

Strengthening of surface layer of material by wave deformation multi-contact loading

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Abstract. It has been experimentally established that the possibility of multi-contact shock systems can transmit large total energy of the impact pulse to the deformation center. Thus, an increase in the number of instruments in a shock system from two to four, with the constant energy of the shock pulse, made it possible to increase the depth and the degree of hardening in the surface layer. The performance of multi-contact impact systems can be increased by 50% without degrading the hardening parameters by increasing the distance between the tools.

1. Introduction

An increase in the efficiency of impact systems is possible due to a more complete utilization of the energy of the deformation waves. This is achieved by supplying the shock pulse energy to the deformation zone through the intermediate link – a waveguide. This energy supply directly affects the shape of the shock pulse, which determines the fraction of the impact energy expended on elastoplastic deformation.

The research of shock systems with one intermediate link, forming a prolonged shock pulse conducted by Kirichek A.V., Solovyev D.L., proved the effectiveness of their application, for solving a wide range of engineering problems [1-10]. The previously obtained data on the theory of strain wave material hardening are applicable only for single-contact impact systems containing a single rod-shaped tool; therefore, it is difficult to use them in order to describe the process of impact-pulses propagation with multi-contact loading schemes.

The use of multi-contact impact systems, in comparison with single-contact systems, has a number of advantages in affecting the half-space. Thus, in establishing the regularities of the distribution of energy of shock waves in multi-contact shock systems in an isolated loading medium, depending on the type, geometric shapes of individual indenters and their number, it is revealed that [2]:

- when passing through a shock pulse waveguide (or tool), its amplitude decreases, and the duration increases, due to the increase in the wave rise fronts;
- an increase in the eccentricity between the wave guide (or tool) axis of symmetry and the striker contributes to a decrease in the fraction of energy transferred to the deformation center;
- the use of multi-contact loading schemes allows the transfer of an impact pulse large total energy to the deformation center. At the same time, the share of the shock pulse energy per waveguide, in a multi-contact circuit, decreases by 20% in the case of rod-shaped waveguides,



and by 15% - for ball-shaped instruments, with each next waveguide (or tool) installed in the shock system.

The previously obtained data on the features of the energy distribution within the shock system, depending on a number of factors, do not make it possible to obtain an idea of the simultaneous impact on the half-space of shock pulses passing through a multi-contact shock system.

The purpose of these studies is to establish the regularities of impact on the half-space of the summing effect under the imposition of shock waves in multi-contact shock systems.

2. Materials and methods

The investigations were carried out on a specially developed test bench, which allows simultaneous loading of the hardened surface with four tools. The model of the test bench is shown in Fig. 1.

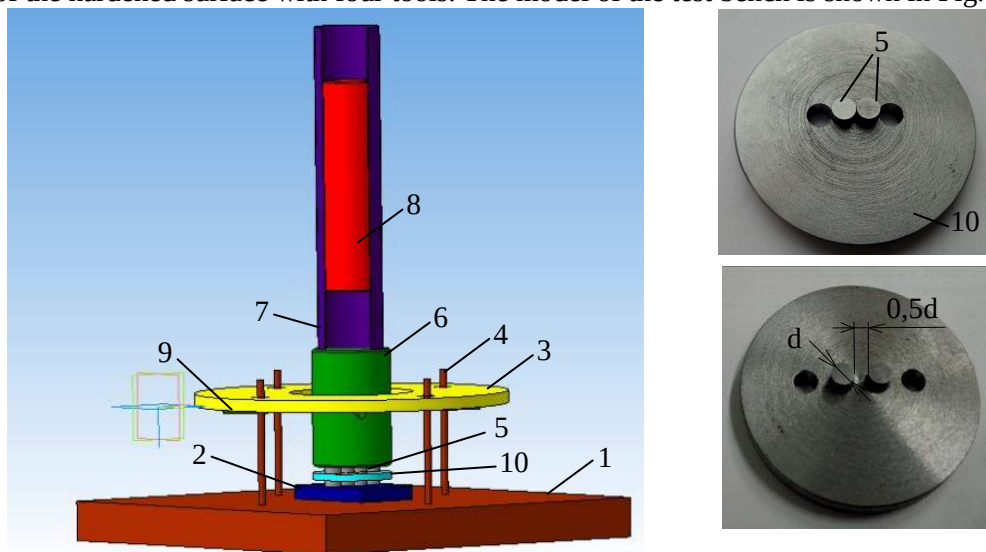


Figure 1. Model of test bench.

The experimental stand consists of base 1, on which loaded sample 2 is placed. Tools 5 carry out a multi-contact loading of sample 2. Tools 5 are placed on loaded sample 2, which create a preliminary static compression through waveguide 6, which is urged to base 1 through stop rods 9, using plate 3 and screws 4. Static preload is necessary for a more complete transfer to the focus of impact pulse energy deformation. Loading of sample 2 by impact pulses occurs through waveguide 6 with the help of striker 8, which moves freely, under the influence of gravity, along guide 7.

For the implementation of loading systems with an intermediate link, a cylindrical waveguide with a diameter of 80 mm and a length of 100 mm and a 50 mm diameter bobbin with the length of 100 mm made of 40X material were used. As tools 5, deforming sample 2, rods with a flat end of 6 mm in diameter and 10 mm in length were used. In a shock system, one to four instruments can be used simultaneously. The accuracy of the placement of tools 5 between themselves and on loaded sample surface 2 is controlled by separator 10. Sample 2, 100 * 100 * 16 mm in size, is made of AMG2 alloy and has an initial microhardness of $H_{\mu} = 490$ MPa.

To assess the impact of the summing effect of wave states formed as a result of the imposition of shock waves in multi-contact shock systems on the half-space, the instruments were placed next to each other without gaps, and then at a distance of 0.5 of the instrument diameter from each other.

At first, one instrument was installed in the shock system and a blow was made. Then the experiment was conducted with two, three and four instruments. In all cases, the impact of the striker along the waveguide was applied with the same energy of 29.6 J. The shock system effectiveness was evaluated by means of microhardness cards. Microhardness at a depth of 0 ... 7 mm was determined by means of measuring microsections in the automatic mode on a digital stationary hardness tester,

KB30S. The microsections were prepared on the LS250A programmable grinding and polishing machine in the automatic mode. The research was carried out on the basis of the research and production laboratory of "Wave strain and combined hardening in additive and subtractive technologies" of Bryansk State Technical University.

3. Regularities of the wave strain multi-contact loading of a half-space

The results of microhardness measurements under the impressions of the impacts of the instruments located without gaps from each other are presented in Table 1 and at a distance from each other equal to 0.5 of the tool diameter - in Table 2. The entire area under consideration on the 7 mm thick sample is almost completely strengthened. The regions predominant on the diagram with the value of $H_{\mu} = 70$ MPa have an elliptical hardened area with a maximum thickness of 5 mm under the center of the impression and a minimum thickness of 2.5 mm along its edges. The highest microhardness value obtained was 980 MPa ($\Delta H_{\mu} = 100\%$).

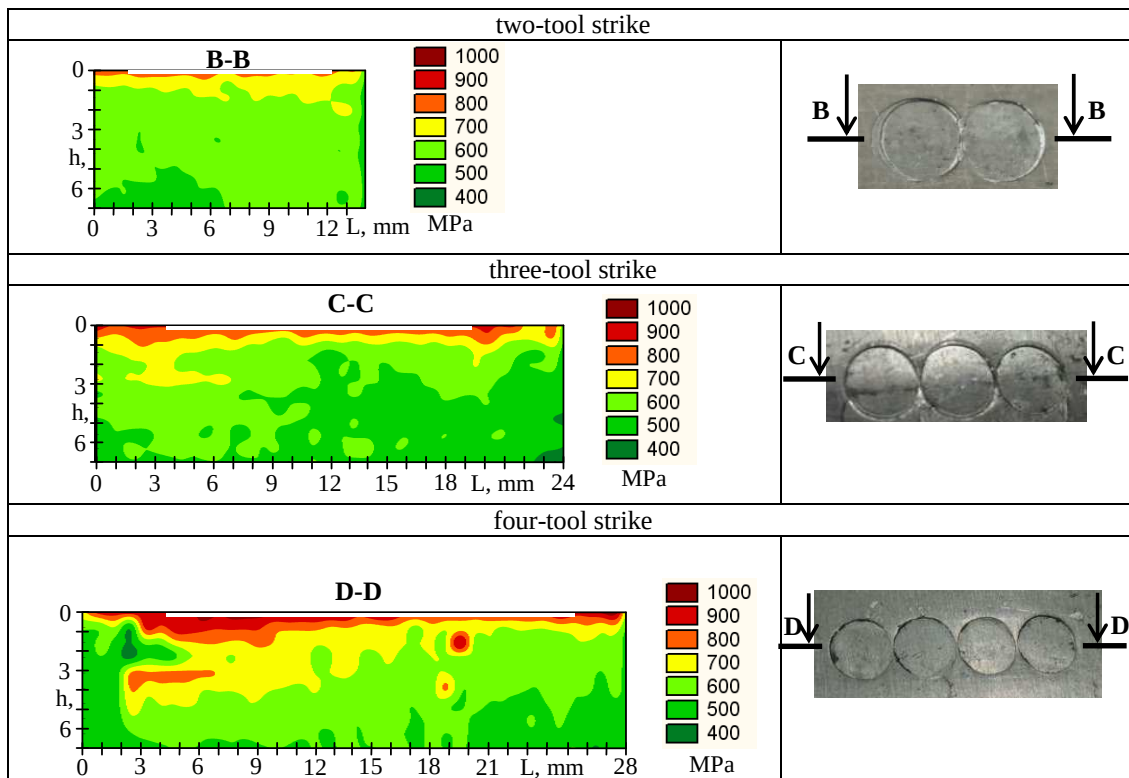
Just like in the single (previous) case, with simultaneous impact on two instruments, the whole considered area of 7 mm thickness was hardened. It was predominant in the sample. The presence of a distance between the instruments in the impact system equal to 0.5 of the tool diameter, unlike the case of the arrangement of the tools next to each other without a gap, made it possible to increase: by 20% (from 1.5 to 2 mm) the average depth of the region with a hardening degree (ΔH_{μ}) of 40%; and by 50% (from 0.7 to 1.5 mm) - with a degree of hardening $\Delta H_{\mu} = 60\%$. When striking two tools without a gap, the maximum degree of hardening was 60%. The presence of a gap between two tools in the impact system equal to 0.5 diameter of the tool allowed increasing the maximum degree of hardening to 70%.

With an increase in the number of instruments in the impact system to three, in the area under consideration, unstable areas appeared, and the overall hardening depth (the arrangement of areas with $\Delta H_{\mu} = 20\%$) when machining with tools located without a gap was 1.5 to 7 mm. If the tools were placed with a gap of 0.5 of the tool diameter, the overall hardening depth was from 2.3 to 7 mm. Areas with hardening values of 40% and 60%, in both cases of the location of the tools at a distance from each other, were formed at a depth of 0.9 mm and 0.6 mm, respectively. The highest degree of hardening of the samples, with the use of the three-instrumental shock system, was 90%, the areas of which are fragmentarily encountered in the surface layer at a depth of no more than 0.3 mm.

The increase in the number of instruments from three to four, in the shock system, allowed us to reduce the unstretched area dimensions and thereby increase the hardening depth 2-2.5 times. The depth of hardening was: in the case of impact on the instruments located without a gap - from 4 to 7 mm, and when using a shock system where the tools are located at a distance of 0.5 of the tool diameter from each other – 7 mm.

Table 1. Microhardness distribution under the impressions of the strikes of the instruments located without gaps

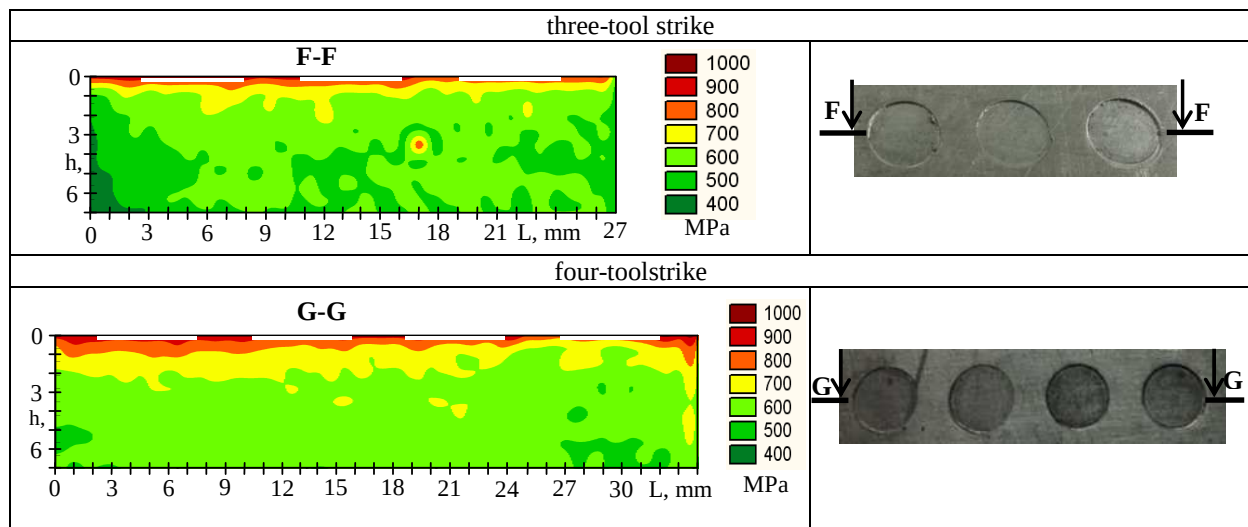
Microhardness distribution in the surface layer, MPa		Impressions of instrument strikes bordering each other	
1		2	
one tool strike			
A-A 0 3 6 h,mm 0 3 6 9 L, mm 1000 900 800 700 600 500 400 MPa		A A	
1		2	



The thickness of the areas with 40% and 60% hardening values in the four-tool strike system, in contrast to the values obtained after impact on three instruments, increased 2.5 and 2 times, respectively, when the tools were placed with a gap, and 3.5 and 3 times, respectively, for the positioning of tools without any gap. At four-tool strikes, it was possible to achieve the greatest degree of hardening equal to 80% at a depth of 1 mm, with the instruments placed without a gap. And for the case of placement of the instruments in the impact system at a distance from each other equal to 0.5 diameter of the instrument, these areas with $\Delta H_{\mu} = 80\%$ occur fragmentarily at a depth of no more than 0.5 mm.

Table 2. Microhardness distribution under the impressions of the strikes of the instruments located at a distance

Microhardness distribution in the surface layer, MPa	Impressions of instrument strikes located at a distance of 0,5 Ø from each other
1	2
two-tool strike	
E-E h, mm L, mm MPa	E ↓
1	2



4. Conclusion

1. It is established that with an unchanged impact energy, an increase in the depth of hardening occurs and the maximum degree of hardening increases with the addition of each subsequent tool (from two to four) to the impact system. This conclusion agrees with the previously obtained data on the capabilities of multi-instrumental shock systems to transmit to the focus of deformation to the large total energy of the shock pulse [2].

2. It is established that the presence of a gap between the tools equal to 0.5 of the tool diameter in the impact systems, consisting of two instruments, leads to an increase in the depth and degree of hardening; of three tools - to the absence of changes in the parameters of hardening; of four tools - it was possible to achieve hardening of the whole area under consideration, but to reduce the depth of the most hardened area.

3. It is established that, based on the analysis of the microhardness distribution diagrams, the productivity of the hardening treatment can be increased by 50% without deterioration of the hardening parameters, at the same impact energy, by placing the instruments at some distance from each other in the impact system, for example at a distance equal to 0.5 of the tool diameter.

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