UDC 621.863 DOI: 10.30977/AT.2219-8342.2022.51.0.06

Analysis of the load-bearing system of the loader according to the results of dynamic tests in the environment of Ansys motion

Shcherbak O.[1], Ragulin V.[1], Suminov A.[1,2]

[1]Kharkiv National Automobile and Highway University, Ukraine
[2]Kharkiv Tractor Plant, Ukraine

Annotation. Problem. *The T-156B hinge frame of the loader, which is an upgraded frame of an agricultural tractor, creates loads during work operations for which it was not designed. Such loads lead to breakdowns and further shorten the life of the entire machine. The frame is the basic element around which the machine is built. The loader that had just been removed from the conveyor did not have built-in durability and reliability. While designing a road construction machine, an account of the features, nature, and conditions of its operation should be taken.* ***Goal.*** *The goal is to develop a hinge frame design technique that takes into account the loads experienced by the frame with a virtual simulation of real-world situations during the loader process.* ***Methodology.*** *The adopted approach is based on the use of a Solidworks computer program with three-dimensional modeling and an Ansys motion program for calculating the dynamics of multicomponent bodies taking into account the hinge and contact interaction.* ***Results.*** *In the work three cases of technological operations of the loader were considered. 1. Lifting a full bucket. 2. Collision with an obstacle that is difficult to overcome 3. Movement over an uneven surface with the raised loader arm. The results of the calculations provided forces and torques in the hinge of the half-frames, as well as the effort of the frame. Based on the results obtained, the endurance of the frame in the Ansys motion software package was calculated.* ***Originality.*** *The analysis of load-bearing systems with a virtual simulation of the machine's actual behavior with the help of Ansys motion software allows to obtain more accurate results, significantly reducing the time for the design and cost of field testing.* ***Practical value.*** *This approach to the analysis of the carrier system behavior can be recommended for designing and determining the technological capabilities of wheeled, tracked, and special machines.*

Key words*: load-bearing system, strength, durability, 3D simulation, dynamics, Solidworks, Ansys Motion.*

Introduction

When designing units of articulated machines, in particular tractors, there is a question of ensuring the strength characteristics and durability of the load-bearing system (frame). When designing the frame considered several design modes: hanging, rotation on the spot, and plowing (for agricultural machines). In the next stage, bench and field tests shall be carried out in all these modes [1-3].

Designing of the loader T-156B frame went by upgrading the serial frame with retaining unification with the agricultural tractors (Fig. 1), since there were no methods to fully analyze the loader's behavior during the design phase, and testing of each new model was very expensive and time-consuming.

This design method is not effective because the upgrade of the serial frame did not consider the working conditions and purpose of the designed machine.

Fig. 1. Rear half-frame of loader

The main disadvantage of the production frame is the presence in the design of the horizontal hinge, which critically affects the stability of the machine, as well as the presence of a rear axle spring suspension, resulting in the rocking of the loaded machine during the execution of work operations.

Analysis of publications

Nowadays the problem of rational design and durability of carrier systems is solved by the finite elements method (FEM) [4-9] and specialized complex calculation programs. Analysis and calculation of the hinge frame with the help of the Ansys design complex were considered in the works [10-13].

The loads obtained during natural experimental studies [14] were applied to the serial frame. Based on the results of load calculations, a prototype welded frame was designed taking into account all tension [15, 16]. But to get acting on the frame loads is not enough for a complete analysis of the carrier system. The durability of the structure plays an important role. The issue of durability was considered in the works [17-19], during which the Ansys calculation complex was also used in conjunction with nCode DesignLife. The results of the calculation showed that during the operation of the loader there are weaknesses in the structure of the frame, which start to break down when they are affected by the workload.

Purpose and tasks

To create a method of strength and durability testing with the help of modern calculation complexes for the newly designed bearing systems by computer model analyzing with modeling the machine working operations. For this purpose, a created computer model of the loader should be the most relevant to the real machine. To determine the workflow load.

Methods of strength assessment of the bearing system based on the results of virtual tests simulation.

Ansys Motion is a specialized dynamic analysis program that contains a range of tools for simulating and designing kinematic systems.

ANSYS Motion combines four closely integrated solutions: rigid bodies, deformable bodies, modal analysis, and EasyFlex. This, taken together, provides a great opportunity to analyze systems and mechanisms.

In the work simulated several similar to the real one's situations of the workflow of the loader T-156B: 1. Lifting the filled bucket. 2. Collision of the bucket with an insurmountable obstacle when filling the bucket. 3. Movement on an uneven surface with a full bucket (loader arm raised maximum).

The T-156B loader model built by Solidworks CAD is used for calculation. The model is imported into Ansys motion, then the model is prepared for calculation. Defined hinges, involved in the calculation, relationships between the units, and written function expression for bodies that will move in the calculation (wheels, loader arm), set the total calculation time, and a number of calculation steps. After all the settings, the calculation starts. After the strength calculation, the fatigue resistance of the structure is calculated and it is possible to determine the areas that are prone to damage.

Strength evaluation of the load-bearing system

In the beginning, the case when the loader on the spot (Fig. 2) performs lifting the loader arm up to the maximum position with the filled bucket was considered. Total lift time – 4 seconds.

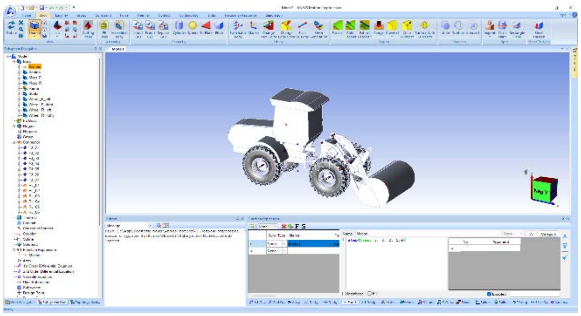

Fig. 2. Postprocessor configuration window for full bucket lifting situation

At the end of the calculation were obtained the graphs of active forces and torque in the hinge joint of the half-frames (Fig. 3-4).

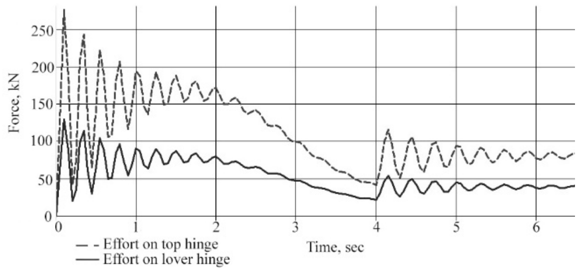

Fig. 3. Force acting in the hinged half-frame joint

The action force and torque curve are extinguished with sharp oscillations at the beginning of the ladle lift and gradually fade to the moment when the ladle is maximally raised (4 seconds).

After stopping the bucket in the elevated position, there are residual vibrations from the inertia of the filled bucket lifting, which also fade out.

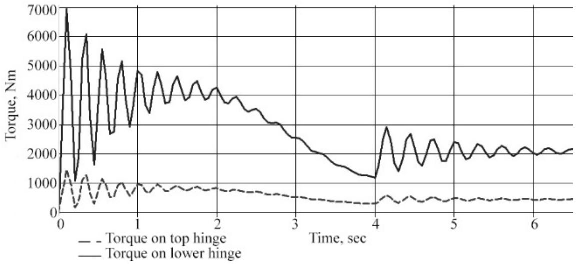

Fig. 4. Torque in the hinge of the half-frames

In order to better visualize the tension flow in the frame, loads on the VonMises scale are displayed. According to the results of the calculation, it can be seen that the maximum tension falls on the portal of the front half-frame at the points of the loader arm attachment to the frame (Fig. 5), (Fig. 6), and reaches 820 N/mm^2. Loads in the hinge and at the junction of the half-frames range from 200 N/mm^2 to 300 N/mm^2. This mode of the loader operation is the least loaded as there are no impact loads.

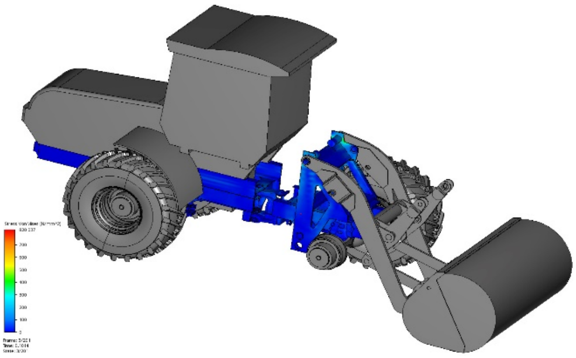

Fig. 5. Tensions in the frame side view (right front wheel hidden)

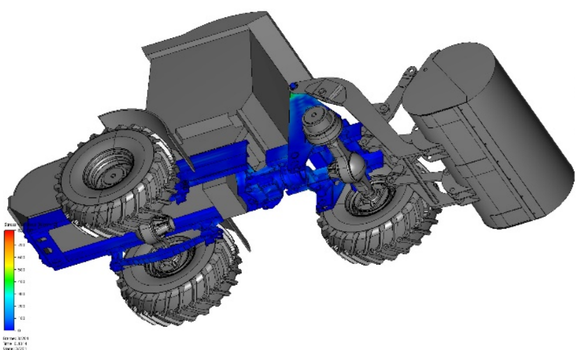

Fig. 6. Tensions in the frame from below (the right front wheel is hidden)

Next, we considered the case of impact load on the frame. The loader moves on a flat horizontal surface at a speed of 5 km/h, the loader arm is lowered, and the bucket in the lower position with the impact interaction of the bucket edge into an obstacle that is difficult to overcome (Fig. 7).

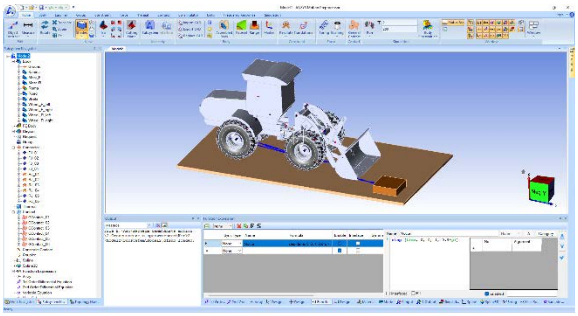

Fig. 7. Postprocessor configuration window for a collision situation with an insurmountable obstacle

At the end of the calculation were obtained graphs of active forces (Fig. 8) and torque (Fig. 9) in the hinge joint of the half-frames. During the start of the movement, there are attenuating vibrations caused by inertial forces due to the movement of the half-frame mass with the bucket and the force of the resistance to moving the bucket over the surface. Short-term surges in load and torque occur at the moment of impact. The force increases at 0.78 s to 1,200 kN and the torque increases to 100 kN·m, at 0.9 s to 590 kN and 45 kN·m, and at 1.1 s to 690 kN and 38 kN·m.

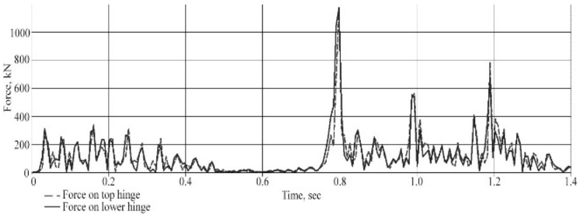

Fig. 8. Joint force of the half-frames

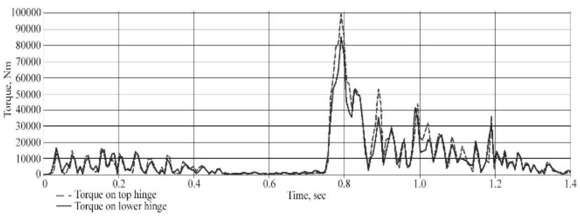

Fig. 9. Torque in the hinge of the half-frames

In order to make the tensions in the frame more visible, we will display the load on the VonMises scale at the moment of collision with an insurmountable obstacle. The hinge joint (Fig. 10), (Fig. 11) has the highest loads which reach up to 1.2 kN/mm^2.

The third calculated case is the movement of the loader on an uneven surface. The loader will move at a speed of 3.6 km/h with the full bucket raised to the maximum position on the platform simulating the pit and potholes (Fig. 12).

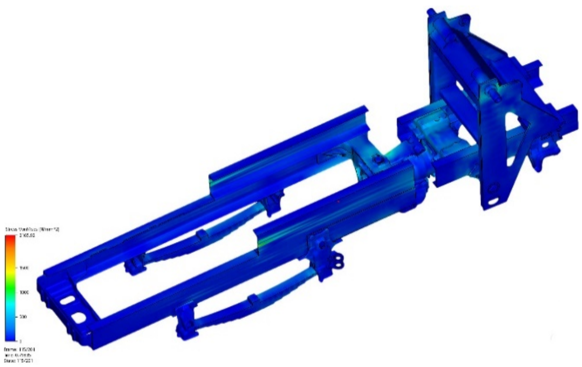

Fig. 10. Tensions in the frame

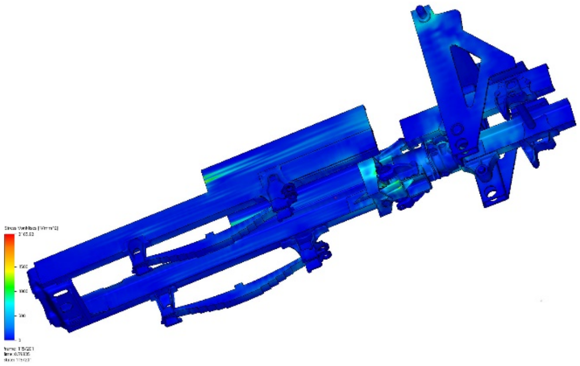

Fig. 11. Tensions in the frame

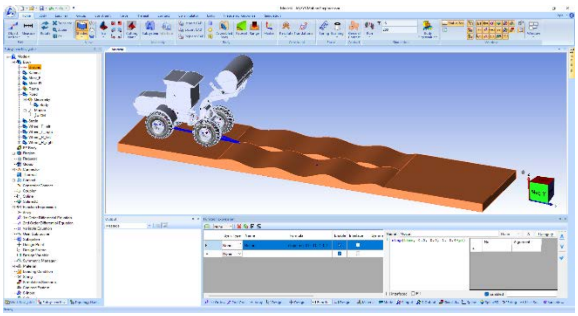

Fig. 12. Post-processor configuration window to calculate the position of the loader moving on an uneven surface

At the end of the calculation were obtained graphs of active forces (Fig. 13) and torque (Fig. 14) in the hinge joint of the half-frames. During the start of the movement, there are oscillations arising from inertia forces due to the movement of the half-frame mass and the full bucket in the upper position. At 2.4 s during the drive of the front left wheel into the pit, there is a hanging of the rear right wheel. The rear half-frame has a large length, which in turn creates a larger shoulder, and thus the hung rear right wheel creates the most force in the hinge of the half-frames. The force is 460 kN and 50 kN m. of torque. This display gives maximum load on the frame. Further roll-ups from the pit to the pothole and exit to a flat surface create less effort.

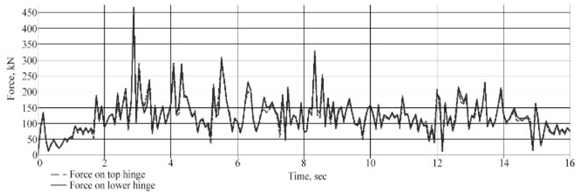

Fig. 13. The force in the hinge of the half-frames.

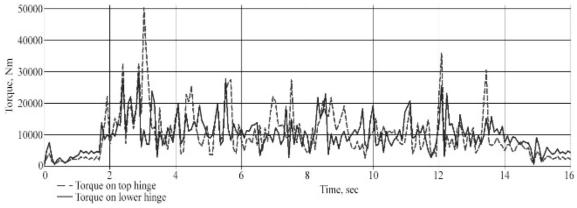

Fig. 14. Torque in the hinge of the half-frames

To make the tensions flow in the frame more visible, we will display the load on the VonMises scale with the rear right wheel hanging when the loader drives the front left wheel into the pit. The most heavily loaded elements are the hinges for fixing the loader arm to the front half-frame, where the loads reach 800 N/mm^2 with extension to the portal sidewalls and lower anchorages of the hinge joints of the half-frames, where the load reaches up to 500 N/mm^2 with extension to the entire hinge assembly and the lengths of the front half-frame (Fig. 15) and (Fig. 16).

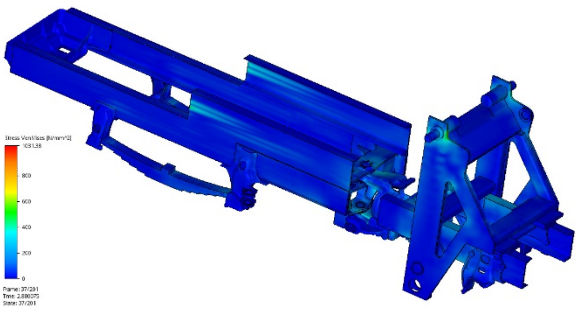

Fig. 15. Tensions in the frame

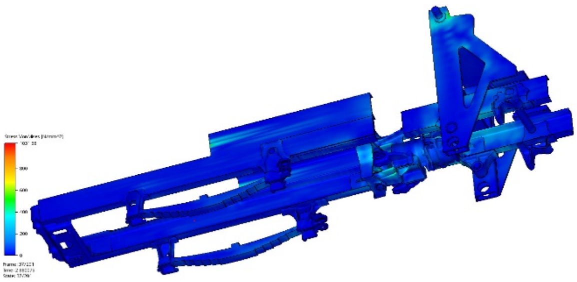

Fig. 16. Tensions in the frame

Evaluation of fatigue durability based on the results of calculations.

Ansys Motion allows calculating the structure of fatigue durability (life cycle) based on the results of the obtained stresses. Fatigue durability is calculated by applying the resultant load to the structure of 1,000,000 repetitions. At the end of the cycle, a calculation is made of which element can withstand how many repetitions, and on the color scale it is possible to analyze which areas need to be strengthened or weakened to optimize the mass characteristics.

In the first situation, when the fixed loader is calculated, the frame does not experience serious loads. In general, the design can withstand a cycle of 1,000,000 repetitions, only at 358,760 cycle repetitions there are small cracks in the sides of the hinge attachment (Fig. 17).

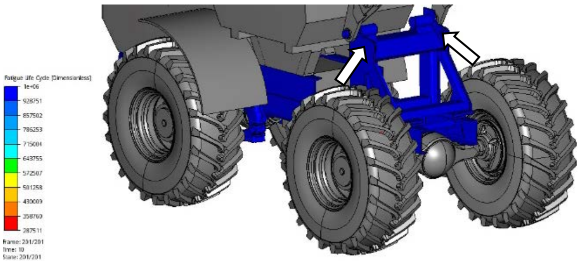

Fig. 17. Endurance of the frame in a full bucket lifting situation

The second situation in which the loader is impacted is the most dangerous for the frame. The hinge joint unit, the portal sidewall at the point of attachment of the loader arm hinge to the portal, and the front half-frame spars are already inoperable after less than 100,000 cycle repetitions (Fig. 18) and (Fig. 19). With all this damage, the loader is completely out of order.

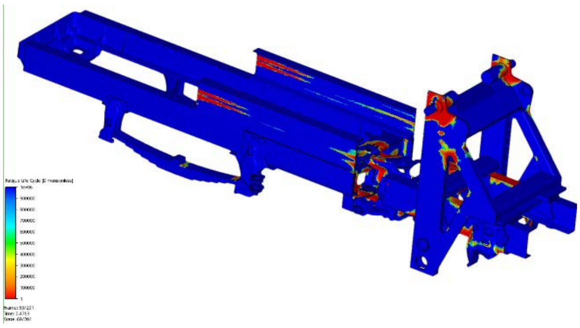

Fig. 18. Frame life cycle

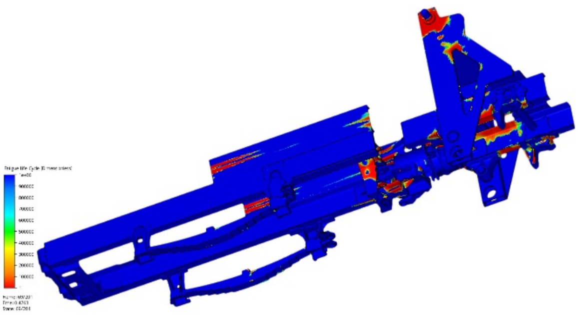

Fig. 19. Frame life cycle

In the third situation, the loader frame is tested by time-varying loads from the beginning of the wheel collision into the pit to the exit to the flat surface. Although in the third situation, the frame is affected by a lower impact load, but still, they are critical.

The least durable is the side of the portal at the point of the loader arm attachment to the portal and the bottom attachment of the hinge of the half-frame joint. These elements fail after less than 100,000 iterations of the cycle. The top attachment of the half-frame hinge is slightly more durable, withstanding 200,000 cycle repetitions (Fig. 20) and (Fig. 21). With such damage, the loader is also completely out of order.

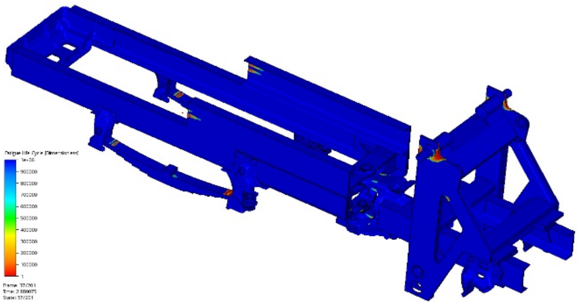

Fig. 20. Frame life cycle

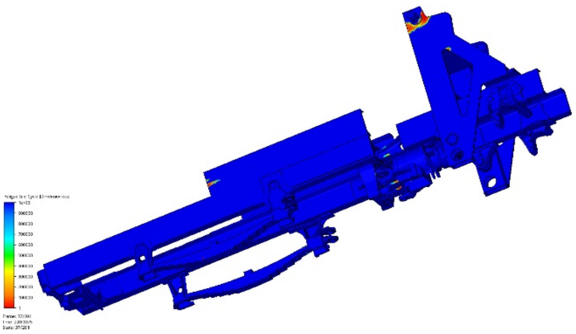

Fig. 21. Frame life cycle

Conclusion

The article presents a method of calculation of the loader frame in dynamics on the example of real working processes of the loader. The results of the calculations are obtained vulnerabilities of the frame that need to be improved.

The most critical is the case of a loader collision with an insurmountable obstacle. The vertical hinge experiences the biggest short-term breaking loads up to 1,200 kN, which negatively affects the reliability of the entire frame.

Fatigue life calculations show that in all three cases, critical frame elements do not go through a full cycle of 1,000,000 repetitions. The frame receives maximum damage in the event of a collision with an insurmountable obstacle. Shock loads greatly reduce the reliability of the frame and already at 100,000 repetitions there is significant damage to the vertical hinge, as well as other important components, such as loader arm attachment points and spars.

This method makes it possible to identify the weaknesses of the designed structures in the shortest possible time and without significant costs.

Conflict of interests

The authors declare that there is no conflict of interest regarding the publication of this paper.

References

1. Шувалов Е.А., Добряков Б.А., Пантюхин М.Г. (1980). *Теория и расчет трактора "Кировец",* Ленинград. Shuvalov E.A., Dobryakov B.A., Pantyuhin M.G. (1980). *Teoriya i raschet traktora "Kirovets"* [Theory and calculation of the Kirovets tractor]. Leningrad. [in Russian].
2. Шувалов Е.А., Добряков Б.А., Борисов Ю.И. (1974). *Трактор "Кировец". Описание конструкции и расчет,* Ленинград. Shuvalov E.A., Dobryakov B.A., Borisov Yu.I. (1974). *Traktor "Kirovets" Opisanie konstruktsii i raschet*. [Tractor "Kirovets". Design description and calculation]. Leningrad. [in Russian].
3. Холодов А.М. Ничке В. В., Назаров Л. В. (1980). *Проектирование машин для земляных работ*, Харьков. Holodov A.M., Nichke V. V., Nazarov L. V. (1980). Proektirovanie mashin dlya zemlyanyih rabot, [Design of machines for earthmoving]. Kharkov. [in Russian].
4. Зузов В.Н. (2002). *Разработка методов создания несущих систем колесных машин с оптимальными параметрами*. МГТУ им.Н.Э.Баумана. Zuzov V.N. (2002). *Razrabotka metodov sozda-niya nesuschih sistem kolesnyih mashin s optimalnyimi parametrami*. MGTU im.N.E. Baumana. [Development of methods for creating load-carrying systems of wheeled vehicles with optimal parameters]. [in Russian].
5. Русанов О.А. (2009). *Расчетный анализ напряженного состояния и оценка прочности несущих систем тракторов*. МГТУ им.Н.Э.Баумана Rusanov O.A. (2009). *Raschetnyiy analiz naprya-zhennogo sostoyaniya i otsenka prochnosti nesuschih sistem traktorov*. [Calculation analysis of the stress state and assessment of the strength of the bearing systems of tractors]. MGTU im.N.E. Baumana. [in Russian].
6. Герасимова Т.А. (2005). *Исследование и совершенствование методов проектных расчетов несущих конструкций экскаваторов*. Институт вычислительного моделирования СО РАН. Gerasimova T.A. (2005). *Issledovanie i so-vershenstvovanie metodov proektnyih raschetov nesuschih konstruktsiy ekskavatorov*. [Research and improvement of methods for design calculations of load-bearing structures of excavators]. Institut vyichislitelnogo modelirovaniya SO RAN, Krasnoyarsk. [in Russian].
7. Павленко П.Д. (2005). *Методология разработки рациональных конструкций несущей системы и ходовой части большегрузных строительных автомобилей-самосвалов*. Набережные Челны. Pavlenko P.D. (2005). *Metodologiya razrabotki ratsionalnyih konstruktsiy nesuschey sistemyi i hodovoy chasti bolshegruznyih stroitelnyih avtomobiley-samosvalov*. [Methodology for the development of rational designs of the carrier system and chassis of heavy construction dump trucks]. Naberezhnyie Chelnyi. [in Russian].
8. Альбайуб С. (2006). *Разработка методики создания рам грузовых автомобилей минимальной массы, соответствующие требованиям по ресурсу, на стадии проектирования*. МВТУ им. Баумана. Albayub S. (2006). *Razrabotka metodiki sozdaniya ram gruzovyih avtomobiley mi-nimalnoy massyi, sootvetstvuyuschie trebovaniyam po resursu, na stadii proektirovaniya*. [Development of a methodology for creating frames for trucks with a minimum mass that meets the requirements for a resource at the design stage]. MVTU im. Baumana. [in Russian].
9. Астахова Т.В. (2007). *Повышение долговечности рам карьерных автосамосвалов на основе исследования их напряженно-деформированного состояния* Институт вычислительного моделирования СО РАН Astahova T.V. (2007). *Povyishenie dolgovechnosti ram karernyih avtosamosvalov na osnove issledovaniya ih naprya-zhenno-deformirovannogo sostoyaniya* [Improving the durability of frames of mining dump trucks based on the study of their stress-strain state]. Institut vyichislitelnogo modelirovaniya SO RAN [in Russian].
10. Кухтов В.Г., Щербак О.В., Суминов А.В. (2016). Совершенствование методов расчета несущей системы шарнирного тягача. *Науковий журнал "Технічний сервіс агропромислового, лісового та транспортного комплексів"* (5), 141-147. Kuhtov V.G., Scherbak O.V., Suminov A.V. (2016). Sovershenstvovanie metodov rascheta nesuschey sistemyi sharnirnogo tyagacha. [Improvement of methods for calculating the bearing system of an articulated tractor]. *Naukoviy zhurnal "Tehnichniy servis agropromislovogo, lisovogo ta transportnogo kompleksiv"* (5), 141-147. [in Russian].
11. Щербак О.В., Сумінов А.В., Хачатурян С.Л. (2021). Розробка методики проектування спеціалізованих машин на базі шарнірного тягача. *Вісник Харківського національного автомобільно-дорожнього університету*, (95), С. 32-37.

Shcherbak O.V., Suminov A.V., Khachaturian S.L. (2021). Rozrobka metodyky proektuvannia spe-tsializovanykh mashyn na bazi sharnirnoho tiahacha [Development of a methodology for designing special machines based on an articulated tractor]. *Visnyk Kharkiv national automobile and highway university*, (95), 32-37. [in Ukrainian].

12. Кириченко І.Г, Черніков О.В., Роговий А.С., Рагулін В.М., Рєзніков О.О., Табуров О.С. (2021). Особливості комп'ютерного моделювання та дослідження режимів роботи елементів піднімальної платформи *Вісник Харківського національного автомобільно-дорожнього університету*. (95), 143–148. Kyrychenko I.H, Chernikov O.V., Rohovyi A.S., Ragulin V.M., Rieznikov O.O., Taburov O.S. (2021). Oso-blyvosti kompiuternoho modeliuvannia ta dos-lidzhennia rezhymiv roboty elementiv pidnimalnoi platformy [Peculiarities of computer modeling and study of operating modes of elements of the lifting platform]. *Visnyk Kharkiv national automobile and highway university*, (95), 143–148. [in Ukrainian].
13. Єфименко О. В., Плугіна Т. В., Мусаєв З. Р. (2017) Моделювання робочого обладнання малогабаритного навантажувача за допомогою сучасних програмних засобів *Вісник східноукраїнського національного університету ім. Володимира Даля*. (4), 98–102. Iefymenko O. V., Pluhina T. V., Musaiev Z. R. (2017) Modeliuvannia robochoho obladnannia malohabarytnoho navantazhuvacha za dopomohoiu suchasnykh prohramnykh zasobiv [Modeling of the working equipment of a small barite loader using modern software tools]. *Visnyk skhidnoukrainskoho natsionalnoho universytetu im. Volodymyra Dalia*. (4), 98 – 102. [in Ukrainian].
14. Щербак О.В. Р (2002). Разработка рациональных параметров соединительно-управляющего модуля фронтального погрузчика. Scherbak O.V. (2002). Razrabotka ratsionalnyih parametrov soedinitelno-upravlyayuschego modulya frontalnogo pogruzchika. [in Russian].
15. Щербак О.В., Суминов А.В. (2016). Разработка рациональных параметров несущей системы шарнирного тягача *Вестник Харківського національного автомобільно-дорожнього університету*, (73), 229-233. Scherbak O.V., Suminov A.V. (2016). Razrabotka ratsionalnyih parametrov nesuschey sistemyi sharnirnogo tyagacha [Development of rational parameters of the carrier system of an articulated tractor], *Vestnik Kharkiv national automobile and highway university*, (73), 229-233. [in Russian].
16. Черніков О. В., Кириченко І. Г., Москаленко А. І. (2010) Комп'ютерне моделювання та аналіз кінематичних особливостей робочого обладнання фронтального навантажувача *Прикл. геометрія та інж. графіка.* 107–111. Chernikov O. V., Kyrychenko I. H., Moskalenko A. I. (2010) Kompiuterne modeliuvannia ta analiz kinematychnykh osoblyvostei robochoho obladnannia frontalnoho navantazhuvacha [Computer modeling and analysis of kinematic features of front-end loader working equipment]. *Prykl. heometriia ta inzh. hrafika*. (86), 107 – 111. [in Ukrainian].
17. Кухтов В.Г., Щербак О.В., Суминов А.В. (2018). Расчет усталостной долговечности несущих систем технологических машин в nCode DesignLife. *Науковий журнал "Технічний сервіс агропромислового, лісового та транспортного комплексів*" (13), 193-199. Kuhtov V.G., Scherbak O.V., Suminov A.V. (2018). Raschet ustalostnoy dolgovechnosti nesuschih sistem tehnologicheskih mashin v nCode DesignLife. [Calculation of fatigue life of support systems of technological machines in nCode DesignLife]. *Naukoviy zhurnal "TehnIchniy servIs agropromislovogo, lIsovogo ta transportnogo kompleksIv*" (13), 193-199. [in Russian].
18. Кононыхин Б. Д. (2001) Числовые меры и методика сравнительной оценки качества техники *Строительные и дор. машины*. (3), 39–42. Kononyhin B. D. (2001) CHislovye mery i metodika sravnitel'noj ocenki kachestva tekhniki [Numerical measures and methods for comparative assessment of the quality of technology]. *Stroitel'nye i dor. mashiny*. (3), 39–42. [in Russian].
19. Ловейкін В. С. (2004) *Моделювання динаміки механізмів вантажопідйомних машин*: (Монографія). Миколаїв. Loveikin V. S. (2004) *Modeliuvannia dynamiky mekhanizmiv vantazhopidiomnykh mashyn* [Modeling of the dynamics of mechanisms of van lifting machines]. (Monohrafiia). Mykolaiv. [in Ukrainian].

Shcherbak Oleh[1] PhD, Assoc. Prof. Department of Construction and Road-Building Machinery,
e-mail: olegcherbar@gmail.com,
Phone.: +38-099-540-42-31,
ORCID: https://orcid.org/0000-0002-7953-2135
Ragulin Vitaliy[1] PhD, Assoc. Prof. Department of Construction and Road-Building Machinery,
e-mail: ragulinrvn@ukr.net,
Phone.: +38-050-545-80-70,
ORCID: https://orcid.org/0000-0003-2083-4937
Suminov Andrii[1,2] graduate student Department of Construction and Road-Building Machinery, e-mail: andrey.suminov@gmail.com,
Phone.: +38-099-757-89-54,
ORCID: https://orcid.org/0000-0002-4268-2906

[1]Kharkiv National Automobile and Highway University Yaroslava Mudrogo str., 25, Kharkiv, Ukraine, 61002
[2]Kharkiv Tractor Plant Heroiv Kharkova ave. 275, Kharkiv. Ukraine. 61007

Аналіз несучої системи навантажувача за результатами динамічних випробувань у середовищі Ansys motion

Анотація. Проблема. *При виконанні робочих операцій шарнірна рама навантажувача Т-156Б, яка є модернізованою рамою сільськогосподарського трактора, зазнає навантаження, на які вона не була розрахована. Такі навантаження призводять до поломок і надалі до скорочення терміну служби всієї машини. Рама є основним елементом, навколо якої побудована машина. Таким чином тільки що випущений з конвеєра навантажувач вже не має закладеної довговічності та надійності. При проектуванні дорожньо-будівельної машини слід враховувати особливості, характер та умови її роботи.* ***Мета.*** *Розробити методику проектування шарнірної рами, в якій будуть враховані навантаження, що діють на раму, шляхом віртуального моделювання реальних ситуацій при ви-конанні технологічних операцій навантажувача.* ***Методологія.*** *Прийнятий у роботі під-хід заснований на використанні комп'ютерної програми тривимірного моделювання Solidworks і програми для розрахунку динаміки багатокомпонентних тіл з урахуванням шарнірних та контактних взаємодій Ansys motion.* ***Результати.*** *У роботі було розгляну-то три випадки виконання технологічних операцій навантажувача. 1. Підйомання повного ковша. 2. Зіткнення з непереборною перешкодою під час наповнення ковша. 3. Переміщення по нерівній поверхні з піднятою стрілою. За результатами розрахунків були отримані сили і крутні моменти в шарнірі зчленування напіврам, а також зусилля, що діє на раму. На основі отриманих результатів було проведено розрахунок на втомну довговічність рами в програмному пакеті Ansys motion.* ***Оригінальність.*** *Аналіз несучих систем шляхом віртуального моделювання реальної поведінки машини за допомогою програмного пакету Ansys motion дозволяє отримати більш точні результати, завдяки гнучким налаштуванням, істотно скоротити час проектування і витрати на дороге проведення натурних ви-пробувань.* ***Практична цінність.*** *Даний підхід до аналізу поведінки несучої системи може бути рекомендований для проектування та визначення технологічних можливостей абсолютно різних колісних та гусеничних машин, а також інших механізмі.*

Ключові слова: *несуча система, міцність, довговічність, тривимірне моделювання, динаміка, Solidworks, Ansys Motion.*

Щербак Олег Віталійович[1], к.т.н., доцент кафедры будівельних, дорожніх машин та обладнання ім. А.М. Холодова,
e-mail: olegcherbar@gmail.com,
тел.: +38-099-540-42-31,
ORCID: https://orcid.org/0000-0002-7953-2135
Рагулін Віталій Миколайович[1], к.т.н., доцент кафедри будівельних і дорожніх машин
ім. А.М. Холодова, ragulinrvn@ukr.net,
тел.: +38-050-545-80-70,
ORCID: https://orcid.org/0000-0003-2083-4937
Сумінов Андрій Володимирович[2]**,** аспірант кафедри будівельних і дорожніх машин
ім. А.М. Холодова,
e-mail: andrey.suminov@gmail.com,
тел.: +38-099-757-89-54,
ORCID: https://orcid.org/0000-0002-4268-2906

[1]Харківський національний автомобільно-дорожній університет, вул. Ярослава Мудрого, 25, м. Харків, Україна, 61002.
[2]Харківський тракторний завод, пр. Героїв Харкова, 275, м. Харків, Україна, 61007.