Prevention of Safety Accidents Caused by Structural Defects in Concrete Pump Car Booms

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ABSTRACT : *Concrete pump cars are indispensable in modern construction due to their ability to efficiently pour concrete into required locations. However, structural failures in boom components have caused several catastrophic accidents, resulting in fatalities and equipment damage. This study analyzes the causes of such failures, with a focus on the second-stage boom, which experiences the highest stress during operation. Finite Element Analysis (FEA) reveals that the second-stage boom has a maximum stress of 895.39 MPa, with a critically low safety margin of 0.04. The study proposes design enhancements such as increased material thickness and steel plate reinforcements. These measures aim to improve structural robustness and reduce the risk of failure, ensuring safer construction environments.*

KEYWORDS -*Concrete pump car, finite element analysis, safety accidents, structural defects, boom reinforcement*

I. INTRODUCTION

A Concrete Pump Car is an essential piece of equipment in the concrete pouring process of buildings. It simultaneously performs the functions of mixing and distributing concrete from the hopper to the mixer, and transports the concrete supplied by ready-mix trucks to the pouring site, delivering it as needed. Large-scale concrete pouring is difficult to achieve with manual labor alone, so the use of a pump car is essential for efficient pouring operations. Particularly, when pouring concrete through manpower or pipes, cold joints may occur due to the time difference in the setting of the earlier and later poured concrete, which could lead to quality issues in the concrete. Therefore, using a pump car for pouring is recognized as the most efficient method not only from a quality control perspective but also in terms of work speed. However, in recent years, there have been frequent accidents involving the failure of pump car booms during concrete pouring operations. In response, some construction companies are considering imposing restrictions on the age of equipment due to safety concerns about aging equipment. On the other hand, the Ministry of Land, Infrastructure and Transport, equipment manufacturers, and the equipment rental industry have denied responsibility for equipment defects and have pressured construction companies seeking to impose age restrictions. This study aims to address these issues by exploring improvements in design standards at the manufacturing stage of pump cars, as well as systematic improvements in inspection standards and rental systems for older equipment. Furthermore, the study seeks to analyze the causes of accidents, identify problems related to mechanical defects and inspection systems, and propose concrete and practical improvements to prevent equipment defect-related accidents.

II. SCOPE OF RESEARCH

This study focuses on accidents caused by mechanical defects in concrete pump trucks over the past two years. Specifically, it:

2.1Examines accident data to identify common characteristics of boom failures.

2.2 Reviews inspection standards and proposes enhanced non-destructive testing (NDT) methods.

2.3 Evaluates the structural integrity of booms using finite element analysis (FEA).

III. METHODOLOGY

3.1 Accident Analysis

Three major boom failure cases from 2021–2022 were investigated, involving equipment with boom lengths of 55–63 meters. Common failure points were identified as the second boom section, which exhibited structural vulnerabilities.

		
2021.03.09,(EVERDIGM 55CS-5, 55m),	2022.05.24,(EVERDIGM 60CS-S, 60m)	2022.08.05,(KCP63ZX170, 63m)

Fig. 1. Accident status during concrete pouring

3.2 Finite Element Analysis (FEA)

FEA models from prior studies were reviewed to evaluate stress distribution across the boom sections. ANSYS Workbench 19.0 was utilized to assess structural stability. Material properties of the steel (Stren 700) were analyzed, focusing on tensile strength, fatigue behavior, and safety margins.

3.3 Limitations of the Inspection System

The current inspection system is inadequate for preventing boom failure accidents. According to data from the Ministry of Land, Infrastructure, and Transport, there were five cases of boom failure and twelve overturning accidents over the past five years, resulting in seven casualties. Some defects were not detected during legal inspections and non-destructive testing, revealing a gap in the effectiveness of the inspection system. Additionally, the cost of regular inspections (82,500 KRW) is insufficient for large equipment, potentially compromising inspection quality. Moreover, incidents occurring despite non-destructive testing highlight the need for stronger responsibility and management within inspection agencies. Over the past five years, 5,648 concrete pump cars failed regular inspections, with over 16% accumulating safety issues annually.

Table 1. Data submitted to the National Assembly (Unsuitable for regular inspection of pump cars, 2018. 1~2022. 7)

Sortation	2018	2019	2020	2021	2022 (~7M)	Total
Inconsistence	1,324	1,310	1,190	1,149	675	5,648
Ratio	17.9%	18.0%	16.9%	16.7%	16.6%	17.22%

3.4 Equipment Scaling and Insufficient Technical Response

As construction projects grow taller, equipment size and boom lengths have increased, but the technical and regulatory responses have not kept pace. Accidents mainly occur in large concrete pump cars with booms over 55 meters, signaling the need for improved structural integrity and inspection systems. A case study of Company D revealed a failure due to the continued use of equipment without proper boom reinforcement design.

3.5 Need for Clear Responsibility Allocation in Accidents

The current legal framework lacks clarity in assigning responsibility for accidents. In boom failure cases, unclear responsibility between manufacturers, owners, and inspection agencies has led to ineffective preventive measures. A systemic mechanism where all parties share responsibility is needed to strengthen accident prevention and improve safety management.

IV. RESEARCH RESULTS

4.1 Analysis of Structural Issues in the Boom

To analyze the structural weaknesses of the concrete pump car boom, finite element analysis was utilized. The results showed that the second-stage boom experiences the highest stress, and the low margin of safety (M.S.) in this area was identified as a major cause of boom failure. According to the finite element model analysis, the second-stage boom was found to exceed the maximum stress of the fifth-stage boom by approximately seven times, clearly indicating the need for structural reinforcement in this area during the design and manufacturing stages. The fatigue load on the second-stage boom is exacerbated by repeated vibrations and shock, making additional reinforcement and increased stiffness essential. These structural defects were identified as the primary cause of boom failure.

Table 2. Margin of Safety by static analysis

Sortation	Stress [MPa]	M.S
Boom 1	4.95	29.71
Boom 2	12.83	10.85
Boom 3	26.83	4.67
Boom 4	34.37	3.42
Boom 5	25.68	4.92

4.2 Analysis of the Limitations of the Inspection and Management Systems

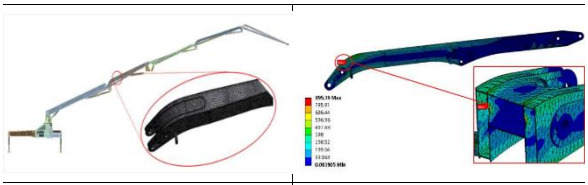
Issues related to the inspection and management systems for pump car equipment were identified. Non-destructive testing and regular inspections play crucial roles in accident prevention, but due to limited inspection budgets and insufficient inspection levels, the effectiveness of the inspection system is reduced. Particularly, there is a lack of long-term solutions for addressing equipment aging, and preventive measures for detected defects are insufficient. In the case of Company D's accident, a failure occurred despite no abnormalities found during the inspection, highlighting the serious reliability issue of the inspection and management system. Furthermore, the lack of clarity in responsibility during accidents led to inadequate preventive measures, exacerbating the situation. To resolve this, the responsibility of inspection agencies must be clarified, and the cost of inspections should be adjusted, along with enhancing the standards of non-destructive testing.

4.3 Analysis of Issues Due to Equipment Scaling

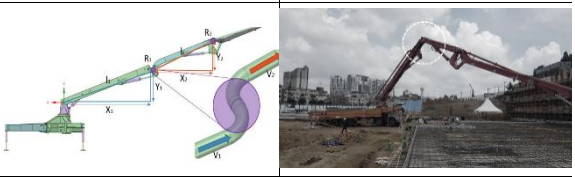
With the increase in the construction of high-rise buildings, the size of pump cars has grown, leading to longer booms. However, the inspection and management systems have not kept pace with this growth and are unable to sufficiently address the risks associated with larger equipment. As the length of the boom increases, the risk of structural defects becomes more significant, making the reinforcement of design standards and periodic inspections even more critical. Given the large impact of boom size on structural stability, the existing inspection and management systems must be upgraded accordingly. A solution to this issue includes strengthening the design standards for booms and preemptively reinforcing them to address the structural issues associated with larger equipment.

4.4 Finite Element Model Analysis Results

This study re-evaluated the structural safety of the pump car boom by considering fatigue loads caused by repeated vibrations during the pouring process, based on dynamic analyses presented in previous studies. The finite element model analysis confirmed that the second-stage boom is the most vulnerable part of the structure. The results indicated that the thickness of the second-stage boom components needs to be increased and additional reinforcement plates should be added at the upper part, as shown in Fig. 3Ⓑ. Furthermore, additional reinforcement for pump cars currently used in construction sites is also recommended. Additionally, as concrete is transported through the pumping pipe, impact loads are applied to the boom in the direction shown in Fig. 2Ⓐ. This phenomenon occurs due to periodic swinging of the boom during the pouring process, proportional to the inlet and outlet speeds. Fatigue stresses on the boom, analyzed through vibration and dynamic analysis, showed the highest fatigue stress occurring in the second-stage boom, as summarized in Table 2. Therefore, additional reinforcement and increased component stiffness for the second-stage boom are essential.



Ⓐ2nd Booms Boundary of a Pump Car | Ⓑ2nd Boomers of concrete pump cars



Ⓒ Pumping test of concrete pump ca | Ⓓ‘D 사’ 2nd Boom fracture accident

Fig. 2 Stress distribution of boom

V. DISCUSSION

This study analyzes concrete pump car boom failure accidents and suggests preventive measures.

5.1 Need for Safety Certification and Reinforcement of Strength

Currently, concrete pump cars are not classified as hazardous machinery under industrial safety regulations, so safety certification is not mandatory. However, as pump cars become larger and accidents can cause significant damage, they should be classified as hazardous machinery and required to undergo safety certification. Additionally, improvements such as reinforcing safety devices, increasing plate thickness, and enhancing structural stiffness are necessary. These measures should be addressed within the framework of industrial safety laws.

5.2 Prevention of Safety Risks Due to Equipment Size Increase

As pump car boom lengths and equipment sizes increase, the weight of the equipment rises, sometimes leading to reduced plate thickness to lighten the load. This compromises safety, especially as inappropriate adjustments are made to meet the 50-ton weight limit under road traffic laws. Such actions can lead to accidents. For example, cracks and corrosion were observed in the second boom, as shown in Fig3, highlighting the structural vulnerabilities.

5.3 Improvement of Inspection and Non-Destructive Testing Systems

Over time, equipment performance deteriorates, and it becomes difficult to maintain initial performance. Non-destructive testing is conducted to monitor the health of equipment, but it is often superficial and fails to identify defects. To improve this, the responsibility of inspection agencies should be strengthened, and national standards for non-destructive testing should be established. Additionally, improving the reliability and accuracy of inspection results is crucial.

5.4 Realistic Inspection System and Cost Improvement

The current inspection system is insufficient. For instance, a tragic accident occurred 23 days after a regular inspection indicated no issues, yet a boom failure resulted in the death of two workers. The inspection fee of 82,500 won is insufficient to cover all necessary checks. Thus, inspection costs should be adjusted, and the reliability of inspection items should be improved. Legal mechanisms should also be established to clarify responsibilities and address risk transfer issues in contracts.

Fig. 3. A sectional photograph of the pump car boom breakage of company D社 (death 2).

VI. CONCLUSION

This study focused on analyzing recent boom failure accidents of concrete pump cars and identifying their causes, with the goal of presenting practical solutions to prevent such accidents. The findings revealed that boom failures predominantly occur in the second-stage boom, which is structurally the weakest part of the equipment. Moreover, the limitations of the current inspection system and the challenges posed by increasing equipment size were found to be significant contributors to these accidents. Based on these insights, several conclusions and recommendations are made.The finite element analysis showed that the second-stage boom experiences the maximum stress, making it the most vulnerable point. Enhancing structural reinforcement during the design and manufacturing stages, especially by adding reinforcement plates at points of maximum stress, is crucial for ensuring structural safety. These improvements will play a key role in preventing boom failure accidents.The current inspection system is insufficient in preventing boom failures, with inadequate technical capabilities and inspection standards. To address this, it is necessary to improve the precision of non-destructive testing technologies and adjust inspection costs to ensure realistic and effective inspections. Reducing the interval between inspections and establishing a systematic framework to ensure reliable results is also crucial. Moreover, clear accountability between inspection agencies and equipment owners must be established, with institutional measures to share responsibility in the event of an accident.The

unclear distribution of responsibility in boom failure accidents often hampers effective accident prevention. Legal and institutional improvements are needed to clearly define the roles and responsibilities of manufacturers, equipment owners, and inspection agencies. Equipment owners and users should conduct joint inspections and take proactive measures for accident prevention, while manufacturers must improve quality control and design standards to prevent structural defects.With the increasing scale of construction sites, large pump cars, especially those with booms longer than 55 meters, have seen more frequent accidents. These large machines require additional safety designs and more stringent inspection standards. It is essential to assess the structural strength of these machines based on boom length and to use high-strength materials to improve design strength. Therefore, additional safety inspections and reinforcements should be conducted for large equipment.Finally, ongoing education and training for those responsible for the safe operation and maintenance of pump cars are critical. Strengthening the qualification requirements for operators and ensuring continuous education on equipment operation and maintenance are essential for preventing accidents. Regular training for new equipment should also be provided to ensure users understand the equipment's characteristics and can follow safety protocols accurately.

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