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LONG-TERM CONTROL OVER SERVICE LIFE INDICES OF METAL STRUCTURES

1 Methods of early diagnostics of cracks in structures of transfer cranes using magnetic structuroscope.

One of the factors preconditioning the ageing and wear of structures is cyclic exposure, i.e. multiply repeated loads and strains.

For metal structures operating under cyclic loads, local ageing or local wear of material in certain zones called as stress concentrators is characteristic feature. End result of cyclic exposure is occurrence of micro-macro-cracks in a material. Unfortunately, regulations (PB 10-382-00 «Rules on arrangement and safe operation of cargo lifting cranes») and standards do not specify the minimal size of admissible cracks. Probably, cracks detected by traditional flaw detection methods (ultrasonic, magnetic particle testing; visual and measuring control) should be considered as inadmissible.

Revealing of structure sections having exhausted their cyclic strength is one of the tasks of specialists performing on-site inspections of construction. Here, zones, where occurrence of cracks within the period between inspections is most probable, is meant.

Large number of studies are devoted to the problem of operative field search of local worn-out sections defining the service life of construction. During examination of transfer cranes of various design by the OAO «SibPSC» specialists, magnetic characteristic of metal – "coercive force" – is measured in the most loaded points. Magnetic characteristics are determined by means of structuroscope KRM-C-K2M under the methodology RD IKC «KRAN»-007-97/02 (RD IKC «Kran» - 07-97/02 «Magnetic testing of stressed-strained state and remaining service life of lifting structures during performance of their inspection and technical diagnostics (expert examination of industrial safety)» – M.: 2002).

We shall consider the results of investigations, conducted by specialists of OAO "SibPSK" on cranes-loaders of different design.

EXAMPLE 1

The low belts of crane-loader box beams are by company VTA KRAFT (fig. 1, fig. 2).

Fig. 1. General view of loader

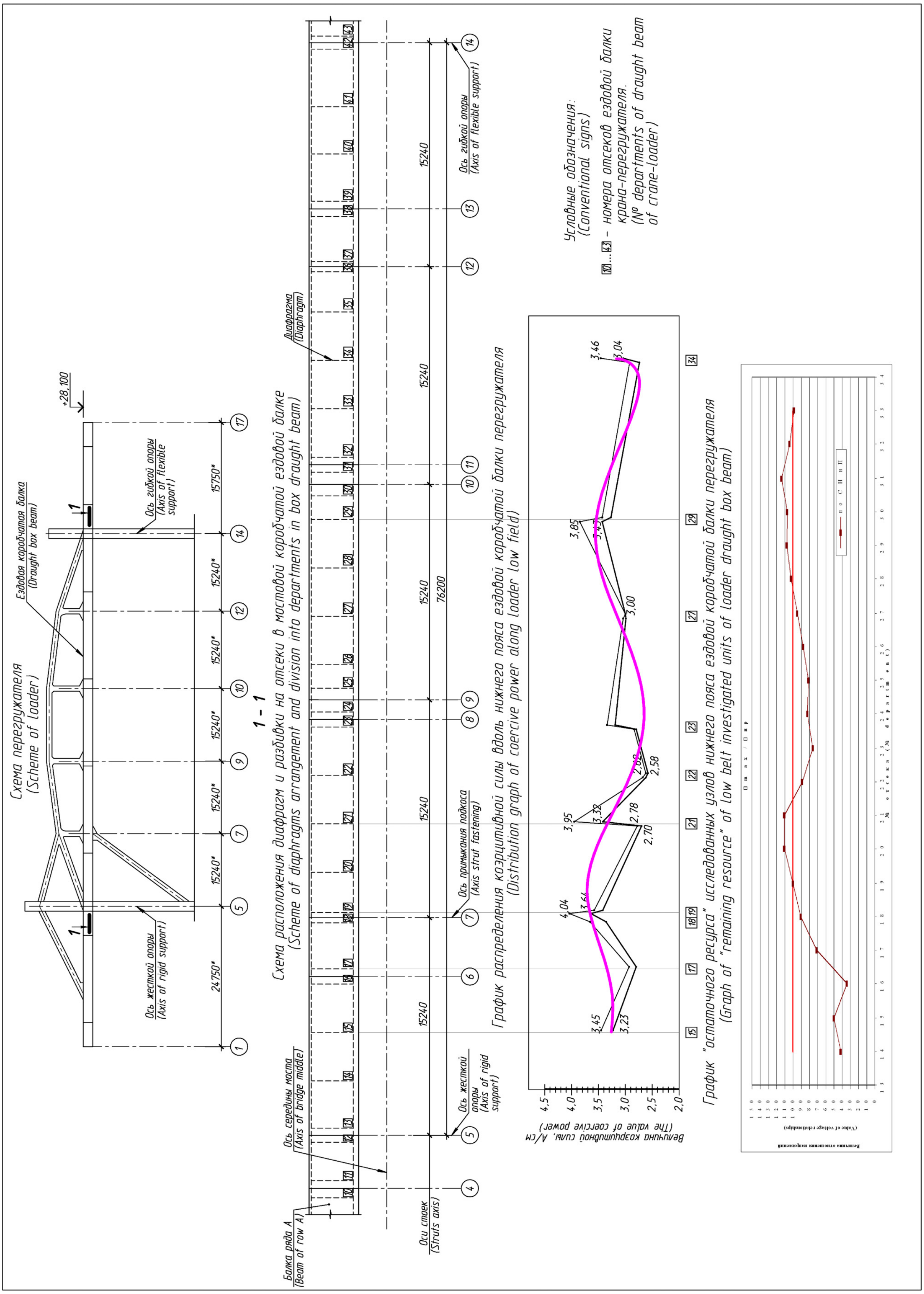

Fig. 2. Scheme of loader

Box-like beams - welded asymmetrical in section. The size is 1950*1950 mm. They are made in Germany in 70-h years. Steel on stress and plastic characteristics is corresponding to the steel by mark 09Г2С-12 on GOST 19281-89, on chemical composition it is corresponding to the steel by marks St3sp5 on GOST 535-88* (fig.1- General view of loader).

The results of calculations

The accounting voltages in low belt are from minus 1365кг/sm2 to plus 1159 kg/sm2, number of cyclic loading is more than 2 million. Since main factor, reducing resource here are the cyclic influences, all rated checking are conducted to adduced cyclic voltages.

On fig.2 there is expressed the graph of the resource production by low belts of crane draught beams. It is the graph of maximum indices relations of adduced cyclic voltages in sections of the crane low belt to the limit admissible index of adduced cyclic voltages Gp/G1. The voltages are calculated on SNIP II-23-81* "Steel designs" during tests. For clarity the graph is expressed under longitude scheme of box-like beam with indication of compartments numbers, in which voltages were calculated.

It is seen that the peak of graph is found in the area of the strut fastening node aside bay.

There are the results of coercive power dimensions on design.

During examination in joining nodes of transverse diaphragms to low belts magnetic characteristic of metal is measured (fig. 2- Scheme of loader). The determination of the magnetic characteristics is executed by means of structural scope KRM-C-K2M on methods RD IKC "KRAN"-007-97/02 (2).

Coercive power, according to studies, conducted in MNPO "Spektor", IKC "Kran" and so on characterizes the production of the cyclic resources by metal. There is installed by abovementioned researchers:

- By increasing the value of coercive power it is possible to speak about decrease cyclic metallic resistance, actually there is the accumulation of the large number of micro defects in metal, which change its magnetic characteristics.

It is necessary to note that other factors exercise the essential influence on the value of this power: rolling quality, type of the metal processing, thickness, chemical composition and others. Designs defects such as voltages strength are badly yield to the registration because of poor combination of the cross-section sizes of voltages strength zones and sizes of the measuring sensor - a sensor is significantly larger. The size is 95 mm.

So received graph has such more chance nature. However, peaks in zones, worked out the resource, are obviously looked over.

There is the fragments research in laboratory.

For restoration of resource characteristics of design there is accepted the decision to change worked out areas of metal on new.

The removed areas are explored in laboratory of nondestructive checking OAO "SibPSK" (fig. 3).

(Fragment 1) (Fragment 2) (Fragment 3) (Fragment 4 with crack)

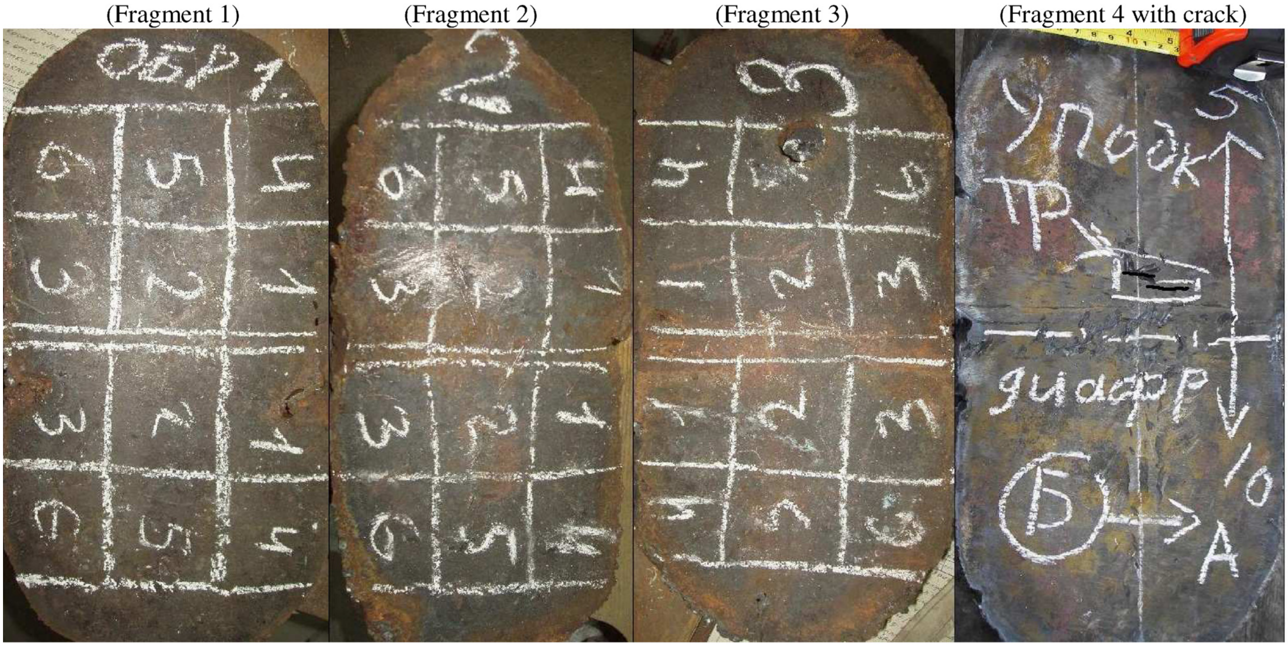

Fig. 3. General view of investigated fragments of low belts of loader draught beam

During thorough examination of fragment 4 (fig. 3- **G**eneral view of investigated fragments of low belts of loader draught beam) face cracks are discovered by length 30 and 26мм, depth before 5мм, not fixed in field condition. This fragment is subject to detailed analysis:

- By method of magnetic memory with the help of instrument "Measure of the voltages concentration magnetic metric IKNM-2 FP";
- By method of coercive power measuring.

The first method (the magnetic memory) is turned out to be labor-intensive.

All available fragments were researched by method of coercive power measuring.

The Fragments are divided of the same type areas, on which were conducted measuring.

There is established that all measured values of coercive power are turned out to be much smaller limiting value then installed value for like steel 9 A/sm2.

However, on graph of average and maximum values of coercive power it is seen that the destruction is more probably in fragment 4 (fig. 4).

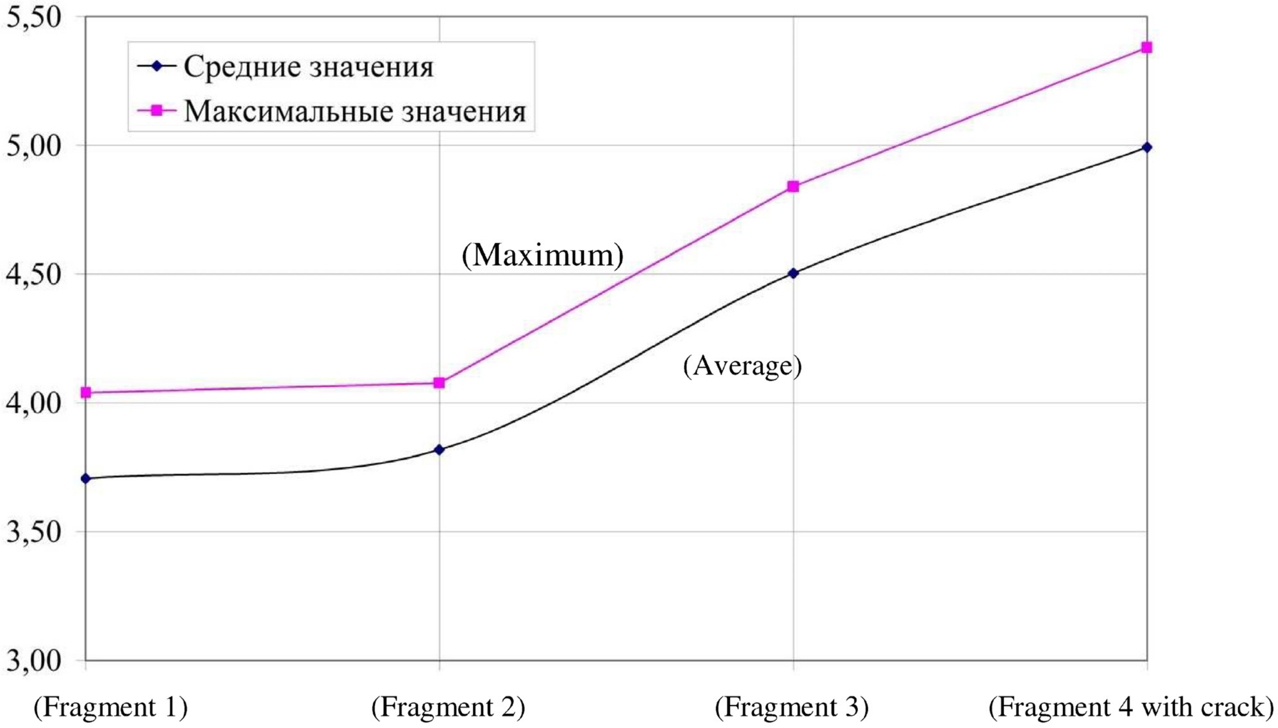

Fig. 4. Values of coercive power, measured on fragments

As shown earlier, the destruction not revealed under visual checking on design exactly exists in fragment 4.

EXAMPLE 2

Tubular crane-loader is made in PO "Sibtyazhmash" see fig. 5, fig. 6.

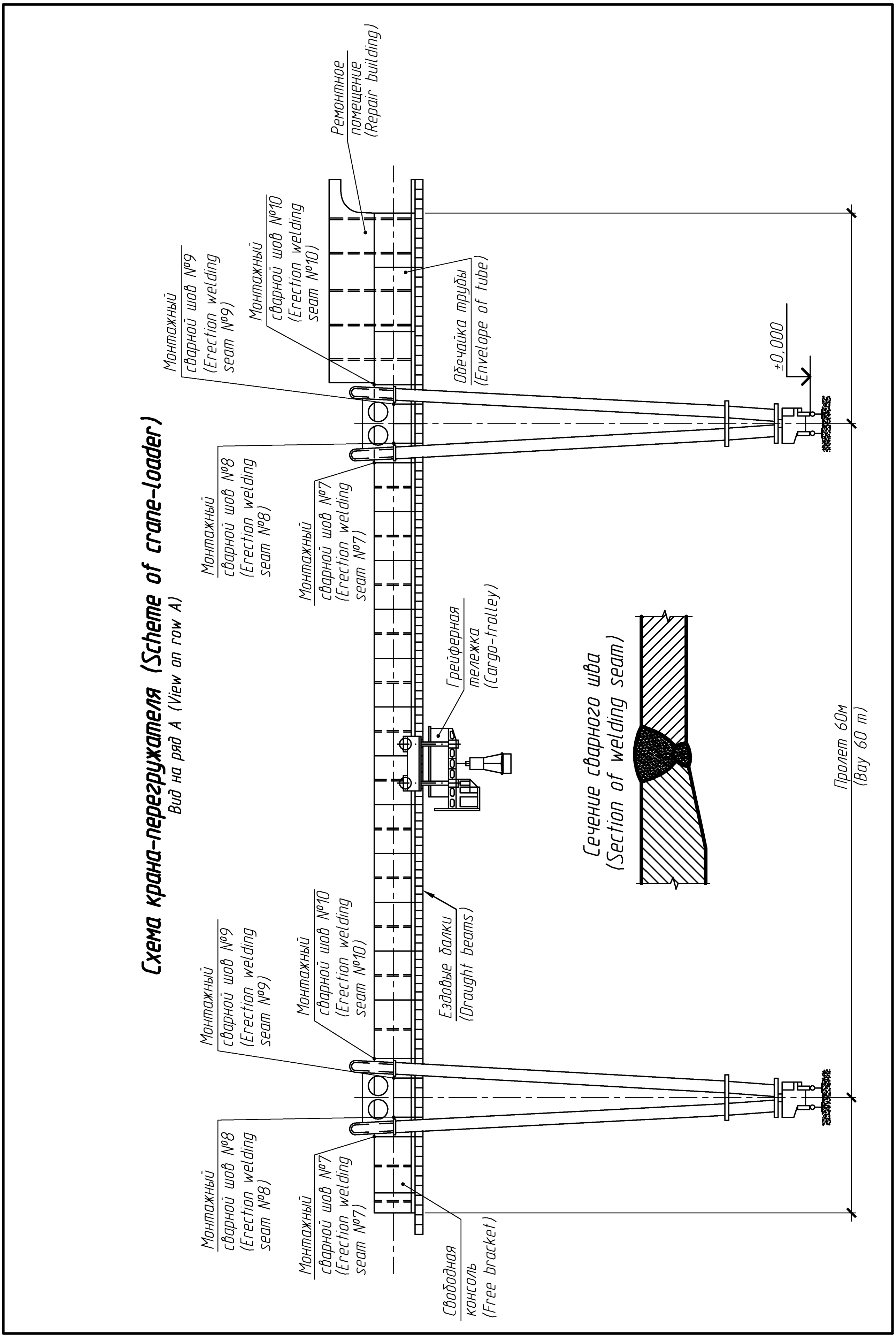

Fig. 5. Scheme of crane-loader

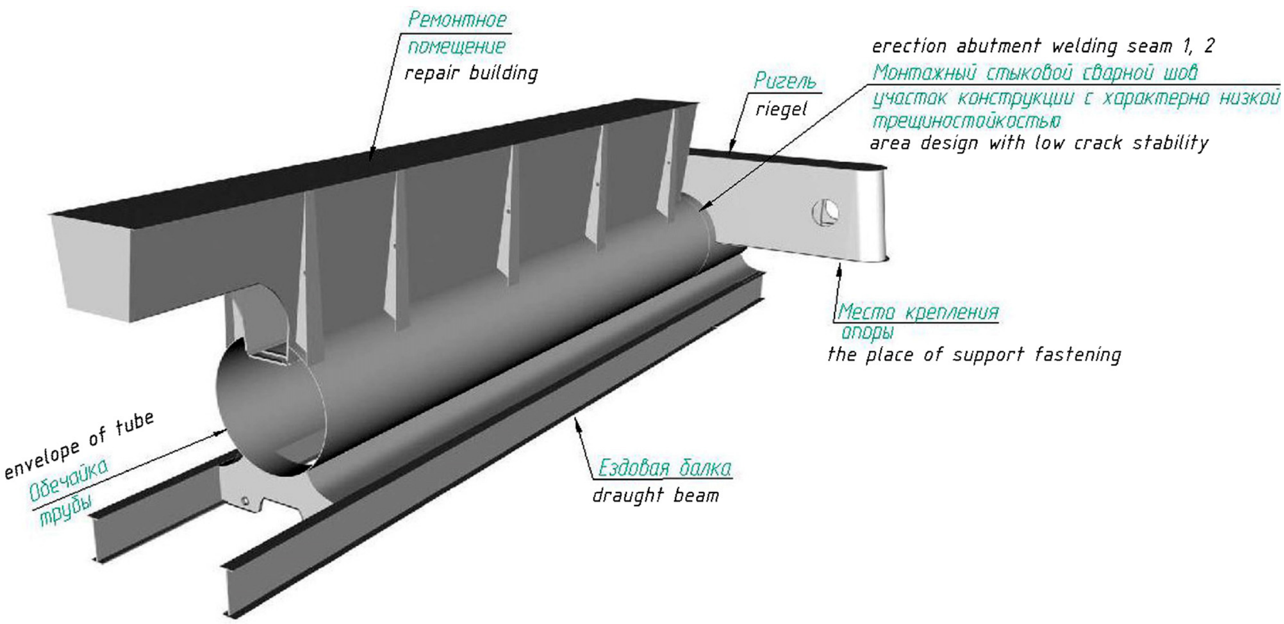

Fig. 6. Repair bracket of crane, perspective geometry

Upper zones of abutment erection, weld seams of gap building envelope near bearers are the most responsible here, see fig. 2.2.

Surface cracks, depth up to 4-h mm, in welding seams 4, 7, 10 were discovered during investigation in 2000. For ensuring winter operation it is solved to choose and weld cracks on one hand on specially worked welding technology.

The observation was installed for crane (once half a year).

In addition two times magnetic characteristics were measured on perimeter of welding seams; averaged data are given on fig. 7. From drawing it is seen that average value of the magnetic characteristic is constantly increased. Peak value and maximum increase are corresponding to the welding seam № 7.

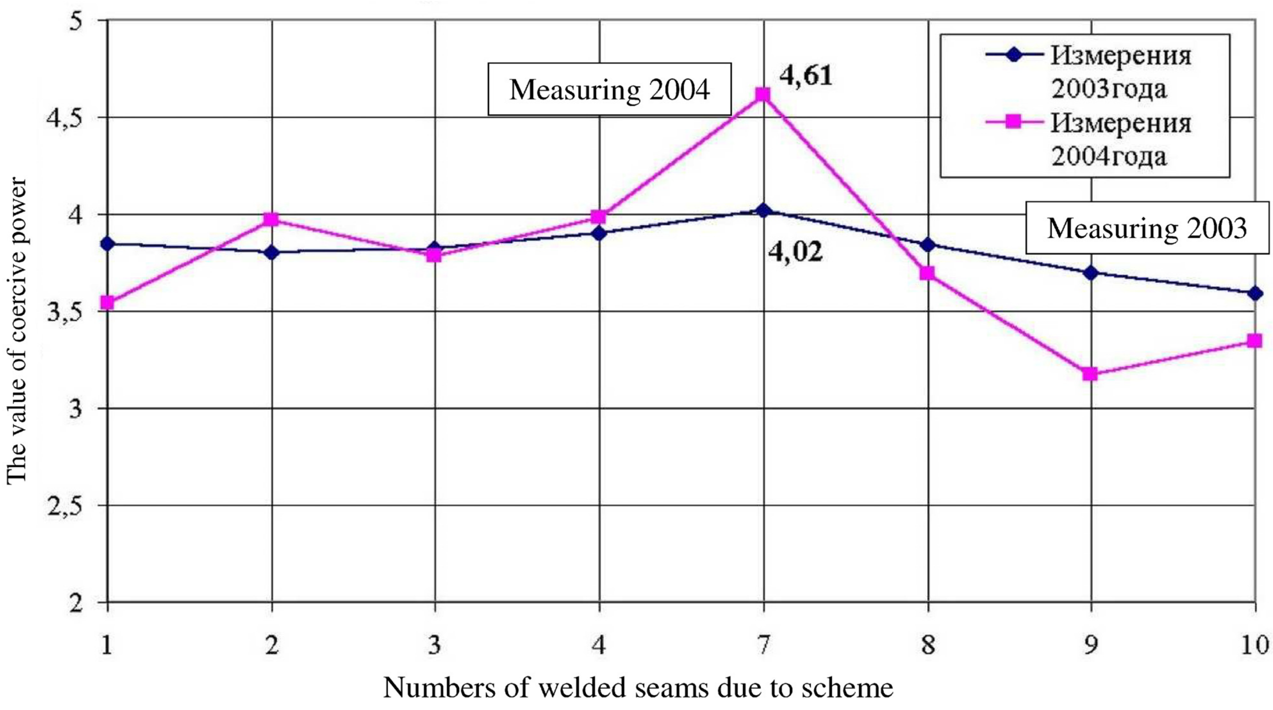

Fig. 7. Average value of coercive power in zenith welding abutment seams

In 2005 upper zones of welding seams are cut out and replaced on new metal.

For additional tests samples from welding seam № 1 and seam № 7 were taken see fig. 8.

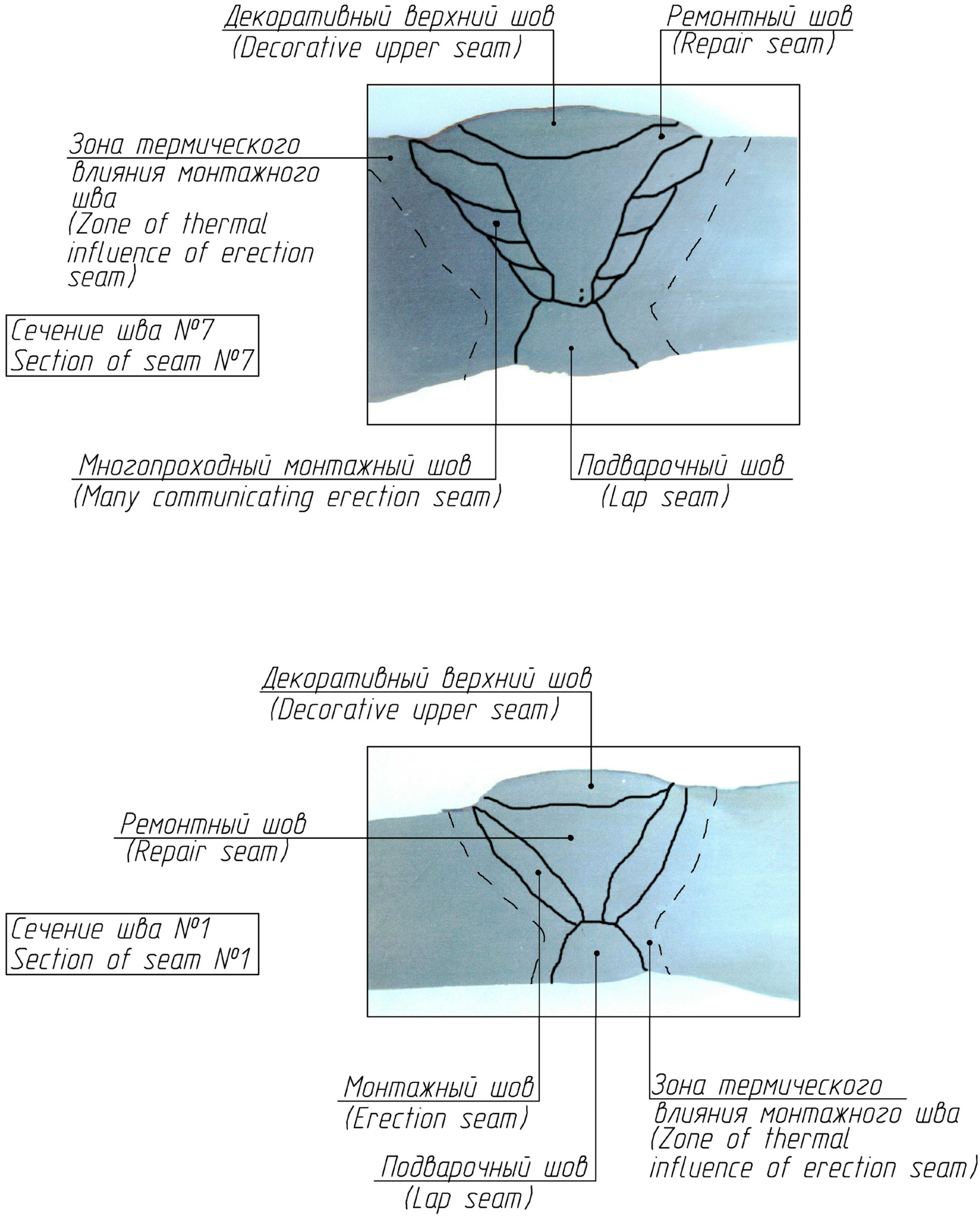

Fig. 8. Transverse polishers of welding seams № 7 and № 1 crane-loader

In the root of seam № 7 repair welding there was discovered through clearance and crack by length 1.5 mm (in section), not fixed at UZD. Probably, described crack is registered by the magnetic structural scope in the manner of raised value of characteristic and maximum increase of the magnetic characteristic value. It again proves efficiency of the considered method.

Conclusion:

Coercive force is an integral characteristic of material responding to all variations in the structure of steel.

As nondestructive testing of any other types, method can serve as one of criteria during adoption of one or another engineering decision on operational conditions of diagnosticated equipment in the intervals between examinations.

With all its drawbacks related mainly with insufficient methodological elaboration, this method can be used for operative, on-site testing of the metal structures state.

2 Long-term control over service life indices of metal structures (specimens-witnesses of remaining service life).

In essence, above presented examples are the cases of early detection of the working-out of remaining operation time by individual zones of metal structures. Naturally, any measurement methods possesses with certain accuracy, trustworthiness, etc.

The most correct method for determination of remaining service life of operated structures is to take and study comprehensively samples of metal from bearing structures. By the state of metal, it is possible to speak with certain degree of probability about the material degradation extent and, hence, working-out of the remaining operation time of structure. Results of an analysis of material taken from the main bearing structure of crane can be called as results of monitoring of the construction state.

In fact, piece of metal was within the composition of crane structure from the moment of its manufacturing and was taking up all loads and exposures. Unfortunately, such method of determination of the remaining service life has no prospects due to the fact that sampling by itself varies significantly the shape of structure and, hence, reduces considerable the service life of remaining structure.

For the long-term control, it is proposed to attach to structures specimens possessing with known and given in advance characteristics. Specimens are installed on structures in cartridges. Every specimen within a cartridge possesses with cyclic strength characteristics corresponding with different terms of working-out of the predicted remaining service life - 10, 50, 80, 90%, for example (fig. 9). By the destruction of first specimens, it is possible to adjust indices of subsequent ones. Finally, accuracy of service life determination by the results of detection of destructions in first three specimens must be high enough (due to availability of statistical data). Process of observation over specimens does not present any complexity: it is necessary only to inspect periodically cartridges with record of appeared specimen destructions in log. By the set of destruction data, engineer in charge for the crane safe operation can estimate the remaining service life of crane.

Proposal fits well into the solution of problem of endurance tests of experimental models of large-size cranes, which, in my opinion, are performed rarely under RD (ruling documents) requirements… Through application of specimens, manufacturing plant can observe its cranes operated within functioning production facilities and obtain even through a quite short period of time data on service life of assemblies and elements. To that end, to set other characteristics of specimens within a cartridge - 1%, 3%, 5%, 10% of service life, for example (fig.9). We have succeeded to achieve installation of specimens-witnesses of remaining service life on a metal structure of casting crane within one of the metallurgical enterprises.

In the process of installation, the following methods were debugged:

- setting of endurance characteristics of specimens;
- installation of specimens and control over their state;
- methods of determination of service life of crane metal structures by indices of specimens.

Samples range - witnesses of the crane remaining resource (servise life)

10% от P (of remaining servise life)
50% от P (of remaining servise life)
80% от P (of remaining servise life)
90% от P (of remaining servise life)

Samples range – witnesses of crane designs condition for resource tests of experimental pattern-crane in active industry

1% от P
3% от P
5% от P
10% от P

Fig. 9