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SOME ASPECTS OF LAUNCHING THE PRODUCTION OF SPRING CLIPS FOR RAIL FASTENINGS

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ABSTRACT

Modern technology of hardware production occupies an important place in ensuring the fabrication of metal products for various industries. Production of steel rail fastening elements, such as spring-loaded clips, which play a significant role in improving the efficiency and safety of rail transport, is an important application of such technology. These products are characterized by complex shape, high quality requirements, as well as high level of physical, mechanical and performance properties. OJSC "MMK-METIZ" is one of the leading Russian companies producing railway hardware. Currently, to maintain its position in the market of rail fasteners, the company implemented a number of research, development and engineering works in the field of organization of production of bar-shaped spring clips OP-105 and ZhBR. As a result of these works, the required level of quality of the finished products has been achieved, allowing the use of manufactured spring clips on the railways of Russia.

1. Introduction

Up-to-date hardware production occupies an important place in fabrication of metal products for many industries. Possibility of manufacture of products with complicated shape with preset level of quality, as well as physical, mechanical and operating properties from different metals and alloys is the main cause of wide distribution of such technological processes. Hardware products are also characterized by low cost of manufacturing process [1–7]. Fabrication of steel elements of rail fastenings, such as spring clips, baseplates, components of thread joints etc., play the leading role in safety providing of railroad transportation.

It should be noted that the loads on the main railroads have been increased substantially during recent years, owing to elevation of train mass, transportation speed and traffic intensity. Thereby the problems of safety providing and financing stability of the railroad transport are very important at present time. Transportation safety mainly depends on railway track structure that provides direction of train motion, perception of force effects from wheels and their transfer to substructure. The track structure presents a complex construction with intermediate rail fastening as one of the main components. Such fastenings should correspond to the following requirements [8]: providing stability of track width; pressing of rails to a basement (eliminating take-off and creep of rails); creating the optimal temperature conditions of rail operation; possibility of adjusting the rail position along track width and height, replacement of fastening components without interruptions in train timetable; possibility of mechanical joining and maintenance of fastening blocks; providing the rational spatial line elasticity and vibration resistance of fastening blocks; electric isolation of rails from their basement; economical efficiency of construction of track structure.

To provide implementation of these requirements, especial attention at the railroad should be paid to construction and quality of fastening components. The world practice of railroads operation includes different constructions of intermediate rail fastenings that can be classified according to the following indications [9]:

1. Purposes of fasteners: separate (when fixing of baseplate to sleeper and rail to baseplate is provided by different fasteners — KB and KD fastenings); non-separate (when fixing of baseplate to sleeper and rail to baseplate is provided by the same fasteners — BP fastenings); combined (when rail is fixed to a sleeper together with baseplate, as in separate fastening, and baseplate is additionally fixed to a sleeper by separate fastener — DO fastenings).

2. Presence of baseplate: with baseplate (KB, KD, BP, ZhBR-65PSh fastenings) and without baseplate (ARS, ZhB, ZhBR-65, Pandrol-350 fastenings).

3. Characteristics of a pressing element (clip): rigid (KB, KD, K2 fastenings), rigid plate-type (ZhB, ZhBR), rigid bar-type (ARS, ZhBR-65, Vossloh W14 etc.).

4. Type of sleeper fasteners: bolt (KB, BP, ZhBR-65 fastenings), anchor (ARS fastenings), screw-dowel (K2, ZhBR-65Sh, ZhBR-65PSh and other fastenings).

The clip-bolt fastening of KB type (figure 1) are most widely distributed on the Russian railroads. In this fastening, a rail is pressed to a baseplate by rigid steel clips that are put on clip bolts, while shaped bolt heads are moved in slots of baseplate flange. Elastic washers are mounted under nuts of clip bolts. A baseplate is fixed to a sleeper by insert bolts. In this case bolt heads are leant on a steel

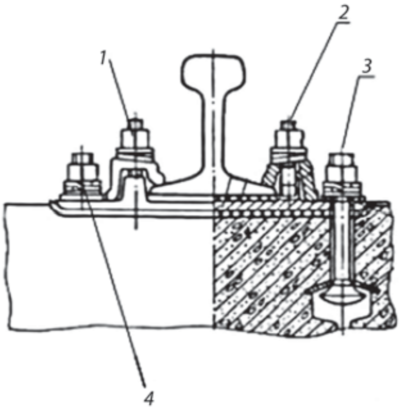

Fig. 1. Clip-bolt fastening of KB type:
1 — nut; *2* — clip bolt; *3* — insert bolt; *4* — dual-turn nut

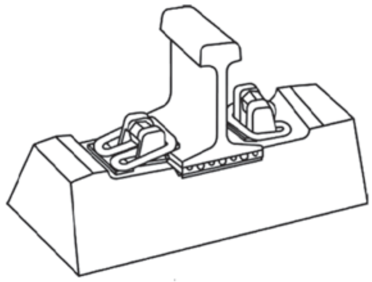

Fig. 2. Anchor-bolt fastening of ARS type

washer that is arranged in concrete as monolith. Thereby this steel washer provides uniform load on concrete during fixing of mounting nuts. Electric insulation between baseplates and sleepers is provided by clip plate on a sleeper and cloth laminated sleeve joint that is mounted on a rod of an insert bolt and then is deepened in the hole of metallic baseplate.

The following disadvantages of this clip-bolt fastening (see **fig. 1**) are noted: large number of components; high material intensity; large number of bolts requiring corresponding content per 1 km of railway; presence of thread joints.

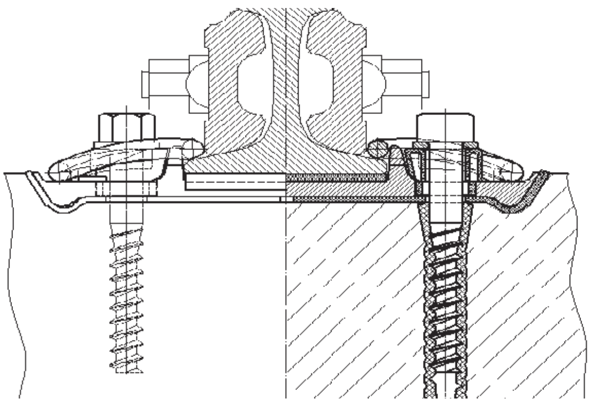

Fig. 3. Fastening of ZhBR-65PSh type:
1 — bolt track hex head; *2* — gasket; *3* — spring terminals ZhBR; *4* — guide insert; *5* — cushion; *6* — cushion; *7* — lining ZhBR; *8* — shim; *9* — bolt M22-8gx175.36; *10* — nut M22-7H.5

It was mentioned previously that the requirements to reliability, repairability and safety of rail fastenings become more strict at present time, thereby the designers and producers of railroad hardware suggest the new technical solutions and constructions. Rail fastenings of ARS type (**fig. 2**) and ZhBR-65 type (**fig. 3**) can be emphasized.

Non-dismountable anchor of framed-and-arched type, arranged as monolith in undr-rail area of a concrete sleeper, is a feature of construction of the anchor-bolt fastening of ARS type. This anchor clasps rail foot and unites operation of two clip assemblies consisting of two W-shaped bar-type clips [10]. It allows to apply this fastening on straight railroad sections, as well as on curved sections with radius 260 m and more, with width of rail track 1520 mm and without any restrictions in freight traffic density. Such fastening does not need regular maintenance of thread joint, owing to its absence, and thereby increases equal freight rigidity [10].

Mass and number of components of the fastening construction of ZhBR-65PSh type (see fig. 3) are decreased more than by 1.5 times in comparison with separate fastening of KB type. Such rail fastening saves the constant track width, countervails rail creeping, provides volumetric track elasticity, vibration damping, possibility of rail lines adjusting in width and in the plan.

2. Production of rail fastenings at OJSC "MMK-METIZ"

OJSC "Magnitogorsk Hardware and Sizing Works "MMK-METIZ" is one of the leading enterprises specialized in fabrication of steel components of rail fastenings. This enterprise has long-term experience of railroad hardware manufacture, and it allows to produce more than ten kinds of these products (i.e. anti-creep angles, track screws, spring washers, elements of thread joints of rail fastenings etc.). MMK-METIZ has recently mastered the production technology for elongated track screws with hexagonal head (TsP-54). These screws are used in fastenings of ZhBR-65PSh type and are used rather widely in building of railroads in Russia. The experience of mastering of production of steel bar-type clips for rail fastenings at this enterprise should be also noted. A bar-type spring clip of OP-105 type (**fig. 4**) can be mentioned among such products in the framework of shape and dimension ranges of products manufactured by MMK-METIZ.

Steel spring bar-type clips have volumetric geometric form and are related to the group of products with complicated shape, nevertheless of their type and construc-

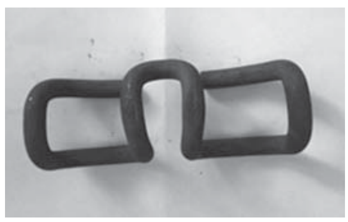

Fig. 4. Bar-type spring clip of OP-105 type

tion. Precise realization of clip dimensions and geometry is based itself on usage of non-conventional approaches for solving the technical problems in the field of providing production, development of technological equipment and accessories for this kind of products. The enterprise has implemented a series of scientific-research and pilot-engineering works in mastering fabrication of bar-type spring clips of OP-105 and ZhBR types, in order to save its positions at the market of rail fastenings. However, onlybar-type spring clip of OP-105 type has been put into serial production; it is used at present time in Russia mainly for mounting of turnout switches. Realizing of this task became possible after solving of the complex of technical problems required to provide manufacture of this product. The following solved problems can be underlined among the above-mentioned ones: modernization of technological equipment, development and/or adaptation of technological procedures for production of spring clips as well as providing of production facilities with corresponding billets allowing to meet the requirements of customer in operating and geometrical parameters of finished products [11, 12].

Bar-type spring clip of OP-105 type is manufactured according to the requirements of OST 32.156-2000 standard entitled “Spring bar-type clips for rail fastening. Technical regulation” (see fig. 4). It is related to low-rigid clips. Such clips can be used for rail fixing in separate fastenings of KB and KD types, i.e. serial components of the mentioned fastenings are used in fixing assembly, and that is the important advantage of application of these clips at the Russian railroads. This fact simplifies putting into practice and operation of such bar-type spring clips at railways.

The methods of cold or hot bending, as well as die forging are considered as efficient procedures for forming of complicated volumetric contour of OP-105 clip. Their high efficiency is confirmed by long-term practice. Intermediate flat billet is a pattern of a bar-type П-shaped spring clip; its form is close to “ω” (omega) letter (**fig. 5**), and such billet can be fabricated via preliminary cold bending of specially prepared round steel bar.

Providing of possibility of realization of small curvature radii in finished products [16–19] is the problem aspect in usage of cold bending method as a forming operation in manufacture of steel flat billets for spring clips. This method for fabrication of billets for spring clips at one position requires larger concentration of technological transitions and connected components of technological accessories in operating volume of a system. It is recommended to conduct rationally forming of final shape of ready products via the method of hot bending — die forging.

Technological forming process of intermediate product shape during cold bending can include three transition steps of forming the clip billet angles with simultaneous execution of a central loop with small radius. To make forming of small curvature radius in a loop more easy, it is important to envisage the operation for providing increase of ductility level of billet metal in production process. It is necessary for optimizing of bending process, for achieving of precise geometrical parameters both in the shape of intermediate product and in dimensions of finished clips. Spheroidizing annealing of steel bar-type billet has been recognized as a successful method for improvement of metal ductility. To provide the required level of operating properties of clips, the finally formed products are subjected to heat treatment — quenching with consequent tempering [13, 20]. The measurement results of hardness in control specimens of products after quenching and tempering are presented on the **fig. 6** [15].

Three technological flows have been formed during organization of serial production of steel spring clips at OJSC “MMK-METIZ”:

1. Technological flow of preliminary metal preparation;
2. Block of technological operations for forming the shape of ready clip;
3. Complex of operations including final heat treatment, aimed on providing of the required level of properties in finished products.

The second technological block mostly satisfies to the necessary conditions of rational structure of technological process. This block includes combination of operations conducted at the specialized production line equipped with the required transmission units.

Final processing of railroad spring clips during the mastering period of their production, including tempering after

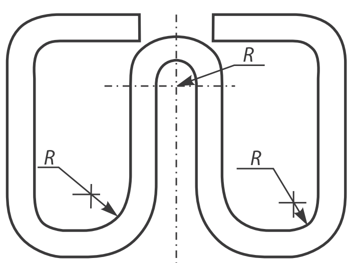

Fig. 5. General view of ω-shaped OP-105 clip

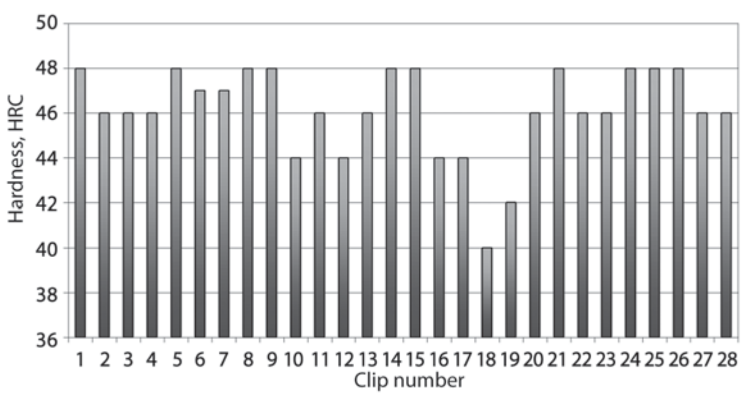

Fig. 6. Hardness of clips after quenching and tempering

finalizing of the second operating block, has been conducted in thermal units of discontinuous operation with time pause after quenching from stamping heating; it has led to appear of metal rejects with quenching origination. This problem has been eliminated via varying of the technology in final heat treatment operations of forged clips, using quenching and tempering units widely used in hardware production. Usage of such equipment allows to cu the time period between quenching and tempering, stabilize processes of structure forming and forming of physical and mechanical properties, as well as decrease the level of metal rejects in products with thermal origination.

As soon as application of bar-type spring clips has to be provided by high-quality parameters of metal internal structure, its surface, physical and mechanical properties and, the most important, by stable conducting of the processes forming the quality of finished products at the technological stage, it is expedient to use the following guidelines during realization of the production process:

– structure of grained pearlite should be considered as an optimal state of annealed metal for the conditions of cold bending of a clip flat billet;

– usage of controlled protective media with varying carbon potential is necessary during metal preparation to cold plastic deformation, in order to decrease decarbonizing effect of these media;

– optimization of speed conditions at production line and step of billet laying on a transmission transporter in induction furnace are required for rise of uniformity of temperature distribution in a clip flat billet during its heating before hot forging;

– completing of several production flow lines is expedient in the period of expanding production of bar-type spring clips and mastering of the new types of such products.

The next step of mastering fabrication of innovative kinds of railroad hardware included pilot-engineering and technological examination of possibility of production of bar-type spring clips for rail fastenings of ZhBR-65 type in the conditions of "MMK-METIZ". This universal fastening has been developed on the base of wide operation testings of domestic fastenings of BP, ZhB and ZhBR types. Spring clip ZhBR was used in this fastening as an elastic element. ZhBR-65 fastening meets all requirements of the best foreign analogues in its parameters, in the meantime it is rather cheaper. Insufficiently developed production base for manufacture of elastic elements of fastenings is the main problem in solving the task to put into practice advanced rail fastenings at the Russian railroads. Thereby the problems of development of manufacture of such elements in Russia and improvement of the technology for their manufacture at all production stages are especially actual.

Despite of visible commonality of shapes in separate constructions of spring clips, ZhBR clip has its features. It is manufactured from more thick bar billet (diameter 17 mm) and it has principally other configuration. The above-mentioned circumstances don't allow to use in fabrication of ZhBR clip the known technical solutions that were tested before on spring clip OP-105. It predetermined necessity of conducting of independent research and pilot-engineering works for provision of manufacture of ZhBR spring clip at OJSC "MMK-METIZ".

The contour forming principle, based on cold plastic deformation processes, has been designed in the base of the initial pilot fabrication technology of ZhBR spring clips (**table 1**). Sequence of bending transitions has been developed for realization of the described principle, as well the method of final contour forming of clips has been determined, special bending machine and die forging machine (mounted on PC 10M1 press) have been designed and fabricated at the plant. Hot-rolled steel (40S2 grade, 18 mm diameter) has been used for production of pilot-industrial party consisting of 200 items. The block of preparing operations has been realized in accordance with the pilot technology of clip production, and sizing rolled bars (17 mm diameter, ~520 mm specific length) have been produced using drawing technology. Then annealed

Table 1. **Composition of initial pilot technology for production of ZhBR spring clips at OJSC "MMK-METIZ"**

Stages of technological process	Kind of operation	Used equipment
Block of preparing operations	1. Structural annealing of hot-rolled steel, 18 mm diameter, on grained pearlite	Bell-type furnace
	2. Preparation of metal surface	Complex of pickling baths
	3. Sizing or grinding of bar billet surface for 17 mm diameter	Drawing mill or grinding machine "Kieserling" for bar billets
	4. Recrystallized annealing or tempering of rolled products	Bell-type or roller furnace
	5. Preparation of metal surface to cold bending	Complex of pickling baths
Block of technological and forming operations	6. Straightening and shearing of specific length of bar billets	Complex of forming equipment and accessories
	7. Cold bending of flat billet	
	8. Billet transfer in a stamping die	
	9. Cold bending and die forging of clip	
Block of final operations	10. Clip heating for quenching	Quenching and tempering unit
	11. Clip quenching	
	12. Clip tempering	
	13. Watering	
	14. Acceptance tests of ready clips	

and sized bar billet has been subjected to cold bending in flat shaped billet, and then to cold deformation in perpendicular plane at a bending stamp until forming the final shape if ready clip. Formed clips were subjected to final heat treatment (quenching and tempering) in the SNO 3.0×6.5 chamber furnace in laboratorial conditions, or at SKZA line in production conditions.

Cold bending is a kind of forming operations, where plastic deformation is realized in special bending units for separate billet sections. In this case it is necessary to provide receiving of required accuracy of products and realization of plastic deformation via pressure without billet destruction. Quality of metal products manufactured via cold contour forming is determined mainly by the value of residual stresses, arising in metal during plastic deformation. Relaxing of residual stresses can lead to undesired varying of geometric dimensions of finished products. Residual stresses in steel billets also have effect on metal technological properties, while residual stresses in finished metal products influence on development of the processes of retarded destruction, fatigue and brittle strength, corrosion resistance.

3. Results and discussion

In connection with the observed problem, during implemented works, the calculated [21] and experimental evaluation of accuracy of contour fabrication of ZhBR spring clip have been conducted. For this purpose, clip billets and finished products at all technological stages have been subjected to geometrical control in special points. Determination of the effect of technological parameters on accuracy of contour fabrication of ZhBR clip was the main aim of execution of these measurements. Ready and thermally processed clips were subjected also to control of their microstructure, hardness and value of decarbonized layer.

Analysis of measurement results of clip geometrical parameters before and after final heat treatment displays that contour fabrication of products in industrial conditions is not stable in spite of quite normal metal preparing to cold plastic deformation. Additional and essential distortion of clip shape after heat treatment is observed after heat treatment. Most part of controlled dimensions differs substantially from their nominal values and exceeds allowances required by the drawing.

Relaxing of the residual stresses accumulated by metal in the process of cold deformation (both during bending of flat billet and during cold bending — die stamping with manufacture of ready clip) is considered as one of the main causes of varying of clip dimensions and clip corrugation during heat treatment. Additionally, part of these stresses is relaxed just after unloading, and part of them — during heating in the process of heat treatment, and it makes shape forming according to an accepted technology unstable and unpredictable. Such explanation agrees well with the results of calculations and experimental investigations. E.g. the distance between the bended clip ends should vary by 6 mm in accordance with calculations, but it has really varied by 2.9 mm during experimental examinations after heat treatment. Remained part of elastic springing has been realized after unloading in bending units.

It was established on the base of the results of conducted investigations that the yield of finished products during clip fabrication via the pilot technology with usage of cold plastic deformation made 50–60%. Based on these results, expedience of organization of ZhBR clips manufacturing process using hot forming has been concluded.

The hot bending process of bar billets does not change principally a deformation route, thereby relative deformations for different bending radii of edge of forming punch remain practically the same as for cold plastic deformation. Metal heating has been conducted up to temperature 930–960 °C during manufacture of spring clips via hot deformation. Heating is possible also by high frequency current.

The main influence of heating is realized (from the point of view of metal forming) via lowering of the values of deformation resistance σ_s and elasticity module E. For the steel 40S2A these values are as follows: $\sigma_s = 88$ MPa, $E = 1{,}1\times10^5$ MPa (in hot state), and $\sigma_s = 650–700$ MPa, $E = 2{,}1\times10^5$ MPa (in cold state). Such decrease of mechanic properties of the initial steel during its heating ensures significant lowering of force required for forming of preset shape. It should be also noted that the effect of residual stresses can be not taken into account during hot deformation of bar billet, because these stresses are relaxing during bending and consequent cooling. The results of calculations and experimental investigations of elastic springing for different clip elements in hot state are concluded in substantially lower (appr. by 4 times) values of variation of shape bending angles. Decrease of elastic springing during clip hot bending can provide more high accuracy and dimensional stability of clips in comparison with cold forming.

4. Conclusions

Thereby the technology using hot plastic deformation should be the main option in mastering of production of ZhBR spring clips. It can provide the following advantages: more short technology (structural annealing (50–60 hours) and pickling are excluded); higher stability in providing shape accuracy eliminating the factor of elastic post-effect in processed material; more cheap cost of products. Realization of such variant is expedient at specialized automatic equipmqnt, because most of the processes included in this technology can be localized easily combined and wee automatized. The automatic line of LA A7522 model for manufacture of elastic spring clip billets for railway rail fastenings (produced by "Tyazhpressmash", Ryazan) can be considered to such equipment. However, nevertheless to a large volume of conducted works, based on the existing economic situation and taking into account arisen risks, the ZhBR-65 spring clip for intermediate rail fastening was not accepted by the works for serial production.

At the same time, the high quality level of steel bar-type spring clips for rail fastenings has been achieved during implementation of several scientific-research, pilot-engineering and technological works aimed on mastering of these products [22–24]. This level meets the requirements of standard technical regulations and allows to use manufactures clips for operation at the Russian railroads. The practical experience in development of hardware production has been also accumulated and was estimated to be very useful in mastering of other kinds of metal products as well.

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