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Burnishing Tool Face Optical Control Method

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Abstract: Commonly used organoleptic methods of evaluating surface deterioration do not guarantee manufacturing quality control required in mass production. It is necessary to control efficiently the machining tool status based on planned replacements and regular surface analysis. An algorithm and software for quick evaluation of burnishing tool wear has been developed.

Introduction

Definition of the extent of machine parts and tool face wear is an extremely important task for all fields of machine building industry. Methods of surface wear analysis can be split up into organoleptic and instrumental. Main task of wear analysis method under study is evaluation of workability of tools for surface treatment by plastic deformation – burnishers. Quality of tool surface directly affects quality of workpiece surface, so application of the method under study can reduce costs in different production plants, ensure taking a right decision on tool replacement not according to the planned replacements procedure but rather based on actual digital photograph analysis.

A group of authors in Republic of Chile developed an optical control method for conveyor belt wear used to detect holes and surface tears [1]. The method includes continuous analysis of belt surface without removing the belt. Application of the method does not require any additional modifications to the belt.

French scientist Nicolas Bonnot in his research studied a machine vision system for ground parts surface control. The method includes a circular surface lighting system to illuminate the surface at different angles [2].

At present, there are many researches to develop instrumental control methods. There are methods based on evaluation of grey level, contour analysis as well as methods with adaptive highlighting of the test area. Taking into account that all scanning methods evaluate wear area based on actual digital photograph, it is important to set the level of acceptable errors for this evaluation.

Optical method of analysis was selected for study as the least expensive and technically feasible; still, its automation requires development of adaptive algorithms for image analysis.

Calculation algorithms and respective software were developed for automated definition of burnishing tool face wear.

The following method was proposed to define the surface wear area:

1. The digital photograph is taken on a special bench, sketched on (Fig. 1), where the object under study (1) is put on a white plane (2) in front of the lens (3) of the digital photo camera (4). Photographing is made in close-up mode with a piston-type ring flash used to avoid flares on the tool's working surface.
2. The raster image of the tool working surface is then processed in a graphics editor to enhance contrast and to prepare the digital photograph of the studied object's working surface for determination of actual wear contact scar with the software.
3. The actual wear scar of the burnisher is determined with the specially developed software.

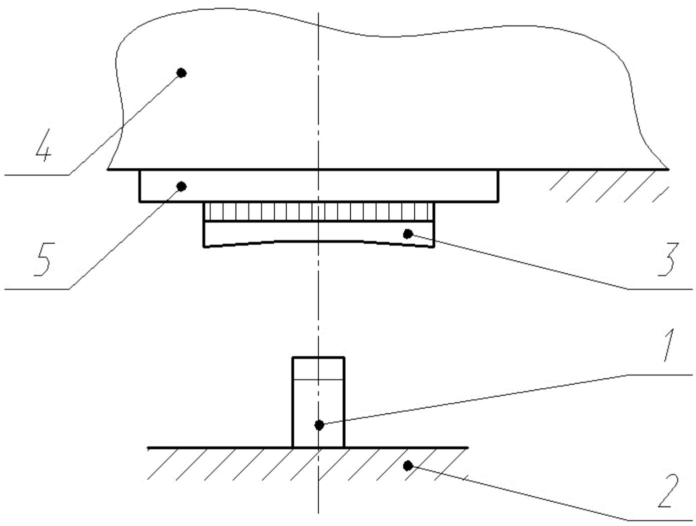

Fig. 1 – Scheme of a bench for burnisher face photographing where 1 – object under study; 2 – white screen; 3 – lens of digital photo camera; 4 – digital photo camera; 5 – round flash

Theory

Let's consider in more detail the calculation algorithm, on which the program is based. There are known mathematical relationships for exact solving of the analytical problem of finding the area of a plane figure; generally it can be solved by integrating the given figure subject to the type of the function describing the area boundary:

$$S_{wear} = \int_{x_1}^{x_2} f(x)dx, \quad (1)$$

where f(x, y) is a curve forming a geometric figure, in this case it is a curve describing projection contours of a wear scar of the burnisher working surface; x1 and x2 are integration limits.
Theoretically, this method of determining the wear area gives the most accurate result. However, it is quite difficult to describe a wear scar, using mathematical function. In the program, the wear scar projection Swear is limited to a closed loop consisting of a set of graphics primitives: line, elliptical arc and circular arc. Setting of each such primitive means solving the problem of inclusion of certain bitmap elements in the filled area, showing the worn surface of the tool.
When the wear area is marked by primitives, taking into account the bitmap image nature, expression 1 can be written like:

$$S_p = \sum\nolimits_{x=1,y=1}^{N_x,N_y} f_p(x,y), \quad (2)$$

where x, y is the image size by X axis and Y axis respectively, in pixels; fp(x,y) is a procedure that determines whether the relevant pixel belongs to the wear area or not:

$$f_p(x,y) = \begin{cases} 1\, if\ Color_{x,y} = Iznos \\ 0\, if\ Color_{x,y} \neq Iznos \end{cases}, \quad (3)$$

where Colorx,y are color parameter values of the relevant pixel, RGB; Iznos (Wear) are color parameter values of the pixel included in wear area by the set primitive, RGB.
When the tool wear area is calculated by formula 2, the wear area value is obtained in pixels. The following calculation should be done to transform the obtained value into standard units.

$$S = S_p \cdot K_{mas}^2, \tag{4}$$

where S are values of the burnisher wear area, mm2; Kmas is a coefficient expressing the image scale, mm/pixels.
In expression 4, Kmas coefficient is determined by the following formula, with equal pixel sides horizontally and vertically:

$$K_{mas} = L_{AB}^{actual} / L_{AB}^{pix.}, \tag{5}$$

where L_{AB}^{actual} is an actual distance between two points of the image, mm; $L_{AB}^{pix.}$ is a distance in pixels between the same-name points, determined by the following formula:

$$K_{mas} = \sqrt{(A_x - B_x)^2 + (A_y - B_y)^2}, \tag{6}$$

where Ax, Bx are coordinates of A and B points in the X-axis respectively, pixels; Ay, By are coordinates of A and B points in the Y-axis respectively, pixels.

Algorithm

The following algorithm was developed based on formulas 1 to 6 (Fig. 2) to determine the tool's wear area:
1. Download a raster image (*.bmp) of the worn-out working surface of the tool. The *.bmp format or any other non-compressible format is needed to make proper analysis, because if an image is saved compressed with high compression ratio, certain typical artifacts appear.
2. Determine actual scale of the image.
3. Identify the wear scar by means of elementary geometrical figures.
4. Calculate actual area of the wear scar.
Precision of Swear calculations under formula 2 in IZNOSOMER software will be limited to precision of the computing algorithms and to the number of meaningful figures considered in computation; in general – this means an aggregate of software and hardware errors.
Computing resources available nowadays have rather little hardware error. For example, floating-point approximation in calculations done by the most software products existing today takes into account 14 to 17 significant digits; if necessary, there are algorithms that increase this number, and thus the calculation accuracy.
However, there is the error of method associated with transition from vector to bitmap images, i.e. the error associated with approximation of smooth boundaries of the area, described by a particular function, by discrete boundaries of the bitmap image. Conversion from vector image to bimap is done according to Brezenhem algorithm [3].
After mathematical transformations, the following formula of software error to define wear area was made:

$$\Delta_S = \frac{\sqrt{1+k^2}}{4\sqrt{2} b_S R} \cdot 100\%, \tag{7}$$

where bS is wear scar width, mm·10-1; R is photographing resolution, pixels/cm; k=b/a – ratio of width of the circumscribing rectangle to its height.

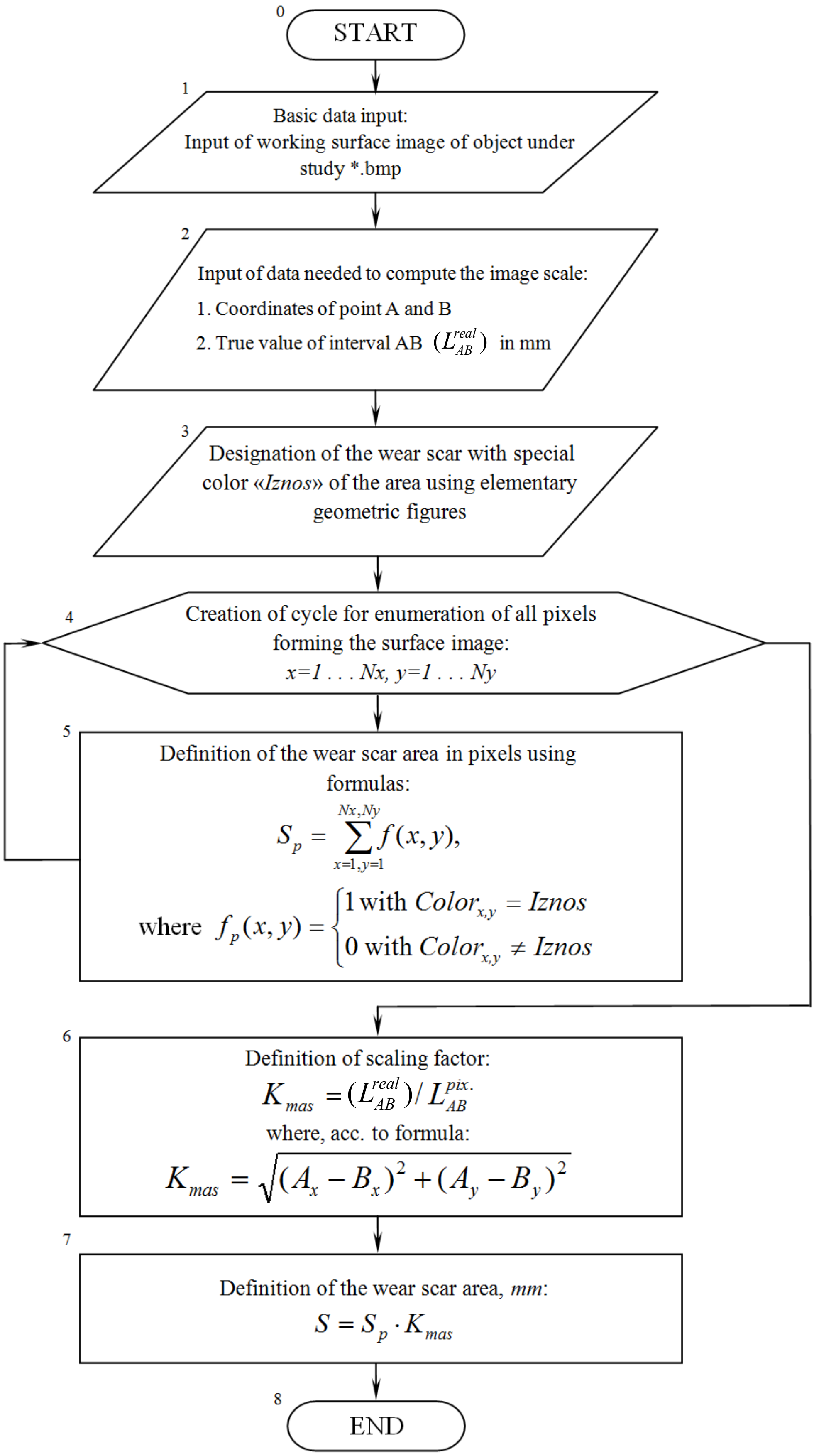

Fig. 2 – Flow chart of surface wear area determination algorithm

Analyzing the formula based on software error determined for tool wear area calculation, it can be concluded that the error will be minimum under the following conditions:

$$\Delta_{S\min} = \lim_{k\to 1, b\to\infty} \frac{\sqrt{1+k^2}}{4\sqrt{2}b} \cdot 100\% \to 0, \quad (8)$$

So, image resolution increases with higher number of pixels on the width of wear scar, thus bringing vector-to-bimap conversion error to minimum level. As k ratio goes up, the geometrical figure circumscribing the wear area is tending to a line, that is $l \to \infty$, $S \to 0$, which increases calculation error as per equation 8.

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Conclusions

1. Methods based on using optical elements and further analysis of data array are the most optimal ones to be implemented in mass production environment.
2. The methods and algorithm developed to make math-models of wear extent evaluation can be implemented with minimum costs.
3. The software package developed allows for evaluating surface wear extent using modern matrices with minimum error.

It will be possible with the software developed to make fast and adequate study of the components wear, which is especially critical for high-volume production.

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