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Analysis of Stress Concentration Factors using Different Computer Software Solutions

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Abstract

Computer software for analysis of stress concentration factors was developed at Faculty of Mechanical Engineering Sarajevo. The software name is AlfaK. To test AlfaK software, analysis of stress concentration factors was done by using various others computer software. In addition to AlfaK, analysis was performed using Microsoft Excel modules developed within the book [1]. The goal of this paper is to show that with a good knowledge of programming languages, small software applications can be developed for specific engineering problems, in order to avoid purchasing expensive software packages.

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Keywords: stress, concentration, factor, computer, software

1. Introduction

One of the problems for engineers, in developing countries, is to get access to expensive computer science packages. In most cases, engineering software packages such as CAD/CAM/CAE systems [2] are too expensive for small private companies or universities. On the other hand, in practice and in research, engineers are often faced with characteristic engineering problems which can be efficiently solved using computers. Solving them require to purchase expensive software package.

One such problem is stress concentration caused by sudden change in form of machine elements [3]. In design process of machine elements analysis of stress concentration can be done using software like ANSYS [4], CATIA V5, SolidWorks and NX, or using diagrams obtained experimentally for various geometric configurations involving abrupt changes in geometry. These software are based on some of numerical method (Finite element method FEM,

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Finite volume method FVM, etc). The above mentioned software are extremely expensive and they are not cost effective to purchase just for analysis of stress concentration. On the other hand, the analysis using experimentally obtained diagrams is relatively imprecise, because it means that engineer need to manually determine value from diagrams. From the above can be seen the need to find cheaper solution, but solution with appropriate accuracy. One solution, which is elaborated in [1] involves the use of Microsoft Office Excel.

This paper want to prove that with a good knowledge of programming languages like C# small computer software can be develop for analysis of stress concentration. This software will work independently of the others programs on the computer and it will allow simple and accurate analysis.

2. Stress concentration

In the development of the basic stress equations for tension, compression, bending, and torsion, it was assumed that no geometric irregularities occurred in the member under consideration. But it is quite difficult to design a machine without permitting some changes in the cross sections of the members. Rotating shaft must have shoulders designed on them so that the bearings can be properly seated and so that they will take thrust loads, also the shafts must have key slots machined into them for securing pulleys and gears, etc. [3]

Abrupt changes in geometry can give rise to stress values that are larger than would be expected. This can be a source of difficulty for designers. Consider, for example, the state of stress in the tension member of two widths illustrated in Fig. 1 [1]. Near each end of the bar the internal force is uniformly distributed over the cross sections. The nominal stress in the right part can be found by dividing the total load by the smaller cross-sectional area, the stress in the left part can be found by dividing by the larger area. However, in the region where the width is changing, a redistribution of the force within the bar must take place. In this part, the load is no longer uniform at all points on the cross section, but the material in the neighborhood of points B in Fig. 1 is stressed considerably higher than the average value. The stress situation is thus more complicated, and the elementary equation (1) is no longer valid [3].

$$\sigma_{nom} = \frac{P}{A} \quad (1)$$

The maximum stress occurs at some point on the fillet, as at B, and is directed parallel to the boundary at that point.

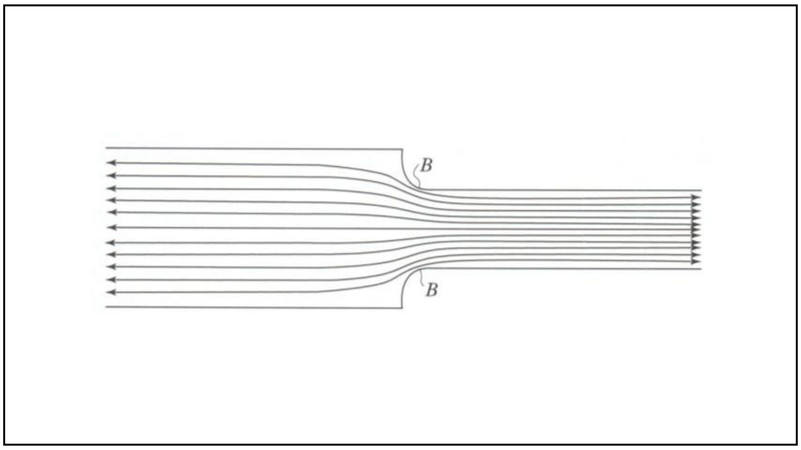


Fig. 1. Stress concentracion caused by a sudden change in cross section.

The stress distribution along the cut surface is practically uniform until the neighbothood od the fillet is reached, where it suddenly increases. This irregularity in the stress distribution caused by changes of form is called stress concentration. It occurs for all kinds of stress, axial, bending, or shear in the presence of fillets, holes, notches, keywayes, splines, tool marks, or accidental scratches. Inclusions and flaws in the material or on the surface also serve as stress raisers. The maximum value of the stress at such points is found by multiplying the nominal stress as given by the elementary equation by stress concentration faktor K , or K_t [3].

$$K = \frac{\sigma_{\max}}{\sigma_{nom}} \tag{2}$$

Where is $\sigma_{\max}$ - highest value of actual stress on fillet, hole, etc., σ_{nom} - nominal stress as given by (1) The subscript t in K_t means that this stress concentration factor depends for its value only on the geometry of the part.

This is why it is called a theoretical stress concentracion factor. It can be noticed that as geometric changes are made gradually, the effect of stress concentration factors is decreased. Sometimes the designer can specify the removal of material to secure a more gradual transition in size [5].

2.1. Stress concentration factors

The analysis of geometric shapes to determine stress concentration factor is a difficult problem, and not many solutions can be found. Most stress concentration factors are found by using experimental techniques. Though the finite element method has been used, the fact that the elements are indeed finite prevents finding the true maximum stress. Experimental approaches generally used include photoelasticity, grid methods, brittle-coating methods and electrical strain-gauge methods. Stress concentration factors have been determined for a wide variety of geometric shapes and types of loading. The best known summary of results for various geometric shapes is the work by Peterson and is based on results from photoelastic testing done prior to 1951 [1]. For example, the results for a shaft with a shoulder fillet in axial tension are given in Fig. 2.

More recently, researchers have developed mathematical models to approximate this classical data. Some of the best examples of these approximating models are documented by Norton, Pikley, and Young.

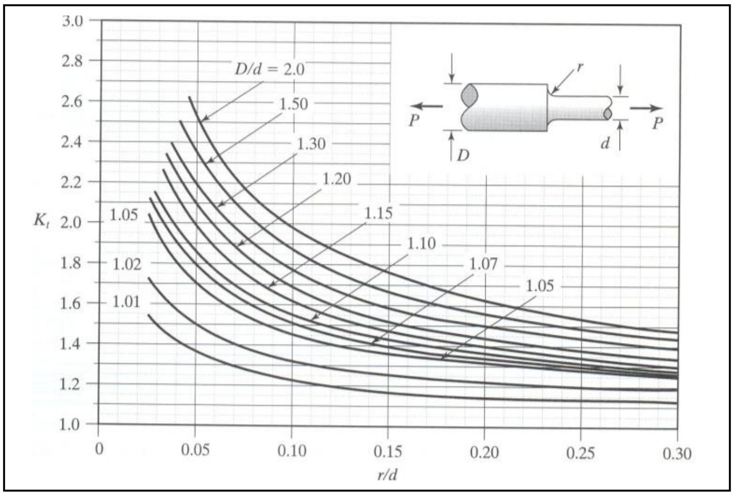


Fig. 2. Stress concentration factor for a shaft with a shoulder fillet in axial tension.

3. "AlfaK" software solution for analysis of stress concentration factors

AlfaK software development has gone through the following phases: [6], [7]:

- Problem identification and determination of goal,
- Mathematical approximation of the results obtained in [3], for six characteristics geometrical cases,
- Program design,
- Coding and testing.

3.1. Problem identification and determination of goal

Today in the world, software which is developed just for stress concentration analysis can't be found. In most cases engineers use some kind of modules which are developed using Microsoft Office Excel [1]. The aim is to develop a simple and precise software for analysis of stress concentration, which will be independent of other software packages. Software should enable engineers to quickly find the stress concentration factor for the characteristic cases of change in form on machine elements.

3.2. Mathematical approximation of experimental results

Using experimental technique, curves of stress concentration factor for characteristic cases of changes in form, are obtained [3], example is given in Fig. 2. Using Microsoft Excel a mathematical approximation of given curves was done, and mathematical functions were obtained, usually these functions are polynomial of third, fourth or fifth order. Also these functions precisely describe behavior of the stress concentration factor for a given geometry and case of load (Fig. 3).

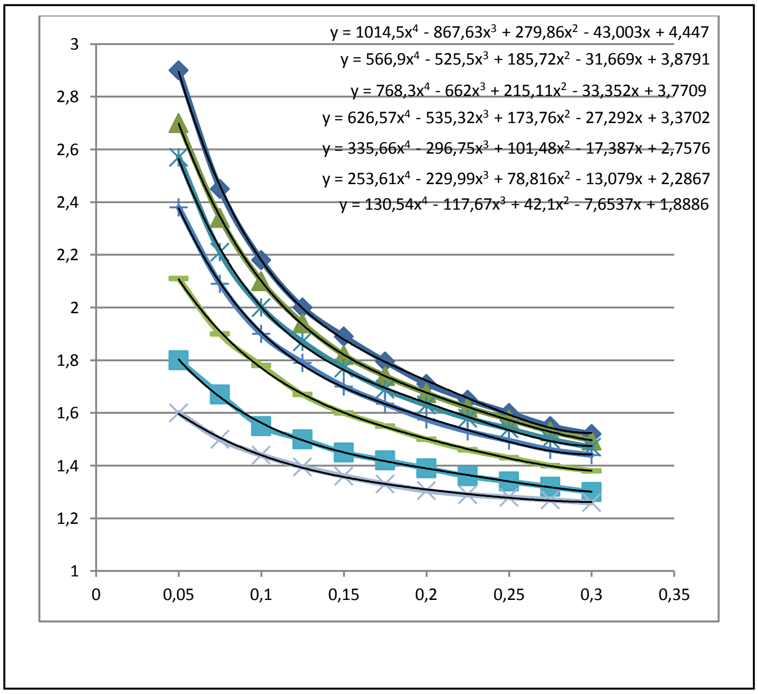


Fig. 3. Mathematical aproksimation of stress concentration factor for a flat element with grooves and for bending stress.

3.3. Software design

Design of AlfaK software was done using Microsoft Visual Studio 2008. The software is simple it has only two windows (forms), welcome window and main software window. Main software window has two parts. First part (Fig. 4) represent the part where user can choose geometric shape for analysis. As it can be seen AlfaK software can be used for analysis of stress concentration factor for six characteristic cases of changes in form

Second part of main window enable user to enter geometrical data, data for load, also this part of the window shows results of analysis (Fig. 4).

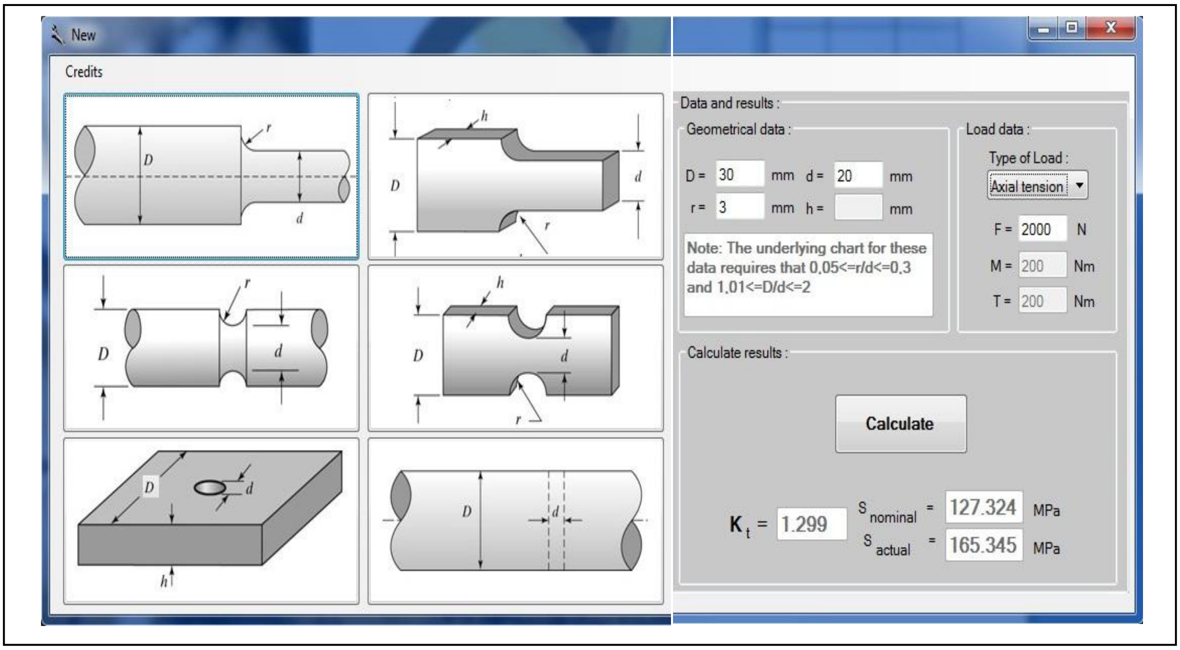


Fig. 4. Main „AlfaK“ form.

3.4. Coding and Testign

“AlfaK” software is Windows application with all elements as any other Window application. Installation process can be started by starting Setup file and using usual “Next” approach. After installation the software will set icon on computer desktop and in start menu. It is completely independent in relation to another computer software, and this is his big advantage in relation to spreadsheets modules [1]. Coding of the software AlfaK was also done in Microsoft Visual Studio 2008, with programming language C#.

Testing of the software is done through more than 200 student project assignments at course Machine elements one at Faculty of Mechanical engineering Sarajevo. On this way mistakes in coding are found and corrected.

4. Analysis of stress concentration factor using different computer software solutions

In order to verify the accuracy of the AlfaK software, analysis of stress concentration factor was performed using a spreadsheet module [1]. These spreadsheets utilize some of the models of Norton and also some linear interpolation from the data provided in the work of Peterson.

The same as AlfaK, these modules should enable the designer to find quickly the necessary concentration factors for a variety of geometric conditions. Analysis was performed for all six characteristic cases of geometry and for all types of load (Axial tension, bending, torsion). Input data are given in Tab. 1. and results in Tab 2.

Table 1. Input data.

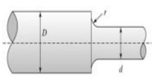
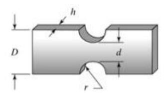
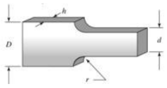
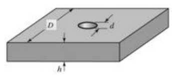
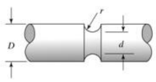
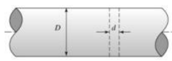
No.	Type of geometry	Geometric data (mm)	Stress data: Axial tension F (N)	Stress data: Bending M (Nm)	Stress data: Torsion T(N)	No.	Type of geometry	Geometric data (mm)	Stress data: Axial tension F (N)	Stress data: Bending M (Nm)	Stress data: Torsion T (Nm)
1.		D = 30 d = 20 r = 3	2000	200	200	4.		D = 30 d = 20 r = 3 h = 5	2000	200	---
2.		D = 30 d = 20 r = 3 h = 5	2000	200	---	5.		D = 30 d = 5 h = 5	2000	200	---
3.		D = 30 d = 20 r = 3	2000	200	200	6.		D = 30 d = 5	---	200	200

Table 2. Results.

No.		Stress concentration factor		Nominal stress (MPa)		Maximal stress (MPa)	
		AlfaK	Moduls [1]	AlfaK	Moduls [1]	AlfaK	Moduls [1]
1.	Axial tension	1.678	1.675	6.366	6.366	10.681	10.663
	Bending	1.507	1.51	254.64	254.647	383.778	383.563
	Torsion	1.299	1.30	127.324	127.323	165.345	165.549
2.	Axial tension	1.864	1.887	20.000	20.000	37.276	37.734
	Bending	1.580	1.62	600.000	600.000	948.264	973.327
3.	Axial tension	1.983	2.012	6.366	6.366	12.626	12.809
	Bending	1.714	1.74	254.648	254.647	436.562	441.936
	Torsion	1.387	1.40	127.324	127.323	176.542	177.645
4.	Axial tension	2.252	2.268	20.00	20.00	45.034	45.351
	Bending	1.821	1.85	600.0	600.0	1092.52	1111.51
5.	Axial tension	2.579	2.559	16.00	16.00	41.270	40.940
	Bending	1.828	1.96	1920	1920	3509,78	3771,86
6.	Axial tension	2,091	2,11	105,223	105,223	219,979	221,495
	Bending	2,76	2,77	43,942	73,942	121,577	121,719

In Tab. 2. very good fit of data, between two software, can be noticed. From this results it can be seen that AlfaK software has an expected accuracy.

5. Conclusion

This paper presents the results of stress concentration factor analysis using two software, one of them was developed at Faculty of Mechanical Engineering Sarajevo. The goal of the paper is to prove that, with good knowledge of computer languages (like C#), small software, for specific engineering problems, can be developed. On this way engineers can avoid buying expensive computers software packages. In Tab. 2. very good fit of data, between two software, can be noticed. From this results it can be seen that AlfaK software has an expected accuracy. AlfaK software enables analysis of stress concentration factor only for six characteristic cases of geometry. In practice, engineers can encounter much more cases of geometry, because of that, AlfaK software have a lot of space to future development and research. Also, from practical point of view it would be good to take into account different types of materials, and make the analysis of stress concentration factor for that cases using experimental technique. Future research and development of AlfaK software will go in direction of enabling automatic optimization of stress concentration factor by adding additional shoulders, fillet, holes etc.

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