ТЕХНИЧЕСКИЕ НАУКИ

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CREATION MATHEMATICAL MODEL OF A FILM SOLAR COLLECTOR USING EVOLUTIONARY SEARCH ALGORITHM

Abstract. The construction of a mathematical model of a film solar collector based on an evolutionary search algorithm is considered. The aim of the work is to build a mathematical model based on a limited set of experimental data from a range of permissible parameters. The dimensionless complexes characterizing the work of the collector are used. The total array of experimental data is divided into two arrays - a training sequence and a test sequence. As a criterion for the adequacy of the model, the criterion of the minimum deviation of the simulation values from the experimental data was used. The model was built on the points of the training sequence and tested on the test. As an example, a numerical solution to the problem of optimizing the work of the collector is shown under restrictions on permissible parameters. To solve the problem of constructing a model and the optimization problem, an evolutionary search algorithm was used.

Keywords: solar collector, heating systems, hot water systems, experimental studies, evolutionary algorithms, dimensionless appearance, math search.

Introduction

To create complex hot water supply or heating systems based on film solar collectors, it is necessary to have a mathematical model of the collector. The resulting mathematical model should be as close as possible to the physical model in a variety of parameters, which is necessary for further research and construction of a mathematical model of a common hot water supply and heating system. Film solar collectors are attracted by their simplicity of construction and the corresponding low cost. One of the possible designs of film solar collector is available in the technical solution [1].

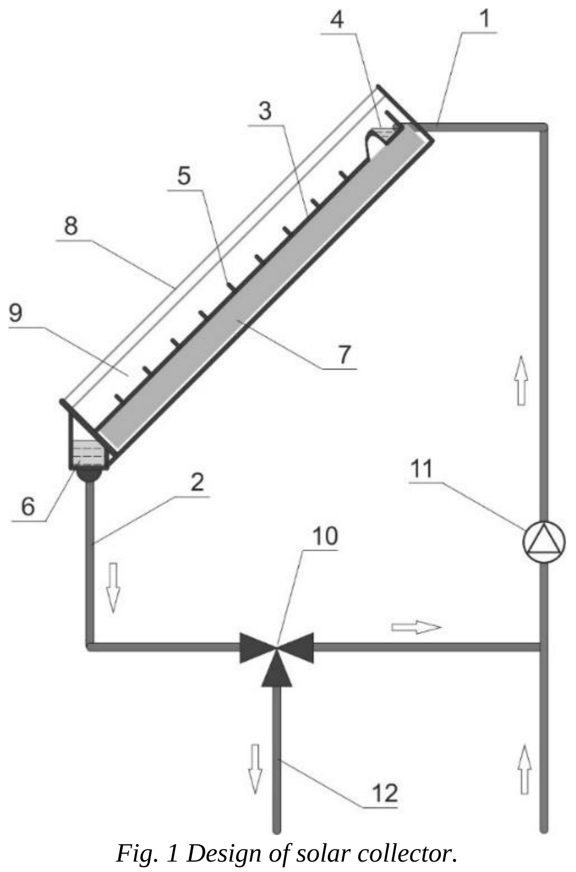

Fig. 1 Design of solar collector.

1) liquid inlet;
2) liquid outlet;
3) heat exchange surface;
4) slit liquid dispenser;
5) protrusions on the surface;
6) fluid storage;
7) thermal insulation material;
8) translucent surface;
9) air gap;
10) three-way valve;
11) fluid pump;
12) exit from the collector;

The article [2] describes the experimental technique for this collector and gives experimental results. In this paper, the task was to construct a mathematical model of film solar collector based on experiments [2].

Table 1.

The results of the experiment with a solar film collector.

Input parameters							Output parameters	
Тн.вод.	Тк.вод.	Тпов.	H	h	Рсон.	G	Qвод	Qкін.
24,5	27,7	30,97	57	2	99,999	6,67	64	199,998
24,3	28,4	30,71	57	2	98,862	6,67	82	197,724
24,5	28,6	31,33	57	1	88,161	6,67	82	176,322
24,7	29,3	31,16	57	1	100,491	6,67	92	200,982
26	29,5	28,87	57	1	107,467	6,67	70	214,934
26,2	30	29,39	57	1	97,374	6,67	76	194,748
26,9	31,8	29,22	37	1	100,465	5	98	200,93
27,1	32,2	29,3	37	1	101,282	5	102	202,564
27,5	32,7	30,09	37	2	91,177	5	104	182,354
27,7	32,9	30,71	37	2	98,862	5	104	197,724
27,8	32,1	28,26	37	2	74,74	5	86	149,48
27,1	34,8	30,36	21	2	111,016	3,85	154	222,032
27,2	34,4	28,78	21	2	89,27	3,85	144	178,54
27,3	34,8	27,75	21	2	94,154	3,85	150	188,308
27,4	34,4	30,89	21	2	61,763	3,85	140	123,526
27,4	33,6	30,89	21	1	83,502	3,85	124	167,004
27,1	34,8	29,83	21	1	86,186	3,85	154	172,372
27,7	33,9	28,52	21	1	113,943	3,85	124	227,886
28,2	34,6	29,04	21	2	112,004	3,85	128	224,008
28,3	32,9	29,13	21	2	76,28	3,85	92	152,56

де: Тн.вод. (^{0}C) - water temperature at the inlet to the solar collector;

Тк.вод. (^{0}C) - water temperature at the outlet of the solar collector;

Тпов. (^{0}C) - air temperature in the shade;

H (cm) - the difference in the height of the water between the storage tank and the inlet;

h (cm) - the distance between the translucent and the sorption surfaces;

Рсон. (mW/cm^2) - intensity of solar radiation;

Qвод. - the amount of energy that came into the collector;

G (gram/sec) - water consumption;

Qкін. (W) - the amount of solar energy supplied to an area equal to the collector area;

As a result of an experiment with film solar collector, three dimensionless complexes of 20 elements were created: p_1 – temperature complex, p_2 – geometric complex, p_3 – complex efficiency of the device [2].

$p_1 = \frac{\Delta T}{T_{пов}}$, where ΔT - the difference in temperatures at the inlet and outlet of the solar collector.

$p_2 = \frac{h^2}{F}$ where h - the distance between the translucent and the sorption surfaces, F- the area of the translucent surface.

$p_3 = \frac{C_{вод} * G * \Delta T}{q_{сон} * F}$ where $C_{вод}$– water capacity, G - water consumption, $q_{сон}$- intensity of solar radiation.

Table 2.

Experimental results of film solar collector in the form of dimensionless complexes

№	p_1	p_2	p_3
1	0,130865	0,000435	0,564148
2	0,147625	0,000435	0,555286
3	0,121233	0,000435	0,395074
4	0,129296	0,000435	0,473398
5	0,167693	0,000435	0,443518
6	0,174061	0,000435	0,457897
7	0,200712	0,000435	0,519895
8	0,258129	0,000435	0,625568
9	0,217391	0,000435	0,381
10	0,103326	0,001739	0,388186
11	0,133507	0,001739	0,503084
12	0,172815	0,001739	0,518619
13	0,169326	0,001739	0,478304
14	0,152159	0,001739	0,523173
15	0,253623	0,001739	0,485653
16	0,250174	0,001739	0,564739
17	0,27027	0,001739	0,557755
18	0,226611	0,001739	0,793579
19	0,220386	0,001739	0,400099
20	0,157913	0,001739	0,422248

Formulation of the problem

Based on experimental data, it is necessary to obtain a mathematical model of a film solar collector. We will search for a mathematical model of the solar collector in the form $p_3 = f(p_1, p_2)$, where is the function $f(p_1, p_2)$ characterizes the efficiency of the solar collector. It is necessary to find the type of function $f(p_1, p_2)$, at which the deviation is minimized

$$Z = \sum_{i=1}^{n} |p_{3i} - f(p_{1i}, p_{2i})| \to min \quad (1)$$

where: p_{1i}, p_{2i}, p_{3i} – dimensionless complexes from experimental data.

Solving the problem

Using the experimental results in a dimensionless form Table 2, two-dimensional Fig.2 and three-dimensional diagrams of Fig.3 are constructed.

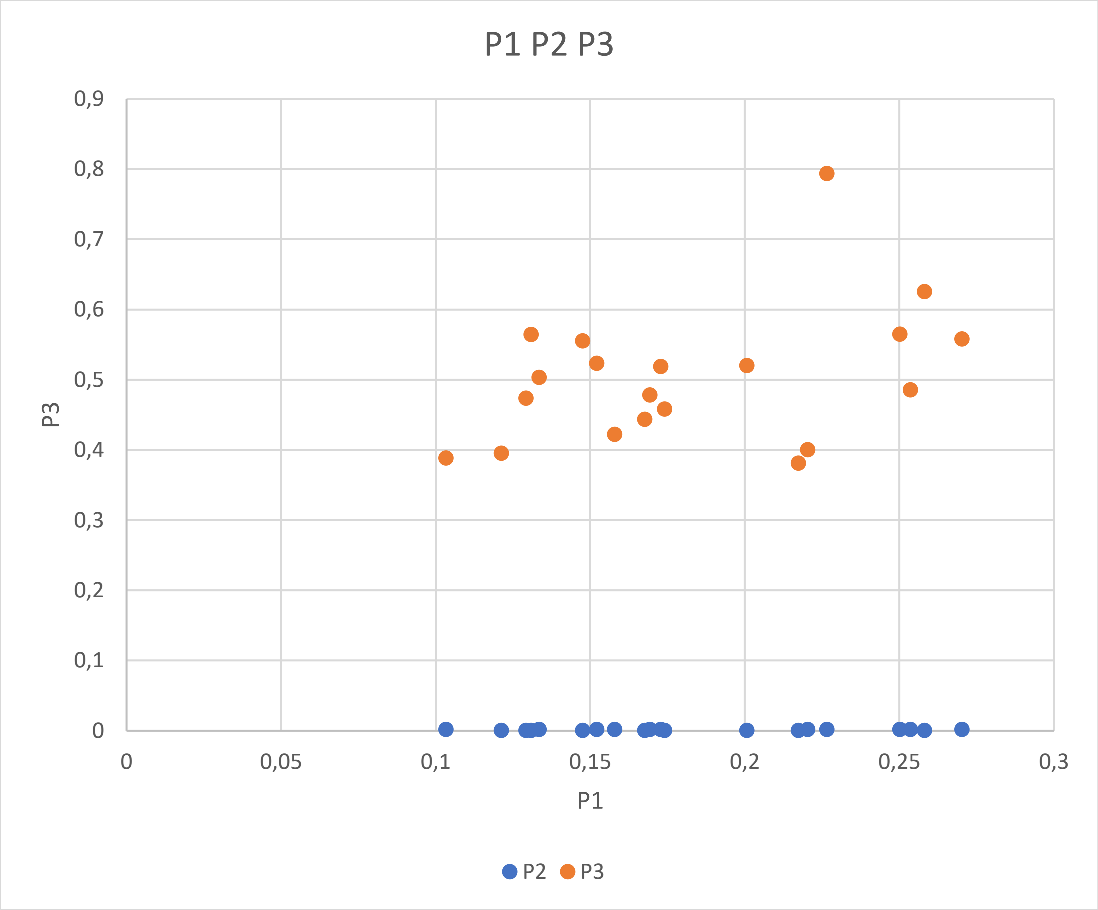

Fig. 2 Two-dimensional diagram of dimensionless complexes p_1, p_2, p_3.

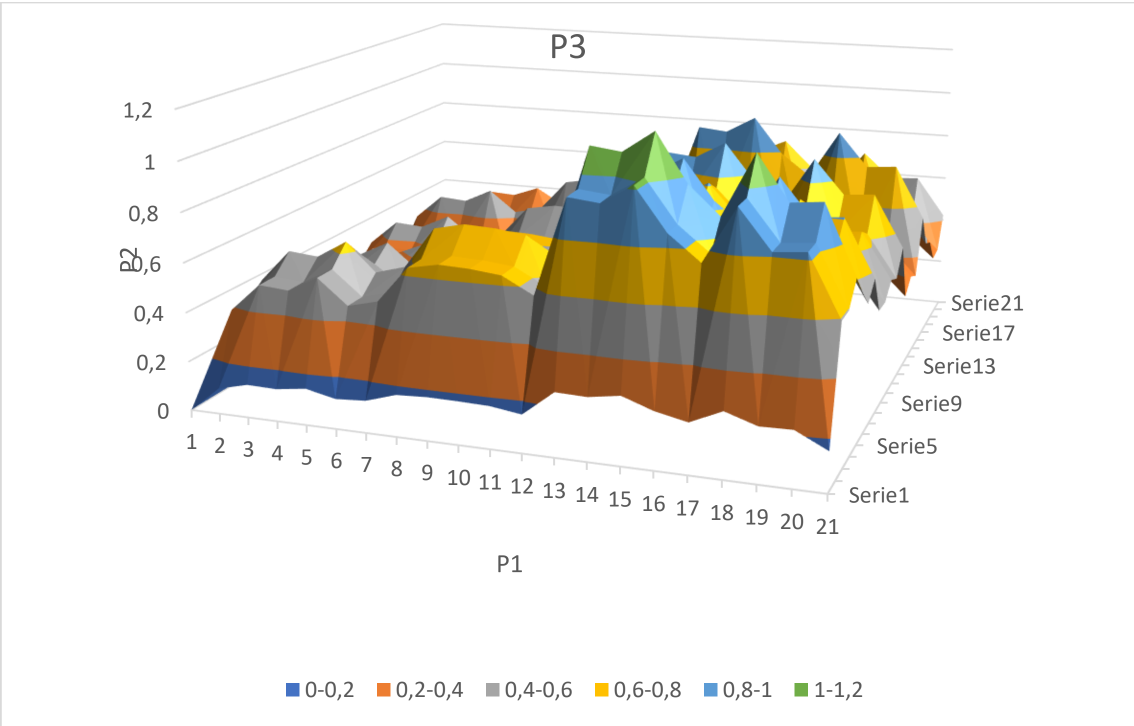

Fig. 3 Three-dimensional diagram of dimensionless complexes p_1, p_2, p_3.

Subsequently, the type of function was selected that reflects the dependence of p_3 on p_1 and p_2.

$$f(p_1, p_2) = a_1 + a_2 \cdot p_1 + a_3 \cdot (1 - p_2) + a_4 \cdot p_1^2 + a_5 \cdot (1 - p_2)^2 \quad (2)$$

The numerical coefficients a_1, a_2, a_3, a_4, a_5 were determined from the minimization condition (1).

To ensure the adequacy of the modeling object, the entire array of experimental data of (Table 1) is divided into an array of the training sequence - points 1,3,5,7,8,9,11,13,15,16,17,19 from table 1 and an array of the check sequence of the points 2,4,6,10,12,14,18,20 from table 1. The coefficients a_1, a_2, a_3, a_4, a_5 were determined from the minimization condition

$$\sum_{i \in I_0} \frac{|p_{3i} - f(p_{1i}, p_{2i})|}{p_{3i}} \to min \qquad (3)$$

And then, the constructed model with the found coefficients a_1, a_2, a_3, a_4, a_5 was checked on a test sequence by calculating

$$\varepsilon_{\Pi} = \frac{1}{n_{\Pi}} \sum_{i \in I_{\Pi}} \frac{|p_{3i} - f(p_{1i}, p_{2i})|}{p_{3i}} \qquad (4)$$

where ε_{Π} – relative error of the model on the test sequence.

As a result of the evolutionary search for the coefficients, the function is obtained:

$$f(p_1; p_2) = 0{,}51 - 0.295 \cdot p_1 + 0.0027 \cdot (1 - p_2) + 3.5 \cdot p_1^2 - 0.23 \cdot (1 - p_2)^2 \qquad (5)$$

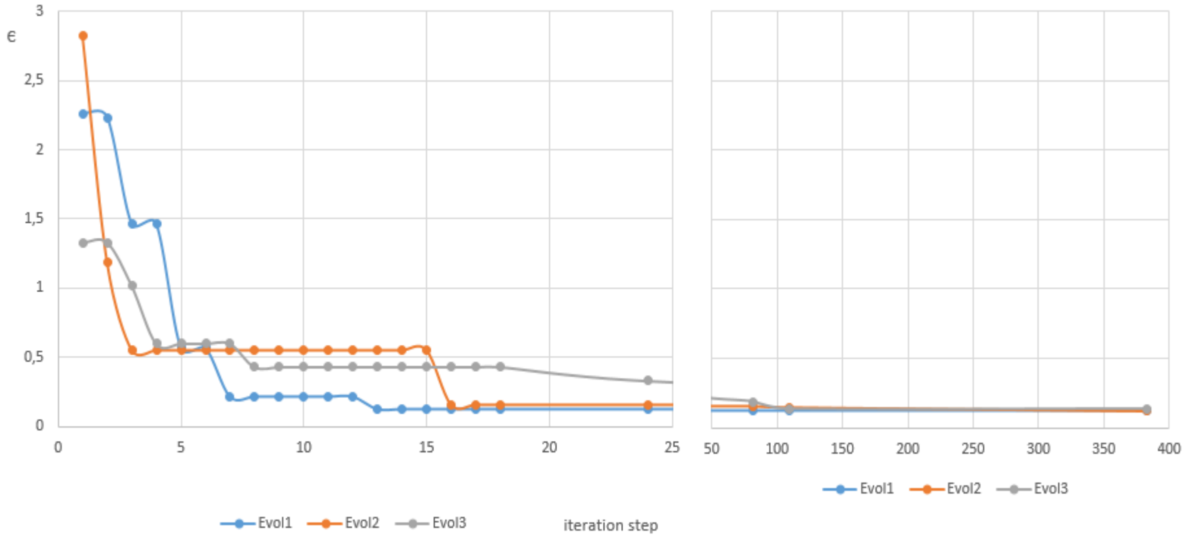

Fig. 4 Graph of convergence of the branches of the evolutionary search according to experimental data.

For many points of the experimental data, the average error of the model is $\varepsilon = 0.1267716$, and for the points of the test sequence, the average error is $\varepsilon = 0.111678$. These results indicate sufficient adequacy of the found model for actual data. The following problem was solved as an example of using the constructed model. It was required to find $f(p_1; p_2) \to max$ by the evolutionary search method under the conditions:

$$0.1 \le p_1 \le 0.3;$$
$$0.0017 \le p_2 \le 0.0043;$$

Figure 5 shows the evolutionary search for a solution to the indicated optimization problem of a film solar collector.

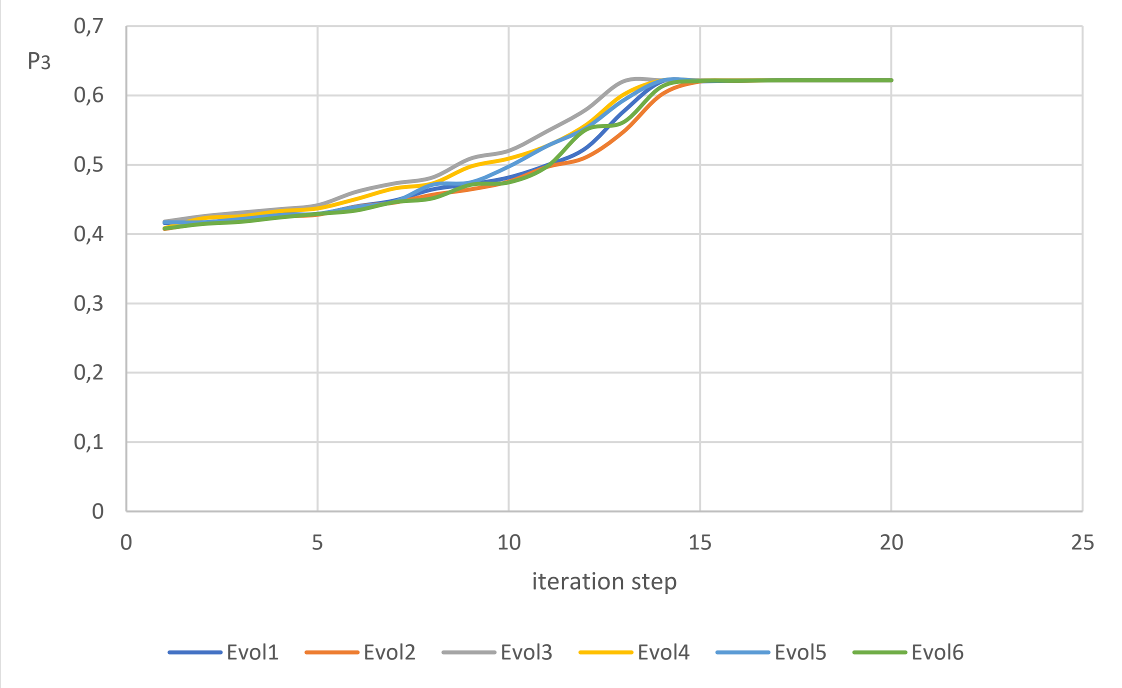

Fig. 5 Graph of the search for points of maximum efficiency of the solar collector, by the method of evolutionary search.

At the 20th step of iteration, a complete match was obtained across all branches of the evolutionary search, with $p_1 = 0.3$; $p_2 = 0.0017$, which corresponds to $\max p_1$ and $\min p_2$ from the allowable range. The value of the function $f(p_1; p_2)$ at these points is 0.62191, i.e. solar collector efficiency 62%.

Conclusions

A mathematical model of the solar collector of the film type is built. An algorithm and program code for evolutionary search is developed, with the help of which the coefficients and accuracy of the mathematical model are calculated. The results were tested on training and test arrays. The mathematical function has been optimized, as a result of which the points found with the maximum efficiency of the solar collector.

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THE STABILITY OF THIN-WALLED OPEN- PROFILE BARS WITHIN THE NONLINEAR ELASTIC DEFORMATION

Abstract. The paper considers researches dealing with the stability of thin-walled open-profile bars. The widespread use of thin-walled bars in engineering constructions is resulted in a significant reduction in the weight of these systems. Considering the relevance of the given problem, the stability of nonlinear deformation to the central axis direction of the thin-walled bars has been investigated. The physical nonlinearity of the bar's material, dependence of the normal tension in its cross-section on the relative linear deformation has been taken as the form of the dual cubic polynomial. An appropriate nonlinear differential complex equation for a single torsion angle has been composed for the determination of the normal and touching tensions at bar's cuts in the non-free torsion of the longitudinal compression of the bar subjected to nonlinear deformations, and free touch tensions in free torsion towards the direction of the thickness of the bar. In order to use the small parameter method for the solution of this differential equation, the small parameter expression is composed of the elastic characteristics of the bar material. The solution line of the form of the nonlinear differential equation due to the small number of parameters is divided into differential equations, so that their solution is easily carried out. As a result, the expression of thin-walled bar's tension is obtained in the third approximation.

Keywords: Thin-walled bar, nonlinear deformation, open -profile, deplanation, non-free torsion, bending, curling moment, sectorial field, sustainability.

INTRODUCTION

The tap of the thin-walled bars in different constructions, especially in shipbuilding, aviation industry, and construction of high-mile buildings, etc., caused a creation of the new computation theory. The famous scientist, Vlasov's fundamental works had an irreplaceable role in the sphere of the creation and development of this theory [1]. Taking into account that the thin-walled bars squeezed in the longitudinal direction are problematic ones, the significant investigations of Peres N., Goncalves R., Camotim D. and others along with Vlasov's survey had a great impact on their work on calculations for sustainability [2-4, 9].

Unlike the closed contoured or the whole cut thin-walled bars, the open-profile bars are slightly resistant to torsion. According to the general theory of open profile thin-walled bars, in the torsion of such bars their cuts are bent, thus various points take different movements in the direction of the central longitudinal axis of the bar. Such longitudinal displacements are called deplanation.

PROBLEM STATEMENT

If the deplanation of the cuts of the bar doesn't occur freely, it implies that normal tensions arise in non-free torsion. In this case touch tensions also arise in the points of the cut of the bar. These touching tensions are indicated as $\tau^{q.s.}$, they are accepted like regularly disseminated in wall thickness of the shaft [1]. In the free torsion the tensile stresses varying by linear law in the direction of bar thickness are called free touching tensions, and are indicated as τ^{s} (see Fig. 1).

a) *b)*

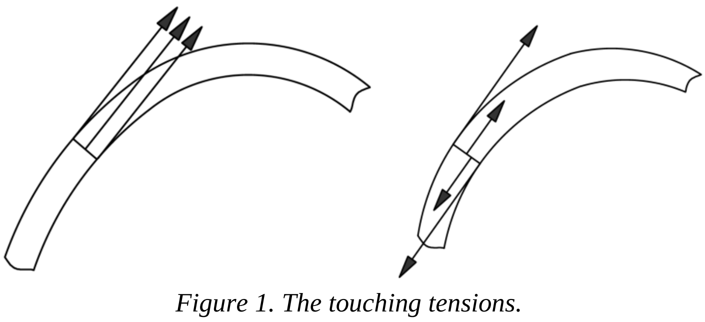

Figure 1. The touching tensions.
Non-free torsion; b) Free torsion