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Simulation of New Multilayer Waveguides by Explosion Welding

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Abstract. The possibility of obtaining multilayer cylindrical waveguides by explosion welding is investigated. The fact that the technological welding scheme has a significant impact on the shaping of workpieces and the value of edge effects was established. The studies demonstrated that the nature of wave formation during the manufacture of multilayer cylindrical waveguides from a homogeneous material by explosion welding using a central rod is identical to the wave formation when welding flat multilayer compositions on a rigid base.

Introduction

Since the use of the coaxial arrangement of pipes method, adopted when cladding pipe billets for the manufacture of a multilayer shell, is not possible due to the lack of the necessary assortment of pipe billets of the corresponding diameter, a method, described in this paper, implies winding a metal strip with a guaranteed gap on a mandrel in the form of a pipe from a similar or other metal for obtaining multilayer shells [1-5].

There were three types of experiments conducted for welding multilayer cylinders:

- without the use of a throwable shell [6-9];
- with a throwable shell, located at the top welded shell [10-13];
- with a throwable shell, located with a gap in relation to the welded shells [14-17].

The Goal of the Research. To develop a model for the production of new multilayer waveguides by explosion welding from the sheet material.

Materials and Results of the Research

Technological scheme of the fist welding type. The spiral was wound onto a pipe billet made of steel 20 with a gap set with the help of textolite inserts, which progressively increased towards the center. An explosive charge was located directly on the outer coil of the spiral [18-19]. The explosives were initiated by a "spider" of eight equal cuts of the DSH-A detonating cord [20-21], evenly spaced along the outer perimeter of the charge. In order to prevent crushing of the welded shell, a steel rod was inserted into the inner tubular billet, separated from the latter by a layer of water. The process of preparing a sample for the explosion according to this scheme is shown in Fig. 1.

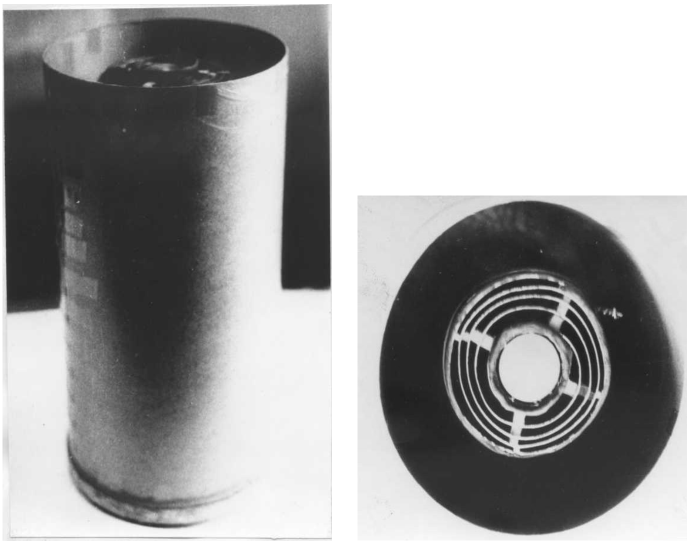
The second type of welding implies the tape to be wound onto a pipe with a constant gap, for which a 1 mm diameter wire was placed along the entire length of the tape edge. A pipe made of XI8H9T steel with a wall thickness of 1.8 mm was used as a throwable shell, which was put on with an interference fit on the spiral immediately after winding.

The explosive charge was located directly on the surface of the throwable shell. Structurally, the charging device is similar to that given in [22-24] and is as follows. A layer of a DSH-A detonating cord is wound in the form of a snail turn to turn in the upper part of the explosive charge. A die of inert material was fixed at the upper end of the throwable shell. Ammonite 6 ZhV was placed on top of the die, which was initiated by a detonator from a central point [25].

This scheme has the following advantages in comparison with the previous one:

- sustainable detonation front along the entire perimeter of the explosive charge is maintained;
- the placement of an interlayer of explosives with high energy characteristics (DSH-A) in the upper part of the charge makes it possible to reduce the value of the edge penetrations due to an earlier exit of the projectile shell to the welding angle. The third type of welding is as follows.

The spiral was fixed at the edges with metal rings after winding. The throwable shell was positioned with a gap against the spiral, which was ensured by fixing the shell in the annular groove of the base.



a b

Fig. 1. Sample preparation for explosion according to the first variant of the welding technological scheme: a - spiral winding view; b - complete sample

One of the key problems of multilayer cylindrical shells manufacturing by explosion welding is to obtain products of the correct geometric shape that require minimal machining [26-27]. The conducted studies proved that the shape of the resulting shells depends largely on the technological scheme of welding.

When using the first type technological scheme of welding, the resulting workpiece along the outer perimeter has the shape of a polygon with a number of faces corresponding to the number of segments of the detonating "spider", which initiated the main charge. In addition to that, "wrinkle" shaped defects formed from crushing of the outer layers of the spiral and local ruptures are observed on the surface of the workpiece, apparently caused by the unevenness of the detonation process. This initiation scheme leads to the formation of edge non-weldings of 40-60 mm. The view of the shells obtained using the first option technological scheme is shown in the photograph in the Fig. 2, and a closeup of the interfaces between the layers of the shell, obtained by welding according to the first option, is shown in the Fig. 4.

The shape of the samples obtained using the second and third options of welding technological schemes is shown in the Fig. 3.

As may be observed, the shells obtained according to these schemes have a regular cylindrical shape without visible defects and discontinuity, which is due to the perfection of the initiation scheme, which ensures a uniform detonation front along the entire perimeter of the main charge. In addition to this, the use of an explosive interlayer with high energy parameters in the upper part of the charge makes it possible to reduce the value of edge penetrations to 20-25 mm.

Fig. 2. The shell, obtain when using the first technological scheme welding

The samples made according to the second option showed a complete absence of welding between the outer shell and the spiral, which is caused by the absence of a gap between them during welding (Fig. 5).

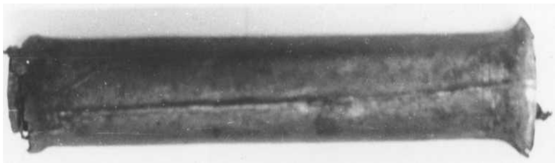


Fig. 3. The shell, obtain when using the second and the third technological scheme welding

Investigations of samples made according to the third option reveal a well-developed wavy surface of the connection between all layers (Fig. 6). At the same time, it was found that the degree of development of waviness decreases as the welding surface moves away from the throwable shell, but the waves on the last welding surface are higher than on the previous ones.

As the welding surface moves away from the outer cylinder, the amplitude of the waves increases and their frequency decreases on cylindrical multilayer shells of copper and brass [28]. This is explained by the influence of stress waves and it is concluded that the process of wavy weld surfaces formation is associated with the fact that, when passing from the cylinder axis to its periphery, the number of interfering elastic waves, reflected from the inner and considered welding surfaces, increases. The current study proves that this assumption is untrue (Fig. 6). Moreover, this cannot explain the nature of waves on the joint surfaces in samples made of a homogeneous material, where the intensity of stress wave reflection is minimal.

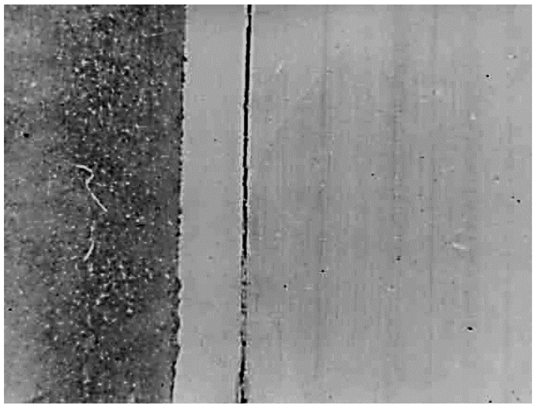


Fig. 4. A closeup of the interfaces between the layers of the shell obtained by welding according to the first option

The obtained result of a multilayer shell welding fully corresponds to the case of welding of multilayer copper composites resting on a massive copper plate [29]. Apparently, the centering rod, separated from the inner pipe by a thin layer of water in our case, played the role of a massive base (similarly to the flat version), which explains the identical patterns of the obtained weldings.

Metallographic studies of the welding boundaries showed that on the samples made according to the first and second options, there is also a wavy joint surface with a small amplitude (0.05 ... 0.03 mm), and the amplitude decreases as the layers move away from the outer surface.

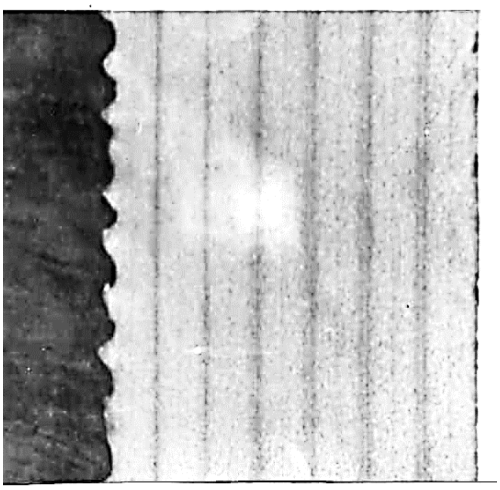


Fig. 5. A closeup of the interfaces between the layers of the shell obtained by welding according to the second option

Discontinuous melted areas at the weld edge, which are located on the crests and below the wave crests were observed for all samples, especially significant in the samples made according to the third option. However, as shown [31], the disconnected melted areas do not lead to a deterioration in the quality of welding; their formation may indicate the presence of a continuous and strong adhesion. Porous defects were observed in some places of the melted areas, which must have appeared, as a result of the air collapse during explosion welding.

Microhardness measurements have shown that the microhardness of the shell layers obtained by explosion welding is 440-460 HB, while the microhardness of the starting material is 230-250 HB. The microhardness of the fused areas is much lower (240-260 HB), which is apparently due to their porosity.

A reliable test of weld quality is the flattening test, which is carried out according to the GOST 8695-75.

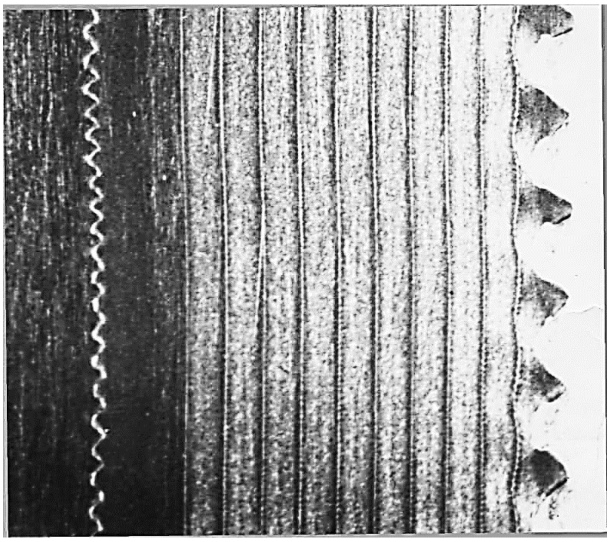


Fig. 6. A closeup of the interfaces between the layers of the shell obtained by welding according to the second option

The test was conducted for the second and third types cylindrical shell welding. The 20 mm rings were cut for testing.

During the tests, the samples were placed between the press panels so that the welding zone of the outer edge of the spiral was located at a 90 ° angle to the axis of the load application (similar to the weld of welded pipes). Flattening was carried out until the destruction of the samples.

As a result of the tests carried out, the following was established. The destruction of the samples occurred along the axis of the load application and in the plane of the location of the outer edge of the spiral. Significant delamination of the inner shell was observed, onto which the spiral was wound for both types of samples. Certain delamination of the outer shell was observed only in the samples of the second type, which is explained by the absence of a gap between the outer shell and the spiral during welding. Delamination did not take place for the third type samples. A fracture, tyFigal for the monolithic metal without any signs of delamination was found in the places of the destruction of the samples, which is an indicator of satisfactory adhesion between the welded layer.

Summary

The possibility of obtaining multilayer cylindrical shells by explosion welding was investigated. It was established that the technological scheme of welding has a significant impact on the shaping of the workpieces and the value of edge effects.

The analysis of the obtained experimental data demonstrates that the most satisfactory results in terms of strength, continuity, and adhesion quality were achieved at the third type welding technological scheme. In this case, the welding boundary is wavy with separate disconnected fused sections, which means it is close to the optimal form.

The studies have revealed that the nature of wave formation in the manufacture of multilayer cylindrical shells from a homogeneous material by explosion welding using a central rod is identical to the wave formation when welding flat multilayer compositions on a rigid base.

A fracture, tyFigal for a monolithic metal without any signs of delamination was found in the places of the samples destruction, which is an indicator of satisfactory adhesion between the welded layers.

References

[1] M.V. Zagirnyak, V.V. Drahobetskyi, New methods of obtaining materials and structures for light armor protection, International Conference on Military Technologies (ICMT 2015). (2015) 15292611.

[2] O. Markov, O. Gerasimenko, L. Aliieva, A. Shapoval, Development of the metal rheology model of high-temperature deformation for modeling by finite element method, EUREKA, Physics and Engineering. (2) (2019) 52-60.

[3] J. Bast, S.M. Gorbatyuk, I.Yu. Kryukov, Horizontal hcc-12000 unit for the continuous casting of semifinished products, Metallurgist. 55(1-2) (2011) 116-118.

[4] V.V. Kukhar, A.V. Grushko, I.V. Vishtak, Shape indexes for dieless forming of elongated forgings with sharpened end by tensile drawing with rupture, Solid State Phenomena. 284 (2018) 408-415.

[5] I. Lutsenko, Identification of target system operations. Development of global efficiency criterion of target operations, Eastern-European Journal of Enterprise Technologies. 2(2) (2015) 35-40.

[6] V.P. Babak, V.V. Shchepetov, S.D. Nedaiborshch, Wear resistance of nanocomposite coatings with dry lubricant under vacuum, Naukovyi Visnyk Natsionalnoho Hirnychoho Universytetu. (1) (2016) 47-52.

[7] V. Kukhar, O. Kurpe, E. Klimov, E. Balalayeva, V. Dragobetskii, Improvement of the method for calculation the metal temperature loss on a coilbox unit at the rolling on hot strip mills, International Journal of Engineering & Technology (UAE). 7(4.3) (2018) 35-39.

[8] O.E. Markov, O.V. Gerasimenko, A.A. Shapoval, O.R. Abdulov, R.U. Zhytnikov, Computerized simulation of shortened ingots with a controlled crystallization for manufacturing of high-quality forgings, International Journal of Advanced Manufacturing Technology. 103(5-8) (2019) 3057-3065.

[9] M.M. Moroz, S.O. Korol, S.M. Chernenko, Y.O. Boiko, O.M. Vasylkovskyi, International Journal of Engineering and Technology(UAE).7(4) (2018) 135-139.

[10] V.V. Bogoboyashchii, I.I. Inzhin, Mechanism for conversion of the type of conductivity inp-Hg1-xCdxTe crystals upon bombardment by low-energy ions, Russian Physics Journal. 43(8) (2000) 627-636.

[11] N. Hrudkina, L. Aliieva, P. Abhari, O. Markov, & L. Sukhovirska. Investigating the process of shrinkage depression formation at the combined radialbackward extrusion of parts with a flange, Eastern-European Journal of Enterprise Technologies. 5(1-101) (2019) 49-57.

[12] E. Belas, V.V. Bogoboyashchyy, R. Grill, I. I. Izhnin, A.P. Vlasov, V.A. Yudenkov, Time relaxation of point defects in p- and n-(HgCd)Te after ion milling, Journal of Electronic Materials. 32(7) (2003) 698-702.

[13] V.V. Bogoboyashchii, A.P. Vlasov, I.I. Izhnin, Mechanism for conversion of the conductivity type in arsenic-doped p-CdxHg1-xTe subject to ionic etching, Russian Physics Journal. 44(1) (2001) 61-70.

[14] E.P. Gribkov, A.V. Perig, Research of energy-power parameters during powder wire flattening, International Journal of Advanced Manufacturing Technology. 85(9-12) (2016) 2887-2900.

[15] I. Lutsenko, E. Vihrova, E. Fomovskaya, O. Serdiuk, Development of the method for testing of efficiency criterion of models of simple target operations, Eastern-European Journal of Enterprise Technologies. 2(4) (2016) 42-50.

[16] V.L. Kalyuzhnyi, L.I. Alieva, D.A. Kartamyshev, I.G. Savchinskii, Simulation of cold extrusion of hollow parts, Metallurgist. 61(5-6) (2017) 359-365.

[17] A. Shapoval, I. Savchenko, O. Markov, Determination coefficient of stress concentration using a conformed display on a circle of a single radius, Solid State Phenomena. 316 (2021) 928-935.

[18] M.G. Naumova, I.G. Morozova, P.V. Borisov. Study of metal surface with color image obtained with laser marking, Solid State Phenomena. 299 (2020) 943-948.

[19] I. Lutsenko, E. Fomovskaya, Identification of target system operations. The practice of determining the optimal control, Eastern-European Journal of Enterprise Technologies. 6(2) (2016) 30-36.

[20] L.S. Malinov, I.E. Malysheva, E.S. Klimov, V.V. Kukhar, E.Yu. Balalayeva, Effect of particular combinations of quenching, tempering and carburization on abrasive wear of low-carbon manganese steels with metastable austenite, Materials Science Forum. 945 (2019) 574-578.

[21] A.A. Shapoval, D.V. Mos'Pan, & V.V. Dragobetskii, Ensuring high performance characteristics for explosion-welded bimetals, Metallurgist. 60(3-4) (2016) 313-317.

[22] N. S. Hrudkina, L. I. Aliieva, Modeling of cold extrusion processes using kinematic trapezoidal modules, FME Transactions. 48(2) (2020) 357-363.

[23] A. Shapoval, V. Drahobetskyi, I. Savchenko, A. Gurenko, O. Markov, Profitability of production of stainless steel + zirconium metals combination adapters, Key Engineering Materials. 864 (2020) 285-291.

[24] O.E. Markov, V.V. Kukhar, V.N. Zlygoriev, A.A. Shapoval, A.S. Khvashchynskyi, R.U. Zhytnikov, Improvement of upsetting process of four-beam workpieces based on computerized and physical modeling, FME Transactions. 48 (4) (2020) 946-953.

[25] N. Hrudkina, L. Aliieva, O. Markov, I. Marchenko, A. Shapoval, P. Abhari, M. Kordenko, Predicting the shape formation of hollow parts with a flange in the process of combined radial-reverse extrusion, Eastern-European Journal of Enterprise Technologies. 4/1 (106) (2020) 55-62.

[26] I. Savchenko, A. Shapoval, A. Gurenko, Modeling dynamic parameters of hard alloys during shock wave regeneration, IOP Conference Series: Materials Science and Engineering. 969(1) (2020) 012079.

[27] I. Lutsenko, E. Fomovskaya, I. Oksanych, S. Koval, O. Serdiuk, Development of a verification method of estimated indicators for their use as an optimization criterion, Eastern-European Journal of Enterprise Technologies. 2 (2017) 17-23.

[28] A. Shapoval, R. Kantemyrova, O. Markov, A. Chernysh, R. Vakulenko, I. Savchenko, Technology of production of refractory composites for plasma technologies, Proceedings of the 25th IEEE International Conference on Problems of Automated Electric Drive. Theory and Practice (PAEP). (2020) 9240830.

[29] A. Anishchenko, V. Kukhar, V. Artiukh, O. Arkhipova, Application of G. Lame's and J. Gielis' formulas for description of shells superplastic forming, MATEC Web of Conferences. 239 (2018) 06007.