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Stress Formations of Steel Track Roller and Slot of Sliding Cabinet Door under Static Conditions

Mustafa Murat YAVUZ[1*]

[1]Department of Industrial Engineering, Osmaniye Korkut Ata University, Osmaniye, TURKEY

***Sorumlu Yazar:**
E-mail: muratyavuz@osmaniye.edu.tr

Abstract
In this work, stress formation of a track roller of sliding cabinet door is investigated under static conditions. These rollers are the main part of carrying the door and provide motion properties. For this purpose, they are interaction with a slot system and transfer the carried weight and forces into the interacted slot, which is the support of the whole system. In literature and technical reports, some failure conditions have been reported as failure of whole roller, damaged slot bed, non-symmetric stress distribution and deformation, wear and etc. are detected. In this study, to determine the situation of mechanic behavior of the system, a numerical study is carried out. Finite element analysis (FEA) is applied to the prepared model that includes a slot and a roller mechanism. Applied force is selected as a typical door weight and the used material properties are selected as standard steel. The one arm connection between roller and door support causes a non-linear contact stress distribution that causes local peak stresses. The stress locations have been determined. Maximum deformation occurs at the force application area of the roller tip surface. When addition of fillet and increasing fillet radius are applied, deformation and stress results get larger. The results are discussed in detail.

Keywords: Stress, deformation, FEA, track roller, fillet

INTRODUCTION

Lots of different commercial and industrial doors are available and new designs are applied to increase their usability, manufacturing, strength/weight and mobility. One of them is sliding doors those are commonly used. The main parts include a slider slot, a track roller and a stopper. Their simple and effective usage provides popularity. But, some disadvantages are seen, especially in their mechanical properties in usage. There are lots of patent data and knowledge is available, but less data can be achieved about sliders and their strength directly. But main mechanism is contact interaction of track roller and slot surface, whose data can be achieved with contact interaction studies.

Chin et al. [1] design an oven with considering opening the over door easily and accessibility, safety from heat and height adjustability. They use a sliding slot system and make static analysis. Most of the cases are examined contact stresses. This phenomenon occurs in these sliding slot systems. Ryu et al. [2] examine stress-dependent fatigue wear mechanism of pure copper surfaces. They are exposed on sliding motion and it is detected that surface damage gets increasing under compression stresses and decreasing tensile stresses. Song et al. [3] study on 2D sliding frictional contact of an elastic solid with plane strain and couple stress elasticity theory. They predict contact stresses by couple stress elasticity which supports more accurate prediction than classical elasticity analysis for half plate at the same boundary conditions. Linz et al. [4] study on directional development stage of residual stresses and surface fatigue during sliding contact and they detect that residual stresses are found to be higher transversal to the moving direction than longitudinal. Sun and Bailey [5] investigate sliding conditions effect on AISI 304 stainless steel for considering tribo-electrochemical phase. They discuss mechanical damages by sliding and wear-pit growth relation during their search. Zhang et al. [6] make an optimization research on micro-textures for bearing sliders. The aim is improving tribological performance and they find better tribological improvement effects. Pu et al. [7] investigate rolling and sliding contact fatigue of surfaces that includes sinusoidal roughness. They detect that sliding provides to a significant reduction of contact fatigue life and rough surface asperity causes to acceleration of pitting failure.

Chong and Chidlow [8] examine sliding and adhesive contact for a multi-layered elastic solid. The layered solid contains homogeneous coating bonded includes a functionally graded layer. They find that when adhering conditions are weak, Coulomb traction assumption suffices to determine the displacements and subsurface stresses within the multi-layered solid. Shen and Zhou [9] investigate thermal response of titanium alloy fretting sliding with respect to the friction dissipation, plastic dissipation, surface roughness and wear. They use numerical methods and they mention that friction and plastic energy dissipations function together as the heat source which causes the temperature rise in the contact zone. Coulibaly et al. [10] try to model sliding cable to create formulations. Savolainen and Lehtovaara [11] study on subsurface fatigue failures in a rolling/sliding contact with a twin disc test device. They examine various surface hardened test discs with different load levels. They detect those critical locations in the discs beneath the disc surfaces. Zhao et al. [12] investigate rolling and sliding effects between non-spherical particles. They use discrete element analysis.

This study includes investigation of stress formations of steel track roller and slot of sliding cabinet door under static conditions. Stress contours and deformations of parts are given. Finite element analysis is applied to provide the investigation. All the models, conditions and results are explained in detail.

MATERIALS AND METHODS

The study is carried out by using numerical methods, which is selected as finite element method. A computational model is created and it is transferred to a suitable finite element solver. A slot, a track roller and a stopper are created and their assemble geometry is shown in Fig. 1. All dimensions are given in S.I. metric units. Slot has a length of 800 mm, a width of 50 mm and a height of 65 mm. There is a C shape rectangular channel is created for assembling the track roller, which has a width of 30 mm and a height of 45 mm. Width and height dimensions of roller track is also as similar as channel dimensions. A stopper is modelled as two stepped 10 mm thickness, is placed at the one end the slot. No friction is applied between track and slot surfaces. The stopper is bounded to the slot.

A numerical test is carried out into the slot by applying force that has a magnitude of 100 N. The roller has a radius location near the edge of larger and smaller diameter interaction location at the larger section edge. No-fillet (default case) and fillet radius of 1 mm, 2 mm and 4 mm case studies are examined. Backside great surface is fixed at the determination of boundary condition.

Steel material properties are selected which has a density of 7800 kg/m^3, Modulus of Elasticity 205 GPa, Poisson's ratio 0.3, tensile yield strength of 350 MPa and ultimate strength of 420 MPa. Von-Mises stresses are used to show stresses, which is suitable for linear elastic isotropic material failure theories.

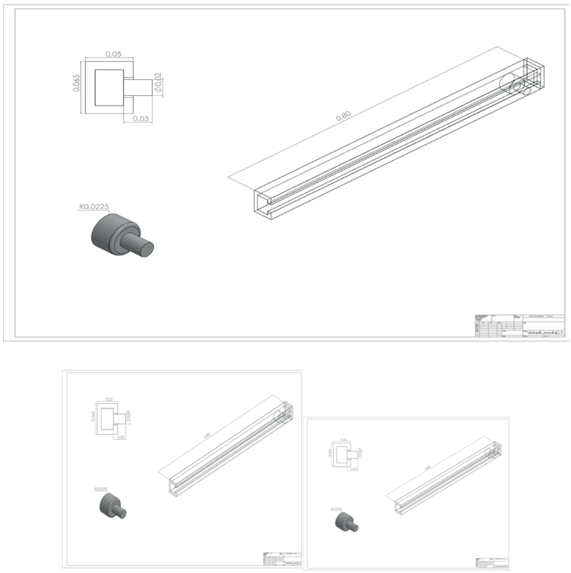

Figure 1. Assembly model of slot, track roller and stopper

RESULTS AND DISCUSSION

Deformation results of only slots are given in Fig. 2, 3, 4 and 5. It is observed that whole deformations occur at the interaction location between track roller and slot surfaces. When adding fillet condition and increasing fillet radius, deformation results get larger. Largest deformation location is detected as the side upper frontal interaction location of slot that interact the track roller highly.

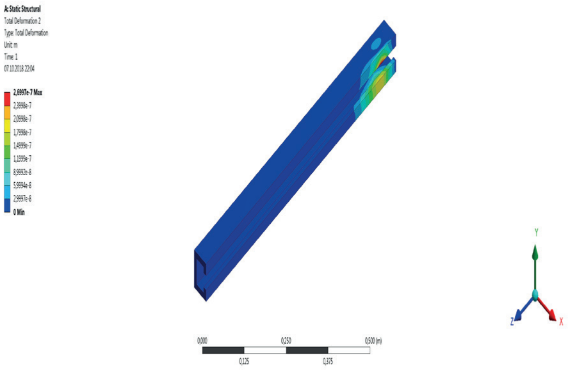

Figure 2. Total deformation of default case slot

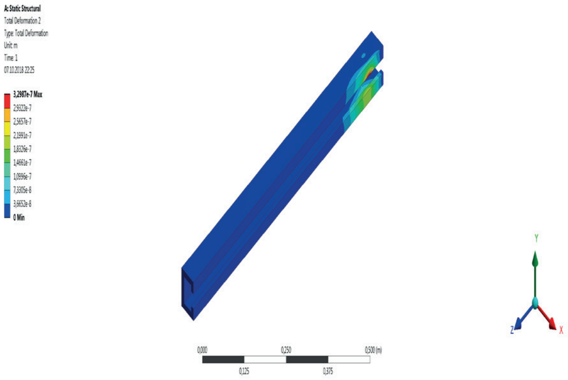

Figure 3. Total deformation of 1 mm fillet radius case slot

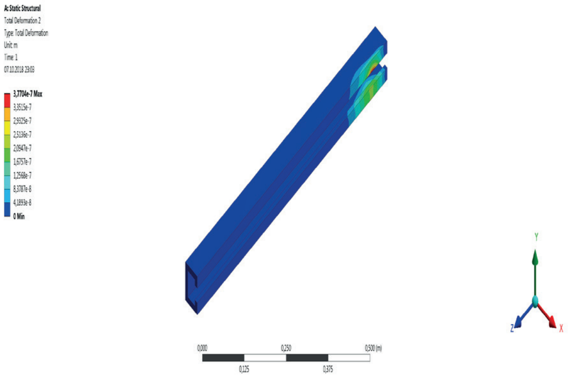

Figure 4. Total deformation of 2 mm fillet radius case slot

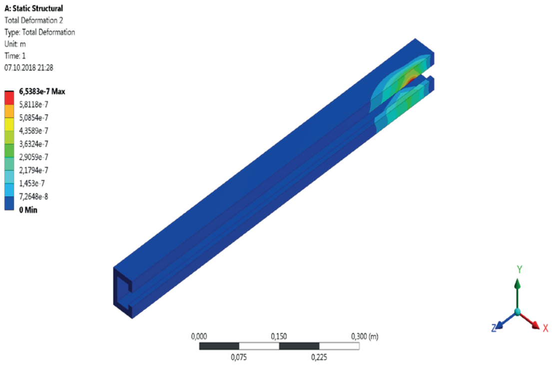

Figure 5. Total deformation of 4 mm fillet radius case slot

Figure 6. Von-Mises stress of default case slot

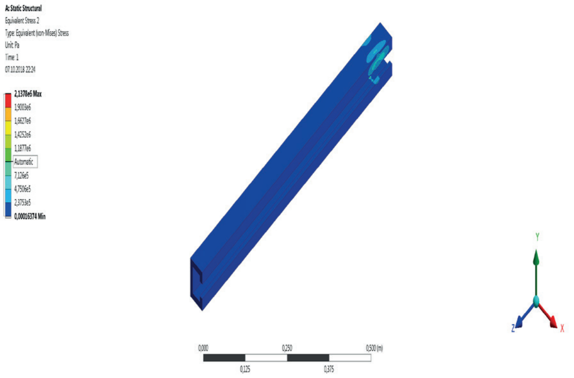

Figure 7. Von-Mises stress of 1 mm fillet radius case slot

Figure 8. Von-Mises stress of 2 mm fillet radius case slot

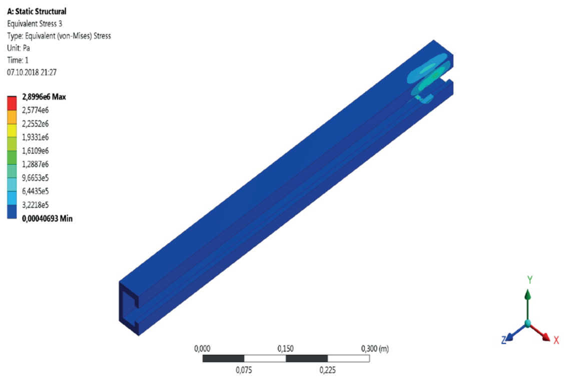

Figure 9. Von-Mises stress of 4 mm fillet radius case slot

Von-Mises stress results of only slot are given in Fig, 6, 7, 8 and 9 for the cases. The stress values get larger when addition and increasing the fillet radius of the track roller edge. But all the greatest stress values are smaller than yield strength of steel. Hence, it can be safe with considering only static analyses.

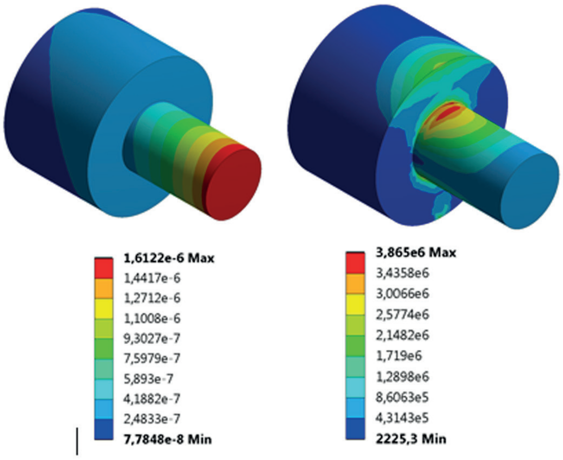

Figure 10. Deformation (left) and Von-Mises stress (right) results of default case track roller

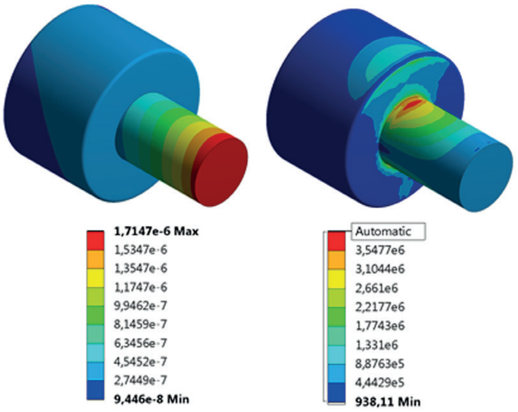

Figure 11. Deformation (left) and Von-Mises stress (right) results of 1 mm fillet radius case track roller

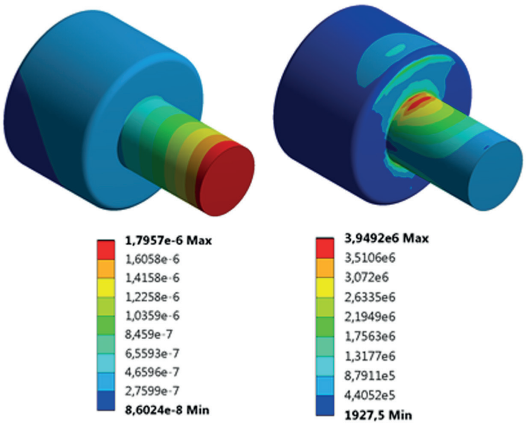

Figure 12. Deformation (left) and Von-Mises stress (right) results of 2 mm fillet radius case track roller

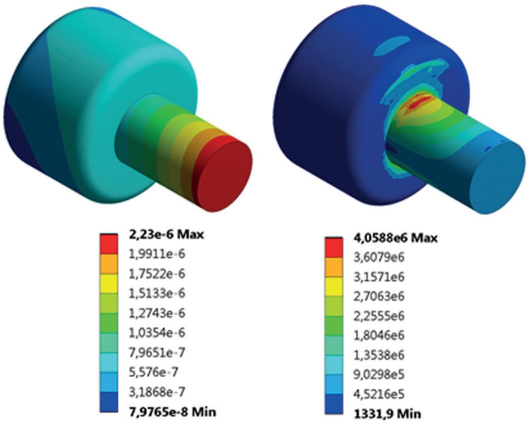

Figure 13. Deformation (left) and Von-Mises stress (right) results of 4 mm fillet radius case track roller

Deformation and stress results of track roller are given in Fig. 10, 11, 12 and 13. When increasing fillet radius, all the stress and deformation results get larger. Maximum deformation occurs at the force application area of the roller tip surface. Maximum stresses occur at the interaction of higher and lower diameter location of the roller.

In Fig. 14, 15, 16 and 17, total deformation results of the whole assemblies are given. Increased fillet radius causes to increase the deformation. Maximum deformation occurs at the force applied location in the whole results.

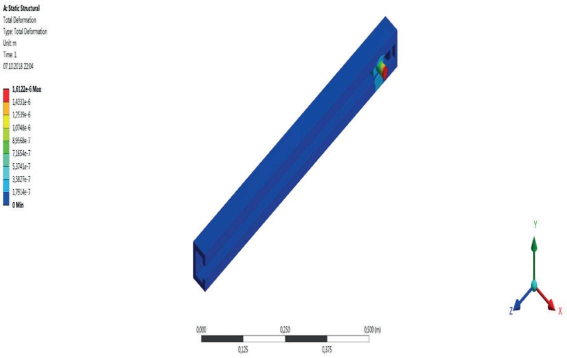

Figure 14. Total deformation of default whole case system

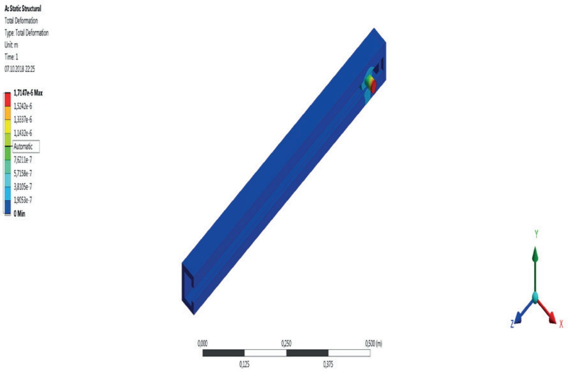

Figure 15. Total deformation of 1 mm fillet radius whole case system

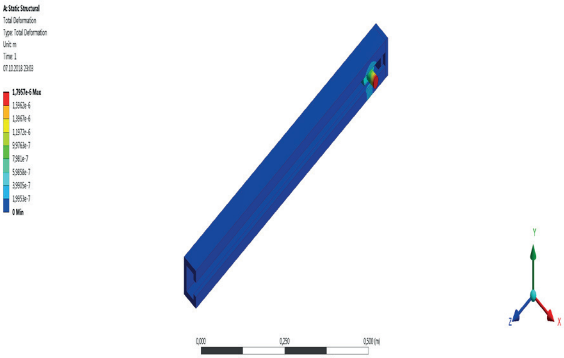

Figure 16. Total deformation of 2 mm fillet radius whole case system

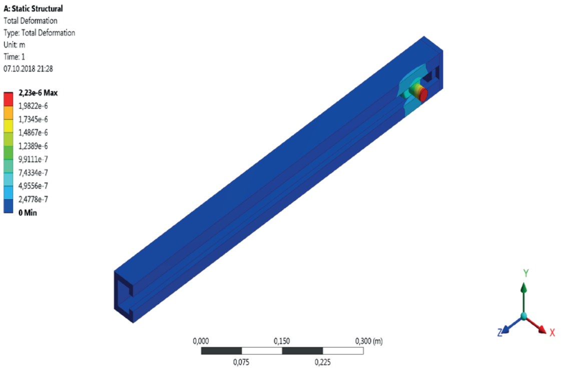

Figure 17. Total deformation of 4 mm fillet radius whole case system

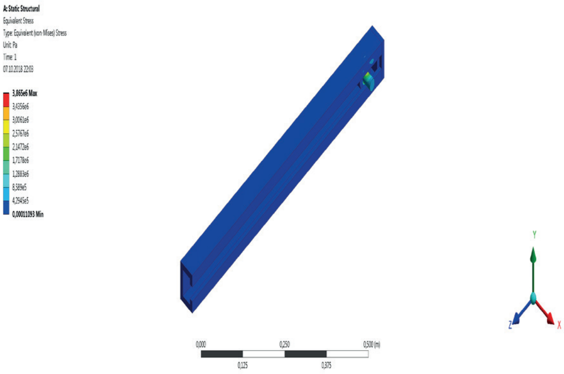

Figure 18. Von-Mises stress of default whole case system

Figure 19. Von-Mises stress of 1 mm fillet radius whole case system

Figure 20. Von-Mises stress of 2 mm fillet radius whole case system

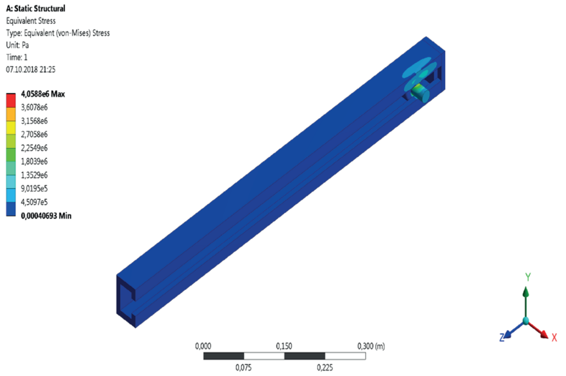

Figure 21. Von-Mises stress of 4 mm fillet radius whole case system

In Fig. 18, 19, 20 and 21, Von-Mises stress results are given for whole assembly. Addition and increasing the fillet radius increase the stress value, but general formation location is the same in whole results, where the interaction of small extension diameter root and slot side surface.

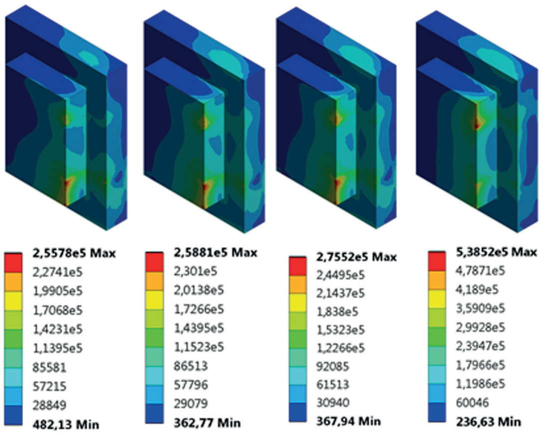

Figure 22. Von-Mises stresses of stoppers in the case analysis from default (left side) to 4 mm fillet radius (right side)

Stopper stress results are also given. Similarly the usage of fillet cause to increase the stress values. Two stress peak points are detected, where is C-shape slot tip edges interaction location on the stoppers.

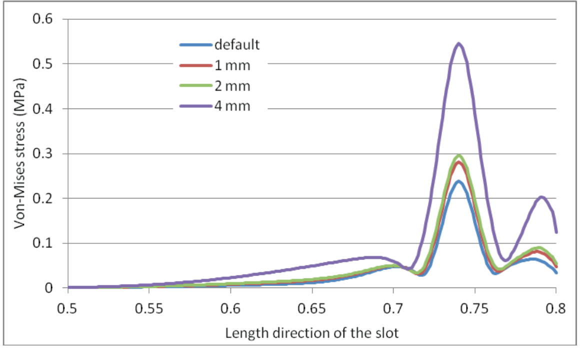

Figure 23. Von-Mises stresses on a path of longitudinal upper edge of slot for all cases (half-section is illustrated)

In Fig. 23, a straight path is selected on the longitudinal upper edge of the slot and stress values are shown for half side. When filleting is included, stress values get increasing. 4mm results are nearly two times greater than default (no-fillet results).

CONCLUSION

In this work, a slot, tracker roller and stopper system is examined under static conditions to observe stress formations and effect of filleting of roller on stresses. Most of the engineering applications, filleting is applied to prevent nodal interaction that mostly causes stress peak points. But in this study, it can be said that;

- When adding fillet condition and increasing fillet radius, deformation results get larger.
- Largest deformation location is detected as the side upper frontal interaction location of slot that interacts with the track roller highly.
- The stress values get larger when addition and increasing the fillet radius of the track roller edge.
- Maximum deformation occurs at the force application area of the roller tip surface.

When static conditions it can be said that no-filleting on the roller has better. In the further analyses, dynamic conditions on this research will be examined.

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