STATISTICAL ANALYSIS OF PIPE WEAR AND FAILURES IN HYDRAULIC SYSTEMS OF AGRICULTURAL MACHINERY CAUSED BY HYDRAULIC SHOCK

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Abstract: This article presents a statistical analysis of the hydraulic shock phenomenon occurring in the hydraulic systems of agricultural machinery, particularly excavators and tractors, and its impact on the wear and failure of technical components, especially pipes and joints. In addition, the direct and indirect effects of hydraulic shock on energy efficiency are illustrated with quantitative indicators.

Keywords: Hydraulic shock, agricultural machinery, energy efficiency

Annotatsiya: Ushbu maqolada qishloq xo‘jaligi texnikalari, xususan ekskavator va traktorlar gidrosistemalarida yuzaga keladigan gidravlik zarba hodisasi va uning texnik elementlar, ayniqsa quvurlar, uzellarining yeyilishiga va ishdan chiqishiga olib keluvchi omillar statistik tahlil asosida yoritilgan. Shuningdek, gidravlik zarbaning energetik samaradorlikka bevosita va bilvosita ta’siri raqamli ko‘rsatkichlar bilan ifodalangan.

Kalit so’zlar: Gidravlik zarba, qishloq xo‘jaligi texnikasi, eergetik samaradorlik

Аннотация: В данной статье представлен статистический анализ явления гидравлического удара, возникающего в гидросистемах сельскохозяйственной техники, в частности экскаваторов и тракторов, а также его влияния на износ и выход из строя технических элементов, особенно труб и соединений. Кроме того, прямое и косвенное влияние гидравлического удара на энергетическую эффективность представлено в количественных показателях.

Ключевые слова: Гидравлический удар, сельскохозяйственная техника, енергетическая эффективность

Introduction. Hydraulic shock is a widely observed phenomenon in hydraulic systems, particularly in agricultural machinery such as tractors and excavators. These sudden pressure surges occur when there is a rapid change in fluid flow, resulting in substantial mechanical stress and degradation of pipeline components.[6] The consequences are not limited to mechanical wear and failure, but also include significant energy losses, directly affecting operational efficiency and system reliability.[2]
This study aims to present a statistical analysis of pipe wear and failure caused by hydraulic shock in agricultural machinery over the period of 2019 to 2023. Data was obtained from technical service centers and operational reports from machinery used in agricultural enterprises. [1][3][5]

Methodology. This study adopts a mixed-methods approach, integrating quantitative analysis of field data with qualitative observations gathered from service engineers and technical operators of agricultural machinery.

The main objective of this methodology is to identify the frequency, patterns, and causes of hydraulic pipe failures caused by hydraulic shock in tractors and excavators used in agricultural operations.

Data Sources and Collection

The primary data source consists of technical service records from the “ABC Excavator Technical Service Center” and affiliated maintenance units covering a five-year period from 2019 to 2023. These records include failure logs, maintenance reports, and parts replacement histories for over 1,800 individual service events related to hydraulic systems. Additionally, author-collected field data was compiled through structured interviews and on-site diagnostics in 2023 at selected agricultural enterprises in the Tashkent and Samarkand regions.

A total of 300–410 machines were analyzed each year, comprising both new and older models, allowing a comparative evaluation across equipment age and usage conditions. Each machine's failure history was categorized by type, severity, repair duration, and cause attribution (e.g., hydraulic shock, mechanical fatigue, lack of maintenance).

Analytical Framework

Descriptive statistics were employed to assess failure rates per year and to detect trends in hydraulic shock-related incidents. Percentages and annual growth rates were calculated to measure the increase in such failures over time. Moreover, conditional probability analysis was used to examine the correlation between machine age, workload, and failure frequency.

To estimate the energy impact, a model was developed based on average operational hours per year (1800 motor-hours), expected downtime per incident, and repair time. This model provided a basis for calculating direct energy losses (due to inefficient operation during shocks) and indirect losses (from downtime).

Results and Discussion. Key findings include the following data and the overall graph representing the failure through the year was shown in the Figure 1.

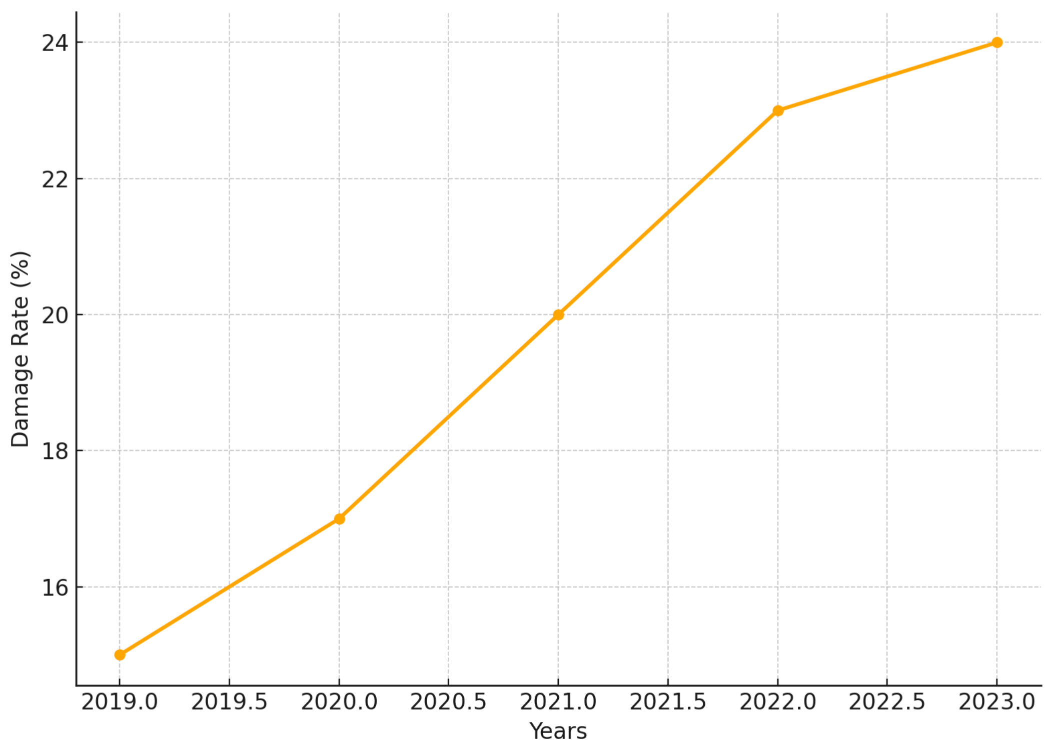

Fig 1. Pipeline wear due to hydraulic shock (%)

- In 2019, 15% (48 out of 320) of machines experienced damage due to hydraulic shock;
- In 2020, 17% (65 out of 380);
- In 2021, 20% (80 out of 400);

- In 2022, 23% (95 out of 410);
- In 2023, 24% (72 out of 300) by mid-year.

The upward trend highlights the need for better diagnostics and preventive measures

The primary contributing factors identified were:
- Aging hydraulic systems;
- Inadequate or poor-quality maintenance;
- Lack of routine diagnostics and preventive maintenance strategies.

Hydraulic-related faults account for approximately 40% of all maintenance requests, with hydraulic shock alone representing 20–25% of these. Older machines, particularly those over 5 years in service and used under heavy loads, show significantly higher rates of failure due to intensified pressure shocks and wear.

Hydraulic shock affects both mechanical durability and energy efficiency.

Direct impact:
- Energy losses during hydraulic shock events are estimated at 7–10%.
- For an excavator operating 1800 motor-hours per year, the excess consumption due to hydraulic shock translates to 90–180 motor-hours annually.

Indirect impact:
- Hydraulic shock-induced repairs result in machine downtime of 2–3 days per incident.
- Two such incidents per year yield 40–60 hours of lost productivity, reducing annual efficiency by an estimated 2–3%.

Total Estimated Energy Loss:

- Direct: 90–180 motor-hours/year
- Indirect: 40–60 motor-hours/year
- Total: 130–240 motor-hours/year

The observed degradation in hydraulic systems can also be linked to the absence of predictive maintenance models within many agricultural enterprises. Unlike industrial automation, where real-time sensor data enables early detection of anomalies, most agricultural machinery lacks integrated pressure monitoring systems. As a result, hydraulic shock is often detected only after significant damage has occurred.
Modern trends in mechanical engineering emphasize the use of IoT-based diagnostics and adaptive load balancing in fluid transport systems. By incorporating smart sensors and AI-driven predictive algorithms, it becomes possible to monitor internal fluid pressure, anticipate abnormal surges, and proactively adjust valve mechanisms before a shock develops.
Furthermore, design-based innovations such as buffer accumulators and pressure dampers are increasingly being utilized in high-pressure systems. These components absorb sudden energy surges and reduce the kinetic impact on critical joints and valves. Field trials in Western Europe have demonstrated that systems equipped with such features show a 35–40% lower failure rate over a 5-year lifecycle.
Conclusion. To effectively reduce failure rates in Uzbekistan's agricultural sector, a shift toward smart mechanization and modular hydraulic architecture is vital. Investment in education, policy-level support for sustainable mechanization, and international cooperation in hydraulic research are key drivers in this transition.
In conclusion, mitigating hydraulic shock not only extends the lifecycle of

machinery but also ensures sustainable energy usage and lowers economic losses across the agricultural production chain.

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