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ASSESSMENT METHODOLOGY OF THE STRESS-STRAIN STATE IN THE HEAT-AFFECTED ZONE OF AUSTENITIC ALLOYS USING A GRID METHOD

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Summary. *Austenitic steels and nickel-based alloys have sufficient sensitivity to hot cracking during fusion welding. Analysis of thermal stress state in the vicinity of the weld pool, including with the use of computer models to determine the basic laws of the formation of cracks and to work out ways of their prevention. The technique of applying the heat-resistant grid on the surface of nickel-based alloy plates and the distribution of local deformation of the surface layers of metal in the close-to-welding zone was developed. The presence of significant tensile strains in the longitudinal direction, which can promote the formation of transverse cracks during welding, was shown.*

Key words: *Ni-based alloys, stresses, strains, grid method.*

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Setting of the problem. Austenitic steels and nickel-based alloys are one of the frequent used classes of constructive metals that endure extreme temperature and power loading and are able to resist the action of aggressive environments. During fusion welding of alloys with firm austenitic structure the appearing of hot cracks is possible in the vicinity of austenitic zones. Local plastic flow facilitates the appearing of these cracks, as a result of thermal cycle influence of welding during the formation of welded joints.

Analysis of the known results of the investigations. Austenitic steels and their welded joints are sufficiently sensitive to hot cracks. This sensitivity is roughly increased in the case of fusion welding of firm austenitic steels and nickel-based alloys that reserve face centered cubic lattice through the whole temperature interval. Taking into consideration the difficulty of thermal deformation processes which are available during fusion welding of mentioned materials and the variety of crack’s kinds that appear during the welding, the estimation of sensitivity of these materials to the formation of cracks and their classification till now are actual tasks [1]. Under investigation the aptitude for the formation of cracks during the welding the practical interest presents the experimental research of the nature of distribution of welding stresses and deformations. For more detailed analysis of the nature of this distribution in the heat affected zone (HAZ), in the vicinity of the fusion line, the method of heat-resistant grids was used.

The purpose of the investigation. To devise the methodology of layering of heat-resistant grid on the surface of nickel-based alloys plates of alloying system Ni-Cr-Co-Mo-Ti-Al, and to research the distribution of deformations of local surface layers of metal in the heat-affected zone on the side of primary part and on the side of the amplification of the welding joints.

Setting of the task. Modern information about the strained-stressed state during the welding process is accumulated by means of experimental and estimated ways. As measuring boosters of moving mechanic devices are used (deform-meters) and tensor-resistors. Moreover, for the dimensions of different kinds divisible grids and fragile surfaces are being used. During the usage of deform-meters for dimension in metal the basic perforation are drilled in

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accordance with using construction of deform-meter. Taking into consideration some difficulties connected with the mechanic finishing of nickel alloys and the peculiarities of their structural state for determination of residual deformations in close-to-welding zone the grid method was used.

Methods of grid coating lies in: on the surface of smooth flat model polished and chemically degreased in advanced with roughness not higher 0,63 uniformly sprayed coating lacquer photoconductor such as POSITIVE 20 with the next thorough model drying temperature 70°C during 20 minutes. Produced on the transparent pellicle with the help of phototypesetting machine Scitex Dolev4press VEG 750 (parameter delimiter 6 MP) the original of dividing grid was arranged on the model surface. For firm adjoining of former to model vacuum rig was used. The original of coordinate grid was placed with scheme to the model surface. Dividing grid imprint on the light sensitive protective covering lacquer photo-resistor, polished on the model surface, is produced by the way of exposition under mercurial quarts lamp such as ДРТ 240, the duration of exposition is 120 s, distance from the resource of radiation to the pattern surface is 250mm.

For the imprint display of the divisible grid after the radiation the pattern was plunged into the pool with lean solution of Na OH (7g of caustic soda to 1l of cold distilled water). After that the model was rinsed out in the distilled water and dried.

After the drying out the pattern was plunged into the electrolytic mixture which contains such chemical elements in the proportion, ml (table 1): concentrated sulfuric acid, strong ortho-phosphorus acid, distilled water.

Table № 1

The composition of the mixture for electrolytic etching, ml

Concentrated sulfuric acid	300
Concentrated phosphoric acid	600
Distilled water	100

By further electro and chemical outline (contour) erosion of unprotected by photo-resistor model zones got the system of holes on the model surface. Diameter of holes is 0,02mm, depth – 2-3mkm. Treated with a mordant models were washed in the flowing water, plunged into 10% salt solution Na CO3, again watered and dried. Remnants of photo-resistor took away with solvent like “646”.

In consequence of holes erosion on the metal surface, such grid is able to sustain serious deformations, especially at high temperatures; it is inherent in sufficient exactitude, permanent step and contrast range.

For imprint photographing of coordinate grid the system collected with the usage of binocular microscope like МБС-10 with optic system was used; it supplies 100 multiple (aliquot) increasing of digit camera with divisible power 6 mega pixel and lighting device which supplies parallel coherent lighting of working zone through the another microscope eyepiece.

To work up the methods of resilient-plastic condition estimation by the grid method flat models were produced, on which the coordinative grid with density 25 points/mm^2 was marked. Sketchy model imprint, the place of grid marking and the position of strain indicator points is shown on Figure 1.

Calculation of shifting between grid points is conducted in automatic regulations by means of specifically created software. Photography of grid imprint in the investigated place before deformation and after it is loaded into computer, where bitwise digitization of half-tone photography is implemented. According to logic design the coordinates of grid points centers are determined, the identification of proper points on the prints of the material starting condition and after deformation, and also in the automatic regulations their shifting is being computed.

On the basis of determined movements, with the usage of material deformation chart, the calculation of strain deformation state and the sizes of plastic zone are realized. Ready results of deformation measuring by means of strain indicators and by the grid method are shown on Figure 2.

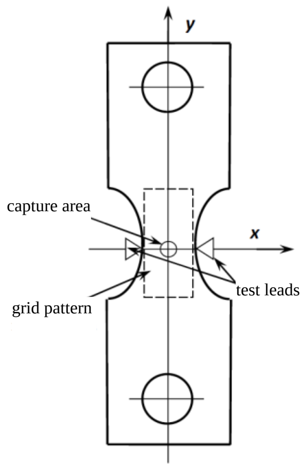

Figure 1. Schematic view of the specimen

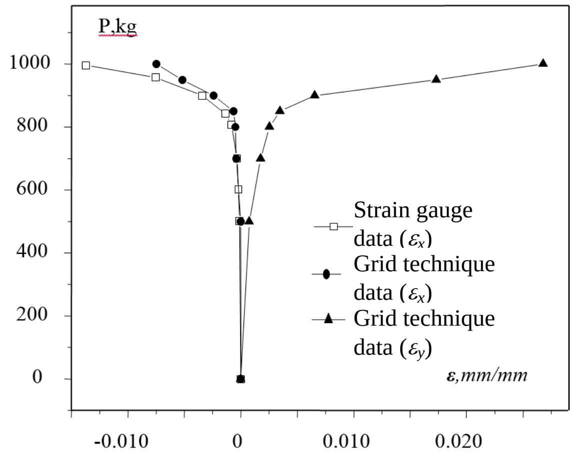

Figure 2. Strain of flat specimen measured using strain gauges and grid pattern

On the left side of zero line compression deformations are illustrated, they are measured in the transversal direction by means of strain gauges and the grid. By analyzing got results it can be seen that we have satisfactory similarity of measuring results by means of strain gauges and the grid. This affirms that grid methods can be realized for further investigation of deformation distribution under welding.

Under welding strain investigation the patterns with the size 35x40 mm and thickness 2 mm were made of stable austenitic material. On the pattern surface the grid with density 100 points/mm^2 and hole's diameter 0,02mm were made in accordance with above given methods. Grid imprints in local zones were photographed before and after welding (Figure 3).

Welding joint was executed by electron-beam welding in the chamber to avoid tarnishing of plate surface. Welding was accomplished on the grid surface and after the entire plate refrigeration the shifting of grid joints was measured in lengthwise and transversal directions. After the welding, in the heat-affected zone, near the fusion line the cracks were observed with the length 0,3-0,7mm (Figure 4).

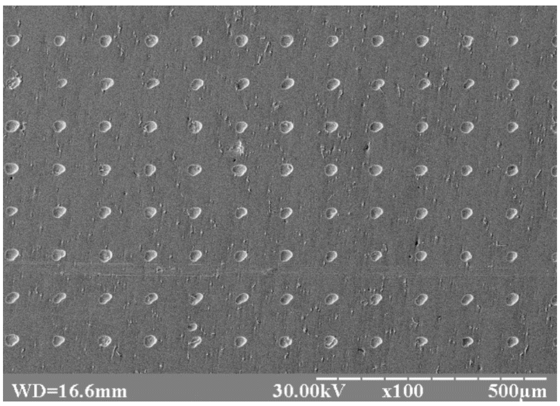

Figure 3. Grid before welding

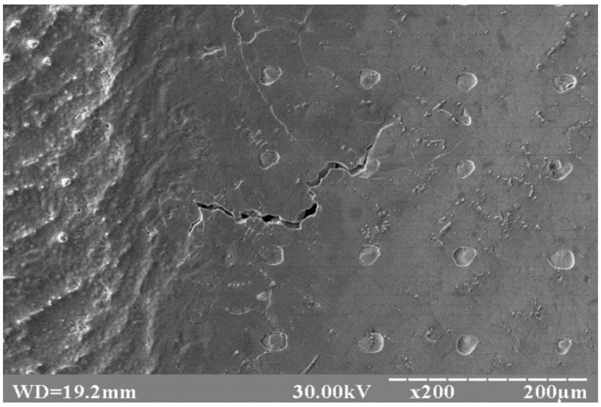

Figure 4. Cracks in HAZ of nickel-based alloy after welding

Strain distribution in the transversal relative to fulfillment of welding joint direction on the pattern surface in HAZ on the joint side is shown on figure 5. On the figure is illustrated that during welding of nickel-based alloy in the HAZ in the transversal direction residual strains appeared, moreover, strain achieve maximal meanings near fusion line.

Deformation calculated in longitudinal direction (Figure 6) has shown the availability of heavy strain with maximal significances near fusion line. The width of strain zone for given investigation condition is approximately 3mm.

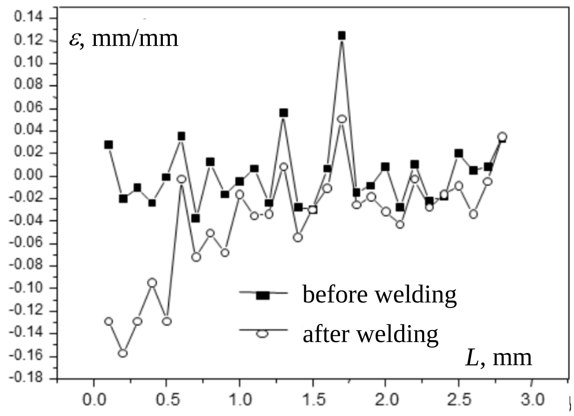

Figure 5. The distribution of strains in the transverse direction

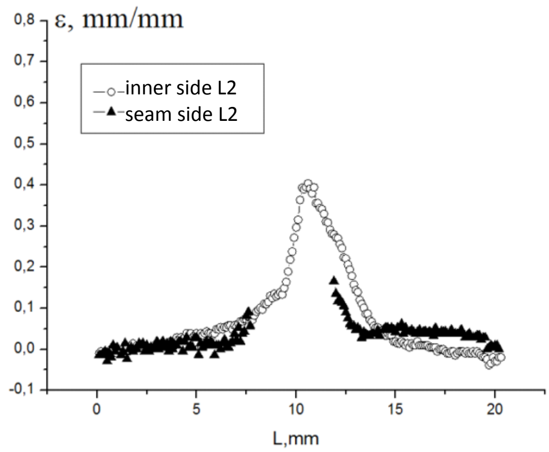

Figure 6. The distribution of strains in the longitudinal direction

Received experimental data are used for data verification under the building of mathematic model of stress-strain state during fusion welding in the heat-affected zone of alloys with austenitic structure and the determination of thermo mechanic conditions of hot cracks appearing in the welded joints.

Deformation of grid lines in the lengthwise direction, received experimentally, has coincided with calculating movements of points, received according to the results of mathematic modeling (Figure 7).

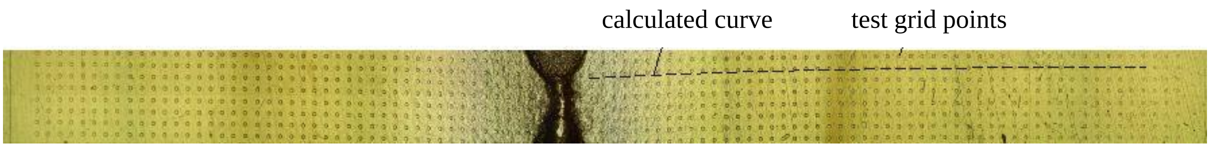

Figure 7. Comparison of calculating and test data of grid points shift on the plate surface

Conclusions.

1.Tested methods of grid application of points system (25-100points/mm^2, point diameter 0,02mm) with constant step on the metal surface with stationary austenitic structure by erosion method.

2.Worked methods of micro plastic deformation determination under fusion welding of nickel-based alloy by grid method, and the availability of considerable strain has been shown in the lengthwise direction, that can cause the creation of transversal cracks under welding.

3.Verification of experimental and calculating data has showed the satisfactory results similarity.

References

1. Boellinghaus T., lippold J., Cross C. Cracking phenomena in welds IV. Springer, 2016, 512 p.
2. Yasnii P.V., Pyndus Yu.I., Marushchak P.O., Fostyk V.B. Pat. 33067 Ukrainy. MPK G 01 N 1/00. Sposib rozmichuvannia poverkhon metalevykh ploskykh zrazkiv, Ternopilskyi derzhavnyi tekhnichnyi universytet imeni Ivana Puliuia, No 200801367; zaiav. 04.02.2008; Publ. 10.06.08, Bull. No 11. [in Ukrainian].

Список використаної літератури

1. Boellinghaus, T. Cracking phenomena in welds IV [Text] / T. Boellinghaus, J. lippold, C. Cross – Editors. – 2016. – Springer. – 512 p.
2. Пат. 33067 України. МПК G 01 N 1/00. Спосіб розмічування поверхонь металевих плоских зразків [Текст] / П.В. Ясній, Ю.І. Пиндус, П.О. Марущак, В.Б. Фостик. Заявник та патентокористувач – Тернопільський державний технічний університет імені Івана Пулюя. – № 200801367; заяв. 04.02.2008; опубл. 10.06.08, Бюл. № 11.

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МЕТОДИКА ОЦІНЮВАННЯ НАПРУЖЕНО-ДЕФОРМОВАНОГО СТАНУ В ЗТВ АУСТЕНІТНИХ СПЛАВІВ ІЗ ВИКОРИСТАННЯМ МЕТОДУ СІТОК

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Резюме. *Аустенітні сталі та нікелеві сплави мають значну чутливість до утворення гарячих тріщин при зварюванні плавленням. Аналіз термонапруженого стану в районі зварювальної ванни, в тому числі з використанням комп'ютерних моделей, дає змогу визначити основні закономірності утворення тріщин та відпрацювати шляхи їх попередження. Розроблено методику нанесення термостійкої координатної сітки на поверхню пластин з нікелевого сплаву та досліджено розподіл деформацій локальних поверхневих шарів металу у пришовній зоні. Показано наявність значних деформацій розтягу в поздовжньому напрямку, що може сприяти утворенню поперечних тріщин при зварюванні.*

Ключові слова: *нікелеві сплави, напруження, деформації, метод сіток.*

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