Determination of restored units spectrum of equipment and development of the assembly unit repair method at industrial enterprises

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Abstract. The article describes the procedure for determining the spectrum of repairable units of equipment, economically feasible to restore by the assembly unit repair method. It gives an example of the development of this method of repair impact in practice under the conditions of the existing mining and metallurgical production. The authors consider the achieved effect from the unit repair aimed at the stable operation of the equipment of industrial enterprises.

1. Introduction

In practice, the list of equipment, the adjustment of which can be organized only on the principles and strategies of regulated repair, is extremely narrow. In fact, the repair of most of the equipment is inevitably based on a combination (in various proportions) of regulated repair and repair based on the technical condition [1-6]. In this case, the “framework” of the structure of the repair cycle is determined by a set of equipment items, the repair of which is based on strategies of regulated repair or age repair. The obtained “rigid” basis of the framework of the equipment repair cycle is superimposed (in its "non-rigid" version) by the timing of the repair of individual elements serviced according to their technical condition [1, 7-10].

One of the most promising methods of repairing equipment for enterprises of any form of ownership is the assembly unit method, in which defective replacement elements (assemblies, units and parts) are replaced with new or repaired ones taken from the working capital. In a number of foreign countries, the replacement of faulty assemblies and units is timed to the scheduled dates of maintenance, and the repair itself is called “planned preventive maintenance” [10-14].

The spectrum of equipment repair by an assembly unit method for each customer enterprise depends on its financial capabilities, the creation of a working stock of spare parts and assemblies, production conditions, the development of its own repair base, its equipment, remote location and many other factors. It is very important to emphasize that the development of the assembly unit repair method is impossible in the first place without the interest of the operational engineering service of the customer company itself [15-22].

As a part of the development of the assembly unit repair method, various directions were worked out to expand the range of repairs based on the repair group units (Figure 1-2). As a result, the following conclusions were drawn:

1. Rejected proposals with a negative result in the end:
• Repair of processing equipment gearboxes. The analysis of the repairs carried out on the gearboxes of the processing equipment of the enterprises of a mining and metallurgical company showed that the total number of repaired equipment is more than 13,200 items, while only 1900 of them are repaired in workshops, the rest are restored either without dismantling from the main unit, or at the work site. Gearboxes in their essence are optional equipment and are attached to the specific type of processing equipment; therefore, as an example for fulfilling the economic calculation, a separate object was selected – an enriching production area. The number of repaired gearboxes at the processing plant is 136 items per year. The calculations of the economic effect show that, taking into account transportation costs, the expected final result is negative (−100 thousand rubles), and the additional capital costs associated with equipping the repair zone with specialized equipment are not taken into account.

• Repair of local ventilation fans (LVF) at enterprises of the mineral resource complex. The calculation was made on the basis of the total number of LVF of mining enterprises - 357 items. The expected economic effect is 2941 thousand rubles. It is achieved due to an expected increase in the life of the LVF from 24 to 36 months. This reduces the purchase of new LVFs. However, the implementation of this proposal will require additional investment costs associated with the acquisition of specialized equipment and attachments, which will adversely affect the final financial result in the first years of the proposal implementation.

2. The following areas were identified as the most promising assembly unit repair methods:
• Restoration of processing gate valves and globe valves on the basis of a specialized area of the repair company. Annual production program of the isolation valve repair section is 1664 items of various unit sizes to the amount of more than 13 200 thousand rubles. Specialized attachments and machinery park on the production area of the site is available. The expected economic effect is 3129 thousand rubles. It is achieved by reducing the estimated cost of repairs.
• Restoration of wheel pairs of underground mine transport (UMT) on the basis of a specialized surface area of a repair company. The annual repair volume of the wheel pairs of the UMT is up to 7106 pcs. The expected economic effect after the implementation of the event is 5500 thousand rubles. It is achieved due to the difference in the ratio of wages between those working in underground and surface labor conditions. In order to implement this measure, it is necessary to additionally develop the production areas from the existing fleet of surfacing units, machine-tool fleet, washing and pressing equipment.
• Repair of industrial pumps of various unit sizes on the basis of a specialized site of a repair company. The analysis of pump repairs carried out at the facilities of the mining and metallurgical company showed that at the present time, the site is overhauling 124 pumps per year. The expected economic effect is insignificant and amounted to 716 thousand rubles per year in the calculations. Customer companies have worked out the issue of increasing pump overhauls on the basis of this site to 257 units per year. However, this proposal does not require additional capital investments (repair equipment available) and will improve the quality of pump repairs carried out.

After coordinating all organizational and technical measures with the customer service, a series of preparatory operations were carried out in the production areas of the repair group enterprises during the year. As a result of joint work with the engineering and operational services of customers, the following production results have been achieved.

2. Repair and restoration of isolation valves
The work at the site is organized in two shifts in order to timely implement the repair of the increased number of valves and due to the increasing complexity of the organization of production. In accordance with the need of the customer enterprises, the site field branches are equipped with portable equipment to carry out repairs to the isolation valves at the installation site.
The fulfillment of the production order for the unit repair of valves of various unit sizes is presented in Table 1.

For 2014 the expected amount is 3520 items of isolation valves, or 105% of the planned amount (Table 2).

The achieved result is the proper quality of repair by the example of restoration of the gate valve DN 250 mm (Figure 3).

**Table 1.** Repair of isolation valves of various unit sizes in 2012 and 2013.

| Customer                  | DN up to 100 mm | DN up to 300 mm | DN> 400 mm | Total pieces |
|---------------------------|-----------------|-----------------|-------------|--------------|
|                           | 2012  | 2013  | 2012  | 2013  | 2012  | 2013  | 2012  | 2013  |
| Mining and metallurgical enterprises | 651   | 1013  | 104   | 174   | 10    | 14    | 765   | 1201  |
| Enterprises of fuel and energy system | –     | 349   | 198   | 153   | 66    | 77    | 41    | 579   |
| Total                     | 1128  | 362   | 302   | 327   | 76    | 91    | 1506  | 1780  |

**Table 2.** Performed amount of repair of isolation equipment in 2014.

| Customer                      | Planned data of 2014, pcs., items | The expected implementation of the plan in 2014, items | Deviation, % |
|-------------------------------|----------------------------------|-------------------------------------------------------|--------------|
| Service of the chief power engineer of the mining and metallurgical enterprises | 1970                            | 2039                                                  | 104          |
| Service of the chief mechanical engineer of the mining and metallurgical enterprises | 154                             | 260                                                   | 169          |
| Customer enterprises of the fuel and energy system | 1042                            | 1042                                                  | 100          |
| Capital resources            | 179                             | 179                                                   | 100          |
| Total                        | 3345                            | 3520                                                  | 105          |

A comparative technical and economic analysis of the restoration of isolation valves by the example of one of the steel plants is presented in Table 3.

The development of the assembly unit method of repair of isolation valves allowed:

- reducing the downtime of the customer’s equipment (for the period of repair) by creating a working capital;
- increasing the period between repairs;
- observing the unit recovery technology;
- improving the production culture of maintenance personnel;
- making additional purchases of new isolation valves due to the achieved economic effect.
Figure 1. Section for unit repair of isolation valves (right view).

Figure 2. Section for unit repair of isolation valves (general view). The floor area is 1617 m². The site is equipped with four overhead cranes, with a lifting capacity of 5 tons, and two air compressors.

Figure 3. Valve: (a) before repair; (b) after repair.

3. Repair of industrial pumps of various unit sizes

In order to develop a specialized site for the repair of centrifugal pumps, as well as to improve the quality of repairs and production culture, a number of technical arrangements were performed:

- a stationary washing installation was made and commissioned;
- a stand for disassembly and assembly of centrifugal sectional pumps;
- a stand for testing of pumping units after recovery has been developed;
- The machine-tool fleet of the site has been re-equipped (turning lathes, milling machines, guillotine shears).

The cost diagram of the overhaul in 2013 by the example of the chemical pump 7 KTS-9 is shown in Figure 4.

Comparative costs for the restoration of chemical pump of type 7 KTS-9 in 2013 are given in Table 4.

For 2014, the expected volume of repair is in the amount of 620 items of industrial pumps or 106% from the projected performances (table 5).
Table 3. Comparative technical and economic analysis of isolation valve repair.

| Standard unit size of isolation valves | Volume, pieces | Cost of repair “in hot work shops”, thousand rubles. | Cost of unit repair, thousand rubles | Savings, thousand rubles | Average cost of new valves (steel), rub. | The quantity of valves purchased due to savings, pieces |
|---------------------------------------|----------------|-----------------------------------------------------|-------------------------------------|--------------------------|----------------------------------------|-----------------------------------------------------|
| Gate valve DN-80                      | 19             | 234.8                                               | 137.0                               | 97.8                     | 4.423                                  | 18                                                  |
| Gate valve DN-100                     | 32             | 408.3                                               | 240.3                               | 168.0                    | 6.994                                  | 18                                                  |
| Gate valve DN-150                     | 29             | 554.1                                               | 334.6                               | 219.5                    | 17.691                                 | 10                                                  |
| Gate valve DN-200                     | 59             | 1592.6                                              | 943.1                               | 649.5                    | 27.778                                 | 18                                                  |
| Gate valve DN-250                     | 2              | 68.4                                                | 40.1                                | 28.3                     | 35.293                                 | 1                                                   |
| Gate valve DN-300                     | 10             | 390.1                                               | 223.1                               | 167.0                    | 58.968                                 | 2                                                   |
| Gate valve DN-500                     | 10             | 589.3                                               | 325.7                               | 263.6                    | 116 376                                | 2                                                   |
| Total                                 | 161            | 3837.7                                              | 2233.8                              | 1593.9                   | 267 523                                | 69                                                  |

Figure 4. Cost diagram of the overhaul in 2013 by the example of the chemical pump 7 KTS-9.

Thus, the development of the method of the assembly unit repair of chemical pumps under the stationary conditions made it possible on 30% to increase time between overhauls, as the quality of repair actions improved. During the repair, such operations as balancing impellers, restoration of pump casings, protective bushings, the trimming of mating parts with the application of machine-tool equipment, hydraulic tests at the end of the assembling, which could not be accomplished under the conditions of the functioning shops of production subdivisions, produced the following results (Figure 5).
Table 4. Comparative costs for the restoration of the chemical pump of type 7 KTS-9.

| Method of repair | Type of repair | Number of repairs per year, items | Repair cost without materials, thousand rubles | Repair cost with materials, thousand rubles | Repair costs, mln rub. | Total expenses, mln. rub. |
|------------------|----------------|----------------------------------|-----------------------------------------------|---------------------------------------------|-----------------------|---------------------------|
| Default          | κ              | 68                               | 95.1                                          | 107.4                                       | 7.3                   | 17.2                      |
|                  | τ              | 136                              | 38.1                                          | 72.8                                        | 9.9                   |                           |
| Assembly unit    | κ              | 52                               | 42.3                                          | 138.2                                       | 7.2                   |                           |
|                  | τ              | 68                               | 38.1                                          | 72.8                                        | 4.95                  | 12.15                     |

Table 5. Performed amount of repair of industrial pumps.

| Customer       | Planned data for 2013, items | Actual data for 2013, items | Deviation, % | Planned data for 2014, items | Deviation of the planned data of 2013 from the planned data of 2014, % |
|----------------|-------------------------------|-------------------------------|--------------|-------------------------------|--------------------------------------------------------------------------|
| Factory 1      | 491                           | 491                           | 100          | 529                           | 108                                                                      |
| Factory 2      | 50                            | 50                            | 100          | 50                            | 100                                                                      |
| Plant          | 16                            | 16                            | 100          | 16                            | 100                                                                      |
| Mines          | 28                            | 28                            | 100          | 30                            | 101                                                                      |
| Total          | 585                           | 585                           | 100          | 620                           | 106                                                                      |

Figure 5. Results of the method of assembly unit repair of chemical pumps implemented in stationary conditions.

4. Repair and restoration of wheelsets of underground mine transport

During 2011, the specialists of the repair service designed the production process of restoring wheel sets of underground mine vehicles and in the subsequent period, equipment, devices and attachments are installed at the territory of the surface site.

The process of creating the surface area of the repair of the wheel pairs of the UST was carried out strictly according to the technology.

Currently, there is a significant need to repair wheel sets of mining enterprises, but, since it is impossible to transfer (lift on the surface) UST assemblies due to time constraints associated with lifting run of coal, there might be a further increase in the volume of repairs. The progress of assembly unit repair of wheel sets for the last period of time is presented in Table 6.

Considering the results described above, achieved by repairmen in recent years, it is necessary to continue to increase the production capacity utilization of specialized sections of repair group enterprises for subsequent medium-term periods, the basic strategy of which is shown in Table 7.
Table 6. Assembly unit repair of wheelsets of underground mine transport.

| Customer    | Planned data for 2013, items | Actual data for 2013, items | Deviation, items | Planned data for 2014, items | Deviation of the planned data for 2014 from the planned data for 2013, items |
|-------------|-------------------------------|-----------------------------|-----------------|-------------------------------|--------------------------------------------------------------------------------|
| Mine No. 1  | 300                           | 554                         | 254             | 1440                          | 1140                                                                            |
| Mine No. 2  | 330                           | 277                         | −53             | 1460                          | 1130                                                                            |
| Mine No. 3  | 936                           | 572                         | −364            | 980                           | 44                                                                             |
| Mine No. 4  | 0                             | 73                          | 73              | 220                           | 220                                                                             |
| Total       | 1566                          | 1476                        | −90             | 4100                          | 2534                                                                            |

Table 7. Strategy of increasing the production capacity utilization of enterprises of the repair group.

| Type of assembly unit repair                                         | The scope of work planned to be carried out by the assembly unit method of repairs, items |
|---------------------------------------------------------------------|----------------------------------------------------------------------------------------|
| Repair and restoration of isolation valves                          | year 2015 year 2016 year 2017 year 2018                                                |
| Basic repair of industrial pumps                                    | 3600 4000 4500 5000                                                                    |
| Repair and restoration of units of underground mine transport       | 620 650 670 700                                                                         |

5. Conclusion

It is necessary to note that the main reason for forming an order for repair group enterprises in certain areas without increasing the scope of work is the inability to increase the repair stock of customer departments, as well as the necessary exchange pool of components and assemblies. Therefore, to achieve a single positive result for the production of finished products, a customer and a contractor should solve production problems together.

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