Improvement of the method of repairing springs from hardened wire

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Abstract. In the process of operation, coil springs undergo considerable temperature, static and cyclic (contact among others) loads and other unfavourable effects. Latent defects in the metal, inadmissible residual deformations, and excessive compression arise in springs. To save the resource and increase the quality of springs repair production enterprises, defense, engineering and auto industries require improvement of the existing methods of repairing the springs having lost their resistance. The recommended methods of spring repairing are the methods of thermo mechanic processing in combination with plastic surface treatment, namely contact predeformation and peen hardening. A new method of spring repairing from preliminary hardened wire is offered. The advantage of this method, in reference to the known ones, is in the extension of technological capacity and improving the quality of repaired springs.

1. Introduction
Springs are widely used in the design of up-to-date mechanisms. A spring is an elastic devise used to store mechanical energy, usually made out of hardened steel [1]. Much attention is paid to high load springs. For instance, these are the springs of the valves of internal combustion engines and fuel injection equipment of diesels, suspension springs, lock valve springs, and other springs operating at high load speeds with coils collision or under static low-cycle contact load between coils exceeding the strength of the compression of the spring. The main consumers of this product are engineering, auto, and defense industries. The improvement of operating characteristics of springs is determined to a large extent by the demands of these industries in terms of increasing their reliability and accuracy [2].

The main malfunction of coil cylindrical springs is relaxation, i.e. loss of their initially set power and geometric characteristics. Reduction of operating load of springs can exceed permissible deviation causing loss of operability of units, mechanisms, and machines. For example, automobile springs cause failures of units and assemblies that make to 18.2 %. Compression of the automobile suspension springs, as a result of coils collision, is accompanied by the early fatigue of frame rails and the body of a car.

There are two ways of repairing machines and mechanisms: replacement of the failed premodularized units and arrangement of restoring repair of separate parts [3]. The latter way is more preferable, since the cost of setting the parts requiring restoration will not exceed 40 % of the cost of new parts, taking into account the restoration. At the same time, the cost of setting the new ones will cost 110–150 % of their own value [3, 4].

To save the resource and increase the operating reliability of machines and mechanisms, the task of improvement of the existing methods of spring repairing having lost their resistance is urgent.
2. Materials and methods
The research is made based on the literature review and the studying of the production experience of the Belebey plant “Avtonormal” (Belebey) and the enterprise “Avtokranservis” (Stavropol) in the field of spring hardening. The results of research works “The research on using the contact predeformation in spring restoration” (the program START-2010) and “The development of the method of increasing the resource of high load compression springs for high-speed transport” (the program UMNIK-2014) were also used. The proposed method of spring restoration is based on using the methods of low-temperature thermomechanical processing, wheel blasting, hardening by the contact predeformation, and metrological monitoring.

3. Results and discussion
There are some known methods which are used for spring resistance repairing of coil compression springs [5, 6].

The method of the spring resistance repairing [5] includes extending, heating, and cooling a spring. To increase technological capacity and improve the quality of a spring, its coils are stretched successively and simultaneously with stretching, are heated and pressed.

The disadvantages of this method are the duration depending on the necessity of successive processing of the coils and the impossibility of the correction the non-perpendicularity of end faces. The method does not take into account the following circumstances: spring steels are characterized by low-thermal conductivity [7]. In this connection, the local uneven heating of the spring can lead to inner stresses and quench cracks while hardening. In this case, the preliminary heating of the spring to 400…500 °C should be performed. The problems of preventing the spring surface from forming a decarbonized layer and correction of surface defects while processing are not solved either. The spring temper after hardening, the peen hardening (used for elimination of stress concentrators after hardening), and predeformation which is necessary for springs are missed as well.

Figure 1. Extension of the spring on the mandrel.
The method of repairing springs from hardened, usually patented or quenched and drawn spring wire [6] is considered. It is performed as follows. The spring is extended on the mandrel (figure 1) with a coil pitch exceeding the coil pitch of a finished spring. Then, the spring is heated to the tempering temperature of 400…420 °C and tempered on the mandrel in the extended state. Then, the processes of peen hardening, repeated tempering at 230…250 °C, and pressing of a spring by axial compression load (figure 2) being equal to 10…300 $F_3$ are performed (where $F_3$ is the spring force before coils contact). It is possible to press a spring heated to 230…250 °C after peen hardening excluding the repeated tempering. The load can be applied in a vibrational mode.

The disadvantage of the method is that the repeated tempering after peen hardening is carried out at the temperature of 230…250 °C. This is the temperature limit for tempering after peen hardening [8]. At higher temperature, the effect of peen hardening will decrease. To prevent softening after peen hardening, it is recommended to carry out the low temperature tempering at 180…220 °C within 30 min [8] for the artificial accelerated ageing of the pinned layer. The disadvantage is that the unheated spring is pressed by the 10…300 $F_3$ load or the spring heated to 230…250 °C is pressed without the repeated tempering. To provide stable power characteristics of the spring, it is necessary to perform the repeated tempering after peen hardening at ≤220 °C within 30 minutes. For the further plastic hardening (pressing) it is recommended to heat the spring to 200…250 °C [8]. The pressing time is 1.5…2 s.

Besides, for the springs operating without coils contact, it is recommended to perform the pressing by 10 $F_3$ load [6]. For the springs operating with coils contact, the pressing load should exceed the spring load in the workpiece by 5 % [6, 9].

To eliminate the shortcomings mentioned, a new method of repairing the springs from hardened wire is offered. It should be performed as follows. After washing and passing control of the power and geometric parameters, the compressed spring should be extended on the mandrel with a pitch exceeding the coil pitch of a finished spring, then heated to 400…420 °C and tempered. Then peen hardening and repeated tempering at 180…220 °C within 30 minutes should be performed. After that,
the spring is pressed at 200...250 °C by axial compression of 10 $F_3$ load for the springs operating without coils contact, and by axial compression exceeding the spring load in the workpiece by 5 % but not less than 10 $F_3$ for the springs operating with coils contact. The pressing time is 1.5...2 s. The loads can be vibrational. Increased power characteristics requirements suggest the spring restriking.

Under the given succession of operations, low temperature tempering after peen hardening stabilizes power characteristics of springs without the risk of their softening. Pressing (plastic hardening) of springs at increased temperature is accompanied by structural changes in the deformed layer. Correspondingly, it is accompanied by increasing its firmness and strength, the formation of favourable residual compressive stress, and qualitatively new macro- and microgeometry of the surface of the spring material [10]. The spring pressing at the temperature of 200...250 °C ensures the increasing of the spring resource up to 40 % and increasing the spring accuracy over the length and the load up to 14.3 % [11].

The technique to specify the allowance and parameters of springs while plastic hardening is known [6].

4. Conclusion
The analysis of the known methods and devices used for spring restoration has been conducted. Their shortcomings have been revealed. The method of spring repairing from hardened wire has been improved. The advantage of the improved method, in reference to the known ones, is in the extension of the technological capacity and improving the quality of repaired springs from preliminary hardened, usually patented or quenched and drawn spring wire. The employment of the proposed method ensures the increasing of the spring resource up to 40 % and increasing the spring accuracy over the length and the load up to 14.3 % as compared to the springs restored by the known methods. This method can be used at repair production enterprises as well as defense, engineering, auto industries and agricultural engineering enterprises.

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