Available online at www.sciencedirect.com
ScienceDirect
Procedia Engineering 150 (2016) 959 – 962
Procedia Engineering
www.elsevier.com/locate/procedia

International Conference on Industrial Engineering, ICIE 2016

Probabilistic Calculation of Tolerances of the Dimension Chain Based on the Floyd-Warshall Algorithm

A.V. Muholzoev[a], V.B. Masyagin[a,b,*]

[a] *National Research Tomsk Polytechnic University, Lenina 30, Tomsk 634050, Russia*
[b] *Omsk State Technical University, Mira 11, Omsk 644050, Russia*

Abstract

The tolerance analysis of the technological processes in mechanical engineering is a time-consuming task requiring automation. Development of an algorithm to identify individual dimension chains makes this task even more difficult. Based upon this, one must create an algorithm to avoid the difficulties of the algorithmization procedure. An approach to the calculation of the probability of closing tolerance units is based on the Floyd-Warshall algorithm – a classical algorithm of the graph theory, which calculates the length of the paths in the graph by adding the lengths of the links in pairs. The algorithm allows calculation without identifying individual dimension chains solving the entire structure of the complex. This approach can significantly simplify the implementation of the computer-aided calculation of dimensional circuits.

Peer-review under responsibility of the organizing committee of ICIE 2016

Keywords: tolerance analysis; algorithm engineering technology; automation; probabilistic method.

1. Intorduction

Construction of dimensional chains in the form of the graph and adjacency matrices allows us to represent the dimensional structure in a simple form, easy to calculate and store the data in the computer memory. It is possible to find a set of solutions for the automation of time-consuming procedures such as analysis of dimensional structures [1-3]. This representation opens the possibility to use of a wide mathematical tools in the calculation. One such tool is the algorithm of Floyd-Warshall [4].

* Corresponding author. Tel.: +7-923-764-34-18; fax: +7-3812-652-698.
E-mail address: masaginvb@mail.ru

Peer-review under responsibility of the organizing committee of ICIE 2016
doi:10.1016/j.proeng.2016.07.070

The advantages of the algorithm are:
1. the absence of special requirements of the order of drawing up and of preparation of input data – the numbering of surfaces is arbitrary, only compliance with the standard conditions is required: the number of constituent units of dimensional chain is one less than the number of surfaces;
2. each computation is performed by adding the two terms;
3. it does not require identification of the individual dimension chains [5].

It remains an open question about the calculation method of partial interchangeability. Method of probabilistic calculation of tolerances require to finding of the vector sum of all the parts of the circuit components in a complex and largely the result depends on the number of constituent units of dimensional chain. At the same time, the algorithm does not provide separate data for individual dimensional chain and each calculation is made by adding only two terms, making difficult the method of probabilistic calculation of tolerances. Thus, a calculation is possible if the equality is true (1):

$$\sqrt{x_1^2 + x_2^2 + x_3^2} = \sqrt{\sqrt{x_1^2 + x_2^2} + x_3^2} \tag{1}$$

It is obvious that the expression (1) is true, and hence Floyd–Warshall algorithm may be applied for calculating the probabilistic method.

2. Description of the algorithm

Consider the application of the algorithm on an example of the calculation of tolerances of the dimension chain (Fig. 1). It is obvious that the expression (1) is true, and hence Floyd–Warshall algorithm may be applied for calculating the probabilistic method.

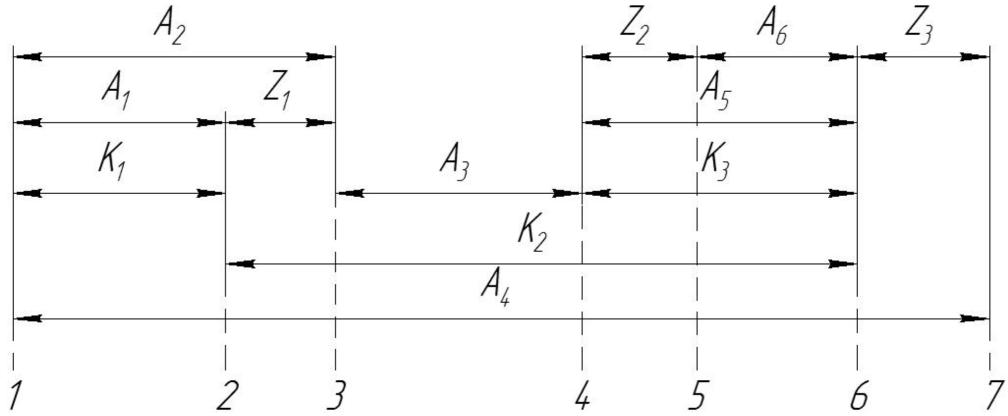

Fig. 1. Dimensional chain.

Assign technological tolerances: TA1 = 0.05, TA2 = 0.3, TA3 = 0.1, TA4 = 0.5, TA5 = 0.01, TA6 = 0.2.

We will form an adjacency matrix of tolerances (Fig. 2 a, b).

Step 1. In line i find a cell that is not zero, we can write its address as $a_{i,j}$, where j – column number of the cell. In the example (Fig. 3a) is selected cell $a_{1,2}$; selected cell $a_{1,2}$ is not zero.

Step 2. In the column j are looking for a cell that is not zero, we can write its address as $a_{k,j}$, where k – line number of the cell. If not, then repeat from step 1. In the example (Fig. 3b) found cells is $a_{1,3}$ and $a_{4,3}$; selected cell $a_{4,3}$ is not zero.

Step 3. If the cell address $a_{i,k}$ has a value that is greater than the sum of the values of the cells $a_{i,j}$ and $a_{k,j}$ or the cell is empty, then write to the expression (2).

$$a_{j,k} = \sqrt{a_{k,j}^2 + a_{i,j}^2} \tag{2}$$

a

	1	2	3	4	5	6	7
1		$A_1=K_1$	A_2				A_4
2	$A_1=K_1$		Z_1			K_2	
3	A_2	Z_1		A_3			
4			A_3		Z_2	$A_5=K_3$	
5				Z_2		A_6	
6		K_2		$A_5=K_3$	A_6		Z_3
7	A_4					Z_3	

b

	1	2	3	4	5	6	7
1	0	0.05	0.3				0.5
2	0.05	0	Z_1			K_2	
3	0.3	Z_1	0	0.1			
4			0.1	0	Z_2	0.01	
5				Z_2	0	0.2	
6		K_2		0.01	0.2	0	Z_3
7	0.5					Z_3	0

Fig. 2. (a) matrix of tolerances with tolerance symbols; (b) matrix of tolerances with numerical values of tolerances.

a

	1	2	3	4	5	6	7
1	0	$\boxed{0.05}$	0.3				0.5
2	0.05	0	Z_1			K_2	
3	0.3	Z_1	0	0.1			
4			0.1	0	Z_2	0.01	
5				Z_2	0	0.2	
6		K_2		0.01	0.2	0	Z_3
7	0.5					Z_3	0

b

	1	2	3	4	5	6	7
1	0	0.05	$\boxed{0.3}$				0.5
2	0.05	0	Z_1			K_2	
3	0.3	Z_1	0	0.1			
4			$\boxed{0.1}$	0	Z_2	0.01	
5				Z_2	0	0.2	
6		K_2		0.01	0.2	0	Z_3
7	0.5					Z_3	0

Fig. 3. (a) matrix of tolerances – Step1; (b) matrix of tolerances – Step 2.

Values $a_{1,3}$ and $a_{4,3}$ cell substitute in the formula (2) (Fig. 4a). Result of the expression (3) is written into the cell $a_{1,4}$.

$$a_{1,4} = \sqrt{a_{1,3}^2 + a_{4,3}^2} = \sqrt{0.3^2 + 0.1^2} = 0.316 \tag{3}$$

Step 4. Cells with location when $i = j$ is not calculated.

Step 5. Repeat the cycle with step 1, is in the matrix does not remain empty cells. The cycle is repeated as long as the cell values do not stop changing. This point of the algorithm is presented for the selection of the shortest paths between the surfaces. (Fig. 4b). Matrix filled.

a

	1	2	3	4	5	6	7
1	0	0.05	0.3	$\boxed{0.316}$			0.5
2	0.05	0	Z_1			K_2	
3	0.3	Z_1	0	0.1			
4			0.1	0	Z_2	0.01	
5				Z_2	0	0.2	
6		K_2		0.01	0.2	0	Z_3
7	0.5					Z_3	0

b

	1	2	3	4	5	6	7
1	0	K_1 = 0.05	0.3	0.316	0.374	0.316	0.5
2	K_1 = 0.05	0	Z_1= 0.304	0.32	0.377	K_2= 0.32	0.502
3	0.3	Z_1= 0.304	0	0.1	0.224	0.1	0.583
4	0.316	0.32	0.1	0	Z_2= 0.2	K_3 = 0.01	0.59
5	0.374	0.377	0.224	Z_2= 0.2	0	0.2	0.62
6	0.316	K_2= 0.32	0.1	K_3 = 0.01	0.2	0	Z_3= 0.59
7	0.5	0.502	0.583	0.59	0.62	Z_3= 0.59	0

Fig. 4. (a) matrix of tolerances – Step 3; (b) matrix of tolerances – Step 5.

Since the trailing dimensions disposed between respective surfaces (Fig. 4b):

K1 – between the surfaces 1 and 2, the value of its tolerance: TK1 = $a_{1,2}$ = 0.05;

K2 – between the surfaces 2 and 6, the value of its tolerance: TK2 = $a_{2,6}$ = 0.32;

K3 – surfaces between 4 and 6, the value of its tolerance: TK3 = $a_{4,6}$ = 0.01.

Acknowledgements

This mathematical model allows us to create a simple and efficient algorithm to calculate tolerances of technological dimension chains in a probabilistic manner.

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