REPAIR EXPLOSION CLADDING OF THREADED CHANNEL OF CAR AXLES

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The most common defect of axles of wheelsets of RU1-Sh type railway cars is damage or wear of threaded openings M20 for bolts that fix retainer plates of roller bearings. It is suggested that such threaded openings should be repaired by explosion cladding with a repair sleeve and subsequent cutting a new thread in it. Fatigue tests of the repaired openings showed that their life time is almost identical to that of the new axles.

Keywords: *explosion welding, explosion cladding, car axle, threaded channels, repair, fatigue test*

Increase of service life of rolling stock due to recover of working capacity of the worn parts for railway cars gains significant attention at modern stage of development of railway transport in Ukraine. Advanced technological processes characterized by high reliability with minimum prime cost and sufficiently easy realization under conditions of the car-repair enterprises of «Ukrzaliznytsya» are developed in particular.

The possibility of repair of the axles of wheelsets of RU1-Sh cars (ISO 1005-9–86 standard) has the large importance due to their high cost and significant metal intensity. This is in particular relevant since the car-repair enterprises of «Ukrzaliznytsya» have stored a significant amount of the damaged axles.

A damage or wear of threaded openings M20 for bolts that fix retainer plates of roller bearings is one of the most often and difficult to remove defects of the axles. The problem is that an insignificant mechanical damage of an element of the thread stops running of a bulky structure of critical application standard life time of which makes 8–15 years. A threaded opening has the high requirements on static strength, fatigue strength and accuracy of geometry.

Sealing using CO_2 welding or coated-electrode welding with subsequent drilling of an opening and cutting of a new thread is the most widespread method of repair of the threaded openings. However, given methods of repair have the disadvantages lying in high expenses on purchasing of new specialized welding equipment and consumables. It should be noted that A1, A2, A3 and A4 steel grades, from which the car axles are manufactured, refer to a class of limited weldability (GOST 1380–71), i.e. tend to crack formation in welding under standard conditions. This promotes a necessity in development of the special technological measures providing required quality of deposited metal. At that the geometry of plug type welded joint results in complicated weld shrinkage that is an additional factor promoting crack formation in metal of an axle journal. The residual shrinkage shortenings promote deformation of geometry characteristics of the part and as a result inadmissible reduction of diameter of an axle location for roller bearing appears.

Alternative and simpler method is developed for car-repair enterprises of the Russian Federation. It is based on drilling out of the damaged opening, cutting of lager diameter thread in it with subsequent screwing of a cylinder sleeve with internal threaded opening M20. However, the specified method is characterized by low reliability since unscrew of the sleeve can take place under the effect of vibration loadings specific for operation of the axle of railway car during running.

The aim of the present work is a development of virtually new method for repair of the threaded openings M20 without disadvantages specific for methods mentioned above. The proposed method is based on application of the principles and procedure of explosion welding and has the following advantages:

- low cost of assembly equipment and consumables;
- strength of welded joint corresponding to specified mechanical characteristics;
- absence of heat effect typical for fusion welding and crack formation, respectively;
- elimination of formation and structural defects specific for fusion welding (pores, lacks of fusions, undercuts and slag inclusions);
- prevention of shrinkage shortenings and reduction of diameter of the axle journal location for roller bearing.

Materials and methods of investigation. An object for investigation was the damaged threaded channels M20-6N of axle journals RU1-Sh of 180 mm length (Figure 1). The axles with one damaged threaded opening per each end surface were used for adjustment of the repair technology to full-scale axles.

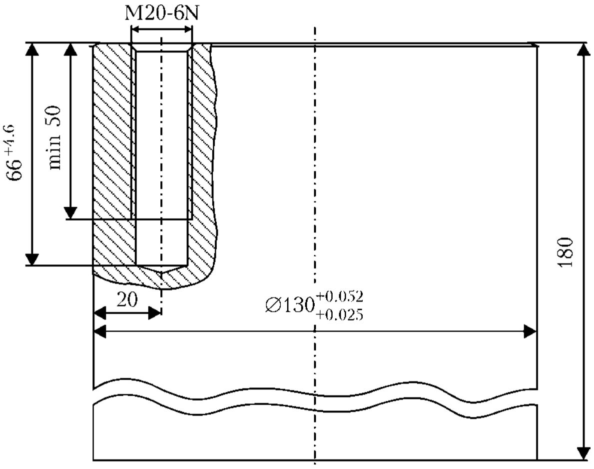

Figure 1. Scheme of axle journal

It is impossible to deposit a repair coating directly over the rests of damaged thread using explosion welding method, therefore, the threaded opening was calculated to a diameter somewhat larger than 20 mm and then polished. The quality polishing was a necessary condition since explosion welding was carried out near a low border of area of welding (the minimum energy was applied for providing safety joint) due to impossibility of positioning of significant amount of explosive in the cladding sleeve and providing of a larger gap. A scheme of internal cladding using core charge (Figure 2), which is the most simple on technology of performance and easy for calculation of a mode of explosion welding, was used for explosion cladding of channels of 10–25 mm in diameter. A mixture of trotyl and ammonium nitrate was an explosive providing 2–3 km/s detonation rate and rate of contact point, respectively.

Steel 20 was selected as a material for cladding sleeve. This is conditioned by the fact that the cladding element is exposed to significant high-speed deformation in explosion welding, therefore, it should be sufficiently ductile and susceptible to cracking. The material with $\delta \geq 25$ % is the optimum for explosion welding if relative elongation in tension δ is used as an index of ductility. The charge with diameter close to critical was used in our case (if diameter of the charge is lower than critical, then a process of propagation of detonation wave does not take place). Therefore, a level of energy spent for plastic deformation of joining zone is to be minimized by means of selection of sleeve material with high ductility characteristics. Besides, the chemical compositions of sleeve and steel of axle should not have significant difference for preventing appearance of galvanic couple which can result in intensification of corrosion processes.

The materials of cladding sleeve and axle according to data of the quality certificate have the following mechanical characteristics: σ_t = 420–425 MPa, σ_y = = 274–286 MPa, δ = 42–43 %; and σ_t = 520–560 MPa, σ_y = 300 MPa, δ = 22 %. Further investigations showed that small static strength of the sleeve in comparison

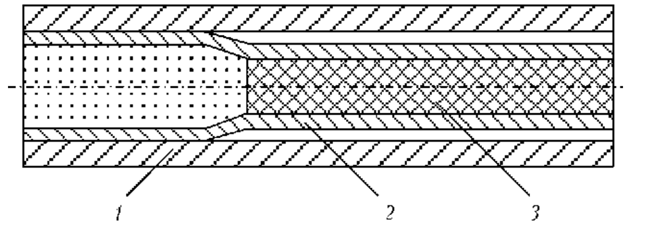

Figure 2. Scheme of internal explosion cladding using core charge: *1* — pipe being clad; *2* — cladding pipe; *3* — charge of explosive

to that of steel of the axle is compensated by sufficient structural strength of a repaired thread whish is, first of all, should be resistant to small on level, but multiple loadings, taking place under conditions of real running of the axles. It should be noted that significant strengthening of sleeve metal takes place at high deformation rate in explosion welding that has positive effect on providing of the necessary structural strength of the thread joint.

Wall thickness of the cladding sleeve was equal 2.5 mm. The following factors were considered at that:

- inner diameter of the repaired surface should not exceed 17.3 mm;
- worn thread was bored to diameter somewhat larger than 20 mm;
- presence of some expansion of the opening at cladding due to effect of high pressure pulse;
- thinning of cladding sleeve due to its expansion in the process of throwing.

A banding was applied to the axle for preventing of significant expansion of opening channel in a process of explosion cladding as well as increasing diameter of axle journal (Figure 3). Nevertheless, at that the diameter of axle journal exceeded its nominal value (by 0.1–0.2 mm), therefore, further correcting turning was necessary.

A fatigue test was used as a method for evaluation of mechanical strength and service life of the repaired thread. The corresponding procedure and bench were developed by the specialists of SE «Ukrainian Scientific-Research Institute of Car-Building». Figure 4 shows a scheme of device providing performance of tensile test simultaneously for two threaded openings at P_{max} = 98 kN (10 tf) and P_{min} = 49 kN (5 tf) with

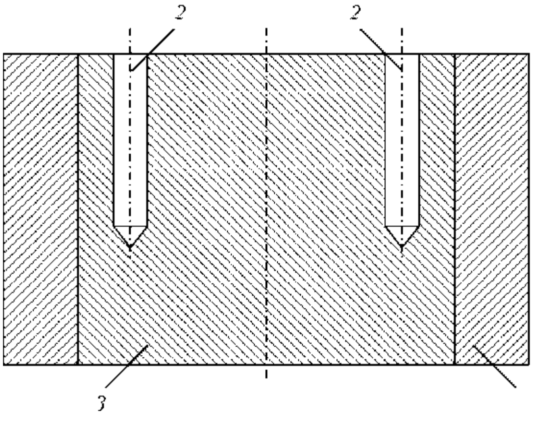

Figure 3. Scheme of banding of axle journal: *1* — tread ring; *2* — repaired openings; *3* — axle journal

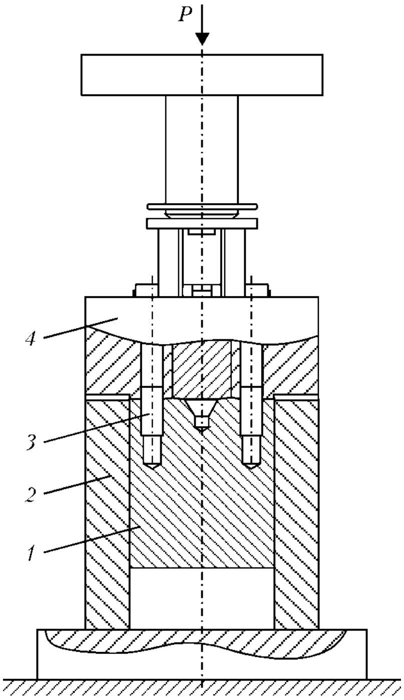

Figure 4. Scheme of device for axle journal testing: *1* — axle journal; *2* — cup; *3* — bolt; *4* — holder

loading frequency 5 Hz. The journals of new axles served as the base samples for comparison. Geometric characteristics of threaded openings M20-6N were verified before the test using Go–No-Go thread gage. Only two first screw threads were loaded, i.e. a bolt was twisted per two screw threads that made the test tougher since the bolt is to be twisted at minimum per 16 screw threads under the real situation of axle running. Loading of more screw threads resulted in break-away of a head or thread part of the bolts and provided no possibility for carrying the thread in the opening to full failure.

Figure 5 shows a cross-section of repaired threaded opening along the channel axis. A lack of penetration of 5 mm length is taking place close to the channel bottom that is character during realization of the process of explosion welding. The screw thread of only 45 mm length is to be cut according to Figure 1, therefore, presence of such a lack of penetration is insignificant and acceptable.

Figure 6 shows the microstructures of joints of steel of axle and repair sleeve along the opening axis at 3, 15 and 45 mm distance from its beginning.

Figure 5. Macrosection of repaired threaded opening

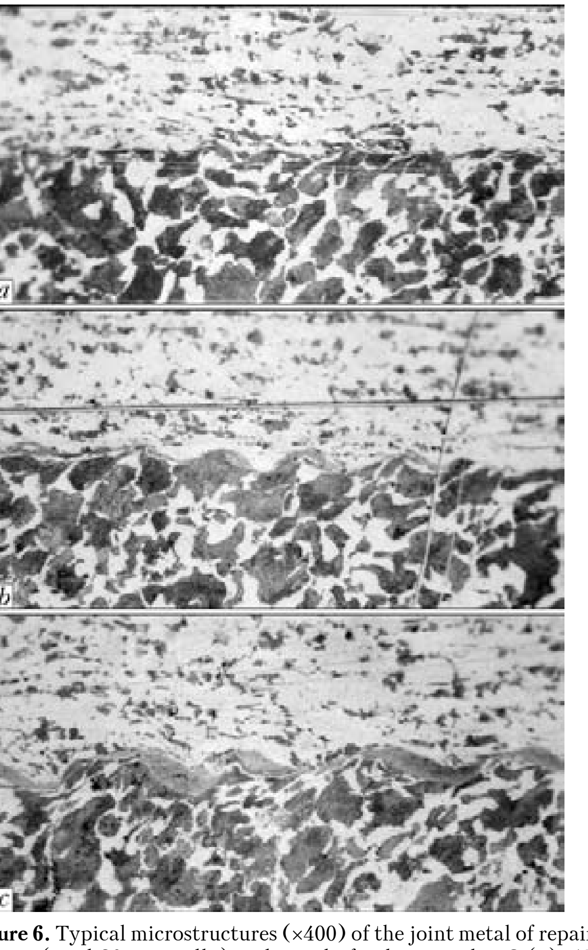

Figure 6. Typical microstructures (×400) of the joint metal of repair coating (steel 20 upwardly) and metal of axle journal at 3 (*a*), 15 (*b*) and 45 (*c*) mm distance from the beginning

Boundaries of the joining zone have mainly wave-like form and characterize by sufficient stability that indicate the presence of quality welded joint. At that dimensions of the wave are very small: excursion (two amplitudes) makes 2 μm and length is 6 μm. This is evidence of the fact that explosion welding was performed at low limit of welding parameter range. No changes of the metal structure outside the joining zone were found.

Results of fatigue tests of the samples of new axle journals of RU1-Sh type and journals with repaired threaded openings are given in the Table. Figure 7 shows the photos of the new and repaired openings of axle journals after the tests.

The minimum life time of the thread $N_p^{\min}$ (minimum number of cycles before failure with probability 0.95) was found by formula

$$\lg N_p^{\min} = \lg N - Z\alpha S_{\lg N},$$

where lg N is the logarithm of life time average value; $Z\alpha$ is the quantile of normal distribution for specified one-sided probability α at $\alpha = 0.95Z\alpha = 1.645$; $S_{\lg N}$ is the root-mean-square deviation of the life time logarithm.

The minimum values of life time $N_p^{\min} = 127,000$ cycles of loading for samples of journals manufactured from the new axles and $N_p^{\min} = 122,000$ cycles of load-

Figure 7. General view of the openings in new (base) (*a*) and repaired (*b*) journals of axle after the tests

ing for samples of the axle journals with threaded openings repaired using explosion welding method were obtained after processing of the test results.

Repair welding of threaded openings M20 on RU1-Sh full-scale axles. Two axles with damaged threaded openings (one per each edge) were represented for adjustment of the developed technology to RU1-Sh full-scale axles and further route tests of SE «Ukrspetsvagon». Figures 8 and 9 show a general view of the repaired axles and threaded channel. Reproducibility of explosion welding mode on full-scale axles and their models (quality of joint was controlled using metallographic investigations) was determined based on similarity of radial deformation of the clad channel. Diameter of the channel after cladding made 17.4–17.5 mm that is quite acceptable for cutting of thread M20-6N.

Repaired axles as a part of one car truck were put under the special car designed for transportation of mineral fertilizers in March 2011 and being used by SE «Ukrzalisnytsya» till present time. Current monitoring of repair welded joints was carried out. The car with repaired axles have already run 23 thou km without a damage and wear of the repaired threaded opening M20 as for October 2011.

Presented technology after insignificant modification can be recommended for implementation at car-repair enterprises of «Ukrzalisnytsya», first of all at «Ukrspetsvagon». One of the variants of practical realization lies in organizing of coming of the mobile teams of engineers from PWI to «Ukrzalisnytsya» enterprises for performance of repair work applying explosion cladding at working areas of a customer.

Figure 8. General view of repaired axles RU1-Sh

Figure 9. Repaired channel for thread cutting

Results of fatigue tests of threaded openings of axle journals

Sample No.	Life time N_p, cycle	
	New axles	Axles with repaired threaded openings
1	156,000	145,000
2	134,000	124,000
3	142,000	145,000
4	165,000	150,000

CONCLUSIONS

1. It is shown that the method of explosion cladding allows depositing of repair coating in the damaged threaded opening M20 of the axle journal of wheelsets for RU1-Sh type cars. At that the cracks in the journal metal and zone of joining with repair coating as well as shrinkage shortenings and reduction of diameter of location of the axle journal for roller bearing are absent.

2. It was determined that minimum values of fatigue life of the axles with threaded openings repaired by explosion welding method made 122,000 loading cycles that only 4 % lower of the base value for the new axles.

3. Two full-scale axles with repaired threaded openings M20 were route tested and showed no damage or unallowable wear after running of 23 thou km according to their condition in October 2011.

4. The developed technology has a perspective to be used at car-building enterprises of «Ukrzalisnytsya».