STUDY ON THE ELABORATION OF AN OPTIMIZATION PROGRAM FOR DIMENSION CHAINS

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Abstract: The technical and economic aspects of solving dimension chains have been and still are a very difficult problem because the designing engineer does not have all the necessary data available to him. This paper presents a methodology which helps us in determining the economic tolerances of the elements of a complex dimension chain. The calculation algorithm of economic tolerances proposed by this methodology consists of 8 steps. In order to apply the solving methodology of complex dimension chains and determine economic tolerances this paper presents a case study of a complex dimension chain that forms at the design and assembly of a tapered gear.

1. INPUT DATA REGARDING THE ELABORATION OF THE SOLVING METHODOLOGY OF COMPLEX DIMENSION CHAINS

In order to apply the solving methodology of complex dimension chains and determine economic tolerances this paper presents a case study of a complex dimension chain that forms at the design and assembly of a tapered gear, figure 1. The following problems were considered for this study:

- establishing the dimension chains and determining unknown elements and unknown tolerances, which require the accurate operation of the reducer as well as pieces interchangeability in production and operation conditions;
- tapered gears conjugation, that is complying with the side clearance between the gears teeth within the admitted limits.

The reducer's construction is made so as the side clearance in the mating gears is irregular. The following are known: the interaxial angle of the transmission φ=90°, gears module m=7 mm; the number of gears teeth z_1=20 and z_2=30.

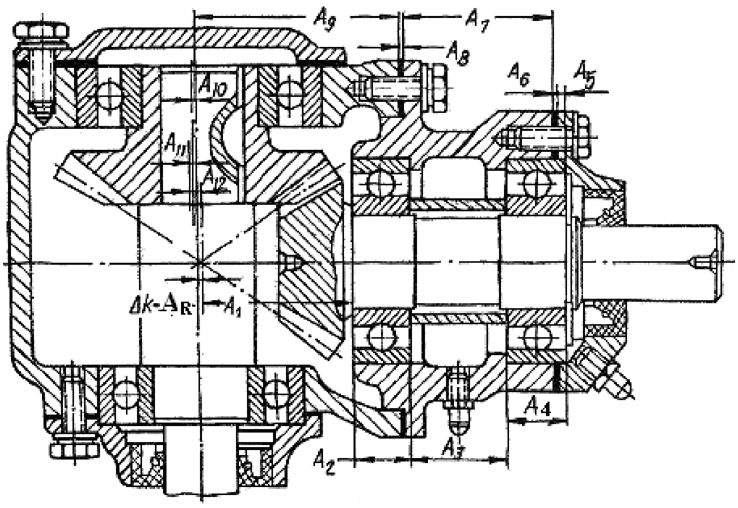

***Fig.1. Scheme of a tapered gear reducer*.**

2. CASE STUDY

The following stages take place:

a. Establishing the primary elements and drawing the scheme of the dimension chain.

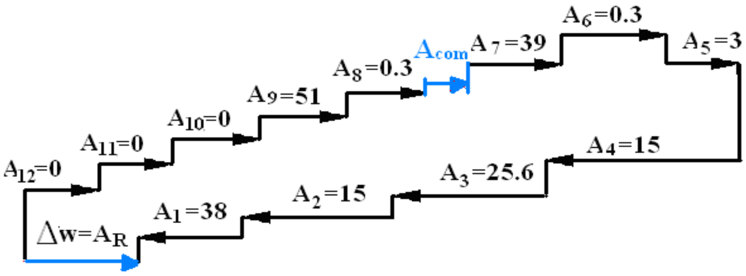

Fig.2. Elements of the dimension chain

The primary elements of the dimension chain are:

$A_1=38^{\,0}_{-0,25}$ mm is the distance from the type of the gear cone to the main edge;

$A_2=A_4=15^{\,0}_{-0,12}$ mm–bearings width, the tolerance will be taken from SR 3041:1993;

$A_3=25,6^{\,0}_{-0,25}$ mm–distance between the gear bearings;

$A_5 = 3^{+0,12}_{\,0}$ mm - cutting depth in the bearing cover;

$A_6= A_8=$ 0,3mm – sealing thickness; the tolerance will be taken from STAS 6577-80 by calculating the sealing strain within the cover bolts fastening process, with experimental data, we get;

A_6=-0,06 and -0,1 mm; $A_7 = 39^{+0,25}_{\,0}$ mm – is the distance between the edges of the reducer's cover;

$A_9=51^{+0,30}_{\,0}$ mm – distance from the case boring axle where the shaft and the gear are assembled to the case supporting edge;

A_{10} = 0±0,02 mm – outer bearing axle movement from the hole axle from the reducer's case due to the clearance between them;

A_{11}=0±0,02 mm – radial range of the ball bearing (the tolerance will be taken from STAS 6671-92).

Inferior faults of elements A_{10} and A_{11} will be neglected, because the calculation includes only the higher fault, therefore we will get A_{10} =A_{11}=+0,02 mm, whose size is not big through comparison.

Dimension chain equation according to fig. **2** is:

$$A_9 + A_8 + A_{comp} + A_7 + A_6 + A_5 - A_4 - A_3 - A_2 - A_1 = A_R$$

where: A_9, A_8, A_{comp}, A_7, A_6, A_5 are the primary increasing elements;

A_4, A_3, A_2 and A_1 – reducing primary elements;

A_R – closing element.

As we can see fig. 2 presents the scheme of the dimension chain of the reducer presented in fig. 1, the difference being that this dimension chain includes another element that is A_{com}, which represents the compensation element.

Paper [7] presents a calculation program for calculating the tolerances of the primary elements of dimension chains, as well as the tolerance of the resulting element, in our case the tolerance of tapered gears divided tips movement. The program was written **in the language C++ as well, and the results of its course are the following:**

```
TRS   =     0.76508
ESRS  =     0.18754
EIRS  =    -0.57754
NR    =     0.00000
TRA   =     1.49000
r     =     0.51348
m     =     1.94751
-----------------
TN(1)=     0.48688
-----------------
TN(2)=     0.23370
-----------------
TN(3)=     0.48688
-----------------
TN(4)=     0.23370
-----------------
TN(5)=     0.23370
-----------------
TN(6)=     0.07790
-----------------
TN(7)=     0.48688
-----------------
TN(8)=     0.07790
-----------------
TN(9)=     0.58425
```

Through the program course we obtained [7]:

- statistic tolerance tapered gears divided tips movement: TRS=0.76508mm;
- superior fault: ESRS = 0.18754mm;
- inferior fault: EIRS = -0.57754mm;
- nominal value of the closing element NR=0,00 mm;
- tolerance reducing factor: r=0,51348;
- primary tolerances increasing factor:, m=1,94751;
- the tolerance calculated through the algebraic method is: 1,4900mm.

In table 1 we introduced the elements of the dimension chain, noted with B_1....B_9, which presents only the nominal values and tolerances for those elements upon which we cannot intervene.

Table 1. Dimension chain elements

Resulting element		Primary element	Element symbol	Known primary elements		Dimensional repartition type
Nominal value	Tolerances, mm			Nominal value, mm	Tolerance mm	
0	0,76509	A_1	B_1	-	-	Simpson
		A_2	B_2	15	0,12	normal
		A_3	B_3	-	-	Simpson
		A_4	B_4	15	0,12	normal
		A_5	B_5	-	-	uniform
		A_6	B_6	0,3	0,16	normal
Normal		A_7	B_7	-	-	uniform
		A_8	B_8	0,3	0,16	normal
		A_9	B_9	-	-	Simpson
No. of primary elements=9			No. of known elements= 4		No. of unknown elements.=5	

b. Establishing the dimensional repartition of the resulting element.
c. Establishing the dimensional repartition of the primary element.

d. The calculation of the average statistic tolerance for the primary elements of the dimension chain.
e. Establishing the necessary data for determining the cost for processing every primary element for two processing variants.
f. Calculation of the processing cost for every primary element separately in the two variants.
g. Calculation of the economic tolerance of the primary elements.

The achievement of **b÷g** stages is necessary for rolling **the program for determining economic tolerances** written in C++ language. All this data is introduced at the computer request and are presented in tables 2, 3, 4, 5, 6.

Table 2. Data regarding A_1 (B_1) element

Element A_1				
Requested data	Variant 1		Variant 2	
	Values	Tolerance, mm	Values	Tolerance, mm
Machine tool cost, RON	291429,06	0,25	291429,06	0,48
Amortization years	10		10	
Capital repairs quota	8		8	
Working days	50		50	
Shifts per day	2		2	
Shifts hours	8		8	
Worker's wage	1500		1500	
Excise costs	52,5		52,5	
Additional time	8		8	
Preparing-closing time	20		20	
No. of pieces in the batch	25		25	
Tool changing time	1,6		1,6	
Main time per operation	15		10	
Cutting tool durability	200		200	
Cutting tool costs	18000		18000	

Table 3. Data regarding A_3 (B_3) element

Element A_3				
Requested data	Variant 1		Variant 2	
	Values	Tolerance, mm	Values	Tolerance, mm
Machine tool cost, RON	268927,70	0,25	268927,70	0,48
Amortization years	10		10	
Capital repairs quota	9		9	
Working days	50		50	
Shifts per day	2		2	
Shifts hours	8		8	
Worker's wage	1400		1250	
Excise costs	35		31,5	
Additional time	0,8		1	

Preparing-closing time	2		2	
No. of pieces in the batch	50		50	
Tool changing time	1		1	
Main time per operation	4		3	
Cutting tool durability	500		500	
Cutting tool costs	5000		5000	

Table 4. Data regarding A_5 (B_5) element

Element A_5				
Requested data	Variant 1		Variant 2	
	Values	Tolerance, mm	Values	Tolerance, mm
Machine tool cost, RON	268927,70	0,12	268927,70	0,23
Amortization years	10		10	
Capital repairs quota	9		9	
Working days	50		50	
Shifts per day	2		2	
Shifts hours	8		8	
Worker's wage	1400		1250	
Excise costs	35		31,5	
Additional time	1		1	
Preparing-closing time	5		5	
No. of pieces in the batch	25		25	
Tool changing time	1		1	
Main time per operation	8		5	
Cutting tool durability	500		500	
Cutting tool costs	5000		5000	

Table 5. Data regarding A_7 (B_7) element

Element A_7				
Requested data	Variant 1		Variant 2	
	Values	Tolerance, mm	Values	Tolerance, mm
Machine tool cost, RON	375955,50	0,12	268927,70	0,23
Amortization years	10		10	
Capital repairs quota	9		9	
Working days	50		50	
Shifts per day	2		2	
Shifts hours	8		8	
Worker's wage	1500		1350	
Excise costs	52,5		33,8	
Additional time	2		2	
Preparing-closing time	10		10	

No. of pieces in the batch	25		25	
Tool changing time	1		1	
Main time per operation	12		10	
Cutting tool durability	500		500	
Cutting tool costs	5000		5000	

Table 6. Data regarding A_9 (B_9) element

Element A_9				
Requested data	Variant 1		Variant 2	
	Values	Tolerance, mm	Values	Tolerance, mm
Machine tool cost, RON	420525,2	0,3	420525,2	0,58
Amortization years	10		10	
Capital repairs quota	8		8	
Working days	50		50	
Shifts per day	2		2	
Shifts hours	8		8	
Worker's wage	1500		1400	
Excise costs	52,5		49,5	
Additional time	1,5		2	
Preparing-closing time	10		10	
No. of pieces in the batch	25		25	
Tool changing time	2		2	
Main time per operation	13		9	
Cutting tool durability	200		200	
Cutting tool costs	20000		20000	

After introducing the data in the above tables, data requested by the program, the computer makes the necessary calculations and displays or prints the economic tolerances that have to be prescribed to the primary elements of the dimension chain, in order for the cost of these primary elements to be minimal.

For the studied case the following values result and are printed:

OPTIMIZATION PROGRAM FOR TOLERANCES CALCULATION
Economic tolerance of element 1 = 0.169mm
Economic tolerance of element 2 = 0.542mm
Economic tolerance of element 3 = 0.003mm
Economic tolerance of element 4 = 0.010mm
Economic tolerance of element 5 = 0.266mm

If we take into consideration the correspondence between the B_i elements, considered elements of the dimension chain for which we can determine economic tolerances and primary elements of the chain noted with A_i given by table 1 the optimal values of the primary tolerances are determined, which are presented in table 7.

Table 7. Determining the final values of the chain elements tolerances

Primary element	Element symbol	Known primary elements	
		Nominal value, mm	Tolerance Mm
A_1	B_1	38	0,169
A_2	B_2	15	0,12
A_3	B_3	25,6	0,542
A_4	B_4	15	0,12
A_5	B_5	3	0,003
A_6	B_6	0,3	0,16
A_7	B_7	39	0,010
A_8	B_8	0,3	0,16
A_9	B_9	51	0,266

The new tolerances have allowed to reduce the manufacturing cost using variants for obtaining the primary elements that correspond to higher tolerances than the existing ones as a result of smaller manufacturing costs.

3. CONCLUSIONS

The possibility to solve dimension chains with the help of computers has reduced the time necessary for designing a machine very much.

Computer use in solving dimension chains, for starters, uses the probabilistic calculation methods of the dimension chain.

Elaborating a new statistic method for solving dimension chains that depends on the way in which dimensional repartitions are made.

Taking into consideration the dimensional repartitions for each element of the dimension chain, a new statistic method for calculating the tolerance of the resulted element with the help of a computer has been elaborated. This method has the following advantages:

- It applies rapidly and efficiently for solving and optimizing complex dimension chains
- It considers the dimensional repartitions of all the elements of the dimension chain.

A program for determining the economic tolerances written in the programming language C++ . this programming language is efficient, economic and portable. It is a good choice for making any type of programs, from text editors to graphic facilities games, management programs and scientific calculations, up to system programs, being one of the most powerful programming tools, which draws a lot of attention in the software industry.

4. **References**

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