and pump can add to the overall operational costs.
   Dependence on Engine Power: Since the hydraulic system is powered by the sweeper's engine, the performance of the side broom is directly related to the engine's efficiency. If the engine is underpowered or inefficient, the side broom's performance could be compromised.

3. **Limited Adjustability:**
   Fixed or Limited Angles: Some hydraulic side brooms have limited adjustability in terms of the angle of rotation or the height at which they operate. If the angle or height is not suitable for certain road conditions, it can result in ineffective cleaning or damage to the broom.
   Inconsistent Contact with Road Surface: If the hydraulic system fails to maintain the correct pressure or alignment, the side broom may not consistently make effective contact with the road surface, leading to uneven cleaning or ineffective debris collection.

4. **Mechanical Failure Risks:**
   Wear and Tear: The side broom's rotating parts, including bristles, shafts, and bearings, are subject to constant friction and stress. Over time, these components wear out, requiring regular replacement or repair. If maintenance is neglected, mechanical failures can occur, which may halt cleaning operations.
   Hydraulic Motor Damage: The hydraulic motor that drives the broom can be damaged by factors like pressure surges, improper fluid levels, or overuse, leading to expensive repairs and downtime.

5. **Impact of External Conditions:**
   Temperature Sensitivity: Hydraulic systems can be sensitive to extreme temperatures. In very cold or hot environments, hydraulic fluid may become too thick or too thin, affecting system performance. This can cause sluggish operation or damage to the motor and pump. *Debris Blockage:* The side broom can get clogged or slowed down by larger debris, such as branches or large trash items, which can restrict the broom's ability to sweep effectively. If debris builds up, the broom's rotational speed may decrease, or the system could be overloaded.

6. **Cost:**
   Initial and Operating Costs: Hydraulic systems can be more expensive to install and maintain compared to simpler mechanical systems. The cost of hydraulic fluid, maintenance, and repairs can add up over time, making the system costlier to operate in the long run.

7. **Environmental Concerns:**
   Hydraulic Fluid Leaks: If there is a hydraulic fluid leak, it can lead to environmental contamination, which is particularly concerning if the sweeper is used in sensitive areas like parks or near water bodies.
   Disposal of Hydraulic Fluid: The disposal of hydraulic fluid needs to be handled carefully

   to prevent environmental damage. It requires proper handling, recycling, or disposal methods, which adds to the operational burden.

PNEUMATIC SIDE BROOM SYSTEM (IMPROVEMENT)

A pneumatic system for side brooms uses compressed air rather than hydraulic fluid to power the broom's movement and adjustments. This transition can address many of the limitations of the hydraulic system while offering a more efficient and cost-effective solution.

Design

Pneumatic Actuation: Pneumatic side brooms use air-powered actuators, which are controlled by valves and regulators. Compressed air is stored in tanks and routed to control the broom's rotation and movement**.**

Brush Rotation: The broom's brush is rotated via a pneumatic motor that operates with compressed air. The motor can be connected to the broom through gears or belts.

Height and Angle Adjustment: Pneumatic cylinders replace hydraulic actuators for adjusting the height and angle of the broom, giving flexibility for different sweeping conditions.

Compressed Air System: Compressed air is delivered through pipes and valves, and the system is controlled using a user interface inside the sweeper cabin.

Points Should Consider While Design

1. Maximum up condition according to current side broom

2. Vertical down travel for side broom – 285mm
3. Pneumatic cylinder ø80 x 150 mm stroke at 6 bar
4. Extended length for cylinder – 556 mm
5. Collapse length for cylinder – 406 mm
6. Maximum in / out angle of current side broom
7. Weight of side broom – 105 kg
8. Ground clearance

CALCULATIONS Force required for Side broom to lift

Annotations

FCYL = Force applied by cylinder Θ = Angle made by cylinder with ground
m = Mass of side broom
L1 = perpendicular distance between force line and Pivote
L2 = perpendicular distance between Pivote and CG point

Take moment at Pivote point is zero
We get equation

$$FCYL = \frac{m \times 9.81 \times L2}{L1} \quad \text{----------(i)}$$

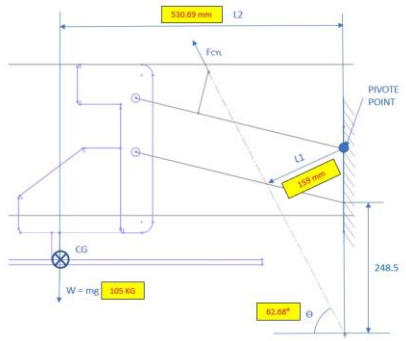

Fig.4Side Broomcylinder at extended condition

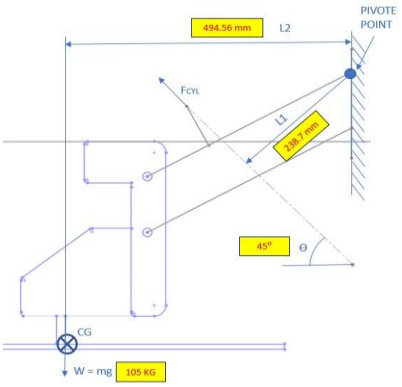

Fig.5 Side Broom cylinder at collapse condition

FCYL REQ	N
MAX UP CONDITION	2947
MAX DOWN CONDITION	2134

Force obtained from pneumatic cylinder

Annotations

P = Cylinder pressure = 6 bar
A = Area of piston head
d = Diameter of piston head = 80 mm

standard formula which we have to use

$$A = \frac{\Pi^2}{d4} \quad \text{----------(ii)}$$

$$P = \frac{TH\ FCYL}{A} \quad \text{----------(iii)}$$

P (PSI)	P (BAR)	Cylinder Dia	Area	TH FCLY (N)
87	6	80 mm	5026.55	3015.93

CONCLUSION

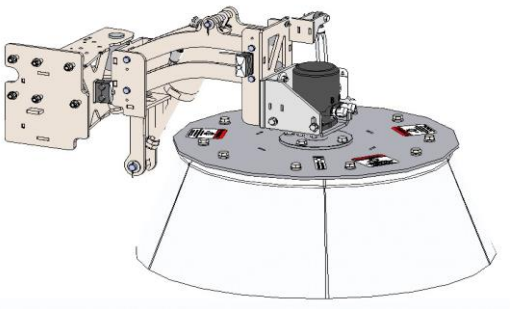

Fig.6 Side Broom using Pneumatic cylinder

Here we can see theoretical cylinder force comes more than the fore we required for lifting the side broom. So our section of cylinder is ok and we can use that pneumatic cylinder in design consideration. The transition from hydraulic to pneumatic side brooms in mechanical sweepers offers significant improvements in terms of reduced maintenance, better fuel efficiency, and simpler designs. Pneumatic systems, while slightly lower in torque, provide the opportunity for lighter and more cost-effective solutions.

FUTURE SCOPE

The transition from hydraulic to pneumatic side brooms in mechanical sweepers has opened new avenues for research and innovation. As the demand for more efficient, environmentally friendly, and cost-effective road cleaning solutions grows, further research into pneumatic side brooms could unlock significant advancements in their design, performance, and adaptability. Below are key areas where future research can be focused:

1. Design and Development of pneumatic motor
2. Advance materials for bristles
3. Optimized Air Flow and Pressure Regulation
4. Integration with Smart Technologies
5. Cost-Effective Manufacturing and Production

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