

# Fuzzy Comprehensive Evaluation of Shoes Comfort Based on Last

Wenli Peng<sup>1,\*</sup>, Lei Lu<sup>2</sup>, Yaping Yang<sup>1</sup>

<sup>1</sup> College of Electro-mechanics Engineering, Jiaxing University, Jiaxing 314001, Zhejiang, P. R. China

<sup>2</sup> Department of Light Industrial, Zhejiang Industry & Polytechnic, Wenzhou, 325003, Zhejiang, P.R. China

**Abstract:** With the people's request on the comfort of the shoe advancing continuously, how to judge the comfort of the shoe on the last becomes more and more important. The fuzzy comprehensive evaluation was used to judge the comfort of the footwear on the shoe last. It was the first time that the comfort of the footwear was judged qualitatively and quantitatively. The factors influencing the comfort of the shoe on the last were analyzed. On the basis of this, the qualitative analysis and quantitative analysis were combined to put forward the way of fuzzy comprehensive evaluation, adopting fuzzy theory and fuzzy thought. At last, the lady pump shoes were taken as an example to demonstrate the practicality of the method.

**Key words:** shoe last; comfort of the footwear; fuzzy comprehensive evaluation

## 1 Introduction

In recent years, with people's request on the quality of life advancing continuously, the comfort of the shoes are paid to more and more attention and even above fashion to be popularity. Thus, how to judge the comfort of the shoes accurately becomes more and more important. There are a lot of factors affecting the comfort of the shoes, containing the physiological feelings and the psychological feelings. Based on the physiological feeling, the comfort of the shoe on the last was judged quantitatively by using the fuzzy comprehensive evaluation in this paper.

## 2 Factors affecting the comfort of the shoes on the last

Shoe last is the matrix and the soul of footwear, which means that the comfort of a pair of shoes is mainly decided by the shoe last. And the factors affecting the comfort of the shoes on the last mostly include the following seven aspects:

(1) Toe spring: the toe spring of the shoe last is based on the natural spring of human's foot with some change according to the style and the structure of the footwear, which is the spring height of the front of the shoe last. If the toe spring is too low, the front of the shoes will be fretted early, and the upper of the shoes will pleat and abrade feet; if the toe spring is too high, the ball protruding of the last will be too big to affect the comfort the shoes, and even bring on the collapse of the horizontal arch.

(2) Toe height: the toe height denotes the height of the hallux on the last. If the toe height of the last is too small, the feet will be squeezed by the shoes made according to the last, especially the leather shoes with hard toe box.

(3) Ball girth: the ball joint is the key area of bending when walking, and at the same time it support the load of people's weight and activities. Therefore, the ball girth is one of the most important factors affecting the comfort of the shoes. If the ball girth is too big, the feet will move in the shoes, which is not good for walking; and if the ball girth is too small, the feet will be squeezed by the shoes.

(4) Basic Width: the basic width means the inner width of the first metatarsus plus the outer width

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\* Corresponding author. Phone: +86-(0)573-83647635. E-mail: [peng\\_wenli@163.com](mailto:peng_wenli@163.com); Project Number:08JK230

of the fifth metatarsus. Once the ball girth was fixed, the shoes would be flat and wide when the basic width was too big, which should bring on the deformation of the shoes and affect the comfort of shoes because of the feet's moving in the shoes; contrarily, if the basic width is too small with the ball girth fixed, the shoes will be narrow and thick. Because the first and the fifth metatarsus are made of many bones and less muscle, and the load of people's weight and activities is mainly support by them, which can be compressed less, the shoes will pinch feet and affect comfort if the basic width of the shoe last is too narrow.

(5) Instep girth: the instep girth has great effect on the comfort of the shoes. If the instep girth is too big, the feet will move forward, because the shoes can't support the arch of the feet greatly and hold the feet perfectly; if the instep girth is too small, the shoes will squeeze the instep.

(6) Heel girth: the heel girth is an important dimension when designing boots. Too small heel girth will bring on difficulties when putting on or off the boots; by contraries, if the heel girth is too big, it will be easy to put on or off the boots, but the feet can't be hold perfectly by the boots.

(7) Back curve: the last should have the back curve because of the shape of the feet, and the back curve of the last is mostly tally with the feet's. The main controlling factors of the back curve are the back break-point arc and back tolerance. If the back tolerance is too small, the shoes will abrade feet; if the back tolerance is too big, the shoes will not hold the ankle perfectly and be easy to collapse.

### 3 Setting up the mathematic model of fuzzy comprehensive evaluation

Fuzzy Comprehensive Evaluation refers to do overall evaluation of some thing or phenomena affected by a variety of factors, which involve the fuzzy factors. It is also known as the comprehensive evaluation. The processes of the fuzzy comprehensive evaluation are as follows:

#### (1) Setting up the factors set

The factors set can be got on the basis of the factors affecting the comfort of the shoes on last.  $T = \{T_1, T_2, T_3, T_4, T_5, T_6, T_7\} = \{\text{toe spring, toe height, ball girth, basic width, instep girth, heel girth, back curve}\}$ .

#### (2) Establish weighing set

Establish the weighing set according to the ponderance of each factor.

$$A = (a_1, a_2, a_3, a_4, a_5, a_6, a_7)$$

$a_i (i=1,2,3...7)$  is the weighing of  $T_i$ , and  $\sum_{i=1}^{i=7} a_i = 1$

The weighing set varies when the style of the shoes changes. For example, the factors  $T_6$  is only used in boots, the weighing of which can be set to be 0 when evaluating other footwear product. As for the sandals, there are even less factors which should be used.

#### (3) Setting up the evaluation set

Different evaluation set can be established in different situation, and usually the simplest evaluation can be set as follow:

$$C = \{C_1, C_2\} = \{\text{comfortable, uncomfortable}\}$$

#### (4) Obtaining the evaluation results

The simplest and most effective way to test the comfort performance of a pair of shoes is trying on. Therefore, the evaluation results needed in the fuzzy comprehensive evaluation were also obtained by the method of trying on in this approach. Before the test of trying on, the trying on evaluation form should be designed according to the factors listed in the factors set, as shown in table 1. Pay attention to use the easily understanding words for the tested people when designing the evaluation rules of the table. The

number of the people who will try on the shoes can be decided according to the actual situation. The evaluation results would be got by the trying on evaluation table, and some of the uncomfortable results include two possibilities.

**Tab.1 Evaluation of Trying On the Footwear**

Num.	Name	Feet Length	Ball Girth	Trying On Shoe Number
Evaluation Rule	Toe Spring	Too High ( )	Comfortable ( )	Too Low ( )
	Toe Height	Squeeze Toes ( )		Comfortable ( )
	Ball Girth	Squeeze Feet ( )	Comfortable ( )	Too Much Space ( )
	Basic Width	Pinch Feet ( )	Comfortable ( )	Feet Move Around ( )
	Instep Girth	Squeeze Instep ( )	Comfortable ( )	Feet Move Forward ( )
	Heel Girth	Hard to Put off ( )	Comfortable ( )	Can'T Hold Feet ( )
	Back Curve	Abrade Feet ( )	Comfortable ( )	Can'T Hold Feet ( )

So, the evaluation matrix can be got as follow:

$$R = \begin{bmatrix} r_{11} & r_{12} \\ r_{21} & r_{22} \\ r_{31} & r_{32} \\ r_{41} & r_{42} \\ r_{51} & r_{52} \\ r_{61} & r_{62} \\ r_{71} & r_{72} \end{bmatrix}$$

(5) Fuzzy comprehensive evaluation

The result of the fuzzy comprehensive evaluation is shown as follow:

$$B = A \bullet R$$

#### 4 Emulational numerical value

For example: the lady pump shoes were tryed on by 100 people to evaluate the comfort on the shoe last.

(1) Selecting factoes set

Because for the lady pump shoes the instep girth and heel girth should not be think of, so the factors set was:

$$T = \{T_1, T_2, T_3, T_4, T_5\} = \{\text{toe spring, toe height, ball girth, basic width, back curve}\}$$

(2) Setting up the weighing set

The value of the weighing was set according to the import of the factors. For the lady pump shoes, the most important factors are ball girth, basic width and back curve. The lady pump shoes are usually designed with higher heels, which would cause most load is concentrated on the metatarsal joint, so suitable ball girth and basic width are important. in addition, the instep of the lady pump shoes is open, which would bring on the loose of the shoes, which can be remedied by a good back curve. Therefore, the

weighing set was set as follows:

$$A = (0.1, 0.1, 0.2, 0.3, 0.3)$$

(3) Trying on experiment

100 people did the trying on experiment, who would fill in the table of evaluation of trying on the lady pump shoes (shown as table 2) after trying on.

**Tab.2 Evaluation of Trying On the Lady Pump Shoes**

Num.	Name	Feet Length	Ball Girth	Trying On Shoe Number
Evaluation Rule	Toe Spring	Too High ( )	Comfortable ( )	Too Low ( )
	Toe Height	Squeeze Toes ( )		Comfortable ( )
	Ball Girth	Squeeze Feet ( )	Comfortable ( )	Too Much Space ( )
	Basic Width	Pinch Feet ( )	Comfortable ( )	Feet Move Around ( )
	Back Curve	Abrade Feet ( )	Comfortable ( )	Can'T Hold Feet ( )

The statistic result of trying on the lady pump shoes were shown as table 3:

**Tab.3 Result of Trying On the Lady Pump Shoes**

Evaluation Rule	Proportion Distributing	Results
Toe Spring	Too High 3%	
	Comfortable 89%	Comfortable 89%
	Too Low 8%	Uncomfortable 11%
Toe Height	Squeeze Toes 23%	Comfortable 77%
	Comfortable 77%	Uncomfortable 23%
	Squeeze Feet 32%	
Ball Girth	Comfortable 47%	Comfortable 47%
	Too Much Space 21%	Uncomfortable 53%
	Pinch Fee 33%	
Basic Width	Comfortable 39%	Comfortable 39%
	Feet Move Around 28%	Uncomfortable 61%
	Abrade Feet 11%	
Back Curve	Comfortable 68%	Comfortable 68%
	Can'T Hold Feet 21%	Uncomfortable 32%

The evaluation matrix could be obtained by the statistic result.

$$R = \begin{bmatrix} 0.89 & 0.11 \\ 0.77 & 0.23 \\ 0.47 & 0.53 \\ 0.39 & 0.61 \\ 0.68 & 0.32 \end{bmatrix}$$

The final evaluation result was gained.

$$B = A \bullet R = \begin{bmatrix} 0.1 & 0.1 & 0.2 & 0.3 & 0.3 \end{bmatrix} \bullet \begin{bmatrix} 0.89 & 0.11 \\ 0.77 & 0.23 \\ 0.47 & 0.53 \\ 0.39 & 0.61 \\ 0.68 & 0.32 \end{bmatrix}$$

$$= (0.581, 0.435)$$

Normalized data

$$\approx (0.572, 0.428)$$

In accordance with the principle of maximum membership degree, the lady pump shoes were comfortable on the last. Nevertheless, the proportion of uncomfortable was not low, so the comfort should be improved by the producer, in order to meet the consumer's pursuit of high-quality products.

## 5 Conclusion

This many a day, the comfort of the shoes was evaluated in a fuzzy way, based on which the fuzzy comprehensive evaluation was brought in to evaluating the comfort of the shoes on the last in this paper. The evaluation of the comfort of the shoes on the last become exacter and easier in the way of combining the qualitative and quantitative methods instead of just qualitative evaluation. When obtaining the evaluation result, the way of filling in the evaluation table was be adopted in this paper, which helped to do the follow-up amelioration. The producer can make the appropriate changes according to the results.

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