УДК 631.12 DOI 10.22314/2073-7599-2018-13-1-4-8

3D Scanning in Repairing Tractor and Automobile Parts and Units

Nail M. Yunusbaev
Ph.D.(Eng.), vice-rector for education,
e-mail: junusbaev@mail.ru

Bashkir State Agrarian University, Ufa, Republic of Bashkortostan, Russian Federation

Abstract. The authors have found that the expenditures in the structure of the production cost of repairing machines depend not only on the cost of spare parts and materials, but also on the assessment accuracy of the technical condition of inspected parts. (*Research purpose*) To study the possibilities of 3D scanning technology, to improve the measuring accuracy of worn parts during fault finding, and to determine a rational way to restore them. (*Materials and methods*) The authors have carried out the entrance control using the Artec Eva Lite portable handheld 3D scanner with the Artec Studio software while finding faults in the worn crankshaft of the ZMZ-409 engine. They have used the Geomagic Control X software product, which allows carrying out three-dimensional analysis of the part and obtain high-precision measurements, determine the wear of mutual rubbing surfaces, the presence of microcracks, damage to internal cavities and dents in complex-shaped parts. Basing on the conventional technology and reference recommendations, they plotted the route of the crankshaft restoration technology. (*Results and discussion*) The authors have compared the measurement results obtained using metrology instruments and reports in the Geomagic Control X program. They have found significant differences, especially in the amount of digital data. It has been determined that the measurement accuracy obtained from the instruments turned out to be lower. Worn connecting rods and main journals of the ZMZ-409 engine crankshaft have been restored by electrocontact welding of filler materials according to the recommended application modes. (*Conclusions*) The research has revealed the possibility of using 3D-scan in the process of repair and restoration. The authors have proved that this method allows increasing the efficiency of fault finding, shorten its duration in 6 times, reduce the level of subjectivity of the technical condition assessment of inspected parts and reduce the complexity of the process by 30 percent. The authors have confirmed the high accuracy of measurements (up to 0.03 millimeters), owing to which the direct costs of filler materials can be reduced by 20 percent. On the basis of the 3D scanning results, the authors have proposed to form databases in the form of digital archives of parts by groups and brands for subsequent operational use.
Keywords: 3D scanning technology, repair and restoration of parts, fault finding, repair quality control.

For citation: Yunusbaev N.M. 3D skanirovanie v tekhnologii remonta detaley i uzlov traktorov i avtomobiley [Prospects of 3D scanning in repairing tractor and automobile parts and units]. *Sel'skokhozyaystvennye mashiny i tekhnologii*. 2019. Vol. 13. N1. 4-8. DOI 10.22314/2073-7599-2018-13-1-4-8 (In English).

3D-сканирование в технологии ремонта деталей и узлов тракторов и автомобилей

Наиль Муртазович Юнусбаев,
кандидат технических наук, доцент,
e-mail: junusbaev@mail.ru

Башкирский государственный аграрный университет, г. Уфа, Республика Башкортостан, Российская Федерация

Реферат. Выяснили, что затраты в структуре себестоимости ремонта машин зависят не только от расходов на запасные части и материалы, но и от точности оценки технического состояния детали. (*Цель исследования*) Изучить возможности технологии 3D-сканирования, повысить точность измерения изношенных деталей при проведении дефектовки, определить рациональный способ их восстановления. (*Материалы и методы*) Осуществили входной контроль с помощью портативного ручного 3D-сканера Artec Eva Lite с программным обеспечением Artec

Studio при дефектовке изношенного коленчатого вала двигателя ЗМЗ-409. Использовали программный продукт Geomagic Control X, позволяющий провести трехмерный анализ детали и получить высокоточные измерения, определить износ взаимно трущихся поверхностей, наличие микротрещин, повреждений внутренних полостей и впадин в деталях сложной формы. Опираясь на известную технологию и справочные рекомендации, составили схему маршрута технологии восстановления коленчатого вала. (*Результаты и обсуждение*) Сравнили результаты измерений, полученных с использованием метрологических приборов, и отчетов в программе Geomagic Control X. Выявили значительную разницу, особенно в количестве цифровых данных. Определили, что точность измерений с помощью приборов оказалась ниже. Восстановили изношенные шатунные и коренные шейки коленчатого вала двигателя ЗМЗ-409 электроконтактной приваркой присадочных материалов по рекомендуемым режимам нанесения. (*Выводы*) Выявили возможность использования 3D-сканирования в технологическом процессе ремонта и восстановления. Доказали, что этот метод позволяет повысить эффективность дефектовки, сократить ее продолжительность в 6 раз, снизить уровень субъективности оценки технического состояния детали и уменьшить трудоемкость процесса на 30 процентов. Подтвердили высокую точность измерений (до 0,03 миллиметра), благодаря которой можно снизить прямые затраты на присадочные материалы на 20 процентов. Предложили на основе результатов 3D-сканирования формировать базы данных в виде цифровых архивов деталей по группам и маркам для последующего оперативного использования в работе.

Ключевые слова: 3D-сканирование, ремонт и восстановление деталей, дефектовка, контроль качества ремонта.

Для цитирования: Юнусбаев Н.М. 3D-сканирование в технологии ремонта деталей и узлов тракторов и автомобилей // *Сельскохозяйственные машины и технологии*. 2019. Т. 13. N1. С. 4-8. DOI 10.22314/2073-7599-2018-13-1-4-8.

To implement all the capabilities and requirements of modern agricultural production, machine-building enterprises seek to improve the machinery level, improving production technology aimed at increasing the quality of manufacturing and assembly of units, components and parts, thereby strengthening their operational reliability. The performance and reliability characteristics of imported machinery in many groups of vehicles are superior to their domestic counterparts.

The number of employed agricultural machines with the standard depreciation and operating conditions, which are older than 10 years, reaches 70%, which leads to their low productivity, disruption of the accepted agricultural deadlines and an increase in product losses during harvesting [1]. Much of the equipment needs substantial repairing. Repair service of machines, according to many experts, will become increasingly important with prolonging their service life. In addition, the dealer technical service of imported tractors and agricultural machinery does not provide for the distribution of technical documentation (regulations, conditions, etc.) for carrying out repair and servicing activities.

In order to keep the machines working, it is necessary to improve the repair technology and ensure sufficient operational reliability without cost increasing. The costs in the production cost structure of the machinery repair depend not only on the cost of spare parts and materials, but also on the accuracy of the technical condition assessment of the parts. To determine the degree of wear use is made of check-and-measuring instruments with a permissible measurement error. The further stage of the repair and restoration technology of separate parts depends on the accuracy and precision of measurements. All operations of troubleshooting are usually performed by fault finding experts. Their experience and skill level influence the measurement result. Studies have shown that, due to poor-quality troubleshooting, the cost of spare parts reaches 30% of the total cost of repair operations [1-3].

The research purpose is to study the capabilities of 3D scanning technology, improve the measuring accuracy of worn parts during troubleshooting, and determine a rational way of their restoring.

Materials and methods. A failure of a unit, an assembly, or a machine can be caused by their wear, fatigue, corrosion, and other processes on working and rubbing surfaces of parts. The rational way of repairing and restoring parts of units and assemblies is chosen basing on the troubleshooting results, taking into account the overall dimensions, shape, nature and size of the part's material wear [2, 4, 10]. Visible wear and kinks are easy enough to detect by visual inspection.

It is relatively easy to determine the wear degree of "volumetric" working surfaces after measurements using special tools (a micrometer, a depth gauge, or a caliper, etc.) using the typical methods. It is much more difficult to measure the degree of wear of the relative position of surfaces, or identify microcracks and damaged internal cavities and dents of complex shaped parts [5]. The more measuring devices and instruments are used to control, the more expensive the repair is. In this regard, the authors have studied the prospects for using the 3D scanning system to estimate the geometrical parameters of worn parts [3].

3D scanner models are distinguished mainly by their accuracy and scanning method [6]. For example, 3D technology is used to repair parts. At the same time, new and worn parts are scanned, obtaining the corresponding clouds of points, which serve as the basis for calculating the worn part parameters and allow for reverse engineering, which means making a similar part with permissible or nominal dimensions [7]. 3D technologies are used to automate and robotize welding of the most difficult fragments of parts and blanks [8]. There are examples of modern methods of measuring and controlling quality in vehicle production. The experience of measuring parts and functional units of complex shape and the advantages of optical digitization methods is based on the practical example of the analysis of plastic moldings of vehicles. With the help of 3D technology, the samples are digitized in high resolution for the subsequent manufacture of an exact copy of the model [9]. There are examples of using 3D scanning as a method of the input control of complex and large-sized parts and assembly units [3, 6]. In case of defects in the technology of repair and restoration of parts, the authors also used the principle of input control with a 3D scanner. The crankshaft of the ZMZ-409 engine was taken as the object of study. Basing on the existing technology and reference recommendations, they made a diagram of the route of the crankshaft restoration technology (*Fig.*). It was built basing on a variable technological chain and the subsequent comparison of the recovery technology. According to the presented scheme, after cleaning and washing, the crankshaft is subjected to fault detection using a handheld 3D scanner and the "traditional" method using measuring instruments and tools.

For this operation, the crankshaft was placed on a marker plate and the part was scanned using an Artec Eva Lite portable handheld 3D scanner with Artec Studio software. The technical characteristics of this scanner allow getting an image with an accuracy of up to 0.03 mm and a detail resolution of up to 0.1 mm, and the software helps to compensate for measurement errors [3].

During the scan, the crankshaft image is transferred to a personal computer, where on the screen one can

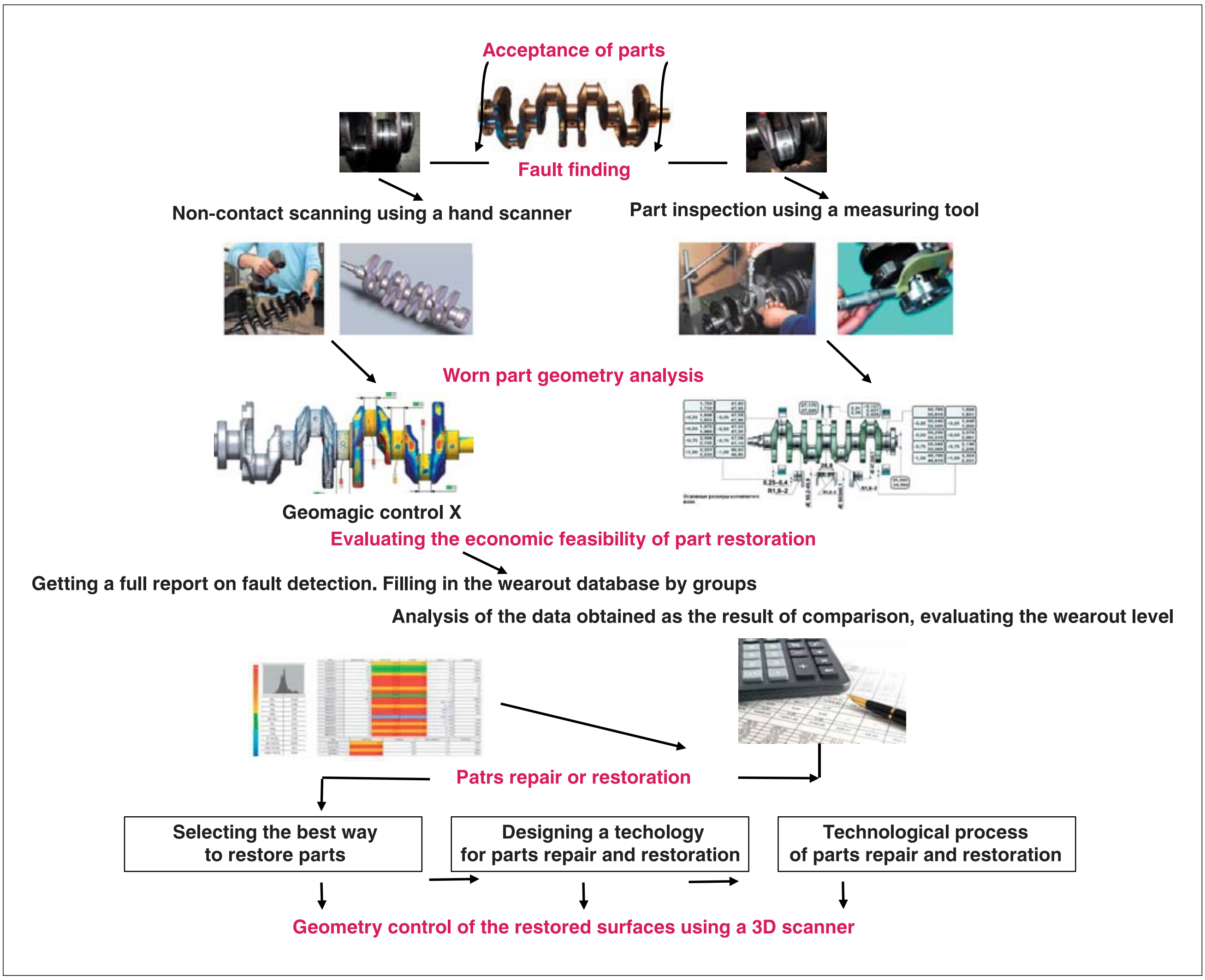

Fig. 1. Technological route of the crankshaft restoration process using a 3D-scanning technology

observe the formation of a 3D model of the crankshaft image (a scanned copy of the worn shaft). Crankshaft scanning and digitizing was performed for 5 minutes.

At the next stage, the researchers performed the geometry control of the part, for which they used the Geomagic Control X program. The program is suitable for three-dimensional analysis as a whole and serves to obtain highly accurate measurements, and also provides for the verification of reconstructed parts [6].

The measurement of the crankshaft parameters in the traditional way was carried out using a micrometric instrument and indicator devices, prisms, templates and profilometers for about 30 minutes.

The Geomagic Control X software analyzes the measured data and compares them with the "reference" data from the database. After the analysis is completed, various reports can be generated [3].

Results and discussion. Comparative measurement results obtained using metrology instruments and reports in the Geomagic Control X program have revealed a significant difference, especially in the amount of digital data. Measurement results with the help of instruments were naturally more numerous and were carried out in full accordance with technical specifications for crankshaft troubleshooting. However, the measurement accuracy was lower: taking account of the measurement error and the specified allowable error of the tool, it was 10-50 microns. According to the fault finding data results obtained according to the conventional methods, a rational method for restoring the crankshaft was chosen [1; 3; 9; 10]. Then the route technology of its recovery was worked out. Worn crankshaft and main bearing journals of the engine ЗМЗ-409 crankshaft were restored at the research and production site of the "Technology of Metals and Machinery Repair" Department of the Bashkir SAU by electrocontact welding of filler materials according to the recommended application modes [3]. The restoring control of the part was carried out according to the same technology as in the case of fault finding with a 3D scanner.

3D scanning in the process reduces the measurement errors. This was shown by preliminary studies as exemplified by a specific part. Due to the use of a handheld 3D scanner, the time spent on fault finding was reduced by 6 times, the measurement accuracy increased to 0.03 mm, which reduces the direct costs of filler materials by 20% as compared with traditional methods of fault finding using measuring instruments and tools.

Any recovery technology makes sense only in the case of its practical implementation in production. To this end, rapid acquisition of accurate digital data using 3D scanning of a worn part as a whole will improve the efficiency of fault finding. The next step to improve the quality of the restoration of parts should be the use of digital technologies for determining a rational method of recovery in real time [3].

Conclusions

1. The technology of fault finding of machinery parts and choosing a rational recovery method based on a comparative comprehensive analysis of the geometry of virtual three-dimensional models of a worn part and a standard use of 3D scanning technology should be considered as promising in the repair technology of units and restoration of automobile and tractor parts.

2. 3D scanning allows increasing the efficiency of fault finding, reduce the time required for it in 6 times, reduce the subjectivity level in the technical condition assessment of the part and reduce the process complexity by 30%; due to the high accuracy of measurements (up to 0.03 mm), the direct costs of filler materials can be reduced by 20%.

3. It is advisable to form the results of 3D scanning in databases as digital archives of parts by groups and brands for subsequent operational use.

REFERENCES

1. Chernoivanov V.I., Fedorenko V.F., Solovjev R.Yu., Olkhovatskii A.K., Lialiakin V.P., Burumkulov F.Kh., Goriachev S.A., Gerasimov V.S., Gurianov E.V., Solonitsin E.V., Mashrabov N.M., Solodkina L.A., Tyurin S.G., Fadeev A.V., Chetyrkin Yu.B., Gitelman D.A., Bogatova N.O., Taranov A.S. Innovatsionnye metody povysheniya posleremontnoi nadezhnosti selskokhoziaistvennoi tekhniki i investitsionnoi privlekatelnosti remontno-obsluzhivayushchikh predpriiatii APK [Innovative methods to increase after repair reliability of farm machinery and investment attractiveness of repair stations in agriculture]. GOSNITI [All-Russian Research Institute on repair and operation of farm machinery]. Moscow: 2012. 399 (In Russian).

2. Lyalyakin V.P., Ivanov V.P. Vosstanovlenie i uprochnenie detalei mashin v agropromyshlennom komplekse Rossii i Belorusii [Restoration and hardening of machine parts in agriculture of Russia and Belarus]. *Remont, vosstanovlenie, modernizatsiya*. 2004. N2. 2 (In Russian).

3. Yunusbaev N.M. Primenenie 3D skanirovaniya v tekhnologiyakh re monta agregatov i vosstanovleniya avtotraktornykh detalei [Using 3D scanning in technologies to repair and restore machine and tractor parts]. *Vestnik Bashkirskogo GAU*. 2018. N3(47). 133-138 (In Russian).

4. Gabitov I.I., Negovora A.V., Fedorenko V.F. Intellektualizatsiya tekhnicheskogo servisa toplivopodayushchikh sistem dizelei: nauch. izd. [Intellectualization of diesel fuel system maintenance: scientific publication]. Moscow: Rosinformagrotekh. 2018. 496 (In Russian).

5. Guzema A.B. Novyi podkhod k obosnovaniyu trebovanii tekhnicheskikh uslovii na defektatsiyu [New approach to prove technical requirements for fault finding]. *Avtotransportnoe predpriiatie*. 2007. N5. 36-40 (In Russian).

6. Lysych M.N., Belinchenko R.A., Shkil'nyy A.A. Oborudovanie i tekhnologii 3D-skanirovaniya [3D scanning equipment and technologies]. *Aktual'nye napravleniya nauchnykh issledovaniy XXI veka: teoriya i praktika*. 2014. Vol. 2. N4-3(9-3). 210-214 (In Russian).

7. Zhai J., Wang Q., Wei X., et al. Repair of Scraper Conveyor Sprocket Based on Metal 3D Printing. Zhongguo Jiguang. *Chinese Journal of Lasers*. 2017. N44(4). 157-168 (In English).

8. Bobrov V.T., Slyadnev A.M. Robotizirovannye sistemy nerazrushayushchego kontrolya i tekhnicheskoi diagnostiki promyshlennykh obiyektov [Robotized systems of continuous monitoring and technical diagnosis of industrial premises]. *Kontrol. Diagnostika*. 2018. N2. 16-31 (In Russian).

9. Bolshakov A. Piat tekhnologiy tsifrovoi ery promyshlennosti [Five technologies for the industry in the digital world]. *Control Engineering*. Rossiya. December. 2017. N6. 76-80 (In Russian).

10. Kurchatkin V.V. Nadezhnost i remont mashin [Reliability and repair of machinery]. Moscow: Kolos. 2000. 775 (In Russian).

БИБЛИОГРАФИЧЕСКИЙ СПИСОК

1. Черноиванов В.И., Федоренко В.Ф., Соловьев Р.Ю., Ольховацкий А.К., Лялякин В.П., Бурумкулов Ф.Х., Горячев С.А., Герасимов В.С., Гурьянов Е.В., Солоницин Е.В., Машрабов Н.М., Солодкина Л.А., Тюрин С.Г., Фадеев А.В., Четыркин Ю.Б., Гительман Д.А., Богатова Н.О., Таранов А.С. Инновационные методы повышения послеремонтной надежности сельскохозяйственной техники и инвестиционной привлекательности ремонтно-обслуживающих предприятий АПК. М.: ГОСНИТИ. 2012. 399 с.

2. Лялякин В.П., Иванов В.П. Восстановление и упрочнение деталей машин в агропромышленном комплексе России и Белоруссии. *Ремонт, восстановление, модернизация*. 2004. N2. С. 2-7.

3. Юнусбаев Н.М. Применение 3D-сканирования в технологиях ремонта агрегатов и восстановления автотракторных деталей // *Вестник Башкирского ГАУ*. 2018. N3(47). С. 133-138.

4. Габитов И.И., Неговора А.В., Федоренко В.Ф. Интеллектуализация технического сервиса топливоподающих систем дизелей. М: Росинформагротех. 2018. 496 с.

5. Гузема А.Б. Новый подход к обоснованию требований технических условий на дефектацию // *Автотранспортное предприятие*. 2007. N5. С. 36-40.

6. Лысыч М.Н., Белинченко Р.А., Шкильный А.А. Оборудование и технологии 3D-сканирования // *Актуальные направления научных исследований XXI века: теория и практика*. 2014. Т. 2. N4-3(9-3). С. 210-214.

7. Zhai J., Wang Q., Wei X., et al. Repair of Scraper Conveyor Sprocket Based on Metal 3D Printing. *Chinese Journal of Lasers*. 2017. Vol. 44. Issue 4. 157-168.

8. Бобров В.Т., Сляднев А.М. Роботизированные системы неразрушающего контроля и технической диагностики промышленных объектов // *Контроль. Диагностика*. 2018. N2. С. 16-31.

9. Большаков А. Пять технологий цифровой эры промышленности. *Control Engineering Россия*. 2017. N6(72). С. 76-80.

10. Курчаткин В.В. Надежность и ремонт машин. М.: Колос. 2000. 775 с.

Конфликт интересов. Автор заявляет об отсутствии конфликта интересов.

Conflict of interest. The author declares no conflict of interest.

Статья поступила в редакцию 28.01.2019
The paper was submitted to the Editorial Office on 28.01.2019

Статья принята к публикации 08.02.2019
The paper was accepted for publication on 08.02.2019