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Research of the stress-strain state of the loaded assembly for friction welded device

Abstract. *This article presents the results of the study of methods for friction welding of dissimilar materials and the calculations to determine the structural strength of the most loaded part of a special friction welding device were made. The analysis showed that the friction welding method has wide technological capabilities and it is used in various industries. The designs of existing devices and machines for friction welding were also investigated. It was revealed that the method of friction welding in the conditions of machine-building plants of the Republic of Kazakhstan (RK) has not found application due to the little knowledge and high cost of technological equipment. The authors have developed a special device for friction welding of dissimilar materials. To optimize the parameters of the parts, in particular the bracket part, the stress-strain state calculations were performed using the ANSYS software package and the strength calculation by determining the acting external critical loads. The results of the calculation showed the applicability of the developed design of the bracket part.*
Keywords: *friction welding, dissimilar materials, stresses, structural strength, device, torque.*

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Introduction

Friction welding is a high-performance and economical process for joining parts of the various materials. In which the mechanical energy supplied to one of the welded parts is converted into thermal energy directly at the place of the future connection. Such a concentrated heat release determines the main features of the friction welding [1].

In subsequent years, in many countries, the possibility of joining difficult-to-weld promising materials by friction welding was investigated. One of the such material is cast iron. In Japan, studies have been carried out on friction welding of the nodular graphite iron (NGI) FCD 450 with corrosion-resistant steels SUS 304 and SUS 430 [1,2,3]. A simplified model is suggested in this research for determining the rate of heat input into dissimilar joints during friction welding using a one-dimensional equation of thermal conductivity [2]. In [4], examples of the friction welding application for joining cast iron and steel are given. These are critical welded units in cars: a ferritic cast iron axle body and a combined steel part; cam camshaft welded from cast iron and steel parts; elements of gas equipment (valves, gates) made of ferritic-pearlitic cast iron and steel. In Romania, experiments were carried out on friction welding of samples from Fgn 500-7 cast iron with steel 17MnCr10 [5]. Cylindrical samples had dimensions of ⌀16 x 40 mm. It has been established that high-quality joints can be obtained only in a narrow range of welding parameters.

In Poland, a series of experiments on friction welding of the cast iron with unalloyed steel and non-ferrous metal alloys were carried out. Welded pearlite NGI and low-carbon steel [6]. The resulting welded joints NGI + NGI and NGI + steel had low mechanical properties. The destruction of all samples occurred along the joint plane. Also, technologies for friction welding of NGI with a copper alloy and NGI with aluminum [3,7], i.e., such pairs of materials that cannot be joined by other types of welding, were also studied.

The results obtained indicate the need for further experiments to optimize the chemical composition and technology of the applying facing and intermediate layers, which ensure the production of the high-quality welded joints of the cast iron with other metals and alloys [7].

From the listed varieties of the friction welding, the most widely used are: in Europe it was conventional friction welding, in the USA it was inertial welding, in Japan they were both varieties mentioned above. The remaining varieties in the industry are still of limited use, but research work is still being conducted in many countries.

In many countries, friction welding is widely used in the manufacture of the automobile parts, tractors, agricultural machines, modern aircraft, metal-cutting and other machine tools, cutting tool blanks, electrical industry products, as well as products of metalworking enterprises in a number of other industries, which belongs to the serial and mass type. productions.

The conducted studies have shown [8,9,10] that the considered method of friction welding in the conditions of machine-building plants of the Republic of Kazakhstan has not found application. The reason for this may be, in addition to the above, the following factors:

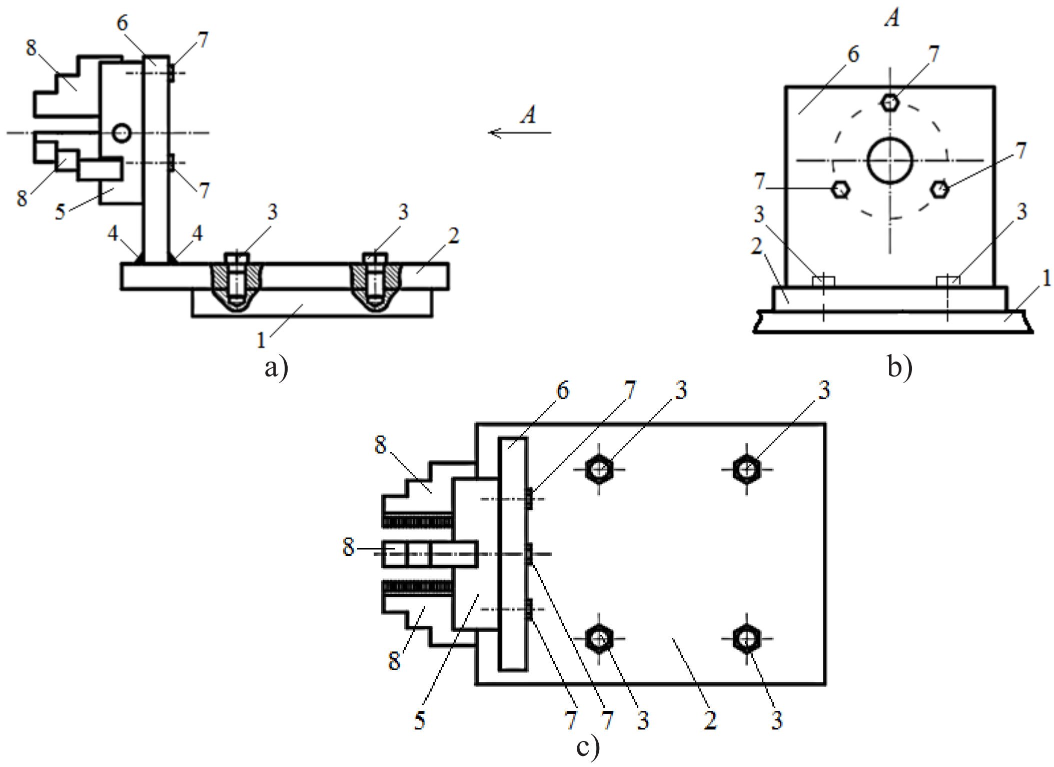
- little knowledge of the friction welding method;
- lack of the serial (or mass) production;
- inexpediency of the purchasing equipment for friction welding due to the high cost.

For the production conditions of Kazakhstan Republic, it is necessary to develop a technology for friction welding of dissimilar materials that differs from the existing ones in high quality and productivity, versatility, low cost, and at the same time, the design of the used equipment was not complicated, but also easy to operate. For this purpose, studies were carried out to study the existing designs of devices and machines for friction welding. The friction welding machine is known for the "pipe-tube sheet" of the` heat exchangers, consisting of a rotation drive, a flexible shaft, intermediate supports, a power drive, a movement mechanism, a control unit [11].

The disadvantage of the known machine for friction welding is the complexity of the design and the high cost of manufacturing, as well as the possibility of welding parts only in a narrow range of diameters. A known installation for friction welding of long and end parts, containing a friction welding machine, on the frame of which a spindle assembly with a rotation drive and a chuck for a rotated part is fixedly mounted, a clamping device with a hydraulic drive, a mechanism and a unit for loading and unloading parts and finished products and welded product are also installed on the frame [12]. Taking into account all the shortcomings and factors identified during the study of the existing methods of the friction welding of dissimilar materials, the authors are developing a new method of the friction welding of dissimilar materials and the design of a special device for its implementation [13].

The main part

Figure 1 shows a complete lathe based friction welder.



a – side view; b – view A; c – top view; 1 – support; 2 – plate; 3,7 – screws for fixing; 4 – welded seam; 5 – mount; 6 – bracket; 8 – cams

Figure 1. A friction welding device based on a lathe

Calculation of the stress-strain state of the bracket part, which is the most loaded base part of the device. To perform the calculation of the stress-strain state of the bracket part, we use the ANSYS software package. The material of the part is the bracket steel 45. In the program database, we determine the parameters of structural steel 45.

Table 1 shows the parameters of structural steel 45.

Table 1. Parameters of structural steel 45

Common Material Properties	
Density	7.85e-06 kg/mm^3
Young's Modulus	2e+06 MPa
Thermal Conductivity	0.060500 W/mm*^{0}C
Specific Heat	4.34e+05 mJ/kg*^{0}C
Tensile Yield Strength	250.00 MPa
Tensile Ultimate Strength	460.00 MPa
Nonlinear Behavior	False

Figure 2 shows the bracket part model.

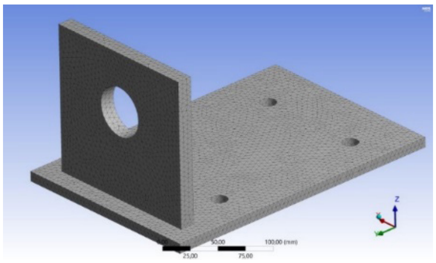


Figure 2. Model part bracket

The state in which internal changes in the metal lead to its destruction is called the limit stress state. The conclusion about the reliability of the design should be made on the basis of a comparison of the maximum stresses that may occur at the most dangerous point with the maximum allowable values for a given material. The ultimate stress state of a structure is the boundary beyond which its operation is unacceptable. The reliability of operation is the higher, the farther from the limit state the level of actual stresses inside the material of the part. Using the ANSYS software package to perform the analysis of the stress-strain state of a welded vertical support makes it possible to obtain output results in the form of three values of the principal stresses σ_0, which are the roots of the cubic equation determined by the components of the stress vector:

$$\begin{vmatrix} \sigma_x - \sigma_0 & 1/2\sigma_{xy} & 1/2\sigma_{xz} \\ 1/2\sigma_{xy} & \sigma_y - \sigma_0 & 1/2\sigma_{yz} \\ 1/2\sigma_{xz} & 1/2\sigma_{yz} & \sigma_z - \sigma_0 \end{vmatrix} = 0$$

Principal stresses are denoted σ_1, σ_2, σ_3. The principal stresses are ordered in such a way that σ_1 is the largest positive stress and σ_3 is the largest negative. The voltage intensity is the absolute value of the largest of the three differences: $\sigma_1 - \sigma_2$, $\sigma_2 - \sigma_3$ or $\sigma_3 - \sigma_1$, i.e.

$$\sigma_1 = max(|\sigma_1 - \sigma_2|, |\sigma_2 - \sigma_3||\sigma_3 - \sigma_1|)$$

The von Mises stresses or equivalent stresses are calculated using the formula:

$$\sigma_e = (S[(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2])^{1/2}$$

The calculation in the ANSYS software package is based on the method of permissible conditional elastic stresses. The stress-strain state of the support is determined by the spatial work of the calculation model under the action of combinations of the operational loads.
Figure 3 shows the load diagram of the support (bracket details).

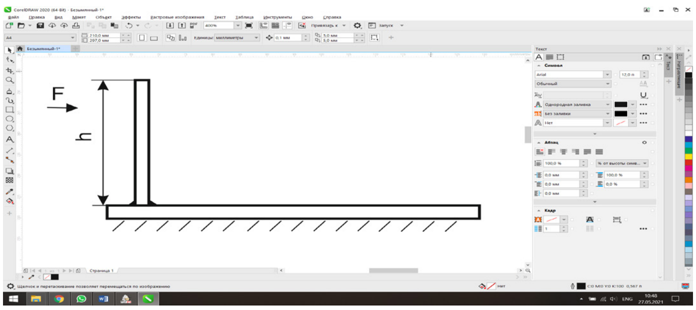
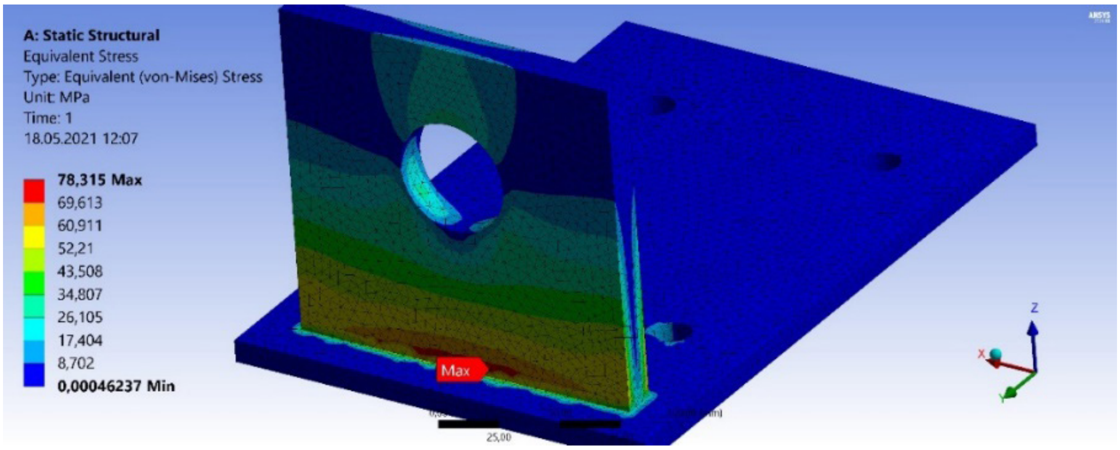
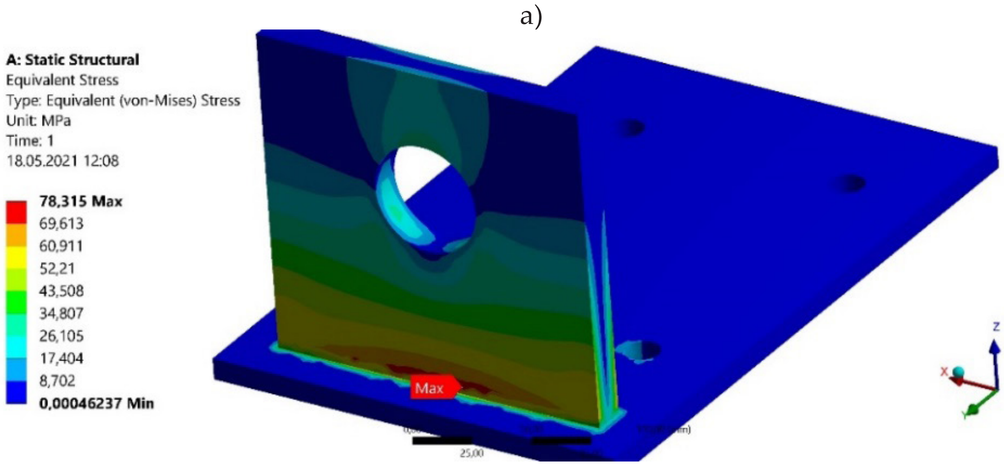


Figure 3. Diagram of the support load (bracket details)

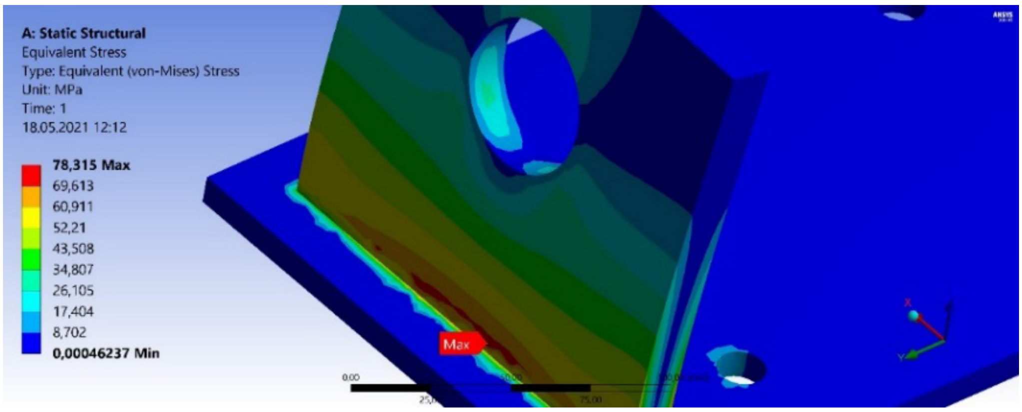
Figure 4 shows the results of the calculation of the support (bracket parts) obtained using the ANSYS program at various time intervals.



a)



b)



c)

a – is the initial period of load application; *b* – is after 60 seconds; *c* – after 300 sec

Figure 4. The results of the calculation of the stress-strain state of the support (bracket parts), obtained using the ANSYS program at various time intervals

Figure 5 shows a graph of the interpretation of the stress distribution results (σ) along the length (h) of the support section.

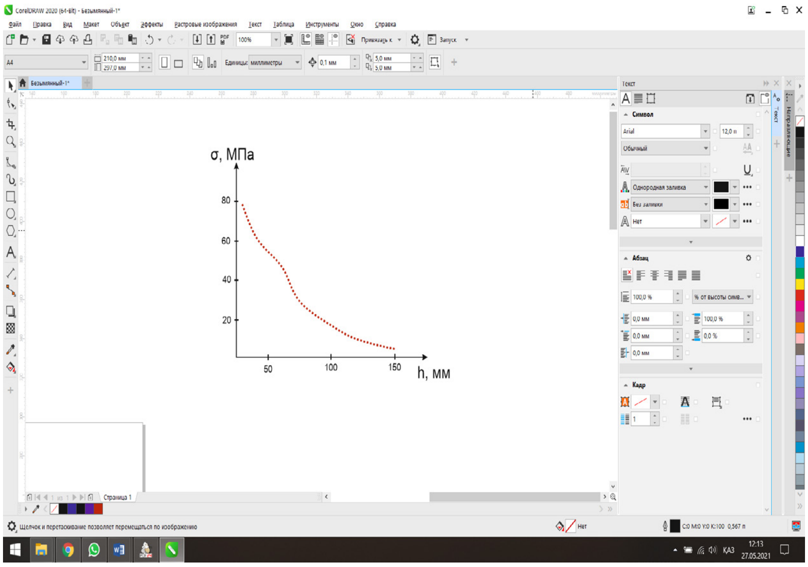


Figure 5. Graph of results interpretation

Let's calculate the structural strength of the bracket part. Let's build a calculation scheme of the acting forces on the bracket part in the process of work. Figure 6 shows the design diagram of the acting forces on the bracket part.

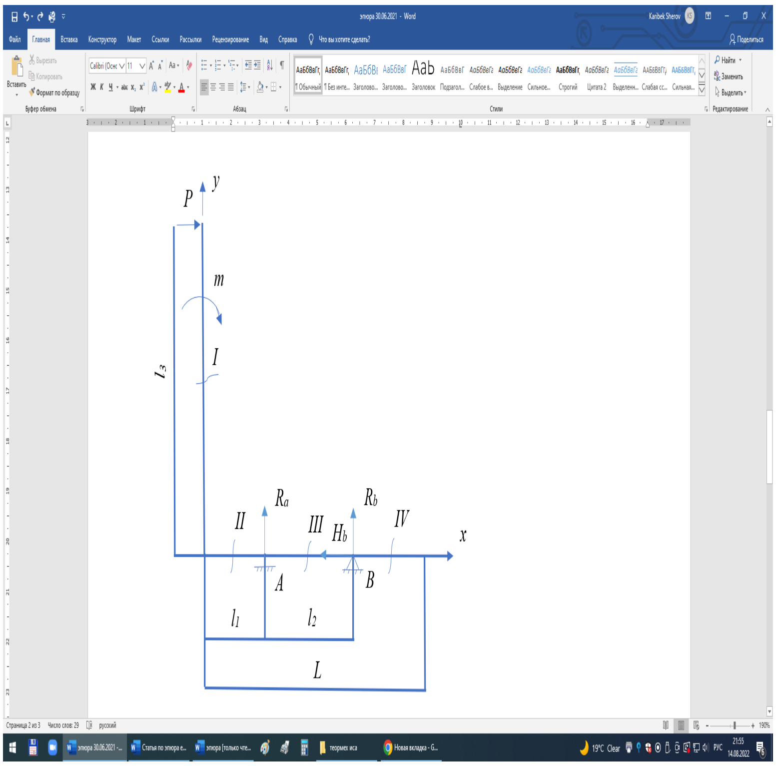


Figure 6. Calculation scheme of the acting forces on the bracket part

The calculation scheme gives: P is resistance force; m is a moment; l_1 is the length of section II; l_1 is the length of section III; l_1 is the length of section I; L is the total length.

For the calculation, it is necessary to find and determine R_A; R_B; H_B and create a diagram.

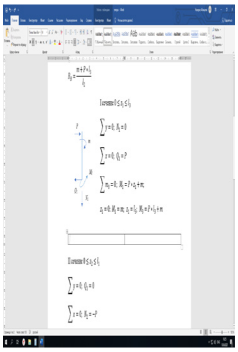
Solution:

$$\sum F_{kx} = 0;\ \ P - H_B = 0;\ \ H_B = P$$

$$\sum F_{ky} = 0;\ \ R_A + R_B = 0;\ \ R_A = -R_B$$

$$\sum m_A(F_k^i) = 0;\ \ R_B * l_2 - m - P * l_3 = 0$$

$$R_B = \frac{m + P * l_3}{l_2}$$



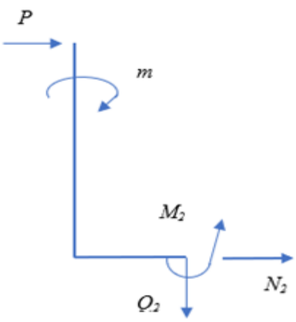
I section $0 \le z_1 \le l_3$

$$\sum y = 0;\ \ N_1 = 0$$

$$\sum x = 0;\ \ Q_1 = P$$

$$\sum m_0 = 0;\ \ M_1 = P * z_1 + m;$$

$$z_1 = 0:\ M_1 = m;\ \ z_1 = l_3;\ \ M_3 = P * l_3 + m$$

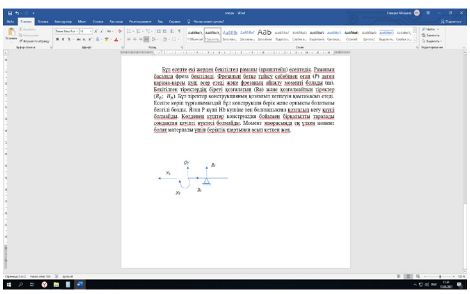


II section $0 \le z_2 \le l_1$

$$\sum y = 0;\ \ Q_1 = 0$$

$$\sum x = 0;\ \ N_2 = -P$$

$$\sum m_0 = 0;\ \ M_2 = P * l_3 + m;$$



III section $0 \le z_3 \le l_2$

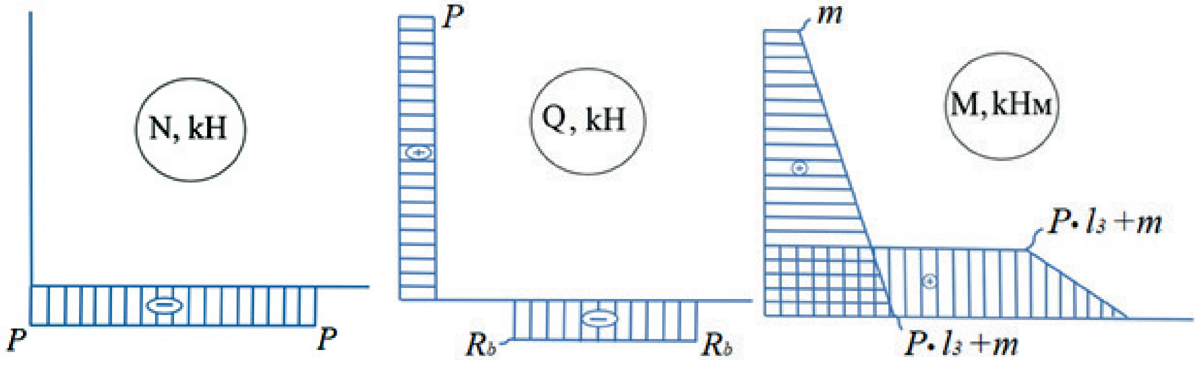
$$\sum y = 0;\ \ Q_3 = -R_B$$

$$\sum x = 0;\ \ N_3 = -H_B$$

$$\sum m_0 = 0;\ \ M_3 = R_B * z_3;$$

$$z_3 = 0:\ M_3 = 0;\ \ z_3 = l_2;\ \ M_3 = R_B * l_2$$

Figure 7 shows diagrams of the forces operating on the bracket.



a) b) c)

Figure 7. Diagrams of the forces operating on the bracket: a is a diagram of longitudinal forces; b- is a diagram of transverse forces; c is a diagram of the bending moment

Discussion

In this example, the structural strength of a bracket fixed in two places is calculated. A mount is attached to the supporting wall of the bracket. In the process of the friction welding, it is affected by the opposite force (P) and torque (m) arising from the rotation of the workpiece fixed in the three-jaw chuck of the machine.

Supports are movable (R_A) and fixed supports (R_B; H_B). These supports provide stability to the structure. As can be seen from the example, this design will be strong and stable, i.e. since the force P is equal to the force H_B, there is no danger of moving. Shear forces are evenly distributed throughout the structure and therefore do not have a dangerous point. In the torque diagram, the maximum torque does not exceed the strength condition for the steel material.

As we can see in the diagram, the longitudinal force N describes the forces acting along the bracket, i.e. along the rod. Therefore, we see that the longitudinal force exists only in the second and third sections of the frame. The transverse force Q characterizes the forces acting perpendicular to the bracket rod. As you can see in the diagram, the first and third cross sections are under the influence of a force. The moment of the force has the greatest value in the second and third sections.

Conclusions

1. The results of the study showed that in many countries scientific research is being successfully carried out to create and improve the technology of friction welding of dissimilar materials. It was revealed that the method of friction welding has wide technological possibilities.

2. The results of calculating the stress-strain state of the bracket part using the ANSYS software package and calculating the structural strength of the bracket part of a special device for friction welding showed that the proposed design and parameters of the main base part (bracket) of the device withstand a critical load during friction welding.

References

1. Sherov K.T., Gurba G., Imasheva K.I., Bykova N.A. Friction welding is a promising direction of thermofriction technology for processing and joining parts (review-2) / Bulletin of Science KazATU named after. S. Seifullin.- Astana: KazAU Publishing House, 2010.– No. 4 (66) – P. 133–138.

2. Shinoda T., Endo S., Tanada K. Friction Welding of Cast iron and Stainless Steels // Quarterly Journal of the Japan Welding Society. 2018. Vol. 14. No. 12. P. 248–254.

3. Metlitsky V.A. Pressure welding of cast iron // Welding production. 2017. No. 4(905). pp. 35–46.

4. Hauswurz G., Schober D. Reibschweifien fur potimierle Guss - Konstruktion // Konstruieren + Gieben, 2019. Bd 21, N4 S. 33–37.

5. Mitelea I., Gugu R., Petrica A. Process parameters in friction of nodular cast iron with low alloyed steels for mechanical constructions // Sudura. 2017 Vol. 17. No. 5. P. 21–27.

6. CiszewskiG. New experimental concept for the fabrication of cast iron to cast iron and cast iron to steel joints by means of friction welding and the mechanical and plastic properties of these joints // Welding and Cutting. 2017. No. 5. P. 288–297.

7. Ciszewski G. New experimental concept of the fabrication of cast iron to (85% Cu) cooper alloy and cast iron to aluminum joints by friction welding and the mechanical and plastic properties of these joints // Welding and Cutting. 2018. N 2. P. 104–110.

8. Yessirkepova A.B., Sherov K.T., Mikhailov V.F., Mazdubay A.V., Taskarina A.Zh. Research of ways of connecting reinforced bars in the production of reinforced concrete products / Journal of Applied Engineering (JAES) Science, Vol. 18 no. 3 (2020) – P. 372–377. https://doi.org/10.5937/jaes18-24319

9. Sherov K., Serova R., Yessirkepova A, Mussayev M., Ashurova N., Mazdubai A., Okimbayeva A., Smailova B., Kassymbabina D. Laboratory tensile testing of unmeasurable parts of reinforcing bars joined by butt welding method / International Journal of GEOMATE, Sept. 2022, Vol.23, Issue 97, pp.196–202. DOI: https://doi.org/10.21660/2022.97.3488

10. Sherov A.K., Mazdubai A.V., Sherov K.T., Tulieva N.B. Friction welding is a promising direction of thermofriction technologies for processing and joining parts (review-3) / Bulletin of Science KazATU named after. S. Seifullin. - Astana: KazAU Publishing House, 2014.– No. 1 (80) – S. 146–152.

11. Mulikov D.Sh., Karetnikov D.V., Rizvanov R.G., Chetvertkova O.V., Rizvanov M.I. Machine for friction welding of the tube-tube sheet assembly of heat exchangers. Patent of the Russian Federation No. 161438. Published 04/20/2016. Bull. No. 11.

12. Vedernikov N.M. Installation for friction welding of long and end parts. Patent RU No. 164441 U1. Published 08/27/2016. Bull. No. 24.

13. Sherov K.T., Sherov A.K., Esirkepova A.B., Imanbaev E.B., Gabdysalyk R., Mikhailov V.F., Baktybay I.S. Device for friction welding / Patent No. 4676 RK for utility model. Published on 02/14/2020. Bull. No. 6.

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Үйкеліспен дәнекерлеуге арналған құрылғының жүктелген торабының кернеулі деформацияланған күйін зерттеу

Аңдатпа. Бұл мақалада әртекті материалдарды үйкеліспен дәнекерлеу әдістерін зерттеу нәтижелері берілген және үйкеліс дәнекерлеуге арналған арнайы құрылғының ең көп жүктелетін торабының құрылымдық беріктігін анықтау үшін есептеулер жасалған. Талдау үйкеліспен дәнекерлеу әдісінің кең технологиялық мүмкіндіктерге ие екенін және әртүрлі салаларда қолданылатынын көрсетті. Сондай-ақ үйкеліспен дәнекерлеуге арналған қолданыстағы құрылғылар мен станоктардың конструкциялары зерттелді. Қазақстан Республикасының (ҚР) машина жасау зауыттары жағдайында үйкеліспен дәнекерлеу әдісі білімнің аздығына және технологиялық жабдықтың жоғары құнына байланысты қолданысын таппағаны анықталды. Авторлар бір-біріне ұқсамайтын материалдарды үйкеліспен дәнекерлеуге арналған арнайы құрылғы әзірледі. Бөлшектердің, атап айтқанда кронштейн бөлігінің параметрлерін оңтайландыру үшін ANSYS бағдарламалық пакетін қолдану арқылы кернеу-деформация күйін есептеу және әрекеттегі сыртқы сыни жүктемелерді анықтау арқылы беріктік есептеу жүргізілді. Есептеу нәтижелері кронштейн бөлігінің әзірленген конструкциясының қолдану мүмкіндігін көрсетті.

Түйін сөздер: үйкеліспен дәнекерлеу, әртекті материалдар, кернеулер, құрылымдық беріктік , құрылғы, айналу моменті.

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Исследование напряженно-деформированного состояния нагруженного узла устройства для сварки трением

Аннотация. В данной статье приводятся результаты исследования способов сварки трением разнородных материалов и выполнены расчеты по определению прочности конструкции самой нагруженной детали специального устройства для сварки трением. Анализ показал, что способ сварки трением имеет широкие технологические возможности и применяется в различных отраслях промышленности. Также были исследованы конструкции существующих устройств и машин для сварки трением. Выявлено, что способ сварки трением в условиях машиностроительных заводов Республики Казахстан (РК) не нашел применения из-за малой изученности и высокой стоимости технологического оборудования. Авторами разработано специальное устройство для сварки трением разнородных материалов. Для оптимизации параметров деталей, в частности детали кронштейн выполнены расчеты напряженно-деформированного состояния с использованием программного комплекса ANSYS и расчет на прочность путем определения действующих внешних критических нагрузок. Результаты расчета показали применимость разработанной конструкции детали кронштейн.

Ключевые слова: сварка трением, разнородные материалы, напряжения, прочность конструкции, устройство, крутящий момент.

References

1. Sherov K.T., Gurba G., Imasheva K.I., Bykova N.A. Friction welding is a promising direction of thermofriction technology for processing and joining parts (review-2) / Bulletin of Science KazATU named after. S. Seifullin.- Astana: KazAU Publishing House, 2010.– No. 4 (66) – P. 133–138.

2. Shinoda T., Endo S., Tanada K. Friction Welding of Cast iron and Stainless Steels // Quarterly Journal of the Japan Welding Society. 2018. Vol. 14. No. 12. P. 248–254.

3. Metlitsky V.A. Pressure welding of cast iron // Welding production. 2017. No. 4(905). pp. 35–46.

4. Hauswurz G., Schober D. Reibschweifien fur potimierle Guss - Konstruktion // Konstruieren + Gieben, 2019. Bd 21, N4 S. 33–37.

5. Mitelea I., Gugu R., Petrica A. Process parameters in friction of nodular cast iron with low alloyed steels for mechanical constructions // Sudura. 2017 Vol. 17. No. 5. P. 21–27.

6. CiszewskiG. New experimental concept for the fabrication of cast iron to cast iron and cast iron to steel joints by means of friction welding and the mechanical and plastic properties of these joints // Welding and Cutting. 2017. No. 5. P. 288–297.

7. Ciszewski G. New experimental concept of the fabrication of cast iron to (85% Cu) cooper alloy and cast iron to aluminum joints by friction welding and the mechanical and plastic properties of these joints // Welding and Cutting. 2018. N 2. P. 104–110.

8. Yessirkepova A.B., Sherov K.T., Mikhailov V.F., Mazdubay A.V., Taskarina A.Zh. Research of ways of connecting reinforced bars in the production of reinforced concrete products / Journal of Applied Engineering (JAES) Science, Vol. 18 no. 3 (2020) – P. 372–377. https://doi.org/10.5937/jaes18-24319

9. Sherov K., Serova R., Yessirkepova A, Mussayev M., Ashurova N., Mazdubai A., Okimbayeva A., Smailova B., Kassymbabina D. Laboratory tensile testing of unmeasurable parts of reinforcing bars joined by butt welding method / International Journal of GEOMATE, Sept. 2022, Vol.23, Issue 97, pp.196–202. DOI: https://doi.org/10.21660/2022.97.3488

10. Sherov A.K., Mazdubai A.V., Sherov K.T., Tulieva N.B. Friction welding is a promising direction of thermofriction technologies for processing and joining parts (review-3) / Bulletin of Science KazATU named after. S. Seifullin. – Astana: KazAU Publishing House, 2014.– No. 1 (80) – S. 146–152.

11. Mulikov D.Sh., Karetnikov D.V., Rizvanov R.G., Chetvertkova O.V., Rizvanov M.I. Machine for friction welding of the tube-tube sheet assembly of heat exchangers. Patent of the Russian Federation No. 161438. Published 04/20/2016. Bull. No. 11.

12. Vedernikov N.M. Installation for friction welding of long and end parts. Patent RU No. 164441 U1. Published 08/27/2016. Bull. No. 24.

13. Sherov K.T., Sherov A.K., Esirkepova A.B., Imanbaev E.B., Gabdysalyk R., Mikhailov V.F., Baktybay I.S. Device for friction welding / Patent No. 4676 RK for utility model. Published on 02/14/2020. Bull. No. 6.

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