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Development of the technology for manufacturing the bracket for mounting the reducer of the metropolitane cars

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Розробка технології виготовлення кронштейну кріплення редуктора вагону метрополітену

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Abstract. *This article discusses the developed technology for manufacturing a gearbox mounting bracket used on rolling stock in domestic metro systems. The article also analyses the design of this bracket and the malfunctions that may occur during operation. The specific nature of metro rolling stock operation, characterised by high traffic intensity, frequent acceleration and braking cycles, and significant dynamic loads, places increased demands on the reliability of each structural element of its running gear. Since a significant part of the bogie parts are manufactured using metal pressure processing methods, the issue of improving the quality of stamped forgings becomes a relevant technical task that affects the safety of passenger transport and the accident-free operation of vehicles. This article analyses other works related to improving the mechanical characteristics of products and increasing their quality, which depend on the parameters and methods of their production. The traditional forging technology discussed above usually involves a multi-stage process that includes the use of rolling grooves for preliminary distribution of metal along the axis of the blank. However, this approach increases the size of the stamping equipment and requires more passes, which leads to higher energy costs and production costs. The authors proposed abandoning the use of a rolling groove, since it is possible to manufacture this forging without changing the geometry of the blank before bending.The results of this work can be used by technologists and engineers in the machine-building industry as one of the promising ways to improve and rationalise the stamping of forgings with similar geometry, since by reducing the number of stamping passes, it is possible to reduce the cost of production and manufacture of dies without significantly affecting the stress-strain state of the resulting forging. The expediency of using computer modelling in the design of production technology is also indicated, as it allows all stages of production to be investigated without significant financial costs and ways to improve and rationalise technological operations to be identified, which will have an impact on improving the quality of manufactured products in the future.*
Keywords: *production technology, stamping, forging, stamping groove, underground railway, gearbox mounting bracket.*

Анотація. *В даній статті розглянуто розроблену технологію виготовлення кронштейну кріплення редуктора, що експлуатується на рухомому складі вітчизняних метрополітенів. Також в роботі була проаналізована конструкція цього кронштейну та несправності, які можуть виникати при експлуатації. Адже специфіка роботи рухомого складу метрополітену, що характеризується високою інтенсивністю руху, частими циклами розгону та гальмування, а також значними динамічними навантаженнями, висуває підвищені вимоги до надійності кожного конструкційного елемента його ходової частини. Оскільки значна частина деталей візка вагону виготовляється методами обробки металів тиском, питання покращення якості штампованих поковок стає актуальним технічним завданням, що впливає на забезпечення безпеки пасажирських перевезень та безаварійну експлуатацію транспортних засобів. У даній статті зроблено аналіз інших робіт, що стосуються поліпшення механічних характеристик виробів та підвищення їх якості, що залежать від параметрів та методів їх виробництва. Традиційна технологія виготовлення поковки, що була розглянута, зазвичай передбачає багатостадійний процес, що включає використання підкатувальних рівчаків для попереднього розподілу металу вздовж осі заготовки. Однак, такий підхід збільшує габарити штампового оснащення та вимагає більшої кількості переходів, що веде до зростання енерговитрат та собівартості. Авторами було запропоновано відмовитися від використання підкатувального рівчака, оскільки для виготовлення даної поковки можливо не змінювати геометрію заготовки перед її згинанням. Результати даної роботи можуть бути використані технологами та інженерами машинобудівної галузі, як один із перспективних шляхів поліпшення та*

раціоналізації штампування поковок схожої геометрії, оскільки за рахунок зменшення кількості штампувальних переходів можливо зменшити витрати на виробництво та виготовлення штампів, без суттєвого впливу на напружено-деформований стан отриманої поковки. Також вказано на доцільність застосування комп'ютерного моделювання в проектуванні технології виробництва, адже це дозволяє дослідити всі етапи виробництва без значних фінансових кладень та виявити шляхи покращення та раціоналізації технологічних операцій, що матиме вплив на покращення якості виготовляємої продукції в подальшому.
Ключові слова: *технологія виробництва, штампування, поковка, штампувальний рівчак, метрополітен, кронштейн кріплення редуктора.*

Introduction. The modern transport engineering industry requires new approaches to production, as scientific and technological progress moves forward, production processes are automated, and equipment is improved. The development and optimisation of production is also facilitated by the use of computer technology, which allows production processes to be simulated before they are implemented in the enterprise, making it possible to identify 'weak' points in the technological chain of operations. These studies, conducted using specialised software such as QForm, Abaqus, SolidWorks, and ANSYS Mechanical, help specialists improve production efficiency, because the earlier an error is detected in the product life cycle, the cheaper it will be to correct it.

When manufacturing running gear components for transport, they undergo many technological operations to get from a blank to a finished part that meets all the specified requirements, standards and tolerances. The running gear of rail transport, namely bogies, consists of parts, most of which are manufactured using metal pressure processing. Accordingly, by pre-modelling these processes, it is possible to predict ways to improve the technology for manufacturing these parts. In particular, the modelling of stamping processes has broad prospects in modern industry, allowing the analysis of product manufacturing in the early stages of its life cycle.

Analysis of literature data and problem statement. The running gear of railway and metro rolling stock consists of many components, the details of which are manufactured using pressure processing technology, in particular, volumetric hot stamping. Since the transportation of passengers and cargo by rail accounts for a significant share of Ukraine's total passenger and freight traffic [1], it is appropriate to improve the quality of manufactured parts, as they affect not only the reliability and strength of the entire structure, but also traffic safety. Specialists in the field of production offer various ways to improve and optimise production processes in order to improve the characteristics of products, including their quality.

In [2], the authors conducted a study aimed at assessing the quality of forgings depending on the forging parameters. It was found that after manufacturing and heat treatment, surface cracks appeared in the forgings, which subsequently affected their reliability and mechanical properties. One of the causes of cracking is the wear of dies and damage during the forging process, which contributes to the formation of non-metallic oxide inclusions and the transfer of surface defects to forgings.

Work is also underway to optimise production processes. In particular, in [3], the hot forging process was modelled in the QFORM software package, which allowed the authors to reduce material and energy costs for forming by using the minimum number of forming passes and a low-power forging hammer. Modelling showed that by combining the blanking and upsetting passes, it is possible to achieve a more favourable blank profile, which improves the metal forming conditions for the selected stamping dies used to produce the forging under study.

In modern research on metal pressure treatment, the creation of new approaches to forging and the rationalisation of its modes are relevant. One of the ways to improve this process is the work [4-7] related to predicting the quality of forgings depending on the deformation mode during forging. This approach in the forging process allows not only to analyse the unevenness of metal deformation during pressure treatment, but also to establish more rational modes of this treatment in order to obtain a uniform distribution of mechanical properties in the product, which will undoubtedly improve its quality and reliability.

Also, in [4], a method was proposed for predicting the unevenness of metal deformation during forging, which allows for a more uniform stress-strain state of the forging, affecting the uniformity of the distribution of mechanical properties in the metal.

Thus, modern research in the field of mechanical engineering mainly concerns the optimisation and rationalisation of production processes, increasing their efficiency, as well as improving the mechanical characteristics and quality of parts manufactured, in particular by stamping. The solution to these problems is greatly facilitated by the use of specialised computer programs, such as QForm [8], which allow the parameters of the manufacturing process to be researched, analysed and improved at the technology development stage. However, the problem lies in finding ways to improve production, as technologies are being modernised and technical progress is not standing still. Accordingly, the 'classic' production schemes that existed earlier are now being supplemented or revised in the context of modern approaches and production equipment.

Purpose and objectives of the research. The purpose of this work is to develop a technology for manufacturing a gearbox mounting bracket used on rolling stock of domestic metros. The authors set themselves the task of investigating the possibility of simplifying the manufacture of this bracket by applying a technology that differs slightly from the classic technology for manufacturing forgings with a curved axis.

Materials and research methods. One of the main components of a rail transport trolley is its traction transmission, which is usually attached to the trolley frame using brackets and suspension. Accordingly, the design of the mounting brackets must meet all the reliability and strength criteria established for them under operating conditions.

For example, the rolling stock of the Kharkiv Metro uses a gearbox mounting bracket consisting of a cylindrical part and an eyelet. This bracket is welded into the crossbeam of the trolley frame [9], as shown in Figure 1.

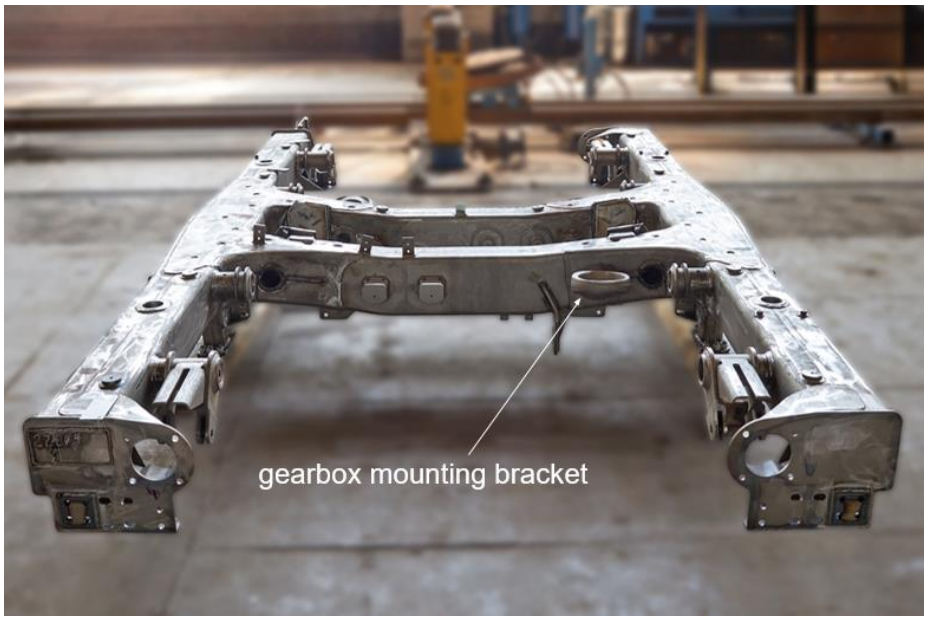


Fig. 1 – Bracket for mounting the gearbox of a 81-717 series carriage bogie.

The eye of this bracket is tilted towards the horizon at an angle of 18º, and the axle of the gearbox suspension is deflected at the same angle to ensure the smallest vertical deflection between the shafts of the traction motor and the gearbox gear when the axle springs are loaded.

This bracket is a very important element of the car's running gear and, accordingly, has high reliability requirements, since its failure, as shown in Figure 2, will significantly affect traffic safety and is unacceptable during operation [10, 11]. To prevent such cases, the bogie is equipped with a comprehensive safety device [12] that prevents the reduction gear suspension elements from falling onto the rail track in the event of their breakage or breakage of the mounting bracket.

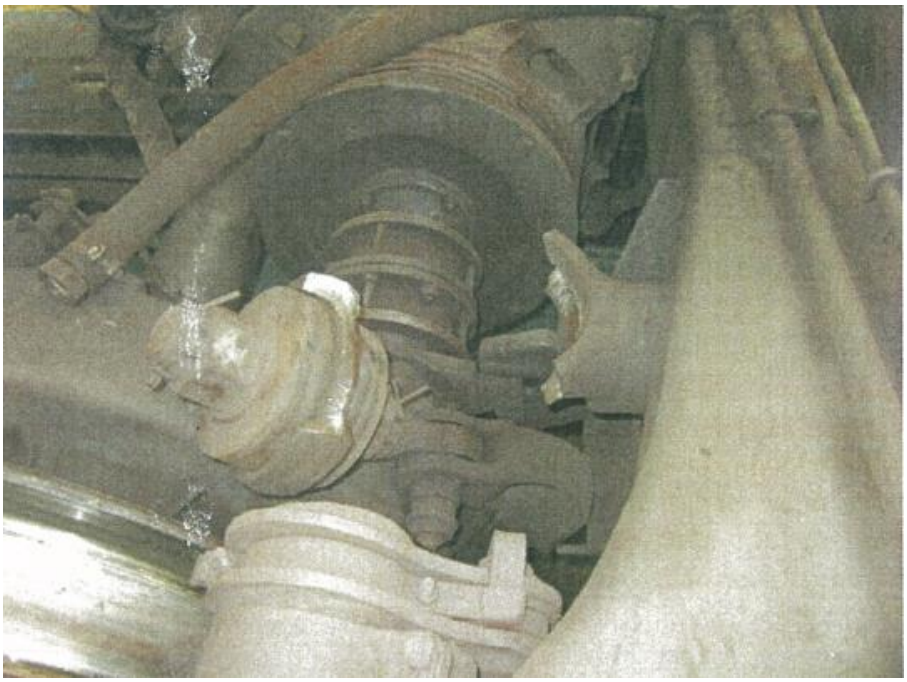
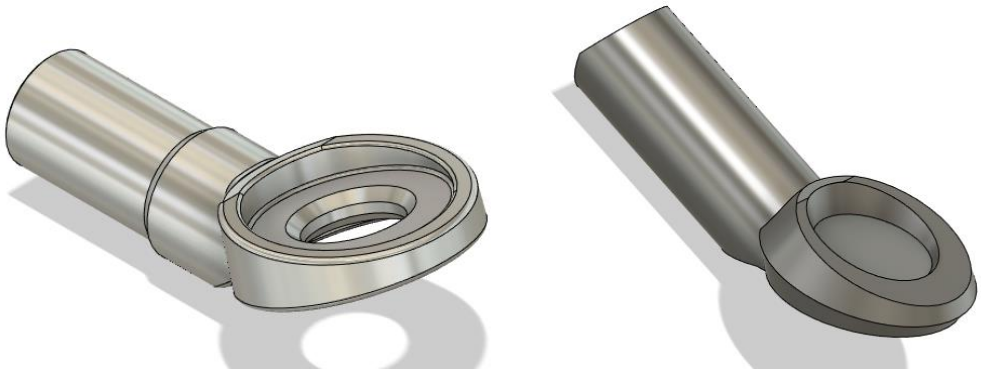


Fig. 2 – Breakage of the gearbox mounting bracket on an E-type carriage.

Many elements of a railway carriage bogie are manufactured using metal pressure processing methods. The gearbox mounting bracket is no exception. The production technology for this bracket involves hot volumetric stamping [13]. A cylindrical blank is used to manufacture the forging for this part.

Research results. The model of the bracket and its forging are shown in Figure 3. This forging belongs to the group of forgings with a curved axis [14].



a) b)

Fig. 3 – Model of bracket a) and its forging b).

Such forgings are stamped using an appropriate combination of die grooves [15]. The classic technology for manufacturing this forging, which has a curved axis, involves the following sequence of stamping passes: rolling groove – bending groove – preliminary groove – final groove.

The authors propose simplifying the production technology for such a forging, namely, not using a roll-up groove, but deforming the cylindrical blank first in a bending groove, and then in the preliminary and final grooves. This decision was made in accordance with the calculated blank (diameter diagram) and its cross-section diagram. These diagrams, shown in Figure 4, were constructed after the forging was unfolded, since its axis has an 18º bend in the area of the lug.

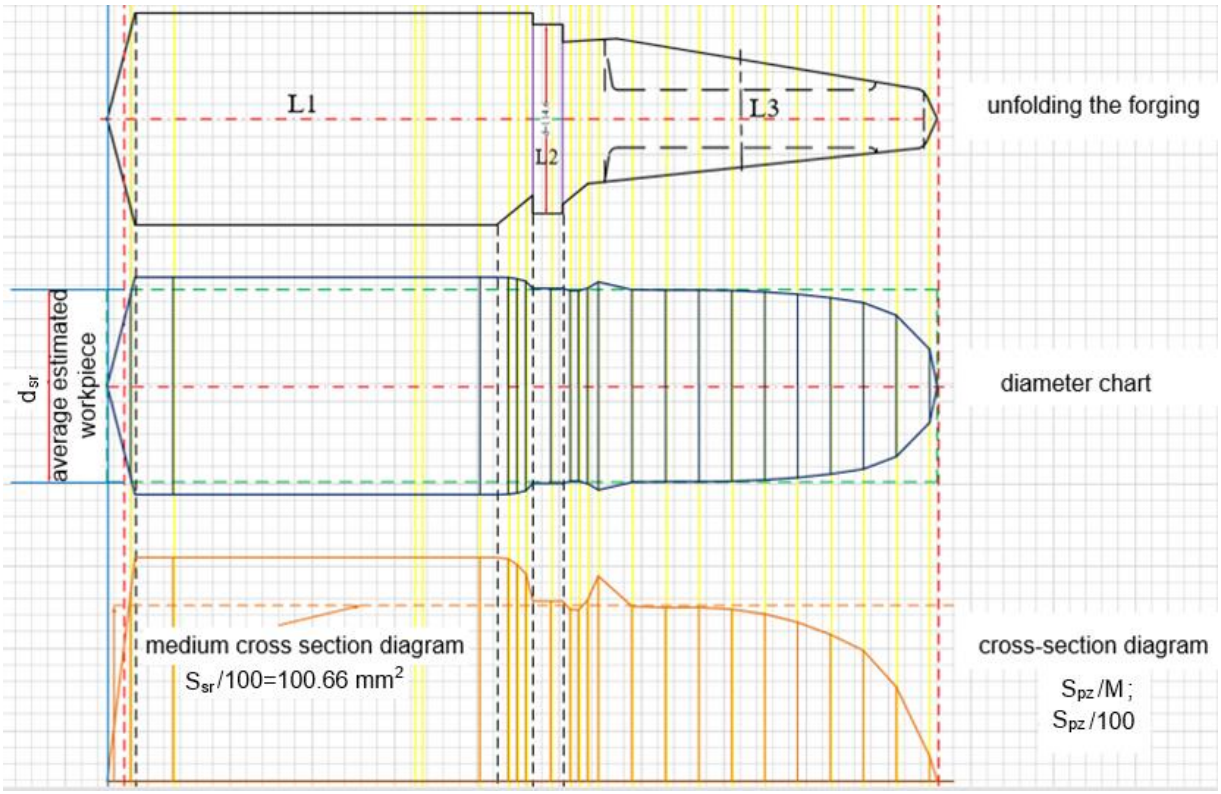


Fig. 4 – Calculated blank and its cross-section diagram.

Since the diameter profile is close to rectangular in shape, it was proposed to abandon the rolling groove for the production of this bracket.

Discussion of results. The development of production technology for any part involves a combination of die grooves that must be used to obtain the re-

quired shape of the forging. The use of modern approaches to the development of forging manufacturing technology, in particular computer modelling, allows for a broader analysis of hot volumetric stamping processes and the identification of ways to improve production, which can have a positive impact on its cost-effectiveness, efficiency and quality. It is this analysis that is promising in the context of this work, which requires a more thorough consideration of the proposed production technology.

This work proposes a way to rationalise stamping processes by minimising the number of passes, which reduces production costs while maintaining the required characteristics of the forging. The authors justify the feasibility of introducing digital modelling systems for virtual testing of technologies. This approach allows identifying the potential for improving operations without additional financial investments, ensuring high quality of products in the future.

Conclusions. A technology has been developed for the production of a gearbox mounting bracket, which is manufactured by metal pressure treatment, namely hot volumetric stamping. Based on the obtained calculated blank and its cross-section diagram, it is proposed to abandon the rolling groove, which is usually used, in particular, for the production of forgings with a curved axis.

Based on the developed technology, it is necessary to conduct a more detailed analysis and modelling to study its impact on the quality characteristics of forgings.

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