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Influence of the Applied Measurement Methodology on the Results of Geometric Measurements of the SB4 Spring Clips

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Summary
The article presents the results of measurements of the "b" dimension of the SB4 spring clips carried out using three measurement methods that differ in the method and width of the base plate contact. The results obtained are presented and the uncertainty of measurement for each method is estimated. Attention was paid to the issues of the obtained dispersion of the value of the "b" dimension. The tolerated dimensions are discussed. The proposed measurement methods can help to identify shape mismatches of spring clips.

Keywords: rail fastening, spring clip, dimensional measurements, clamping force

1. Introduction

The concept of SB3 spring clip fastening used exclusively on pre-stressed concrete sleepers was developed in 1979 at the Railway Scientific and Technical Centre (now the Railway Research Institute). Its modifications and development are described in articles by A. Oczykowski [2, 3]. The main advantages of such fastening are the ease of installation, absorption of vibrations from the rolling stock and electrical isolation limiting traction stray currents.

One component of such a fastening system are spring clips. Quality control of workmanship and performance of the spring clips is performed in accordance with the existing guidelines of the Construction and Commissioning Requirements according to Id-109 Technical Conditions [6]. The geometrical aspects related to the quality of the manufactured spring clips have already been described in earlier studies by the authors [4, 5]. Some researchers [1], dealing with the geometric shape of spring clips, have proposed methods for measuring clips using an optical scanner and special software for dimensional quality control. However, the Construction and Commissioning guidelines according to Id-109 Technical Conditions [6] for the measurement of spring clips, which also include their acceptance criteria, assume direct measurements with workshop tools and gauges. However, these guidelines do not include a precise description of the measurement methodology, e.g.: baseline, which is in fact quite problematic and may provide many doubts about the results obtained.

2. Geometrical aspects of the actual products

SB4 spring clips are usually manufactured by hot forming. In the first stage of the process, sections are cut from the steel rod, which are heated to a temperature of approximately 1,000°C and then given a target shape. The next stage is hardening, followed by medium tempering at around 400–450°C and the application of a corrosion protection coating. Spring clips do not undergo any finishing treatment that could be considered as precise.

Because of this manufacturing process, the shapes of actual products can deviate from perfect symmetry and it can be a challenge for the manufacturer to maintain dimensional accuracy. Of course, if the dimensions remain within the guidelines, this is not a problem. However, it also proves problematic to obtain the correct measurement result as even a slight asymmetry in the product can make it difficult to decide on its final value.

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When checking the quality of the clips for compliance with the requirements, the following dimensions are evaluated: “a”, “b”, “e” and “f”. These are shown in Figure 1 together with the radii for bending the rod into spatial and tangential curves, which are also tolerated dimensions, although they are not included in the test protocol constituting Annex 6 to the Construction and Commissioning Requirements according to Id-109 Technical Conditions [6]. While dimensions “a”, “e” and “f” usually do not pose a great challenge to the manufacturer, dimension “b” sometimes does not meet the dimensional requirements. It is worth noting that dimension “b” is a certain resultant of dimension “e” and the radii of the curves “R1” and “R2”. In addition, clips often have asymmetrical tips. Sometimes this is due to the oval shape of the clip tips created when the rod is cut to a certain length, sometimes to the twist of the tips. Whatever the reason, these inconsistencies often result in the need to measure two dimensions “b”, relative to each of the two tips of the clips.

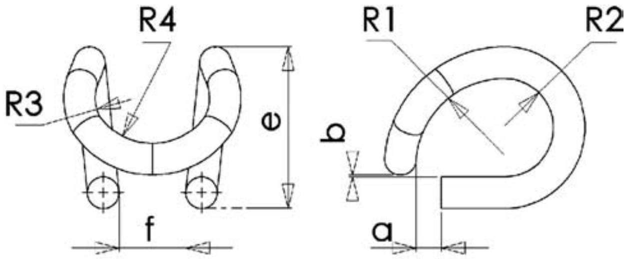

Fig. 1. Tolerable dimensions of the SB4 spring clip [Fig. A. Aniszewicz]

The nominal values of the measured dimensions of SB4 spring clips according to Construction and Commissioning Requirements [6] are as shown in Table 1.

Table 1
The nominal values of monitored dimensions of SB4 spring clips according to the requirements of PKP PLK S.A. WTWiO [6]

The nominal values of SB4 spring clips according to the requirements of PKP PLK S.A. [mm]			
a	**b**	**e**	**f**
13^{+2}	1± 0.5	82 ± 2	34 ± 1

The author’s study based on [6].

3. Measurements methods

According to the guidelines, all measurements were made with workshop tools and gauges. Radii of curves are not among the dimensions monitored probably because of the difficulty of making such a measurement. When measuring dimension “b” we usually get two values, a maximum and a minimum, which are different for both tips of the clips. It is customary to take the mean from these dimensions to obtain one result for the “b” dimension. In extreme cases, the difference in value between the two tips may significantly exceed 0.5 mm, which exceeds the tolerance for this dimension.

Three approaches were used to observe measurement issues during the tests, which differ in the way they were based. These approaches signal that, depending on the methodology chosen, measurement can represent a different value. During the measurement, base plates of different widths were used to immobilise the clip relative to the plane so that the measurement could be performed. The base plates used were 35 mm, 23.5 mm and 20 mm wide. Schematic diagrams of how to perform the measurement, including the positioning of the base plates, are shown in Figures 2, 3 and 4. Depending on the base plate width used, the methods were assigned the symbols A, B or C.

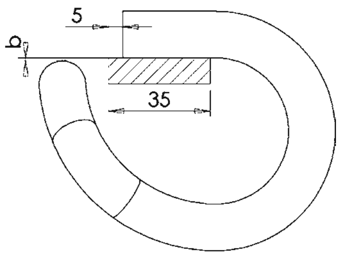

Fig. 2. Dimension “b” of the SB4 spring clip measured with a base plate 30 mm wide (method A) [Fig. A. Aniszewicz]

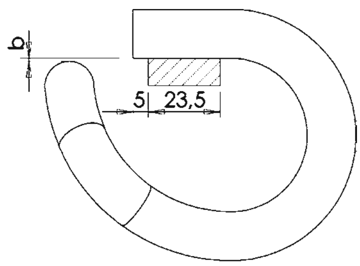

Fig. 3. Dimension “b” of the SB4 spring clip measured with a base plate 23.5 mm wide and 5 mm from the end (method B) [Fig. A. Aniszewicz]

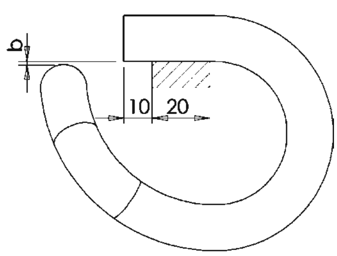

Fig. 4. Dimension “b” of the SB4 spring clip measured with a base plate 20 mm wide and 10 mm distance from the end (method C) [Fig. A. Aniszewicz]

A list of the measurement results depending on the baseline method used is shown in Table 2.

Table 2

Measurement results of parameter "b" depending on the applied baseline method

Clip No	Value of the „b" parameter [mm].					
	A method		B method		C method	
	min.	max.	min.	max.	min.	max.
1	−0.46	−0.94	−0.40	−0.67	−0.18	−0.18
2	0.73	1.20	1.10	1.46	0.96	1.41
3	−1.75	−0.81	−1.29	−0.39	−1.61	−0.68
4	0.36	1.11	0.81	1.49	0.69	1.26
5	0.60	0.81	0.44	1.00	0.85	0.85
6	0.70	0.70	0.85	0.90	0.60	0.90
7	−0.85	−0.65	−0.69	−0.53	−0.72	−0.64
8	0.95	1.20	1.50	1.60	1.00	1.45

[Author's study].

4. Description of results, calculation of uncertainty and discussion

The measurement results shown in Table 2 vary depending on the method used. The clips that do not meet the dimensional requirements are numbered 1, 3 and 7. The remaining clips, after taking the mean of the measurements for each method, can be considered as meeting the acceptance criteria. However, in the case of samples 4 and 5, it should be noted that the results can be considered questionable. For sample 4 the value of the minimum result is outside the tolerance range for the A method, and for sample 5 when measured by the B method.

It is worth considering measurement uncertainty. For this purpose, the measurement for clip 4 was analysed (Table 3). For each method, dimension "b" was obtained as the mean result of thirty measurements taken for both tips of the clip. The results obtained can be described as a minimum and maximum result, which essentially refers to the base, i.e. tight adhesion to the base plate of one of the two free tips of the shaped clip rod (one of the two tips of the clip). Finally, a mean was drawn from these results, and the difference between the readings for both tips is a measure of the asymmetry of the clip, the cause of which may be, for example: vertical twist of the free tips of the shaped rod of the clip. The uncertainty, which is the standard deviation of the 30 measurement points, is calculated for minimum, maximum and mean values for all measurement methods A, B and C. Uncertainty, as estimated by the standard deviation of 60 measurement points, was also calculated, i.e. the combined results for both tips of the clips. The results of the calculations are summarised in Table 3.

Table 3

Uncertainties in determining the value of dimension "b" calculated for the SB4 clip No. 4

Parameter	Determined standard deviation [mm]								
	A method			B method			C method		
	min.	max.	mean	min.	max.	mean	min.	max.	mean
Mean from 30 measurement points	0.36	1.11	0.74	0.81	1.49	1.15	0.69	1.26	0.98
Standard deviation from 30 measurement points	0.010	0.011	0.008	0.008	0.011	0.008	0.013	0.012	0.007
Standard deviation from 60 measurement points	0.377			0.343			0.290		

[Author's study].

The uncertainty, of which the standard deviation is an estimate, for the minimum and maximum values is 30 times smaller than the standard deviation calculated from 60 measurements. The difference is significant and it is important to be aware of it, although similar measurement dilemmas can apply to a great number of other products.

The question arises as to whether any of the measurement methods should be privileged. From the point of view of the positioning of the clip in the cast iron anchor, it is possible to see the greatest similarity in the positioning of the clip in measurements with methods A and B (largest contact area). However, the clip is inserted into the anchor by placing one tip (right) into it first. The other tip is placed in the anchor in the final stage of fastening. For installation reasons, the geometric shape of the first inserted clip tip can be considered decisive for the positioning of the entire clip in the anchor. Very often the asymmetry of the clip tips can be observed during the installation of the clips in the anchor – after inserting the first clip tip, the second clip tip often needs to be hammered in. For this reason, it may be justified to measure "b" based only on the tip with which the foot is installed in the anchor.

On the other hand, the clip may represent different types of geometric inconsistencies, which can be monitored by observing the results obtained by different measurement methods. The differences in the values of the measurement results, presented in Table 2, show that it is most likely that the radii of the curves, which are not required to be checked according to the guidelines, have a great effect on the problems occurring when measuring dimension "b". Observations of the impact of the measurement methodology applied on the final measurement result are useful if they are performed to classify and localise geometric inconsistencies.

It is definitely not a good approach to make the choice of measurement methodology dependent on the type of nonconformity, as a given batch of clips may contain different types of geometric nonconformity. Therefore, the most important approach should be to adopt a single reference point, i.e. to perform the measurement according to one chosen methodology. The results obtained in this way will then be consistent, although they will give us less information about the whole geometry of the clip.

Quite an important issue is the question of how to monitor dimension "b", which should be within the tolerance range < 0.5 ÷ 1.5 > mm [6]. This is a small range of values considering that deformation can occur during heat treatment. The issues surrounding uncertainty have been described previously, and there are two more provisions in the guidelines that may cause additional confusion: (…) 3.2.1.1. *Impact marks on the clip /spring/ – deformation from the actual rod outline – from shaping tools, with a depth of no more than 0.50 mm, are permissible.* (…); (…) 3.2.1.3. Fractures, sharp hollows, cracks and tears deeper than 0.3 mm and other material defects visible to the naked eye are unacceptable (...).

However, dimension "b" is precisely the one responsible for the main task of the clip, i.e. pressing the rail against the sleeper. This function is checked only by the dimensional aspect, since the test of the clamping force provided for in the guidelines is implemented in a way that excludes its association with dimension "b" [5]. Therefore, monitoring this dimension is necessary, however, it is worth considering the verification of the range in which the correct result should fall, while taking into account all doubts so that all entries become consistent.

5. Conclusions

The title of the article states that the methodology used to measure clips affects the measurement results obtained. Table 2 shows the results supporting this thesis. These differences may sometimes appear small, but in the case shown in Table 3 the extreme values for the mean values of the measurements obtained by the A and B methods differed by more than 55%. The procedures associated with the execution of tests and measurements should be sufficiently unambiguous to leave no doubt as to the value of the result. This is an important issue not only for the body making the measurements, but also for the manufacturer who, in the case of receiving a negative product assessment, is forced to implement actions modifying the production process. This often involves high costs. On the other hand, during the execution of tests sometimes the only indicator of non-conformity is when the dimensional tolerance for dimension "b" is exceeded. The following conclusions can be drawn from the tests performed:

1. The use of different baseline methods provides greater opportunities to identify and locate geometric inconsistencies in the clips.
2. A uniform measurement methodology, which assumes a uniform baseline, should be used to test a given batch of clips, with the guidelines being supplemented by the proposal of one well-defined baseline.
3. The acceptance ranges for dimension ,b' should be reviewed. On the basis of the tests performed at the Railway Research Institute, the extent of this verification cannot be clearly assessed. It is therefore appropriate to conduct further research in this direction.

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