Proceedings in MANUFACTURING SYSTEMS
Proceedings in Manufacturing Systems, Volume 19, Issue 1, 2024, 35-42 ISSN 2067-9238

SELECTING A DEVICE SOLUTION FOR ASSESSING THE CIRCULARITY DEVIATION OF A DISC-TYPE PART

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***Abstract**: In the case of some categories of disc-type parts, there may be a requirement that the circularity deviation of the of the outer cylindrical surface does not exceed certain values. On the other hand, in certain situations, it is of interest to study the influence that different factors can exert on the measured values of circularity deviations. The consultation of specialized literature showed that the problem of measuring circularity deviations was a subject of interest for researchers in the field of manufacturing engineering. For such situations, the need to design and build a device was taken into account to allow experimental research to be carried out aimed at highlighting the influence exerted by some factors on the measured values of the circularity deviation. For this purpose, three variants of devices likely to meet the mentioned requirements have been designed. To select a solution when several alternatives are available, researchers have proposed and developed optimal selection methods by using appropriate selection criteria. In the investigated case, the selection of the most convenient solution was carried out using the analytic hierarchy process. Evaluation criteria of the three device variants were proposed, and the two-by-two solutions were compared. The use of a composite evaluation index led to the selection of a device that could be mounted on a universal lathe and that would allow for experimental research on the influence of different factors on the measured values of the deviation from the circular shape in the case of disc-type parts.*

***Key words:** circularity deviation; device; method of the analytic hierarchy process; evaluation criteria; adaptable device on a universal lathe.*

1. INTRODUCTION

Disc-type parts usually have a relatively narrow cylindrical surface and two parallel flat surfaces. In machine building, brake discs, clutch discs, and dividing discs are used in milling operations, some categories of sieves are used on machinery in the food industry, disc cams are used in mechanisms of the type cam-follower, etc. Disc-type parts also often have an axial bore with a circular or other cross-section.

In the case of some categories of disc-type parts, there may be prescriptions regarding:

- dimensional accuracy (corresponding to the outer cylindrical surface, thickness of the disc and diameter of the bore),
- shape accuracy (with the highlighting of some prescriptions regarding the deviations from the cylindrical shape of the outer surface or the axial bore, or from the planar shape of the two side surfaces),
- position accuracy (deviation from the nominal position of the axis of the bore, from the coaxiality of the external cylindrical surfaces and that of the bore, from the concentricity of the circles corresponding to the external cylindrical surface and that of the axial bore in a certain section perpendicular to the axis of symmetry of the disc-type part),
- runout (radial runout of the outer cylindrical surface or of the axial bore, runout of the flat surfaces),
- locating (the deviation from the perpendicularity of the bore axis on flat surfaces, from parallelism of flat surfaces).

As a rule, more rigorous accuracy conditions are required for the two parallel flat surfaces, which must not present frontal runout. However, there are also situations in which the problem arises of meeting some requirements regarding the circularity of the outer cylindrical surface in a certain section perpendicular to the axis of the bore or regarding the radial runout of the outer cylindrical surface.

Circularity considers the circular shape of the outer cylindrical surface or bore in a section perpendicular to the axis of the bore.

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The circularity deviation is defined as the maximum distance between the adjacent circle and the actual circular profile, measured in a cross-section of the cylindrical surface [1–14]. Regarding radial runout, the concepts of circular radial runout and total radial runout are used, respectively.

The circular radial runout is determined as a difference between the maximum and minimum distances between the actual surface and the axis of rotation, measured in a section perpendicular to the axis within the limits of the reference length [3, 15, 16]. *The total radial runout* is calculated as a difference between the maximum and minimum distances between the real surface and the axis of rotation, measured in all sections perpendicular to the axis within the limits of the reference length [3]. It should be mentioned that the circularity deviation is part of the deviation from cylindricity, along with the deviation of the axial longitudinal profile [17].

The determination of the values of circularity deviations and radial runout in the case of disc-type parts presents some similar elements, even allowing the use of the same devices or apparatus for their measurement.

Two of the most common deviations from the circular shape of the outer cylindrical surface of a disc-type part are ovality and polygonality.

In manufacturing technologies, the evaluation of deviations from the circular shape and radial runout constituted problems on which the attention of those interested in such a field was focused.

Thus, Montero analyzed several methods for measuring circularity, starting from the possibilities of digital characterization of different profiles [18].

Saif et al. undertook research that aimed to use a certain type of protocol in order to improve the transmission performance of circularity measurement results between cloud servers and round-hole data sources [19].

Research on the web page of the European Patent Office, starting from the concept of "measuring circularity" highlighted the existence of a number of 212 patents and patent applications and having subjects in connection with the mentioned concept [20]. It should be noted that out of the first 100 patents or patent applications highlighted in this way, 66 have Japanese authors, the patents or patent applications being registered in Japan or outside this country.

Miao et al. has proposed the use of a method of measuring gear shaft radial runout using a line-structured light vision [21]. The method was applied for online measurement of a gear shaft radial runout using a single image and without rotating the shaft.

Yu et al. considered the possibility of using a method that allows predicting the value of the radial runout in the case of the outer ring in a cylindrical roller bearing [22]. They considered that such a method could be used to characterize the rotational accuracy of the assembled bearing.

In addition, in this case, resorting to a search on the website of the European Patent Office and using the concept of "measuring radial runout", it is found that 126 results have were identified [23]. Among these 126 results, 84 patents and patent applications were developed by authors from China.

The above mentioned lead to the idea that the main directions of research in the field of measurement of circularity deviations or radial runout are aimed at identifying new constructive solutions for the devices and instruments usable in this direction, the way of transmission, analysis, processing, and interpretation computer-assisted measurement results.

In the present paper, alternatives for the evaluation of the two deviation under analysis (circularity deviation and radial runout) were identified. The factors capable of affecting the measurement results were first established, and then the requirements that the constructive solutions proposed to perform the measurements must meet. Subsequently, three alternatives for the realization of a device for measuring the circularity deviation of a disc-type part were identified, and a method was used to justify the selection of an alternative that could subsequently be materialized.

Pursuing the development of experimental research that would allow highlighting the influence exerted by different factors on the measured value of the deviation from the circular shape, an additional criterion for selecting a device solution was taken into account, according to such a requirement.

2. USING THE AHP METHOD FOR SELECTING A SOLUTION

The optimization of a technical solution, in general, refers to the selection, among several possible alternatives, of that solution that maximizes or minimizes the quantities taken into account when making the selection. In the case of optimizing a process, the values of independent variables or those ranges of values of the variation of independent variables that maximize or minimize one or more dependent variables are considered.

Given the importance of optimization in manufacturing engineering, it was normal for researchers to focus on defining and using optimization methods capable of leading to better and better results for the criteria that technical or technological solutions or processes must meet in manufacturing.

As such, there are different optimization methods, some being applied to solve specific problems and others presenting a wider spectrum of applications. Thus, if a single optimization criterion is considered, it will be *a monocriterial optimization*. Still, frequently, manufacturing processes or systems require the use of several optimization criteria, which has led to the concept of *multicriterial optimization*.

When faced with a multicriterial optimization problem, some of the first steps in solving the optimization problem are to define and weight the criteria that can be used for optimization. Such optimization methods in which the weighting of previously defined criteria is necessary are most methods from value analysis, the imposed decision method, the method of the analytic hierarchy process (AHP), etc.

The so-called imposed decision technique involves first defining the criteria that can be used to optimize a certain solution and then comparing the criteria two by two and analyzing them using 1:0 ratings when the first criterion is appreciated as more convenient, 0.5–0.5 when the two criteria under comparison are considered to be of equal importance and respectively 0–1 when the second criterion is considered more convenient [24–26].

Afterward, an evaluation of each of the alternatives for solving the problem addressed is used, for each weighted criterion used in the previous stage. The alternatives will then be calculated with some coefficients of importance, resulting in summing the products between the marks awarded for each criterion and evaluating the solution with the help of the considered criterion.

Such a method was promoted by Professor Vitalie Belous and his collaborators under the name of *the imposed decision technique* [24, 25].

The use in the evaluation of the criteria and the respective alternatives to solve the problem, when they are compared two by two only of variants of type 1–0, 0.5–0.5, and 0–1, seems to be somewhat limiting, not allowing a more nuanced evaluation of the two criteria or alternatives.

A solution capable of reducing this disadvantage is offered by *the AHP method*. This method was proposed by the American inventor and architect Thomas Saaty (professor at the University of Pittsburgh) in the 70's the previous century, when he, together with Ernest Forman, invested efforts in creating software that could be used for a justified selection of an alternative from among several possible alternatives [26]. The method may require the participation of experts using specific tools, but it can also be used individually. In principle, when comparing criteria and alternatives two by two, in this case, assessments from 0 to 9 are used to highlight whether two criteria or alternatives are assessed as of equal value and, respectively, how many times a criterion or an alternative of solving the problem is considered more convenient than the criterion or alternative with which the comparison is made [27–30].

It is worth noting that, in relation to the imposed decision technique, the AHP method still uses some additional mathematical tools to check the consistency of assessments and offers options for action when the decision consistency criteria are not met.

After Thomas Saaty published the first considerations on the use of the AHP method, through the contribution of many other researchers, the AHP method was developed, identifying different areas in which it can be successfully applied.

The main stages of applying the AHP method are the following [26]:

1. Designing a model of the problem, which highlights the objective pursued, the alternatives that can be used, and the applicable criteria for selecting the most convenient alternative.
2. A so-called identification of priorities, through which comparisons of alternatives are made two by two.
3. Synthetic highlighting of the hierarchy of alternatives.
4. Verification of the extent to which the assessments carried out are consistent.
5. Formulation of the final decision.

Currently, there is also software that allows the operative performance of the necessary calculations for the evaluation of the criteria and alternatives for solving the problem, which facilitates the application of the method.

2. FACTORS THAT CAN EXERCISE INFLUENCE ON THE RESULTS OF MEASURING THE CIRCULARITY DEVIATION

When it is considered that the circularity deviations could be greater than a certain proportion of the tolerance on the diameter of a disc-type part, it is customary for the mechanical drawings of those parts to be written in symbolic form on the tolerances allowed for these deviations.

Most current solutions for measuring the out-of-roundness of disc-type parts use a dial gauge having a fixed position and whose probe contacts the outer cylindrical surface of the disc-type part.

Locating and clamping the disc-type part with a small clearance on a mandrel placed horizontally or vertically and slowly rotating the disc-type part will allow readings on the dial gauge indicator screen that will provide information on the amount of circularity deviation of the examined cylindrical surface in a certain section of it.

The size indicated by the dial comparator could be influenced by factors such as:

- Deviation in the horizontal plane of the direction of the axis of the dial probe from a direction perpendicular to the axis of the mandrel on which the disk-type part is located and clamped.
- Deviation in the vertical plane of the direction of the dial probe axis from the direction perpendicular to the axis of the mandrel used to locate and clamp the mandrel-type part.
- The size of the clearance between the bore of the disc-type part and the mandrel on which this part is located and clamped.
- The sizes of the clearances in the bearings of the shaft on which the possible mandrel used to locate and clamp the disc-type part is mounted when resorting not to the rotation of the disc-type part on the mandrel, but to the rotation of the mandrel together with the shaft that supports it.

It should be noted that there are also more complex equipment, in which the measurement of circularity deviations takes place by rotating a dial gauge indicator support sub-assembly around the axis of the disk-type part, located in a fixed position.

The problem of determining the amount of out-of-roundness of a disc-type part arises when the outer cylindrical surface of the disc is in movable contact, during operation, with another part.

The topic addressed in the present case was that of designing a device that can be used in a mechanical workshop to measure the deviation from the circular shape of some disc-type parts, in the case of which the outer cylindrical surface has been made, for example, by turning.

The previously mentioned problem was continued with the formulation of some requirements according to which the designed and made device should also allow the study of the influence exerted by different factors (some of them being previously mentioned) on the measured size of the circularity deviation of the outer cylindrical surface in the case of disc-type parts.

2. PROPOSED SOLUTIONS FOR HIGHLIGHTING THE INFLUENCE OF DIFFERENT FACTORS ON THE MEASUREMENT OF THE CIRCULARITY DEVIATION

The development of research on the influence of different factors on the results of some measurements aimed at the circularity deviation of some disc-type parts was considered, starting from the information identified in the specialized literature [31–33]. Three principle schemes of devices designed to meet such an objective have been designed.

Thus, the solution sketched in Fig. 1, involves the locating of the dial gauge feeler on the cylindrical surface of a disk-type part placed, in turn, in the channel with a cross-section having the shape of the letter V of a prism. Slowly turning the part by hand will allow readings on the dial gauge to provide information on the circularity deviation. Such a solution makes it necessary for the cylindrical surface of the disc-type part to have a sufficient length to be able to locate the part on the prism and respectively rotate the part in the prism channel.

The solution in Fig. 2 corresponds to a device that can be located in the tool holder of a universal lathe.

In this case, the disc-type part must have an axial bore, which allows it to be located and clamped with a very small clearance on a mandrel, located and clamped in turn in the universal chuck of the lathe and in a rotating center located in the tailstock quill. The identification of this solution was presented in a previous paper [33].

A specific aspect of this solution refers to the fact that the measurement of circularity deviations can be performed directly on the lathe on which the external cylindrical surface of the disc-type part was previously made without the need to detach the disc-type part from the universal chuck of the lathe.

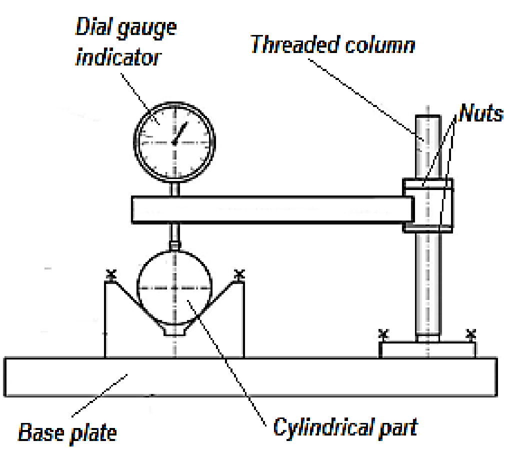

Fig. 1. Schematic representation of a device for measuring the circularity deviation using the locating of the disc part-type in the V-shaped channel of a prism.

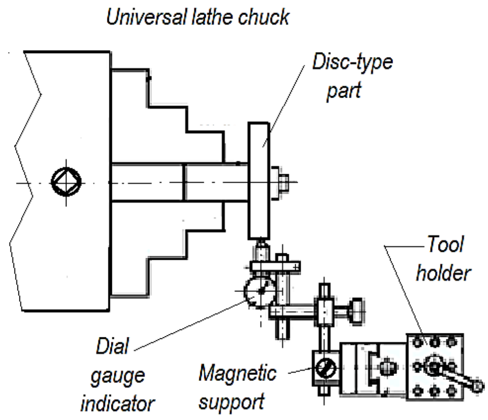

Fig. 2. Schematic representation of a device for measuring the circularity deviation that uses the locating and clamping of the disc-type part on a mandrel located in the universal chuck and the rotating center of a lathe (adapted from [33]).

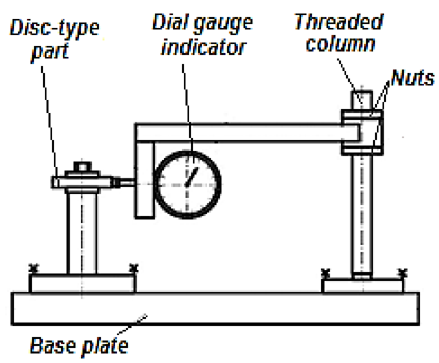

Fig. 3. Schematic representation of a device for measuring the deviation from the circular shape that uses the locating and clamping of the disc-type part on a mandrel whose axis has a vertical position.

Less convenient can be the influence of the measurement results by the values of the clearances in the support bearings of the main shaft of the lathe. It is also necessary that the amount of clearance between the disc-type part and the mandrel on which it is located has a minimum value.

The third alternative that can be used to achieve the proposed objective is the one presented in Fig. 3.

As in the previous case, the disc-type part must have an axial bore for its locating and clamping on a mandrel placed in a vertical position. As the disk-type part rotates, the radial displacement of the dial gauge indicator feeler will allow the reading of values that provide information on the amount of circularity deviation of the cylindrical surface of the disc-type part.

2. USING THE AHP METHOD FOR THE SELECTION OF A DEVICE FOR THE STUDY OF FACTORS ABLE TO INFLUENCE THE MEASURED VALUES OF THE CIRCULARITY DEVIATION

To select one of the three device solutions intended for the development of research on the influence of different factors on the size of the circularity deviation of a disc-type part, the stages corresponding to the AHP method will be used successively.

Thus, the evaluation criteria of the three alternatives considered could be the following:

*C*1: Constructive simplicity; the criterion takes into account the number of parts needed to make the device and the level of complexity of these parts;

*C*2: The ease of purchase or manufacture (manufacturability) of the various components of the device; by including this criterion, the possibilities of manufacturing the device for measuring the circularity deviation of some disc-type parts were taken into account;

*C*3: The level of adaptability to the requirement of developing research on highlighting the influence of different factors on the size of the circularity deviation; as previously mentioned, by designing and manufacturing such a device, the possibility of developing, in the future, an experimental research in the mentioned direction was taken into account;

*C*4: Existence of novelty elements; the inclusion of this criterion was carried out with the aim of identifying innovative solutions for measuring the circularity deviation of disc-type parts and developing experimental research in this regard;

*C*5: Adaptation to some existing equipment in the laboratory; since it was intended to manufacture the device in a workshop that had certain machine tools, it was proposed to research the possibilities of adapting the device to some of the accessible machine tools. This fact could increase the possibility of varying the values of some factors that are capable of influencing the measured values of the circularity deviation.

The three constructive solutions from which the most convenient option is to be selected will be:

*A*1: Device with the locating of the part on a prism provided with a channel showing a V-shaped cross-section; such prisms are in the equipment of some mechanical workshops, being used for the locating and clamping of cylindrical workpieces (Fig. 1);

*A*2: Device with the locating of the part on a mandrel clamped in the universal chuck and the rotating center in the spindle of the lathe tailstock quill (Fig. 2); the possibility of using the device for measuring the circularity deviation of the surface of a disc made by turning on the selected lathe was also taken into account;

*A*3: Device for locating and clamping the part on a vertical mandrel (Fig. 3). It was appreciated that it was possible to use a mandrel on which the disc-type part could be mounted with a small clearance.

For the weighting of the evaluation criteria, Table 1 was developed using the computer program from the web page *https://bpmsg.com/ahp/ahp-calc.php* [30].

The decision matrix, which highlights the results of the comparison of the 5 adopted selection criteria, is presented in Table 2.

To determine the so-called *priority vector*, it is necessary to identify the matrix of normalized relative weights. To this end, one resorts to dividing each element of the decision matrix by the sum of the elements entered in each column of the decision matrix. The matrix of normalized relative weights derived from the initial decision matrix corresponds to Eq.(1):

Table 1

Comparison of the evaluation criteria of the three proposed solutions for the device intended to research the influence of different factors on the size of the deviation from the circularity of some disc-type parts

Line no. 1	**Is *A* more important or *B*?**					**Equality situation**	**How many times is more important**							
2		***A***	**or**		***B***	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Line no. 3 Column no .1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Line no. 4		Simplicity (*C*1)	or		Manufacturability (*C*2)	■								
5		Simplicity (*C*1)	or	■	Research development			■						
6		Simplicity (*C*1)	or	■	Novelty (*C*4)		■							
7	*X*	Simplicity (*C*1)	or		Adaptability (*C*5)		■							
8		Manufacturability (*C*2)	or	■	Research development			■						
9		Manufacturability (*C*2)	or		Novelty (*C*4)	■								
10	X	Manufacturability (*C*2)	or		Adaptability (*C*5)		■							
11	X	Research development (*C*3)	or	■	Novelty (*C*4)			■						
12	X	Research development (*C*3)	or		Adaptability (*C*5)		■							
13		Novelty (*C*4)	or		Adaptability (*C*5)	■								
14	The AHP scale was as follows: 1 – of equal importance; 3 – moderate importance; 5 – great importance; 7 – very important; 9 – extreme importance (values 2, 4, 6, and 8 being intermediate values)													
15	Number of comparisons: 10				Principal eigenvalue: λ_{max} = 5.244									
16	Consistency index *CI* = 0.001247				Consistency ratio *CR* = 5.4									
17	Eigenvector identification: 5 iteration													

Table 2

The decision matrix in the case of evaluation criteria

	*C*1	*C*2	*C*3	*C*4	*C*5
*C*1	1	1.00	0.33	0.50	2.00
*C*2	1.0	1	0.33	1.0	2.00
*C*3	3.00	3.00	1	3.00	2.00
*C*4	2.00	1.00	0.33	1	1.00
*C*5	0.50	0.50	0.50	1.0	1
Sum	7.5	6.5	2.5	6.5	8.0

$$[A]_n = \begin{bmatrix} 0.133 & 0.153 & 0.132 & 0{,}076 & 0.250 \\ 0.133 & 0.153 & 0{,}132 & 0.153 & 0{,}250 \\ 0.400 & 0.461 & 0.400 & 0.461 & 0.250 \\ 0.266 & 0.153 & 0.132 & 0.153 & 0.125 \\ 0.066 & 0.076 & 0.200 & 0.153 & 0.125 \end{bmatrix}. \quad (1)$$

The priority vector is expressed as a column matrix, in which each element is calculated as a sum of the elements of the matrix of normalized relative weights.

The normalized principal eigenvector w will therefore be written in the form of Eq. (2):

$$w = \frac{1}{5}\begin{bmatrix} 0.133 + 0.153 + 0.132 + 0.076 + 0.250 \\ 0.133 + 0.153 + 0.132 + 0.153 + 0.250 \\ 0.400 + 0.461 + 0.4000 + 0.461 + 0.250 \\ 0.266 + 0.153 + 0.132 + 0.153 + 0.125 \\ 0.066 + 0.076 + 0.200 + 0.153 + 0.125 \end{bmatrix} =$$

$$= \frac{1}{5}\begin{bmatrix} 0.668 \\ 0.821 \\ 1.972 \\ 0.829 \\ 0.620 \end{bmatrix} = \begin{bmatrix} 0.133 \\ 0.164 \\ 0.395 \\ 0.165 \\ 0.124 \end{bmatrix}. \quad (2)$$

The main eigenvector, also determined using the specialized software, has the value $\lambda = 5.244$.

The weights and order numbers of the criteria, determined by taking into account the elements of the normalized principal eigenvector, are those mentioned in Table 3.

An additional problem that is taken into account when using the analytic hierarchy process method is that of ensuring *a certain consistency of decisions*. The concept of consistency of decisions takes into account a rational awarding of marks when comparing criteria two by two. Conventionally, a matrix [*A*] is considered to be consistent if $a_{ij}a_{jk}=a_{jk}$, for any values of the indices *i*, *j*, and *k*. On the other hand, there is also a certain risk of there being too much consistency [27].

To solve such a problem, the promoter of the AHP method, professor Saaty, proposed the use of *a so-called consistency index CI*.

The consistency index will be determined as follows:

$$CI = \frac{\lambda_{max}}{n-1} = \frac{5.244 - 5}{4} = 0.061, \quad (3)$$

where λ_{max} is the principal eigenvalue, and *n* is the number of compared elements.

Table 3

Weights and ranks of the criteria

No.	Criterion	Weight	Rank
1	Simplicity (*C*1)	13.3%	4
2	Manufacturability (*C*2)	16.4%	2
3	Research development (*C*3	39.5%	1
4	Novelty (*C*4)	16.5%	3
5	Adaptability (*C*5)	12.4	5

The value of the consistency index *CI* is later used in the definition of *a so-called consistency ratio CR*, which is defined as a ratio between the consistency index *CI* and the random consistency index *RI*.

The random consistency index *RI* can be determined using a reciprocal matrix proposed by Professor Saaty, which takes into account the number of compared elements [26, 30].

It is found that the tabulated value of the average random consistency index for $n = 5$ is $RI = 1.12$.

The consistency ratio will therefore have the value:

$$CR = \frac{CI}{RI} = \frac{0{,}061}{1.12} = 0{,}0544 = 5.44\ \% < \ 10\ \%. \quad (4)$$

Since the value of the consistency ratio is less than 10% of the value of *the average random consistency index*, it is estimated that there is an acceptable consistency of the initial evaluations.

The two-by-two comparison of the 3 device alternatives led to the information included in Table 4. To carry out the two-by-two comparison actions of the considered solutions, the same way of working as that used in the case of the criteria comparison was applied. This meant including the calculation of the principal eigenvalue, the consistency index *CI*, the consistency ratio *CR*, etc.

A synthesis of the results obtained as a consequence of the two-by-two comparison of the alternatives can be seen in Table 5.

The values entered in the penultimate column of Table 5 were determined by taking into account the sum of the multiplication of the weight of each criterion with the weight of each alternative established by using that criterion:

$$A1 = 13.3 \cdot 52 + 16.4 \cdot 40 + 39.5 \cdot 20 + 16.5 \cdot 20 + 12.4 \cdot 25 = 2777 = 27.77\%, \quad (5)$$

$$A2 = 13.3 \cdot 16 + 16.4 \cdot 20 + 39.5 \cdot 60 + 16.5 \cdot 60 + 12.4 \cdot 50 = 4520 = 45.20\%, \quad (6)$$

$$A3 = 13.3 \cdot 28 + 16.4 \cdot 40 + 39.5 \cdot 20 + 16.5 \cdot 20 + 12.4 \cdot 25 = 2458 = 24.58\ \%. \quad (7)$$

The analysis of the results obtained using the Eqs. (5)–(7) and entered in the last column of Table 5 highlights the fact that the most convenient device solution, determined by using the previously mentioned evaluation criteria, is solution no. 2.

7. CONCLUSIONS

The amount of circularity deviation can be important in the case of disc-type parts. The design of devices that allow measuring the values of circularity deviations has been a concern for researchers in the field of machine building. There is a requirement to investigate the influence exerted by different factors on the measured size of the circularity deviation in the case of some disc-type parts. Three solutions of devices usable for this purpose have been designed. Various methods of optimal selection of an alternative among several available most convenient device solution for measuring the alternatives can be used in this direction. To select the deviation from the circularity of some disc-type parts, 5 evaluation criteria were proposed.

Table 4

The results of the two-by-two comparison of the 3 available alternatives by using each of the proposed evaluation criteria (values determined using the reference [30])

Criterion *C*1 (Simplicity)					
Alternativa	***A1***	***A2***	***A3***	**Priority**	**Rank**
A1	1	3.00	2.0	52%	1
A2	0.33	1	0.5	16%	3
A3	0.5	2.0	1	28%	2
Number of comparisons: 3				Principal eigenvalue λ_{max} = 3.009	
Delta = 9.9E-9				Consistency ratio *CR*=1,0 %	
Criterion *C*2 (Manufacturability)					
Alternative	***A1***	***A2***	***A3***	**Priority**	**Rank**
A1	1	2.0	1.0	40.0%	1–2
A2	0.50	1	0.50	20.0%	3
A3	1.00	2.00	1	40.0%	1–2
Number of comparisons: 3				Principal eigenvalue λ_{max} = 3.000	
Delta = 0.0E+0				Consistency ratio CR = 0.0 %	
Criterion *C*3 (Research development)					
Alternative	***A1***	***A2***	***A3***	**Priority**	**Rank**
A1	1	0.33	1.00	20.0%	2–3
A2	3.00	1	3.00	60.0%	1
A3	1.00	0.33	1	20.0%	2–3
Number of comparisons: 3				Principal eigenvalue λ_{max}=3.000	
Delta = 6.2E-33				Consistency ratio CR=0.0 %	
Criterion *C*4 (Novelty)					
Alternative	***A1***	***A2***	***A3***	**Priority**	**Rank**
A1	1	0.33	1.00	20.0%	2–3
A2	3.00	1	3.00	60.0%	1
A3	1.00	0.33	1	20.0%	2–3
Number of comparisons: 3				Principal eigenvalue λ_{max}=3.00	
Delta = 6.2E-33				Consistency ratio CR=0.0 %	
Criterion *C*5 (Adaptability)					
Alternative	***A1***	***A2***	***A3***	**Priority**	**Rank**
A1	1	0.50	1.00	25.0%	2–3
A2	2.00	1	2.00	50.0%	1
A3	1.00	0.50	1	25.0%	2–3
Number of comparisons: 3				Principal eigenvalue λ_{max} = 3.00	
Delta = 0.0E+0				Consistency ratio CR = 0.0%	

Table 5

Evaluating different alternatives by considering each criterion

Criterion	***C*1**	***C*2**	***C*3**	***C*4**	***C*5**	**General composite weight**	**Rank**
Criterion weight **Alternative**	**0. 181**	**0. 149**	**0.123**	**0.457**	**0.091**		
***A*1**	52	40	20	20	25	27.77 %	2
***A*2**	16	20	60	60	50	45.20 %	1
***A*3**	28	40	20	20	25	24.58 %	3
Sum	100 %	100 %	100 %	100 %	100 %	97.55%	

Later, by using the analytic hierarchy process method, the variant that fulfills the proposed criteria to the maximum extent was selected. Applying the method of the analytic hierarchy process involves first identifying and weighting some selection criteria. Afterwards, there is also a comparison of the identified solutions two by two, by considering each criterion. A composite index that takes into account the weight of each of the criteria applied and the evaluation of each of the alternatives by means of each of the previously established criteria allows the elaboration of an ordering of the available alternatives. In this way, a variant of the device was selected to ensure conditions for the further development of research on the influence exerted by different factors on the measured values of the circularity deviation. The selected device variant can be used on a universal lathe. In the future, the practical manufacture and experimentation of the constructive solution selected by the device will be considered in order to highlight the influence exerted by different factors on the measured values of the circularity deviation of the disc-type parts.

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