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NUMERICAL ANALYSIS OF THE STRENGTH PROPERTIES OF THE MOVABLE CONNECTION

The purpose of the paper was to design geometric models of the movable connection made of brass for three different attachment options and three different loads. The numerical analysis of the mechanical properties, stresses, strains and displacements using the finite element method was carried out in SolidWorks 2020 and their comparative analysis was performed. The computer simulations performed will allow the boundary conditions that directly affect the mechanical properties of the engineering materials to be optimised.

Keywords: Movable connection; MES; stresses; displacements; strains

1. Introduction

Computer simulation is a very popular method for determining the properties of engineering materials, which is used in many fields of science, industry, and also in everyday life [1-4]. Since the 1950s, the constant development of computer simulation has been observed and it has dynamically growing over the years [5]. Looking at a simulation, it can be said that it is a structure of step-by-step activities that aims to achieve the research objective. This means that any simulation always goes through specific steps and is not chaotic [6-9]. This process is shown in Fig. 1.

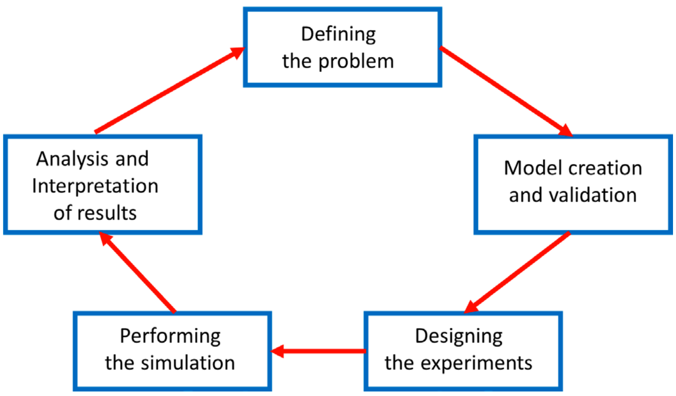

Fig. 1. Diagram showing the course of computer simulation [7]

Computer simulation has also been used in the furniture, automobile and construction industry where the essential element is a movable connection. It is an indispensable element of building machines and devices.

A movable connection is a metal fitting for attaching covers, door leaves and window sashes to allow opening them. Hinges are part of the building hardware, i.e. the group of products designed primarily to close, connect and secure windows and doors, that is connection fittings to be precise [10-12]. Today's movable connection are equipped with additional features to extend their lifetime as well as to improve the user experience. These additional features include the soft-close mechanism, which is designed to slow down the element being closed in case of doors, and its additional advantage is the comfort of getting rid of loud noises from possible slamming by preventing such a situation from occurring. One more feature worth mentioning is the self-opening and closing function, which is used in cupboards. It consists in self opening of the door by applying a slight force to set the movable connection in motion, and also in slowing down the door when it is being closed [10]. Figs. 2-10 show the different types of movable connection.

Fig. 2. Piston movable connection [11]

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Fig. 3. Movable angle connection [11]

Fig. 4. Hidden moving connection [11]

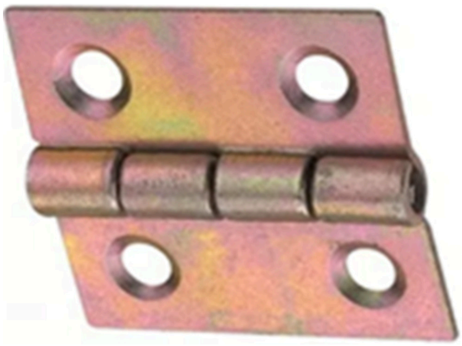

Fig. 5. Braided movable connection [11]

Fig. 6. Cylindrical movable connection [11]

Fig. 7. Glass movable connection [11]

Fig. 8. Refrigerator movable connection hinge [11]

Fig. 9. Middle movable connection [11]

Fig. 10. Complementary movable connection [11]

2. Materials and design

The model of the movable connection together pin is designed with brass, which is an engineering material used to manufacture its, and its properties are shown in TABLE 1. Fig. 11 presents the movable connection model with its dimensions.

The computer simulation was carried out using SolidWorks, which is CAD software [13,14]. It is a parasolid kernel-based program to generate the spatial geometry for the part being designed. It is used for simple designs such as a workplace equipment design, but advanced surface modelling-based designs are

TABLE 1

Material data based on the SOLIDWORKS database

Material	Young's module [MPa]	Poisson's ratio	Density [g/cm^3]	Yield point [MPa]
Brass	100000	0.33	8.5	240

also possible. A braided furniture hinge model was made and the computer simulation of the mechanical properties of the resulting part was carried out using this software.

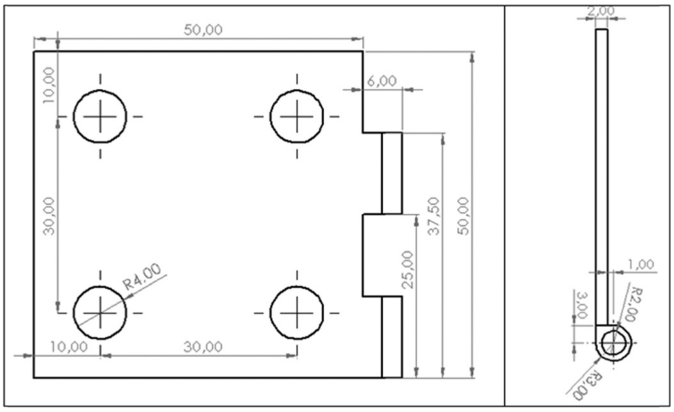

Fig. 11. Overall dimensions of the movable connection

Three models movable connection with different mounting hole locations were made. The simulations were performed for three hinge loads of 100 N, 500 N and 1000 N. As a few mounting holes were made, the forces were evenly distributed between them so that their sum gives the total value. TABLE 2 provides the model numbers with the corresponding loads.

TABLE 2

List of models with the corresponding forces

Model	Force [N]
I – 4 mounting holes	100
	500
	1000
II – 3 mounting holes 2+1	100
	500
	1000
III – 3 mounting holes 1+2	100
	500
	1000

3. Computer simulation

The numerical movable connection model was based on the actual dimensions. The hinge was permanently fixed at three points, in all directions, and then loaded with different forces imitating shelves, cabinets or doors hung on the hinge. Fig. 12 shows the geometric models of the movable connection and Fig. 13 shows the geometric models with the finite-element mesh

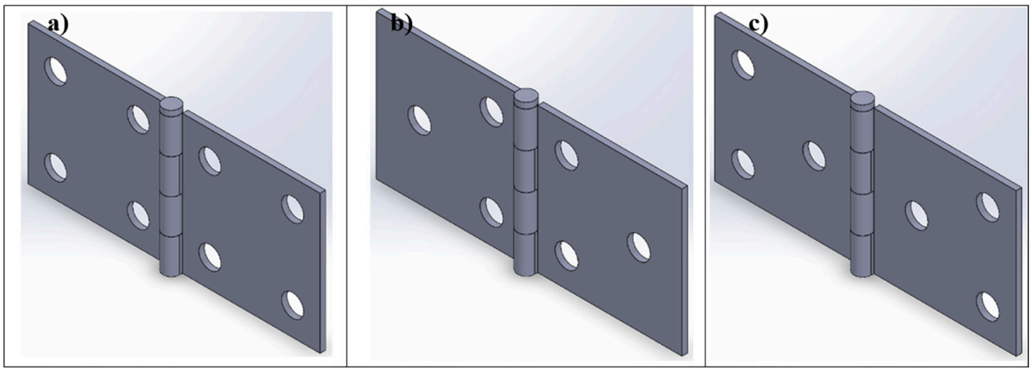

Fig. 12. Geometric model of the furniture movable connection: a) Model I, b) Model II, c) Model III

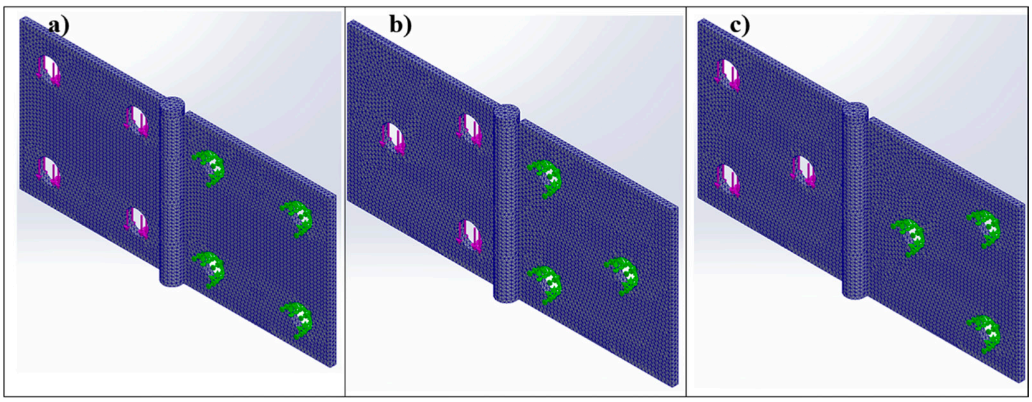

Fig. 13. Geometric model of the movable connection with the finite-element mesh applied and the boundary conditions: a) Model I, b) Model II, c) Model III

applied and the boundary conditions in the form of locking the hinge in bushings to take all degrees of freedom at these points. The standard mesh consisting of three-node triangular finite elements. consisting of 94,565 knots and 55,136 elements, having 16 Jacobian points. Tolerance is on the level of 0.0564791 mm. The force as shown in Fig. 13 was applied.

4. Results discussion

Figs. 14-16 show the distribution of stresses in the movable connection being analysed. In all the models used, the stresses are concentrated at the points where the movable connection wings and the bushings are joined and through which the pin was driven and propagate towards the closest mounting holes. In all these models, the application of a load of 1000 N resulted in damage to the movable connection with the highest stress for Model III which was 555 MPa, where the yield strength for brass is 240 MPa, which means it was exceeded twice. These movable connection are not suitable for operation at such high loads. For the load of 500 N, Models I and II were not damaged, but Model III failed to withstand such a load and was damaged. When loaded with 100 N, the movable connection can withstand the set conditions without any problem. It should be noted that for the force of 500 N in Model I the highest stress obtained is 234 MPa, which means that the movable connection was not

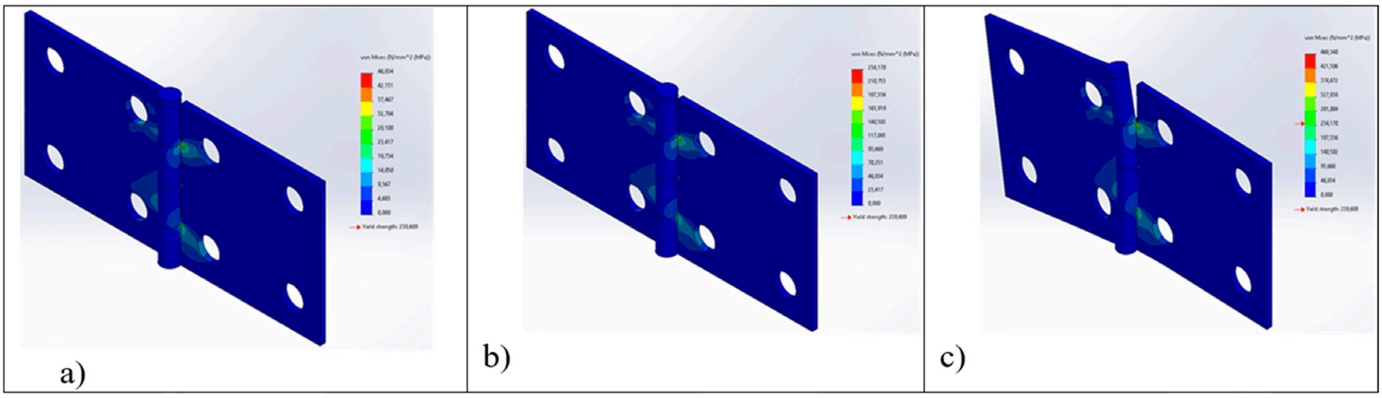

Fig. 14. The von Misses stress distribution in model I for the force of 100 N, 500 N, 1000 N

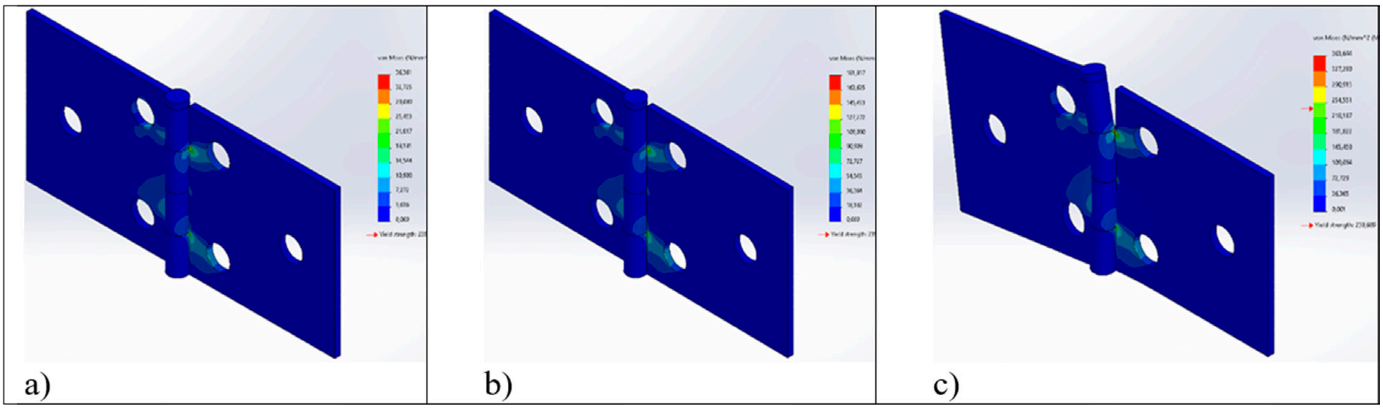

Fig. 15. The von Misses stress distribution in model II for the force of 100 N, 500 N, 1000 N

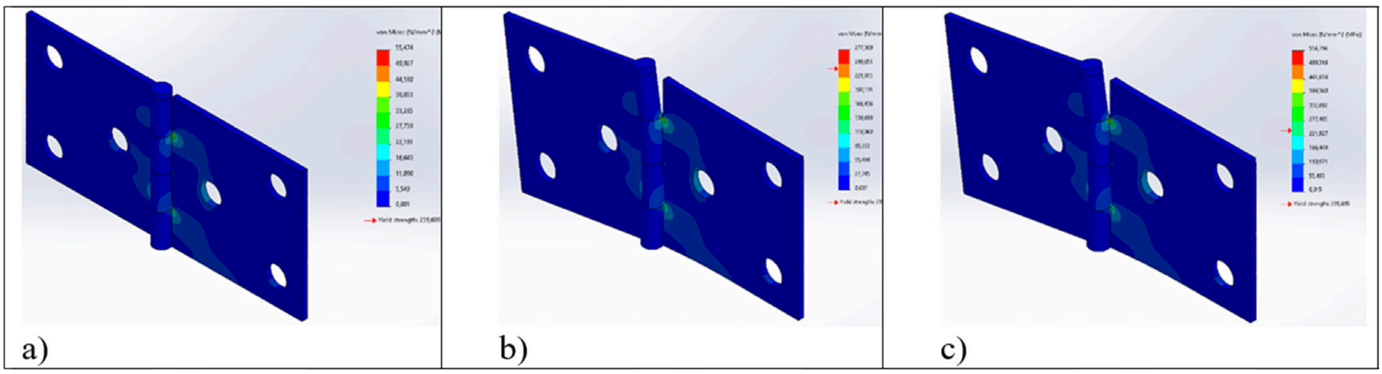

Fig. 16. The von Misses stress distribution in model III for the force of 100 N, 500 N, 1000 N

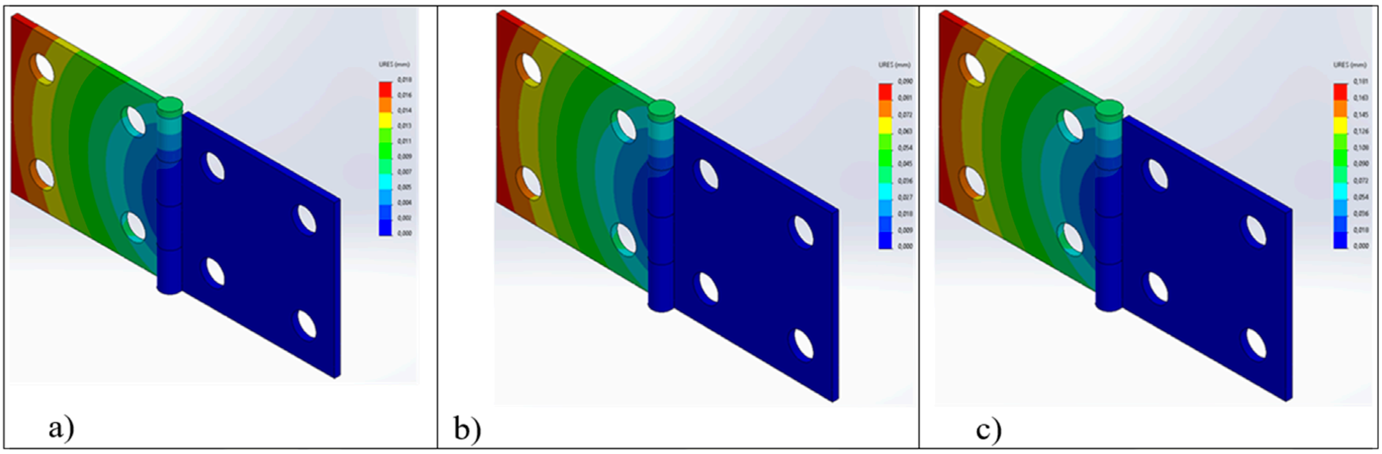

Fig. 17. The displacement distribution in the I model for the force of 100 N, 500 N, 1000 N

damaged. However, this is a result very close to the yield strength of brass and therefore the movable connection operation under these conditions may result in damage to its. The displacement values for all the three forces are lowest in Model II and highest in Model III. Displacements occurred in the wing under load.

The displacement values for Models II and III are similar, while the results obtained for Model III are twice as high, but none of the displacement values obtained exceeded 1 mm. The examples of displacement distribution maps for Model I are presented in Fig. 17. The results of the computer simulation of strains in the hinges being analysed are summarised in TABLE 3. For Models I and II, the strains are distributed uniformly between the bushing and the closest mounting holes, while in Model III they are located around the pin in the form of circles. In all cases, the highest strain values were observed at the joint points between the movable connection wings and the bushings. The results of the computer simulation for stresses, strains and displacements are summarised in TABLE 3.

5. Conclusions

The dynamic development of software and technology allows the design to be modified and adapted economically and qualitatively to the required objectives during the design phase. The computer simulation results showed clearly that increasing the number of fixings in the furniture movable connection does not always reduce the stresses that occur in the hinge during use. In addition to the forces applied, the mechanical properties such as stresses, displacements and strains that occur under load in the analysed elements are greatly affected by the number and location of the mounting holes.

- None of the movable connection withstood the load of 1000 N because the stress value significantly exceeded the yield point of brass. Models I and II withstood the load of 500 N, but the force applied was too much for Model III where the movable connection was damaged. All the three models resisted the applied force of 100 N.
- The computer simulation results showed that increasing the number of fixings in the movable connection does not always reduce the stresses that occur in the during use. It was noted that the 3-hole movable connection design was much better able to handle loads than the 4-hole one. In addition, the arrangement of the mounting holes in the 2+1 configuration is a much better solution than 1+2N.
- In all the models, the displacements concentrated on the movable connection wing under load and did not exceed 0.3 mm.

TABLE 3

Summary of computer simulation results of stresses, displacements and deformations

Model	Force [N]	Maximum values		
		Von Mises stresses [MPa]	Displacements [mm]	Strains
I	100	47	0.018	0.000356
	500	234	0.090	0.00178
	1000	468	0.181	0.00356
II	100	36	0.014	0.000268
	500	182	0.07	0.00134
	1000	363	0.14	0.00268
III	100	55	0.027	0.00043
	500	277	0.134	0.00215
	1000	555	0.267	0.0043

- In all the cases analysed, the strains were located at the joint between the movable connection wings and the bushings. These were the points where the movable connection was damaged under too much load.
- The most favourable stress, strain and displacement values for all three loads of 100 N, 500 N and 1000 N were obtained for Model II, i.e. the movable connection with 3 mounting holes in the 2+1 configuration.

In the computer simulation, simplifying assumptions were accepted both at the stage of creating geometry, determining material properties and modelling itself, which may constitute directions for further development of this research field.

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