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Evaluation of the stress state of a cultivator blade in production and operation

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Abstract: The aim of the work was to determine the quality of a new and used cultivator blade to assess the condition of the metal with the development of rejection norms of its variability in a magnetic parameter – coercive force using various types of equipment – coercimeters. The new cultivator blade shows the highest level of coercive force that is characteristic of its right and left parts and its decrease occurs towards the toe. After operation, variability is noted, characterised by both an increase and a decrease in the indicators of the coercive force. Rejection norms of the metal state, which determine the possibility of restoring a worn cultivator blade, which can also provide satisfactory indicators for their further use in operation, have been proposed. For restoration, it is recommended to use a cultivator blade made of low carbon steel, the zones of which should not change the level of the coercive force > 10.0% during operation. It is not recommended to restore those blades in which, after increasing the indicators, they then decreased to (< 5.0%) and are characterised by close values of the indicators.

Keywords: agricultural machinery; uniformity; metal degradation; rejection norms; coercive force

It is known that cultivator blades for machinery and agricultural machinery are formed by stamping in the production of sheet metal with a thickness of ~ 6 mm and most often from steel 65G (James 1993; Malanin 2005; Volferc 2005; Bazarov 2007; Gribanovsky 2018). This may affect their operational durability. During operation, there are often forms in which not only the metal degrades, but their sizes change (Banaj 2000; Aulin 2016).

The most effective non-destructive method for controlling the stress state and metal degradation can be indicators of the level of coercive force (Matyuk 2010; Solomaha 2013; Bezludko 2014). For a reliable analysis of the metal's condition in different working areas, it is necessary to establish the basic indicators of the original, non-deformed and not subjected to processing by the sharpening zones of the cultivator blade. Such average indicators can be used to determine the rejection norms.

The aim of the work was to determine the quality of a new and used cultivator blade to assess the condition of the metal with the aim of developing rejection norms of its variability in coercive force using various types of equipment – coercimeters.

MATERIAL AND METHODS

To control the stress-strain state of products and metal structures made from various grades of steels and alloys, coercimeters of different types are used.

A KRM-C-K2M magnetic structurescope (Figure 1) can be used on building sites, in the field, when working on high-rise buildings where there are no mains supply or where it is prohibited by the rules of

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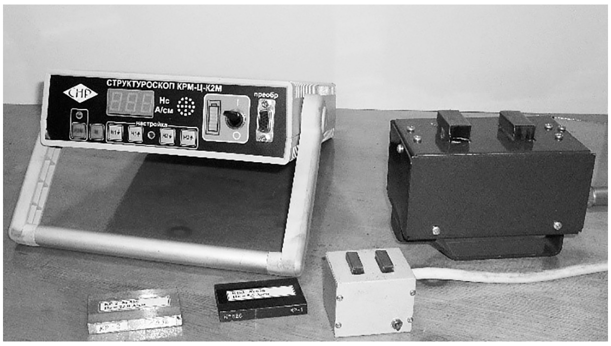

Figure 1. General view of the KRM-C-K2M coercimeter with various strap converters

safe operation (Bida 2000; Bezlyudko 2015; Mahalov 2016; Gorkunov 2019). During the development of rejection norms, the KRM-C-K2M magnetic structurescope can evaluate the mechanical properties and the structural state of steels of widespread use at the main stages of the loading diagram — elastic, elastic-plastic and plastic – by the coercive force (Skoblo 2007). Depending on the size of the magnetic converter, the device allows one to evaluate the level of the coercive force to a depth of 5 and 20 mm.

There are also coercimeters that work only from an electrical network. One of these is the IKS-104-INTEX coercimeter (Special Scientific Engineering LTD, Ukraine) (Figure 2). This type of coercimeter is designed to assess the level of stress at a small depth, even when nano-coatings have been applied.

The measurements were carried out comparatively on the new cultivator blade CNH 9.3 "Tiger Mate II" and then after its operation (Figure 3). The chemical

Figure 2. General view of the IKS-104-INTEX coercimeter with a converterwith various strap converters

(A) (B)

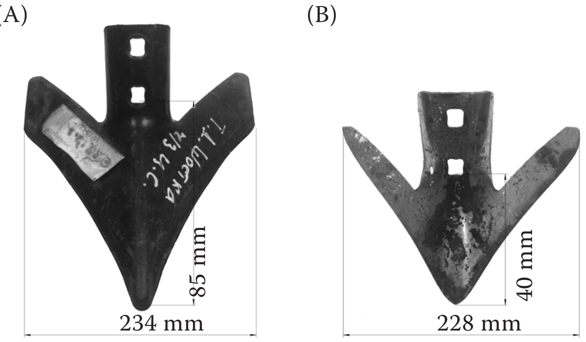

Figure 3. The studied cultivator blades of the (A) new CNH 9.3 "Tiger Mate II" and (B) after operation

composition of the material is as follows (%): 0.25 C, 0.25 Si, 1.31 Mn, 0.84 Cr, 0.23 Ni, 0.0036 B. According to GOST-4543, this corresponds to steel 27HGR

RESULTS AND DISCUSSION

At the first stage, the coercive force was measured using a KRM-C-K2M coercimeter in two directions: perpendicular to and the fractional positions of the converter relative to the cutting edge of the cultivator blade, according to the measurement schemes shown in Figure 4.

From the obtained average values of the coercive force (Figure 5), it can be seen that, in the new cultivator blade, its highest level is characteristic of its left and right parts and a decrease occurs to the toe.

An analysis of the data obtained showed that the scatter of the indications for all the measured zones (Table 1) does not exceed 3.0–9.0% (the average across all the zones of the cultivator blade is 6.3%). Measurements previously performed in a new cultivator showed that during the moulding process, the pressure profiles are not evenly distributed and this determines the formation of local stresses, although the direction of cutting the sheet metal during stamping can also contribute to this. However, judging by the results of the coercive force measurements, estimated in two directions (lobar and transverse), the contribution of this factor to a thin-sheet, well-developed during the metal rolling, does not introduce the influence of this factor in the pattern of variation in the H_c readings. Figure 6 shows the readings of the coercive force in the various measurement zones.

After the end of the service life, variability is noted, characterised by both an increase and a decrease in the readings of the coercive force (their

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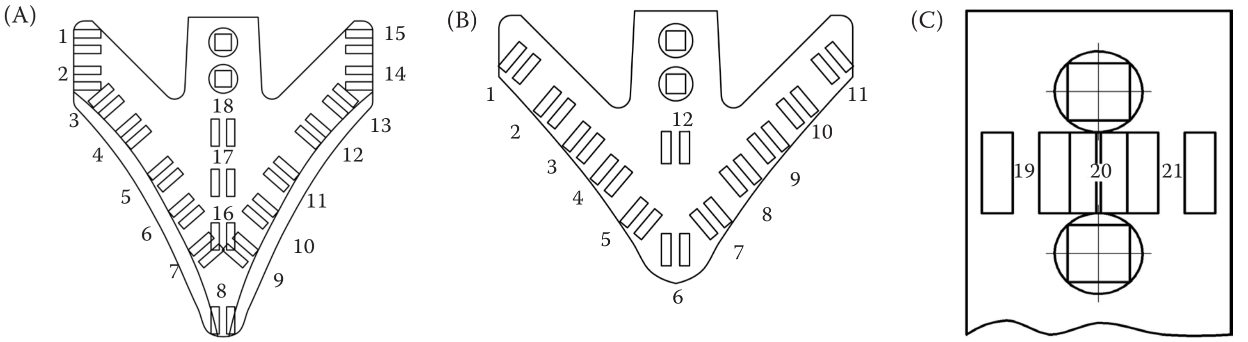

Figure 4. Schematics for measuring the coercive force on the cultivator blade with a KRM-C-K2M coercimeter: (A) on a new one, (B) after operation and (C) in the fastener zone

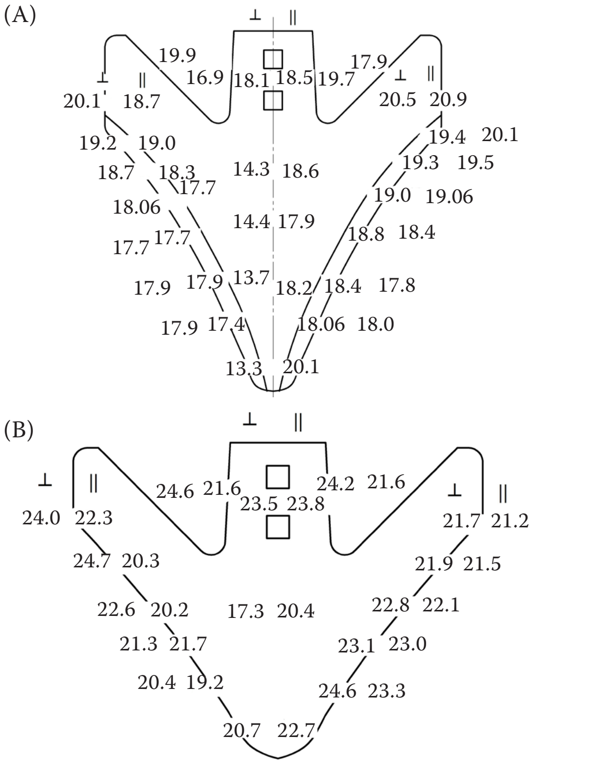

Figure 5. Indications of the coercive force on a (A) new cultivator blade and on the (B) cultivator blade after operation (A·cm^{-1})

⊥ – corresponds to the transverse measurement; || – longitudinal measurement

dispersion), which reflects the level and nature of the stress state and the degree of the degradation (Figure 7). So, in the left part of the cultivator blade, there is an increase in the coercive force in the fractional direction by 70.0%, and in the right part, its decrease, regardless of the direction of the measurement, by 25.0–30.0%. The observed evidence of an additional local deformation on the right part of the cultivator blade and significant metal degradation on the left part is visible. Earlier, such variability of

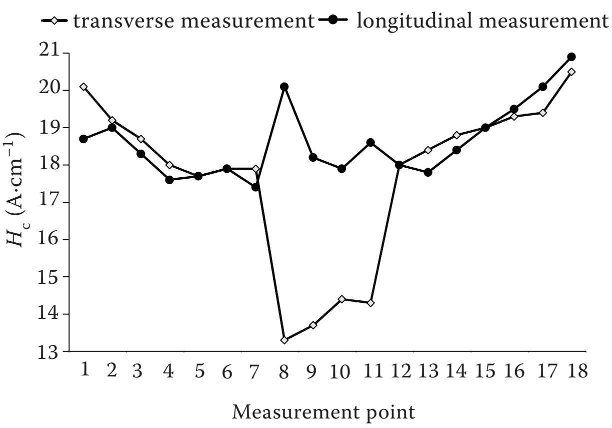

Figure 6. Indications of the coercive force in the new cultivator blade

H_c – coercive force (A·cm^{-1})

Table 1. The average spread of the coercive force readings before and after operation (%)

Characteristics of the cultivator blade (A·cm^{-1})	Left part of the cultivator blade		Right part of the cultivator blade		Middle part of the cultivator blade		Zone of the fastener	
	⊥	||	⊥	||	⊥	||	⊥	||
Before operation	9.0	5.0	8.0	9.0	4.0	7.0	3.0	5.0
After operation	9.0	8.5	6.0	6.0	9.0	5.0	5.0	5.5
Dispersion of indications	–	+3.5	–2.0	–3.0	+6.0	–2.0	+2.0	+0.5

⊥ – corresponds to the transverse measurement; || – longitudinal measurement

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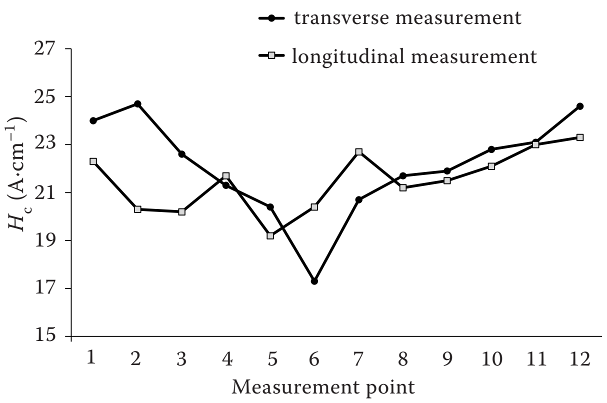

Figure 7. Indications of the coercive force in the cultivator blade after operation

H_c – coercive force (A·cm^{-1})

the coercive force was revealed in steel products operating under local deformations (Skoblo 2014, 2018a, 2018b).

In the remaining zones – the middle and in the area of the fastener holes after operation, both the formation of additional local stresses takes place (see Table 1 with the "+" sign) and the development of degradation phenomena ("–" sign).

The comparative variability of the coercive force values revealed that, on average, this indicator increases by 10.0–27.0% for various zones after testing and is determined by the localisation of the deformations (Table 2). This indicates that under the influence of the local deformations, the degradation of the metal increases significantly during operation, which leads to the increased wear and corresponding change in the profile of the cultivator blade. At the same time, this can also cause destruction, especially in its middle part and in the area of the fastener holes, where the level of local deformations rises by 21.0–27.0%.

To establish the role of a thin surface layer in the development of a stress state, the coercive force was additionally measured using an IKS-104-INTEX device in four directions: the surface horizontal (HD), vertical (VD), back-horizontal (BHD) and back-vertical (BVD) positions convector relative to the cutting edge of the cultivator, according to the measurement schemes presented in Figure 8.

From the obtained average readings of the coercive force (Tables 3 and 4), it can be seen that a similar distribution of the coercive force in the surface zones of the compared cultivator blades is observed. The values in the readings is the only noticeable difference. For example, at the edge of both working parts of the new and used cultivator, the values are 8.6–10.1 A·cm^{-1} and 15.7–19.3 A·cm^{-1} , respectively, which characterises the level of stress state of the

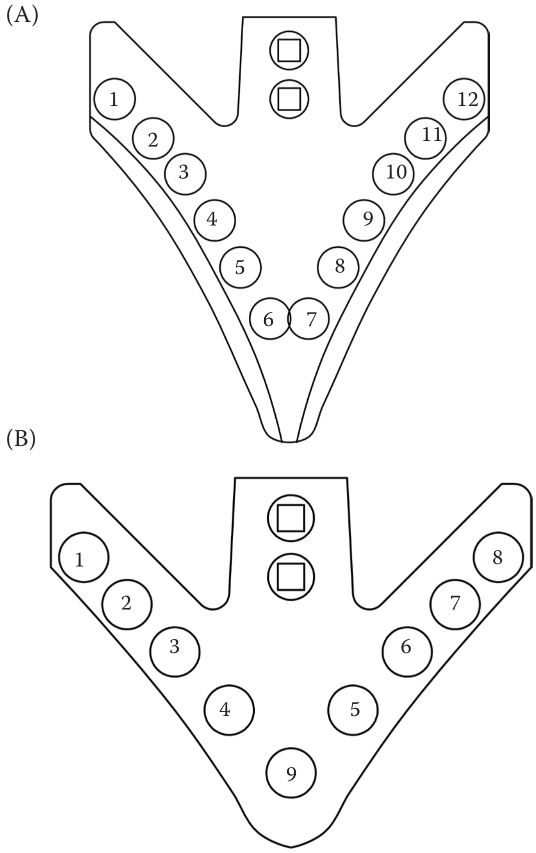

Figure 8. Schematics of measuring the coercive force on the cultivator blades with an IKS-104-INTEX coercimeter – (A) new and (B) after operation

Table 2. The average variability of the coercive force before and after operation

Characteristics of the cultivator blade	Left part of the cultivator blade		Right part of the cultivator blade		Middle part of the cultivator blade		Zone of the fastener	
	⊥	||	⊥	||	⊥	||	⊥	||
Before operation, (A·cm^{-1})	18.5	18.1	19.06	18.0	13.8	18.7	19.23	17.76
After operation, (A·cm^{-1})	22.6	20.74	22.8	22.2	19.0	21.5	22.8	22.2
Dispersion of indications (%)	+ 18.0	+ 10.0	+ 16.0	+ 16.0	+ 27.0	+ 10.0	+ 16.0	+ 21.0

⊥ – corresponds to the transverse measurement; || – longitudinal measurement

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Table 3. Indications of the coercive force of the new cultivator blade (A·cm^{-1})

No. of the measurement zone	HD	VD	BHD	BVD
Left part of the cultivator blade				
1	10.1	8.6	8.7	8.6
2	8.7	8.1	7.6	7.5
3	8.5	7.6	7.5	7.3
4	8.2	7.3	7.2	7.2
5	8.2	7.7	7.6	7.5
6	9.2	8.06	8.03	7.9
Average value	8.8	7.89	7.7	7.6
Right part of the cultivator blade				
12	9.8	9.3	9.03	9.1
11	8.9	8.3	7.9	7.9
10	8.5	8.2	7.8	7.85
9	8.2	8.03	7.7	7.6
8	8.4	8.06	7.9	7.7
7	9.0	8.2	8.2	8.2
Average value	8.8	8.3	8.08	8.05

HD – horizontal direction; VD – vertical direction– ; BHD – back-horizontal direction; BVD – back-vertical direction

Table 4. Indications of the coercive force of the cultivator blade after operation (A·cm^{-1})

No. of the measurement zone	HD	VD	BHD	BVD
Left part of the cultivator blade				
1	15.7	19.3	16.03	18.2
2	13.06	14.2	12.4	13.2
3	10.8	11.2	10.7	10.2
4	9.2	10.4	9.4	9.4
Average value	12.19	13.77	12.1	12.75
Right part of the cultivator blade				
8	15.8	17.1	16.5	16.03
7	11.6	13.1	12.4	12.7
6	10.4	11.5	10.5	11.1
5	8.8	10.5	9.6	10.03
9	10.7	11.8	11.5	11.5
Average value	11.46	12.8	12.1	12.27

For explanation see Table 3

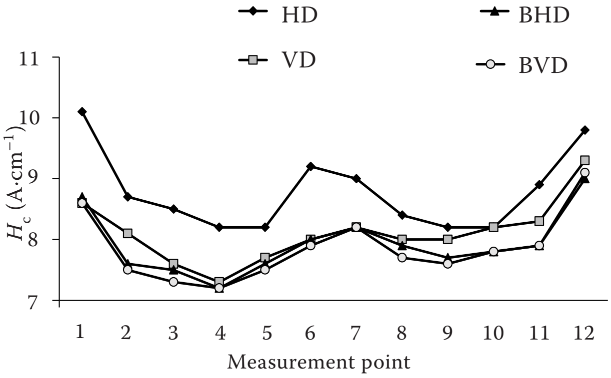

Figure 9. Change in the readings of the coercive force of the new cultivator blade

HD – horizontal direction; VD – vertical direction– ; BHD – back-horizontal direction; BVD – back-vertical direction

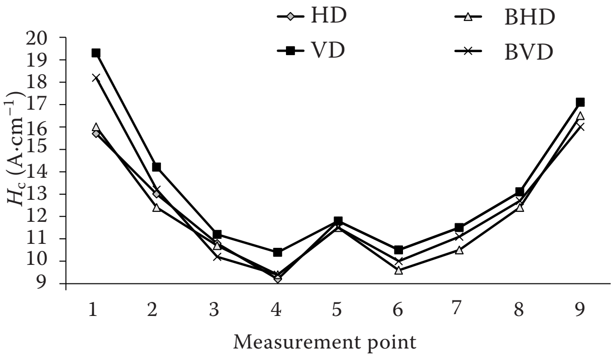

Figure 10. Change in the readings of the coercive force of the cultivator blade after operation

For explanation see Figure 10

surface layer to a greater extent. The coercive force changes are shown in Figures 9–10.

After analysing the obtained data, it can be concluded that, when assessing the stress state of cultivator blades at close readings, this characterises the degree of the degradation phenomena in the metal, which begins from the surface working layer. This is confirmed by Figure 10, describing a small scatter of H_c readings in the analysed zones using the appropriate equipment.

Based on the analysis performed, the following reject norms can be proposed for the restoration of worn cultivator blades, which can provide satisfactory indicators accepted in the practice of their use in operation. In this case, the different zones to be restored should not have an increased level of coercive force (> 10.0%), as well as significantly lower one (< 5.0%) with simultaneously close indicators of variability, which characterises an increased level of irreversible structural degradation changes.

CONCLUSION

(*i*) In new cultivator blades, the highest level of indications of the coercive force is characteristic of the both the cultivator blade parts and their decrease occurs to the toe, which is determined by the quality of the stamping of such parts.

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(*ii*) After operation, variability is noted, characterised by both an increase and a decrease in the readings of the coercive force. This reflects the level and nature of the stress state, and the degree of the metal degradation. It was revealed that in the left part of the cultivator blade, there is an increase in the coercive force in the shared direction by 70.0%, and in the right part, its decrease, regardless of the direction of the measurement, which reaches 25.0–30.0%. This indicates a higher local deformation of the right part of the cultivator blade and a significant degradation of the metal on the left part.

(*iii*) When assessing the stress state of cultivator blades with special measuring equipment, it was shown that a close level of coercive force characterises the degree of degradation phenomena in the metal, the development of which begins from the surface working layer.

(*iv*) Rejection norms are proposed for restoring worn cultivating blades, which can provide satisfactory indicators accepted in the practice of their use in operation. For restoration, it is necessary to use cultivator blades, the zones of which should not have an increased level of coercive force > 10.0%. It is also not recommended to restore those whose variability has lower indices and a small dispersion < 5.0%. This characterises an increased level of irreversible structural degradation changes.

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