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# Application methods changes plastic deformation after welding sill gondola cars

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Abstract
The peculiarities of methods of restriking of plastic deformation during production of center girder of gondola cars are presented. The paper traverses the reasonable use of heat impact free restriking of center girder of gondola cars. The classification of methods of restriking of permanent deformation after welding for carriage building.
Key-words: GONDOLA CAR, PLASTIC DEFORMATION, COLD STRAIGHTENING, THERMAL DRESSING WITH LOCAL HEATING

**1. Introduction**

According to the strategy of development of railway transport for the period until 2020 year, which is approved by the Cabinet of Ministers of Ukraine dated the 16th of December, 2009 No 1555-p. The reliabilization of native park of gondolas is relevant and complex problem, the solving of which requires solution of the following key tasks: development and creation of more perfected design; improvement of manufacturing process; improvement of the system of repairs and maintenance; the usage in service of modern, high-efficient control devices of technical state of cars, increasing their service etc .

In the whole world, for the last years, a great attention is paid to the welding methods of treatment of weld joints. The practice of producing of welded construction with different grade of steel and alloy shows that received weld joints often have other characteristics of strength properties than base metal.

Neither of existing methods of welding provide guaranteed defectless weld joint *without further improvement.* This owes to that the factors having an influence on the quality of joint weld are not only of metallurgical but also technologic and organization character, the task of control and support of which, is not totally solved. [1].

However, while setting the modes for methods of controlling of deformations there appear problems connected with metalware shape, its hardness, metal thickness and others. Besides, the most important is that there is no information about the size of plastic deformation area or active zone. The existent engineering methods of strain are approximate and do not give exact results [2].

**2. Literature data analysis and problem statement**

At the present days, manufacturing process of gondola car framing provides assemblage and welding of technologic assembly components of the frame, deseaming after welding, straightening and weld inspection. Therefore, framing includes the range of working operations, which are connected with plastic deformation of the metal. To the list of these operations belong the following: welding, gas-cutting, assembling excluding welding deformations: thermal, thermomechanical and cold straightening.

Analysis of the reasons of deformations shows that the last arise not only as a result of such technological operations as bending, stamping, transportations and, etc., but generally as a result of thermomechanical influence of welding. Difficulties in the prevention of deformations connected with welding, are conditioned by the specifics of metalwork of framing of gondola car [3].

For improvement of quality of production of welded assembly units of a frame, it is necessary to improve technology of their production in the course of which, welding residual deformations and tension that complicate manufacturing techniques and installation, are formed. [4,5].

1.1.1 MSTU of N. E. Bauman G. A. Nikolaeva [6], the St. Petersburg N. O. Okerblom [7], the Kiev E.O.Paton [8] schools of science made a major contribution to the development of this question.

The works of B. S. Kasatkin [9], where the inevitability of appearance of residual deformations when welding and is proved, and V. V. Vinokurov [2], where the need of the accounting of shift deformations after welding is shown, are refered to the main works in the field of deformations after welding.

Also heavy workload is carried out in car building abroad conserning prevention of deformations [10]. During manufacture of car bodies, twisting deformation of car body covering and deflection of body elements makes about 50% of all types of welding deformations. And expenses on thermal dressing may reach 20% of the cost of production of the car body module.

Literature analysis showed that a question of application of methods of correction of plastic deformation during production of gondola car and elimination of a deflection of body elements is studied insufficiently. Therefore it is necessary to consider in more details the application of correction of plastic deformation after welding of a centre girder.

**3. Purpose and research problems**

The aforesaid defined the purpose of work, which includes investigation of application features of methods of plastic deformation dressing during production of centre girders of gondola cars.The work covers rational directions of use of cold and thermal dressing of body elements and classification of methods of residual deformations dressing after welding in car building is suggested.

To achieve the set task, the following problems were solved:

1. The limits of rational application of cold and thermal dressing are revealed.
2. Requirements to the modes and equipment providing the fullest use of potential opportunities of thermal dressing are defined.
3. Classification of methods of dressing of residual deformations after welding for car building is developed.

**Statement of base material**

Mechanical properties of metals are defined by that how they resist external loads, i.e. resist deformations and damages. During their deformation there observed two different types of deformations - elastic and plastic are observed, - which differ both with external processes and internal gears. It is clear that the properties defining an elastic and plastic condition of metals have to be described by different characteristics.

Elastic deformations occur due to the change of interatomic distances, they do not change structure of metal, its property and they are reversible. Reversability means that after removal of loading the body takes the former form and the size, that is residual deformation is absent.

Plastic deformations arise due to formation and movement of dislocations, they change structure and properties of metal. After removal of loading, deformations remain, that is plastic deformations are of irreversible character.

In the basic relation the existing methods and technological processes of regulation and reduction of deformations arising when welding can be reduced to three main groups [1]:

The first group combines a complex of the actions which are carried out at a design stage of a welded construction (constructive forms, thickness and arrangement of welded connections, etc.). Reduction of volume of metal in plastic deformation zone in the course of welding positively influences the sizes of plastic deformations, which arise at a metal heating stage;

The second group is a complex of the actions, which are carried out in the course of welding (welding mode, order of performance of welded passes, additional heating or cooling, power loading, etc.). There created plastic deformation of an opposite sign in three heat-affected zones (HAZ), which were involved in plastic deformation at a heating stage; it can be provided both during welding process, and after its end;

Area of base metal (fig.1), which joins with metal seam and takes heating during welding, is called heat-affected zone (HAZ).

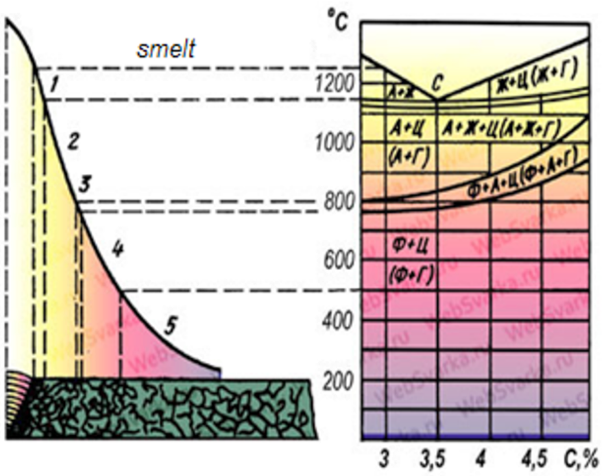



**Figure 1.** Areas of base metal

The third group is connected with weld processing of welded structures for level decrease of residual welding tensions. After welding general and local heat treatment are most widely put into practice for decrease of the level of residual tension, where the principle of compensation of the arisen plastic deformations is used, for example, dressing of residual deformations for creation of plastic deformations in other zones to obtain uniform shrinkage of all element, etc.

Now there are many methods of dressing at the end of production of metalwork: general or local heat treatment, and also corresponding mechanical processing by rolling, impact pneumatic tool, impact ultrasonic treatment, active loading, cold and hot deformation, rolling, etc.

Recovery of geometry of details by method of plastic (residual) deformation is based on the property of metal as a result of processing by pressure to change the form irreversibly. Dressing is applied to recover geometry of details after welding. There are two methods of dressing: cold and thermal. Cold dressing is based on a tension of shortened elements of welded products with design sizes, dressing is fulfilled by means of punches, jacks, rollers or manually by forge tool.

Plastic deformation of cold details requires great external efforts therefore by this method one may restore the details from non-ferrous metals and their alloys, and also steel details with the content of carbon up to 0.3% that weren't undergone heat treatment.

**Deformation methods by external forces**

Cold dressing of the car frame is the easiest and widespread way. However often it does not provide a stable form of the corrected frame details. During operation the eliminated by dressing deformation may arise again. The reason of instability of a form of the corrected detail is the non-uniform residual tension arising on its traverses as a result of uneven deformation of metal. It is necessary to refer high efficiency of dressing within the car for dressing to advantages of cold dressing.

Disadvantages are much greater:

1. Device for cold dressing represent the bulky stationary equipment. These devices cannot be continuously loaded, considerable part of time they stand idle. As a result, floor spaces are used irrationally, and production volume decreases from 1 $m^2$ of useful area.

2. Application of cold dressing is usually limited by constructive and geometrical characteristics of punch (height, width limit of a frame, definite lack of reinforcement ribs and so forth).

3. Properties of base metal after cold plastic deformation worsen: impact strength decreases, the fluidity limit raises.

**Deformation methods by temperature**

Nowadays thermal dressing is one of the most widespread and rational from the point of view of decrease of residual deformations and stabilization of structure. When heating a detail to the temperature equal 0.8-0.9 of temperatures of melting, the effort 12-15 times decreases by plastic deformation without essential changes of physicomechanical properties of metal. Thermal dressing is carried out due to plastic deformations at local high-temperature metal heating by a gas torch. Forms and arrangements of heating areas are in detail described in work [11]. Works [1,11] are devoted to the theories of thermal dressing, both shrinkage distortion and other deformations.

Thermal dressing with local heating. At thermal dressing heating is carried out by gas-oxygen flame or an electric arch. Temperature of heating of the deformed area at thermal dressing fluctuates within

750-850 °C at this temperature the area, which tends to extend, is heated. However cold metal surrounding it limits the possibility of expansion, therefore there are plastic deformations of compression. After cooling the linear sizes of a heated area decrease that leads to reduction or full elimination of deformations.

Method of thermal dressing is thermal impact dressing, which is also called method of warming up of «keys». This method provides warming up of triangles («keys») fig.2 on the Z cross-sections fig.1.

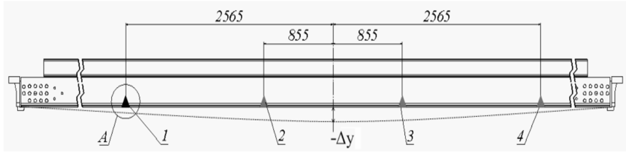



**Figure 2.** Centre girder with places for warming up by "keys" method

On the base of above mentioned review of methods of dressing, classification of methods of dressing of the bearing metalwork of freight cars and their elements, which is schematically shown in figure 3 in the form of the scheme, was suggested.

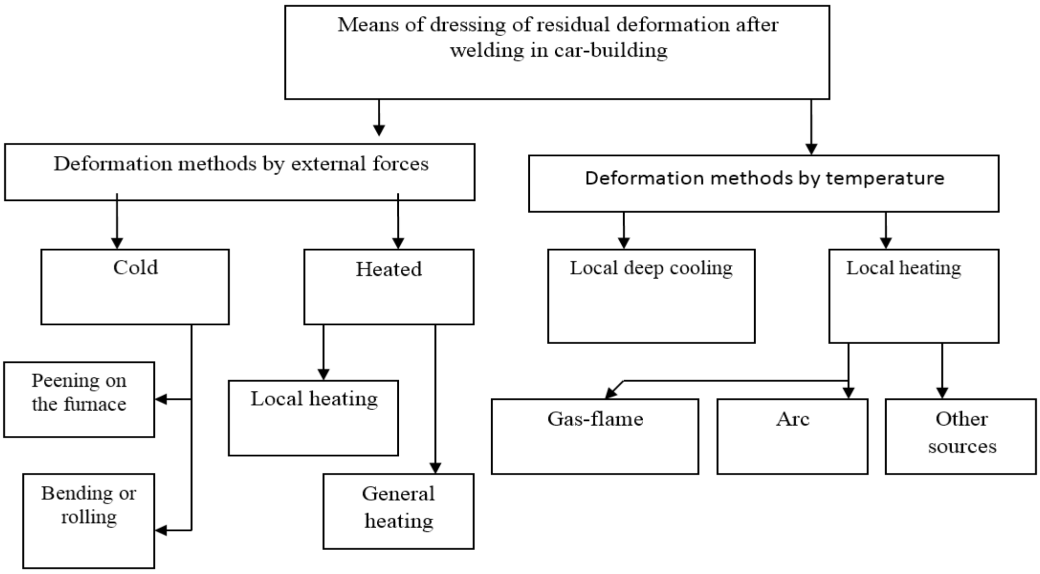



**Figure 3.** Classification of methods of dressing of welded constructions after welding in car building

Due to the types of elements need to be dressed, and character of conditions at car-building plants, which differ in a big variety and considering numerous characteristics according to which, it is necessary to carry out an assessment, which is complicated by finding of a quantitative criterion of an assessment corresponding to all characteristics. It was decided to stop on an expert assessment of each characteristic, which is the graphic ratio of shares of influence according to cold and thermal dressing on this characteristic. For descriptive reasons contrast colors were appropriated to these types of dressing: for the cold one – *black* color, for thermal - *white*. And as the description of the characteristic requires a lot of text material, it was decided to combine tabular creation of material with graphic one that provides easier assimilation of the received dependences.

The purpose of development is the determination of dependences by means of the generalized quantitative values for different characteristics. It was necessary to plan borders of application of two types of dressing, and also to reveal prospects of their further development. All studied characteristics relating to cold and thermal dresing, groups covering design, organizational and operational data respectively are specified in tabl. 1.1 - 1.3. Table 1.4 presents characteristics from the previous three tables by ranging of graphic ratios according to the preferable shares of cold or thermal dressing respectively.

It should be noted that in table 1.4, the obtained dependences are the qualitative assessment of application area of both types of dressing, as the importance of each characteristic which, in principle, could be expressed by change of width of each corresponding this or that characteristic of a strip is not considered, but it would complicate construction and perception of the specified dependences and therefore this option of construction was rejected, but with intention to return to this question later. Analysis of the table 1.4 allows to estimate the prospect of application of thermal dressing, an attempt of the generalized expert assessment of a quantitative ratio of areas of effective application of cold or thermal dressing is made.

**Table 1.1.** Comparison of cold and thermal dressing according to operational parameters

| No | Names of operating parameters | Correlation of efficiency of dressing cold and thermal |
|---|---|---|
| 1 | Presence of equipment only for bending dressing | |
| 2 | Presence of equipment for automates for dressing of bending | |
| 3 | Presence of only automates dressing of bending | |
| 4 | Limits in factory premises | |
| 5 | Shortage of gases | |
| 6 | Shortage of electric power | |
| 7 | Shortage of gases and electricity | |
| 8 | Loading of crane and other transport | |
| 9 | Efficiency of dressing types | |
| 10 | Considering the melted metal properties retention | |

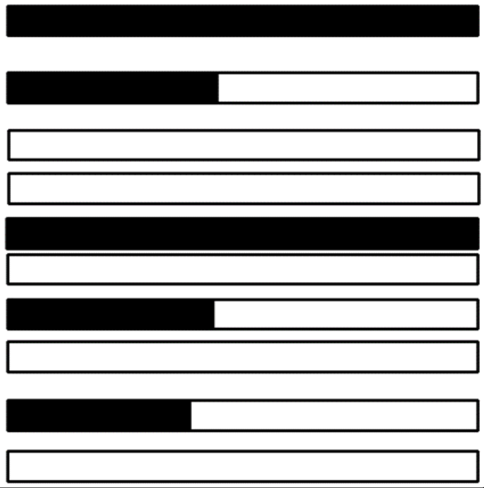


**Table 1.2.** Comparison of cold and thermal dressing according to design parameters

| No | Names of design parameters | Correlation of efficiency of dressing cold and thermal |
|---|---|---|
| | Beams of car bodies of: | |
| 11 | Small length | |
| 12 | Middle length | |
| 13 | Large length | |
| 14 | With welded reinforcements beams | |
| 15 | Box beams or elements | |

**Table 1.3.** Comparison of cold and thermal dressing with organizational parameters

| No | Name of organizational parameters | Correlation of efficiency of dressing cold and thermal |
|---|---|---|
| 16 | Automatic transfer lines | |
| 17 | Aggregate flow-production | |
| 18 | Single production | |
| 19 | Combination of assembling, welding and dressing | |
| 20 | Matching of dressing of shrinkage distortion and bending | |
| | Economical effectiveness | |
| 21 | Prevention of shrinkage distortion | |
| 22 | The use of method of dressing of bending for other | |
| 23 | technological operations (creation of curved beam, dressing of scimitar deformations) | |

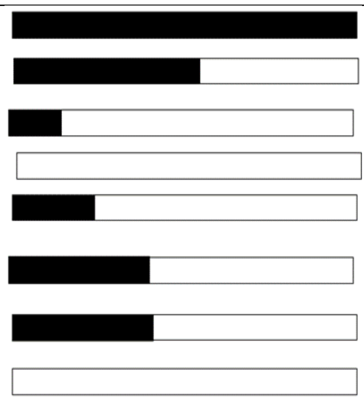
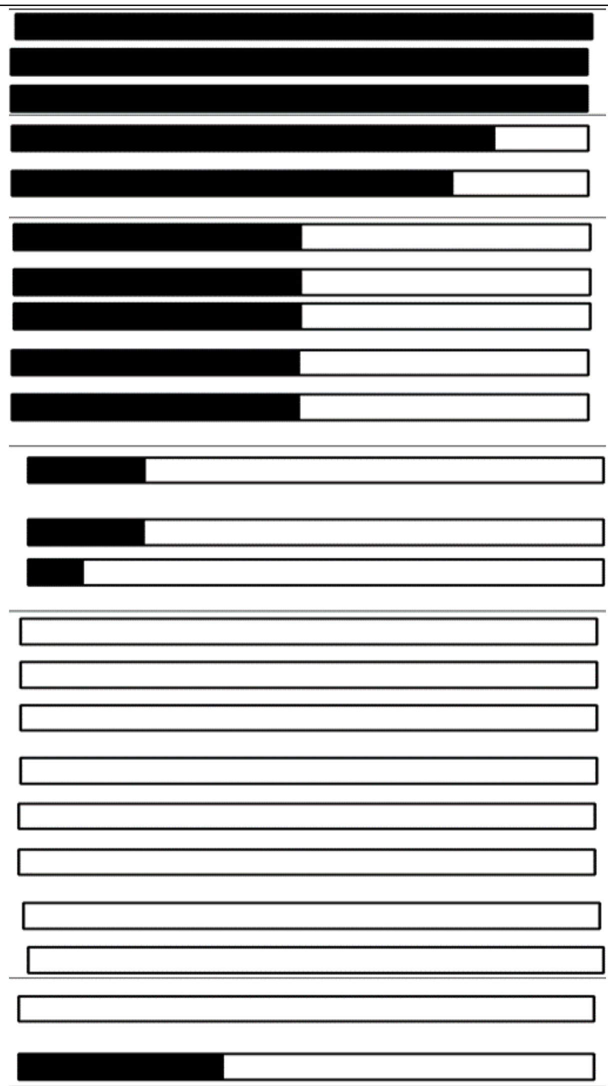


**Table 1.4**. Correlation of rational direction of use of cold and thermal dressing

| Field of application of cold and thermal dressing | Parameter number from the tables 1.1-1.3 | Correlation of efficiency of dressing cold and thermal |
|---|---|---|
| Cold only | 1<br>5<br>19 | |
| Cold preferred | 11<br>9 | |
| Cold and thermal equal | 2<br>7<br>12<br>20<br>24 | |
| Thermal preferred | 23<br>13<br>21 | |
| Thermal only | 3<br>4<br>6<br>8<br>10<br>14<br>17<br>22 | |
| Other areas of application of means of bend dressing | 26<br>25 | |



If one lays off the total amount of dressing of body elements of the considered range in percentage on a horizontal shaft, and on a vertical shaft – the expediency of dressing by cold or thermal mean (percentage), thus horizontally divides total amount into separate groups of elements, than the general picture of comparison of expediency (efficiency) of dressing is presented in the figure 4.

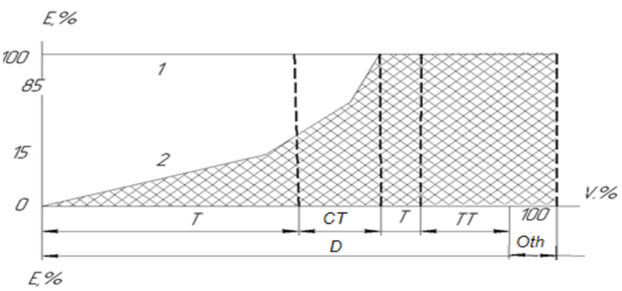



**Figure 4.** Comparison of efficiency of cold and thermal dressing

1,2 - Relative effectiveness for cold and thermal dressing respectively ; D – dressing area;C – the most effective cold dressing; CT –effectiveness of cold and thermal dressing is similar ; T – the most effective thermal dressing
TT – thermal dressing is only possible ; Oth – other areas of use of thermal dressing means

Within the total amount of the corrected elements at car-building plants, it is possible to define four groups:

*the first group* (X) - when dressing is more effectively to fulfill by cold method. It is in case of big series of the same elements. Experience shows that dressing on rollers will be carried out even if the elements need to be carried on rollers from another shop;

*the second group (HT)* is almost identical in the method. This is for cases of small series when preparation processes while dressing by cold mode occupies considerable time (expectation of the crane, transportation on carriages, etc.).

*the third group (T)* - when dressing by thermal mode is certainly effective, these are the cases of manufacturing of single production, manufacturing in the loaded shops when installation of the equipment for cold editing is inexpedient;

*the fourth group (TT)* - when dressing by thermal method is the only possible (figured belts, for example, H-beam ones, when dimensions exceed the possibilities of the equipment for cold dressing, when cold dressing is forbidden, due to the properties of metal, etc.).

If to speak about expediency of thermal dressing, except the specified four groups, in the sum of components of volume of dressing, it is necessary to mention the group of elements, for which the operations similar to thermal dressing are performed: aciniform dressing, creation of curvilinear constructions, etc. This group represents the fifth group, defined in the figure 3.

Dressing rate is defined by the speed of performance of operations of three types (dressings directly, preparatory and final works connected with the equipment for dressing (we will call it auxiliary works of the first type, and the preparatory and final works connected with the transport and crane equipment (we will call it auxiliary works of the second type).

Thermal dressing contains preparatory works of the first type only, and cold dressing - the first and the second types.

The cost of energy consumption can be considered comparable for cold and thermal dressing. Thus, from the point of view of the cost of works, thermal dressing is better. Comparison of application efficiency of cold or thermal dressing is expedient to carry out according to three groups of parameters: I opportunity in specific conditions of plant to correct a concrete element in some manner or other. This opportunity is defined by universality of the available equipment, suitability of the shop, specifications and other specific requirements; dressing process speed.

Thus it is necessary to consider auxiliary operations of the first and second type; cost of works (that is cost of the equipment, energy consumption, shop areas). On the first and third groups of parameters thermal dressing is more advantageous.

Thermal dressing can be fulfilled practically in all range of works concerning correction of vertical deflection of a spine beam and shrinkage distortion, while cold dressing has areas when its implementation is impossible. Besides, thermal dressing can be carried out effectively also for dressing of other types of deformations: sidesway, aciniform elements, etc. Thus, potential opportunities of thermal dressing are higher, than of cold one. However low speed of thermal dressing limits area of wide use. Development of ways of increase of thermal dressing rate is one of the main tasks of further researches.

**Conclusions and recommendations about further use**

In article modern methods and approaches to dressing of plastic deformations after welding of bearing constructions of freight cars and their elements are analysed. Classification of methods of dressing of welded designs after welding in car building is offered. It is established that the most widwspread is the method of *thermal dressing with local heating* as more economically expedient.

On the base of information provided potential opportunities of thermal dressing are higher, than of cold one, however the existing technologies and equipment don't allow to use it effectively during production of various constructional elements of gondola cars therefore development of new technological decisions with justification of borders of rational use of various methods of dressing is required.

Considered material allows to identify the directions of investigations for solution of such important questions:

- Development of ways of increase of thermal dressing rate.
- Development of settlement algorithms for characteristic cases of thermal dressing.
- Investigation of dependence of formation of temperature fields in the welded elements at a variation of such parameters as: sizes and quantities of chocks of heating.

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