thin-walled elements, FEM analysis, carrying capacity, buckling

Katarzyna FALKOWICZ[*], Mirosław FERDYNUS[*], Paweł WYSMULSKI[*]

FEM ANALYSIS OF CRITICAL LOADS PLATE WITH CUT-OUT

Abstract

The work presents the original conception of thin-walled plate element with the cut-out of irregular shape for use as a elastic or bearer element. The influence of geometrical parameters and the shape of the cut-out on the value of the critical load of the structure was researched. To discrete model and to perform numerical calculations used commercial program ABAQUS. Numerical calculations constitued own solution problem of compression structure and are the initial stage of research on work construction in elastic postcritical field with forced torsional-bending form of loss of stability was performed.

1. INTRODUCTION

The uniform, thin plates belong to the group of structural elements relatively cheap to manufacture, but due to the low flexural stiffness can move relatively small loads [1]. When they are compressed, the loss of stability occurs at low load and has a flexural buckling character [2–6]. Known common methods for improving the plate carrying capacity through the use of stiffeners or ribbing, lead to the significant changes in the design, thereby to increase the weight of the thin-walled construction.

However, there is a way to significantly improve the carrying capacity of this type construction, through the execution of the central cut-out and by forcing the work construction according the higher (bending-torsional) form of buckling.

Accordingly, to the basic problems we can include the carrying capacity of this type elements in particular working conditions of structure, and the impact of the size and type of cut-out on the carrying capacity. As a significant contribution in this field we can distinguish the works [7,8], where was considered the limit load capacity of this type elements.

[*] Lublin University of Technology, St. Nadbystrzycka 36, 20-618 Lublin, Poland
+48 (81) 538 42 00, e-mail: k.falkowicz@pollub.pl, m.ferdynus@pollub.pl, p.wysmulski@pollub.pl

However, there not found studies where was researched plate elements with cut-out and in which attempted to force deformation of element by a higher bending-torsional form.

The study addresses the concept of suitably shaped the geometric parameters of thin-walled plate element with cut-out, without change of its overall dimensions, in order to obtain the effect of improving the carrying capacity.

The influence of geometrical parameters and the shape of the cut-outs on the characteristics of the construction work in the field of operational loads was researched and the corresponding form of the loss of stability was determined.

The studies included linear numerical analysis of structures by using the finite element method (FEM) in ABAQUS software [9].

2. SUBJECT AND RESEARCH METHODOLOGY

The calculations assume a structural plate model made of an isotropic material. The research object is a rectangular plate with a central cut-out with different shapes and with variable geometric parameters of cut-out. The plate geometric parameters are shown in Fig. 1.

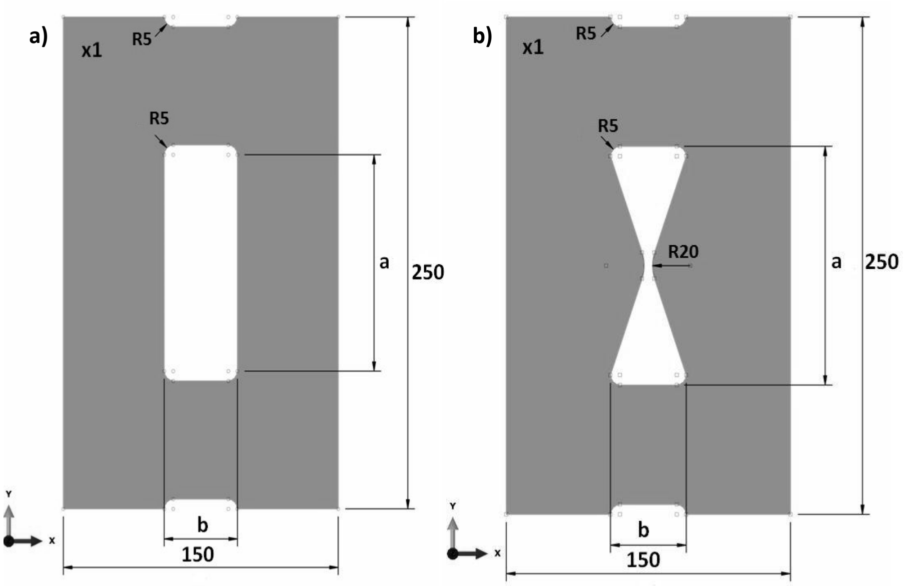


Fig. 1. Rectangular plates with cut-outs a) cut-out with rectangular shape, b) cut-out with hourglass shape [source: own study]

Analyzed plates had a symmetrical cut-out in the middle of the plate, which dimensions constituted geometrical parameters of the structure having a decisive effect on the characteristics of configuration in the loaded condition.

The range of cut-out geometric parameters was respectively: a = 80 ÷ 200 mm and b = 10 ÷ 50 mm.

As a plate material was adopted spring steel 50 HS which properties indicated in Table 1.

Tab. 1. Materials properties for spring steel 50 HS

Young Modulus in Tension E [MPa]	**Poisson Ratio v [-]**	**Yield Strenght Re [MPa]**	**Tensile Strenght Rm [MPa]**
210000	0.3	1180	1320

In case of elastic elements made of material with elastic-plastic characteristics, level of the yield strength determines the limits of construction parameters, while providing a significant limitation in design of this type configurations.

3. NUMERICAL ANALYSIS

To performed the discrete plate model and to carried out numerical analysis used ABAQUS program.

The plate was articulately supported and loaded by a compressive force distributed evenly over the top of edge. Boundary conditions mappers articulately support of plate was defined by blocking the kinematic degrees of freedom of nodes on the top and bottom edges of the element. Discrete plate model is shown in Fig.2.

Numerical calculations concerned the linear stability analysis and included a critical state analysis of rectangular plates with cut-outs. Solution to the eigenvalue problem concerned the determination of critical load values and the corresponding it form of the loss of stability. In each case, were determined 3 the lowest form of buckling, what allowed on determination of a higher, bending-torsional form, providing the staid nature of structure work after buckling (Fig. 3).

As we can see, in the case of the bending-torsional form in compression plate we can identify vertical stripes subjected to bending and horizontal stripes subjected to bending and torsion.

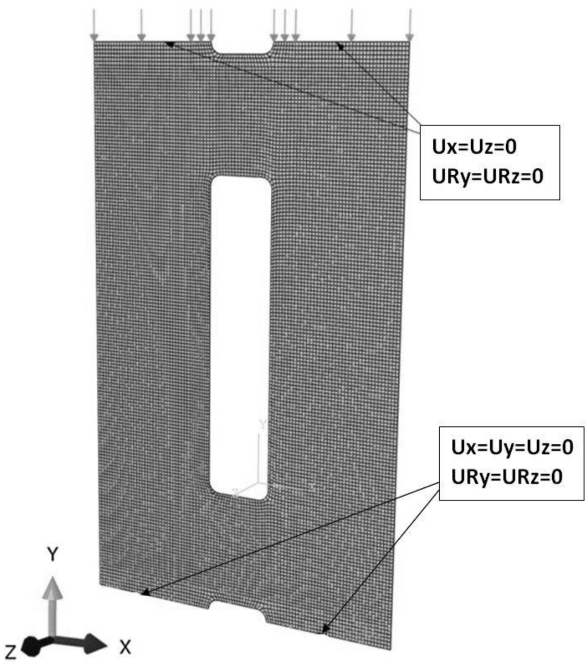


Fig. 2. Discrete model plate [source: own study]

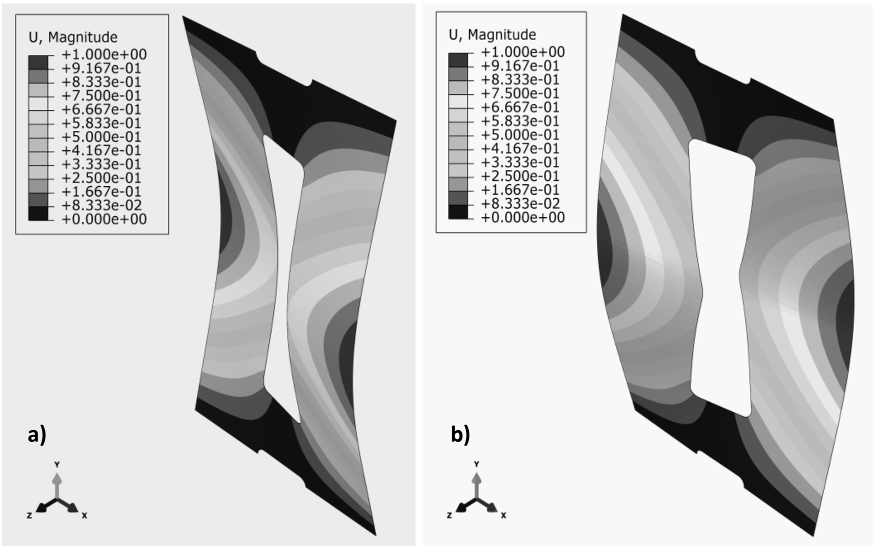
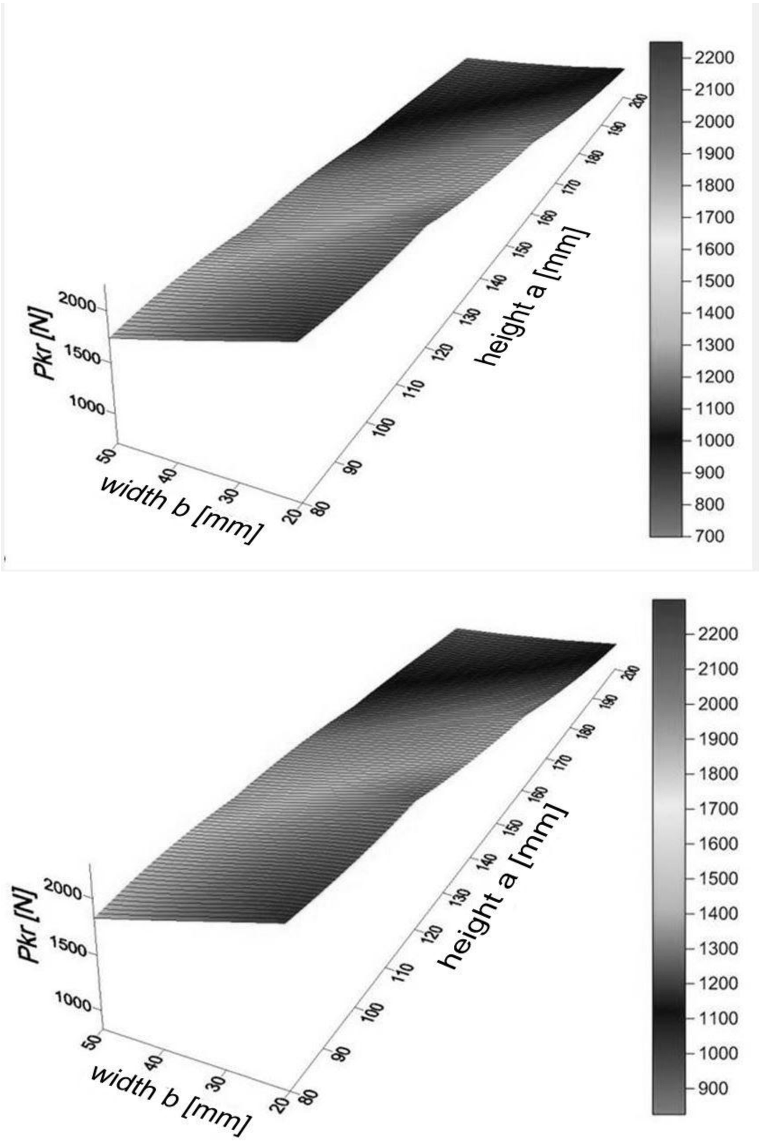


Fig. 3. Examples of buckling form plates with cut-out in ABAQUS program
a) higher buckling form: bending-torsional form of plate with rectangular cut-out
b) higher buckling form: bending-torsional form of plate with hourglass cut-out
[source: own study]

4. RESULTS

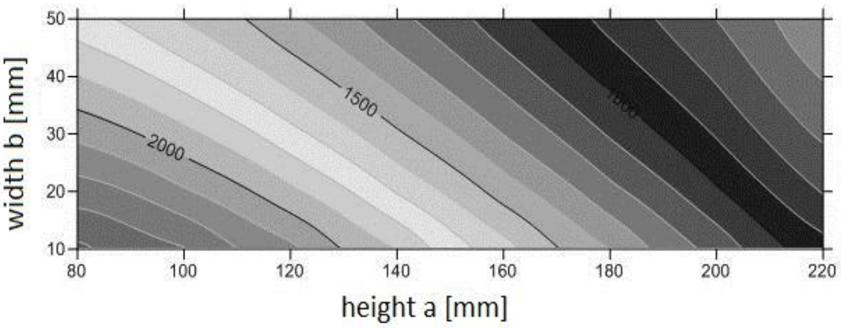
The performed numerical calculations were basis to determine a critical force in analyzed system, in depends on cut-out geometric parameters – height *a* and width *b*, and cut-out shape (Fig.4 and Fig.5).



a) b)

Fig. 4. Critical force depends on geometrical parameters of cut-out *a* and *b* for: a) plate with rectangular cut-out b) plate with hourglass cut-out [source: own study]

a)



b)

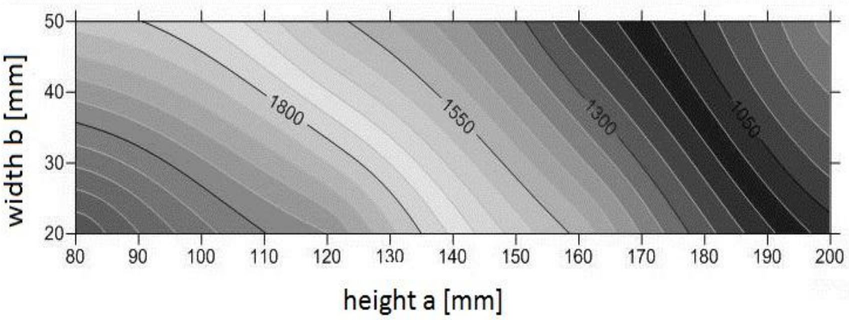


Fig. 5. Critical force in depends on cut-out geometrical parameters in contour form for a) plate with rectangular cut-out, b) plate with hourglass cut-out [source: own study]

On the basis of Fig. 4 and Fig.5 we can see that by changing the dimensions defining the cut-out in plate we can affect on the size of the critical force. The best mechanical properties with regard to the critical load, have a plates with small cut-out width *b* and a relatively small amount of cut-out heigh *a*.

Based on these results, we can see that with the increase of the parameter *a* decreases the value of the critical load. A similar situation occurs with increasing cut-out width *b*.

Wherein, the change of the shape of the cut-out does not have a significant impact on the size of the critical force.

Results of critical force calculations show that by changing the geometric parameters of the cut-out we can affect on its capacity.

The results confirm the possibility of determining stiffness parameters the tested elements in a fairly wide range, while keeping constant the overall dimensions of the structure.

5. CONCLUSIONS

In the work was presented a numerical analysis of linear stability the compression plates with cut-out. The research was conducted in the range of numerical FEM analysis of the critical state for different geometrical parameters of the cut-out, by changing the height *a* and width *b* of the cut-out while maintaining the same overall dimensions of the plate and for different cut-outs shapes.

The results showed a fairly significant impact of cut-out dimensions on the value of the critical load. This concerns in particular the height of cut-out for which the maximum difference in critical load at a constant width cut-out was in the range of 698.59–22497 N in the case of plates with rectangular cut-out shapes and 825.92–2299 N for plates with cut-out shape similar to the hourglass. Wherein, the same shape of cut-outs does not have such a big influence on the critical load value.

This numerical analysis is a preliminary stage to research concerned with the work of construction in elastic postcritical field with forced bending-torsional form of loss of stability.

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