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THE APPLICATION OF MAGNETIC METHODS AT THE QUALITY CONTROL OF WELDED DESIGNS MADE FROM INCREASED DURABILITY STEEL

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Abstract. *The results of determination of the residual tensions in welded elements from the low-alloyed increased durability steel classes X65 and X75, received by a method of holes and means of the final element analysis in the ANSYS softwrae are given in this work. The assessment of influence of thermal processing on the level of the residual tensions in welded elements is made. The comparison of values of the tension received by a method of holes and sizes of intensity of the magnetic field of demagnetized has established correlation dependences for an assessment of tensely deformed condition of welded elements from investigated steel in the initial and thermally processed condition.*

Keywords: *tensely deformed condition, finite elements method, FEM, ANSYS, welded connections, thermal processing, magnetic control*

The assessment of deficiency and quality control of welded designs is carried out by various methods of diagnostics. The most effective method of diagnostics of metal of welded connections for today is magnetic control.

One of the conditions of the safe operation of metal design is the existence of the techniques and the standard documentation, regulating norms of an assessment of the quality of metal of welded connections with the purpose of definition of a resource of safe operation of the "problem" sites revealed at control. A total assessment of loading of a metal construction with defective sites or with degrees of potential danger of a "problem" zone can give settlement pilot studies.

It is known that, temporary and residual welding tensions appeared as a result of heating of the metal caused by the influence of the concentrated source of warmth in a welded design.

Residual tensions in the surface layers are among the factors which essentially influenceon many characteristics of quality of products. Their influence on geometrical accuracy of products with all that it implies is especially great. Thus operational properties of products are defined by both size of residual tensions on surfaces and nature of their distribution on depth of a surface layer [1].

Carrying out welding designs causes additional growth of magnitude of residual tensions and essentially changes tensely deformed condition (TDC) in a zone of a welded seam and in adjacent areas.

It is known that during the work the imposing of residual and working tension are held from various external influences so the existence of residual tensions in certain cases can considerably reduce a resource of welded designs.

First of all, proper tensions makes considerable influence on resilience of corrosion of the material as the application of mechanical tensions leads to the change of balance of forces of resistance to an attraction and pushing away of electronic covers, promoting emergence of superfluous pressure which aspires to return a body to the initial not deformed condition with the minimum thermodynamic potential. In other words, external loading lowers thermodynamic stability of metal that promotes an intensification of processes of interaction of metal with the environment. The more degree of the enclosed tensions, the less the work of an exit of ions from a lattice and the speed of corrosion penetration is higher [2].

Secondly, the increase of internal tensions raises risk of unstable destruction of designs in the conditions of the lowered temperatures and existence of defects.

For the decrease of level of residual welding tensions in designs the former are exposed to the certain the expediency of application of thermal processing in each case proceeding from service conditions. Wide application finds such way of thermal processing as high tempering of the metal design which carrying out the decrease a complex of the properties characterizing reliable operation. Thermo cyclic processing (TCP) [3] is also used for the increase of operational characteristics of welded connections now.The question of the influence of thermo cyclic processing (TCP) on the TDC of welded elements is still insufficiently studied.

The methods of nondestructive control based on measurement of magnetic characteristics are widely used at quality control of welded designs (in particular, level of internal tensions in a material). In case of application of similar methods it is necessary to have statistically reasonable correlation dependences of controllable properties of a material of a design on measured physical sizes.

Importance of residual tensions in various points of welded elements from hypo eutectoid steel classes of durability X65 (brands 09G2S, 17G1SU and 09G2FB) and X75 (10HSND and 10G2FBYU) were determined by modeling in the ANSYS complex and by Matar method for the purpose of obtaining such dependences. The found importances of tensions were compared with magnitude of intensity of a magnetic field of the demagnetized measured in these points. The fragments of pipe in diameter of 200 mm and in thickness of 10 mm with a ring welded seam in the center were used as control samples. Homogeneous connections of pipes from all designated brands of steeland diverse connections of steels brands 09G2S and 10HSND were studied.

The thermal calculation, which purpose was the analysis of distribution and change of temperature in the course of cooling of welded connection from the temperature of the end of welding to environment temperature was carried out at the first stage in the program ANSYS complex. Fields of internal tensions in welded connections are received as a result.

At the second stage the constructional analysis of influence of temperature of cooling of welded connection on intense the deformed condition of studied model and definition of accumulation of residual welding tension is made. The example of results of calculation is presented in Fig. 1.

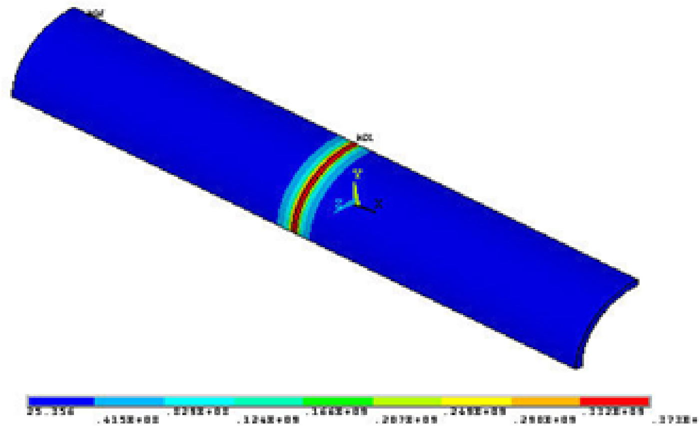


Fig. 1. Calculation residual equivalent tensions (according to Mizes) in welded connections of pipes from the increased durability steel

Thus, by means of finite element method (FEM) it is established that in the welded metal and joining to it a site of studied welded connections the residual stretching tensions reaching the maximum size for homogeneous welded connections in the center of a seam, for connections from different brands of the steel – in a zone of thermoinfluence of less strong steel takes place. The analysis of calculated extreme values of tensions is given in Table 1.

Table 1. The maximum values of residual tensions in the welded connections, received by FEM

Tensions	Welded connection from steel brands					
	09G2S	17G1SU	09G2FB	10HSND	10G2FBYU	09G2S+10HSND
σ_{res}, MPa	100	120	125	200	250	220

It is noted that, as the initial strength weld able steel increases the level of internal residual stresses, in some cases, achieving a level of approximately aspiring mechanical characteristic strength $\sigma_{0,2}$. For further use of the welded construction of such material similar phenomenon is unacceptable.

In comparison to the yield strength steels it is founded that the residual stresses are a percentage of its value:

– for homogeneous welds up to 30 %;

– for the connections of steel of various grades of about 35 %

The maximum values of residual tensions in the points located in the center of the seam and in ten points which are from the center of a seam to the periphery on both sides with a step of 5 mm were determined by method ofholes. The used method is based on measurement of deformations at removal of a fragment of the metal, causing a relaxation of tensions. Shear tensions is comparable small compared to normal, and neglecting their size, residual tensions were calculated in this way:

$$\sigma_{xres} = -E(\varepsilon_x + \mu\varepsilon_y) / (1 - \mu^2),$$

$$\sigma_{yres} = -E(\varepsilon_y + \mu\varepsilon_x) / (1 - \mu^2),$$

where ε_x and ε_y – deformations on two main directions; μ – Puasson's coefficient.

Sizes of deformations were defined by means of measuring system on the basis of strain gauge type sensors. In points where it is necessary to define values of tension strain gauge КФ5Р3 were pasted. Flat-bottomed holes in diameter of 3 mm and depth of 4 mm along the normal to the socket plane were drilled in the center of a tensor rosette.

The results of experimental determination of the maximum post welding tensions of the stretching got by a method of holes, (presented in Fig. 2) confirm the character of the field of propertension established by a numerical method. Thus the error of a settlement method makes about 10 %.

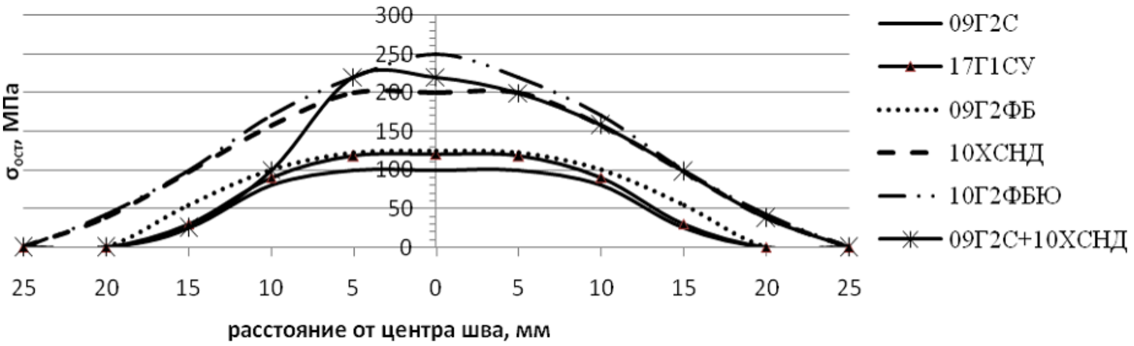


Fig. 2. The field of the maximum residual stretching tensions
in welded connections of the increased durability steel

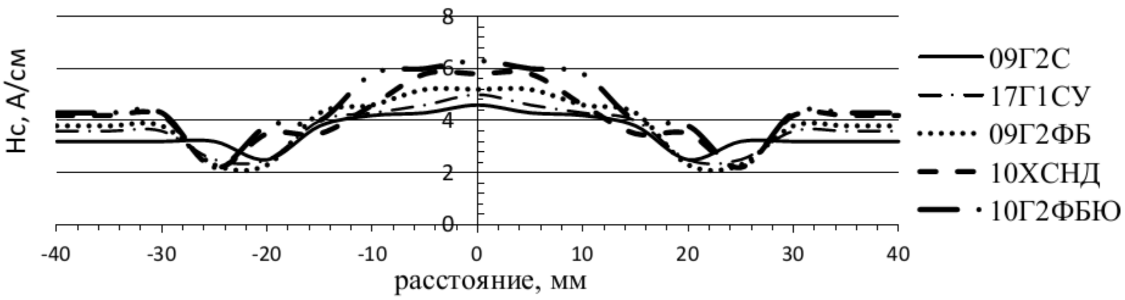


Fig. 3. Distribution of size of coercive force in welded connections

The change of coercive force in points for which sizes of tension were defined was investigated. Results of measurements are presented in Fig. 3.

The analysis of changing of intensity of a magnetic field of demagnetized on section of welded connections confirms the nature of distribution of internal tensions established earlier: for weld metal and HAZ of value of Hc size 3,5 A/m that testifies the existence of tensions of stretching [4].

Using the obtained experimental data, for all studied welded connections the private and generalized graphic were constructed dependences of size of internal tensions on the coercive force, given on Fig. 4.

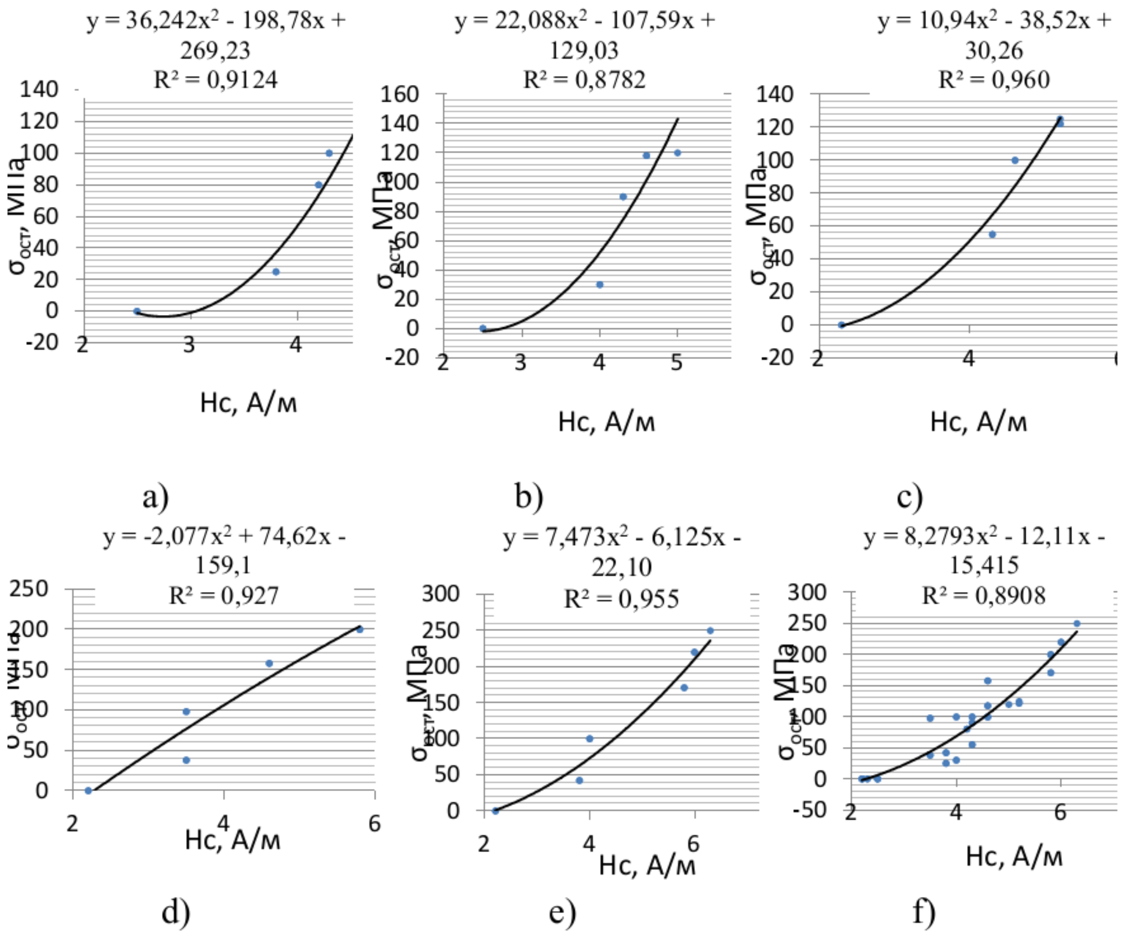


Fig. 4. Dependences of size of residual tension on coercive force in welded connections: a) 09G2CSb) 17G1SU; c) 09G2FB; d) 10HSND; e) 10G2FBU; f) for all investigated steel (generalized)

Thus the equations of approximation established allow to define values of residual tensions on the basis of measurements of intensity of a magnetic field of demagnetized in elements of designs from low-alloyed steel with reliability not lower than 87 %.

The influence of thermal processing on change of level of proper tensions for homogeneous welded connections from steel 09G2S (H65) and 10HSND (H75) and diverse connections 09G2S+10HCND by means of described above methods wasinvestigated.

During the final element modeling, the results of which are presented in Table 2, It was established that thermal processing makes various influence on the TDC of control connections. The most essential positive influence renders tempering of welded connections as a result of which propertension decreases at the average in 10 times, reaching level less than 1 % from a fluidity limit.

Table 2. The maximum values of internal tension in welded connections after the thermal processing, received for ANSYS

Welded connection	Initial condition	holiday	MTTsO	STTsO
	σ_{res}, MPa			
09G2S	100	10	90	97
10HSND	200	15	170	198
09G2S+10HSND	220	20	185	215

The tensions decrease for 10 - 5 %, after thermal cycling commuting processing and medium temperatureTCP practically doesn’t influence on size of the former.

It is also necessary to note, that localization of the maximum sizes of propertension in welded connections in the course of thermal processing doesn't change.

Thus, the made calculations show that thermo cyclic processing doesn't raise the level of internal tension in welded connections, and for a case of pendulum processing promotes its decrease (on size about 15 %), however, propertensions remains rather high.

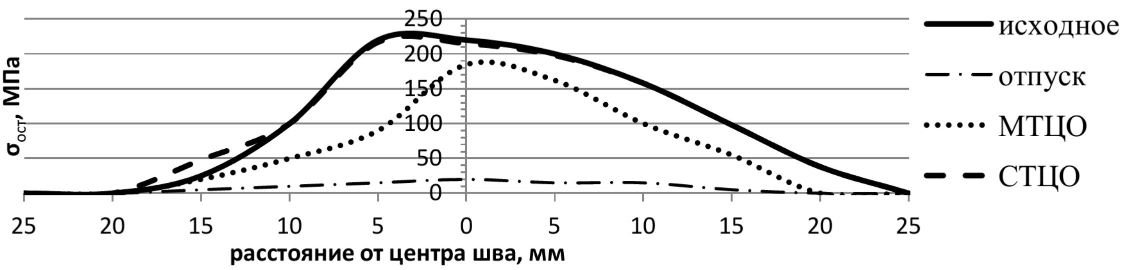
The results of experimental determination of the maximum residual tensions of stretching in samples after welding and the heat treatments received by a method of holes (presented on Fig. 5), confirm the character of change of the TDS of control samples established earlier in analytical way at heat treatment. The error of a settlement method makes about 12 %.

The results of measurements of size of intensity of the magnetic field of demagnetized in control points of studied samples are presented in Fig. 6.

Using experimental data, the generalized graphic dependence of size of internal tension on coercive force for studied welded connections after the thermal processing, designated in Fig. 7 was received.

The use of the received regression dependences allows to estimate the level of residual tensions in welded designs from investigated steel with reliability over 90 %.

a) b)



c)

Fig. 5. The field of the maximum residual stretching tensions in welded connections:
a) Steel09G2S; b) Steel 10HSND;
c) Steel 09G2S (from left to right 09G2S →10HSND)

Thus, the use of the control methods based on measurement of intensity of a magnetic field of a demagnetized allows with high reliability (about 90 %) to define the level of internal tensions in welded connections of low-alloyed increased durability steels, both in an initial condition, and after thermal processing. In turn it allows a nondestructive method to make an assessment of efficiency of this or that method of thermal processing of welded designs by criterion of size of residual tension.

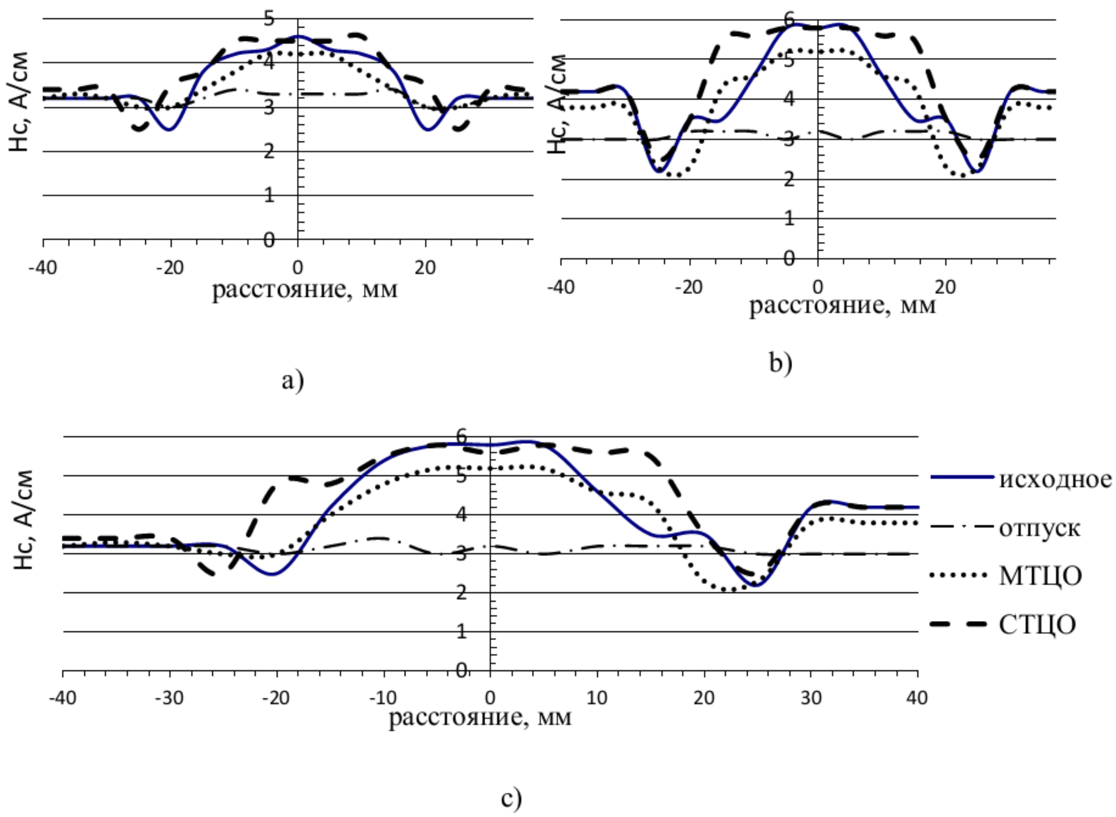


Fig. 6. Distribution of size of intensity of a magnetic field
of demagnetized in welded connections:

a) steel 09G2S; b) steel 10HSND;
Steel 09G2S (from left to right 09G2S →10HSND)

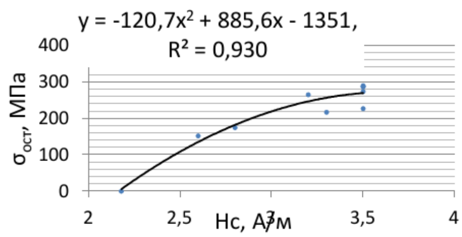


Fig. 7. Dependence of size of residual tensions on coercive force
in welded connections after thermal processing

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