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PASSIVE MOTION SPLINT APPLIED IN TRAUMATOLOGY AND ORTOPAEDICS

PASIVNÍ MOTODLAHA V TRAUMATOLOGII A ORTOPEDII

Abstract

This article deals with analysis of the knee continuous passive motion (CPM) splint used for rehabilitation of patients after surgeries and injuries. CPM splints are used for speeding up the treatment and restoration of the joint mobility and to stop complications caused by immobilization. The goal is to solve kinematic, dynamic, deformation and stress parameters of "Artromot K1 Comfort" CPM splint.

Abstrakt

Tento článek se zabývá analýzou pasivní kolenní motodlahy sloužící k rehabilitaci pacientů po operacích a úrazech. Pasivní motodlahy se používají pro urychlení léčby, obnovu pohyblivosti kloubů a zamezení komplikacím způsobených imobilizací. Cílem je řešení kinematických, dynamických, deformačních a pevnostních parametrů pro motodlahu "Artromot K1 Comfort".

Keywords

Knee passive motion splint; Continuous passive motion (CPM); knee joint trajectory; kinematic; dynamic; stress analysis; MSC Adams; ANSYS.

1 INTRODUCTION

Continuous passive motion (CPM) splint (produced by Artromot company, model K1), see Fig. 1, is used at the Trauma Centre (University Hospital in Ostrava). The design ensures anatomically correct movement of a limb. The range of motion and possibilities of setup: flexion/extension (knee joint -10 deg to 120 deg, hip joint 0 deg to 115 deg), speed 23 to 230 deg/min, pauses in flexion or extension 1 to 59 seconds, patients height from 120 to 200 cm, maximal weight of limb 30 kg.

Fig. 1 Artromot K1 Comfort, see [1]

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Gravitational forces caused by limb are applied to the frame. Their magnitude is given by the maximal load capacity of the splint and distribution of thigh, calf and foot weights as seen in Tab 1. In the solution the weight of the frame is also included.

Tab. 1 Weight distribution

Part of the limb	Percentage [%]	Weight [kg]	Gravitational force [N]
Thigh	12.4	20	196.2
Calf	4.6	7.4	72.6
Foot	1.6	2.6	25.5

2 KINEMATICS AND DYNAMICS

MSC Adams software, see [2], is used for the analysis performed according to the multibody system theory. The CPM splint has 1 degree of freedom, therefore the geometric configuration can be expressed by one parameter length L_P which is the displacement of nut relative to the screw, see Fig 2. For the analysis of the kinematics for the 2 variants A and B splint are selected. The first variant A represents the boundary position in the event of maximum extension of thigh and calf. This option represents the maximum size of the patient's limb. The second variant B represents the minimum size of the patient's limb. Dimensions for each variant are shown in Tab 2.

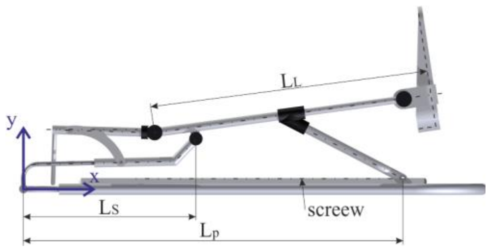


Fig. 2 Dimension of the calf and thigh

Tab. 2 Length of the calf and thigh

Dimension	Variant A	Variant B
L_L [mm]	626	431
L_S [mm]	388	257

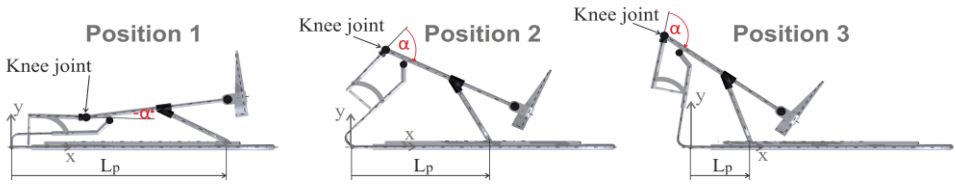


Fig. 3 Position of the splint

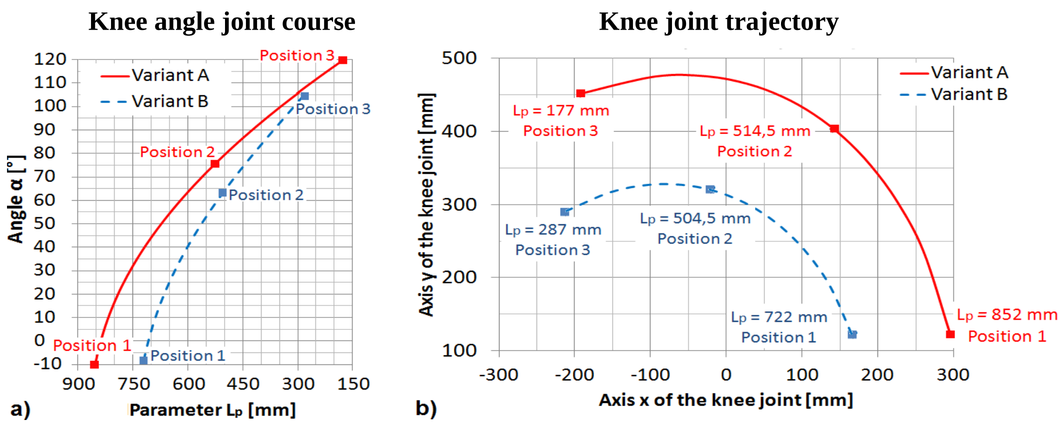


Fig. 4 Kinematic parameters of the splint

The computed magnitude of knee joint angles in dependence on the displacement is shown in Fig 4a. This angle is displayed to the patient on the remote control. In Fig 4b, the knee joint trajectory is shown. The data in the figure were described by the parameter L_P and position 1 to 3 label got for better visualisation. The knee joint trajectory can be used to compare with the new construction version of the splint or to assess correct anatomical limb movement.

For the following dynamics analysis of the splint is selected the variant A because the splint has the highest loads. The results of the dynamics analysis are dependences of the reaction forces in the splint system. These results can be used for stress analysis, for application of forces in different positions or in the fatigue analysis etc. Reactions, loads and gravitational forces are shown in Fig 5 and Fig 7.

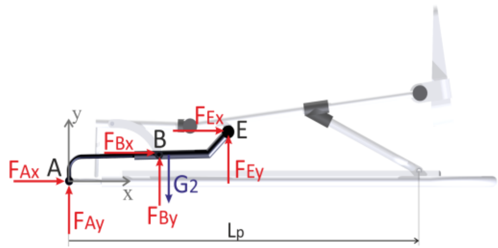


Fig. 5 Forces of the part 2

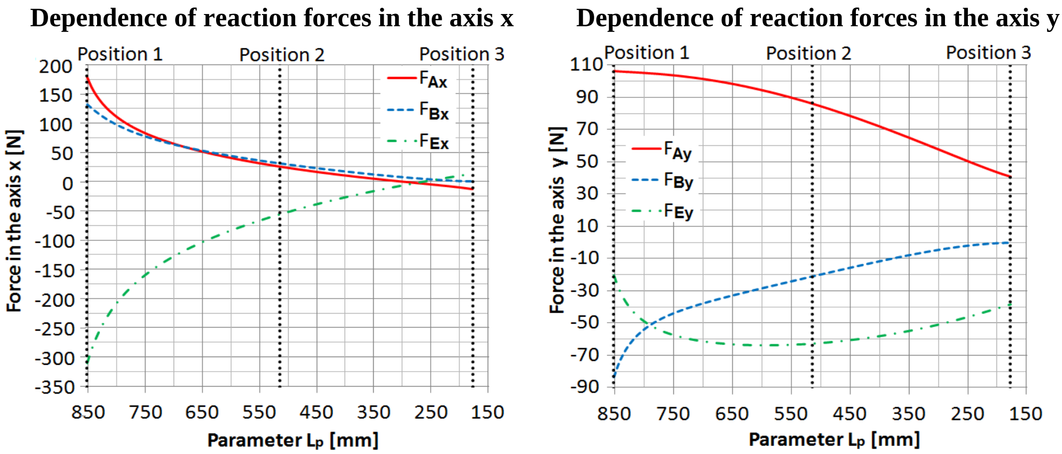


Fig. 6 Reaction forces in part 2

The dependence of reaction forces in the axis x and axis y are plotted in Fig 6 and Fig 8. The results give us an overview of which splint part has the maximum loading. Reaction in screw is plotted in Fig 8 in the opposite direction. This reaction is important for designing screw and determining motor power. Maximum screw load is in initial position 1.

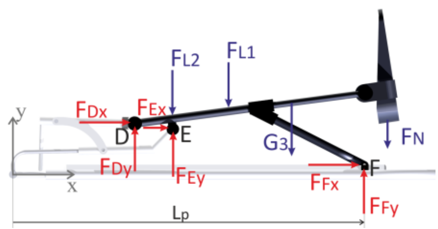


Fig. 7 Forces of the part 3

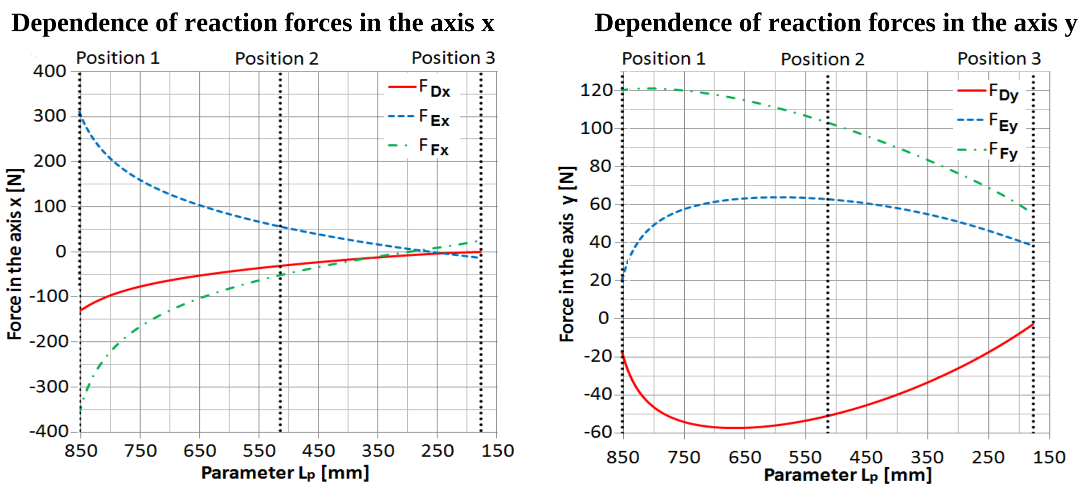


Fig. 8 Reaction forces in part 3

3 STRESS ANALYSIS

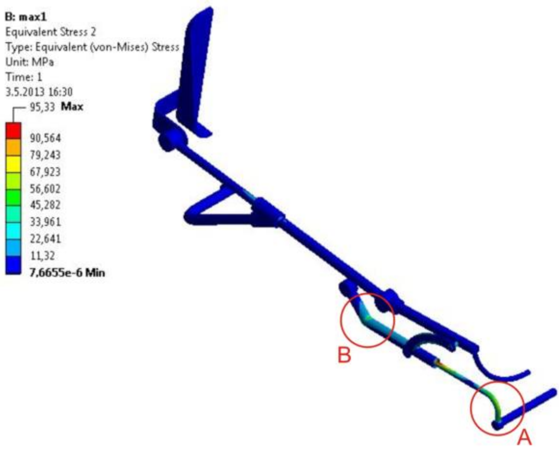


Fig. 9 Important places for comparing stress

Ansys Workbench software version 14 (i.e. FEM) was used for the deformation and stress analyses in the parts of splint. Stress field was caused by the weight of the leg distributed on 4 areas (thigh, calf, and heel). From the computational point of view, this can be considered as a static problem, which is done for 5 positions of the splint for each variant. Totally solving 10 positions. The calculation also involves standard gravity loadings. Splint is considered to be made of Duraluminium. The stress of variant A position 1 (see Fig. 3) is shown in Fig. 9. Three details are shown in the figure. Detail A and B are the most important places on model for comparing stress values of each splint position.

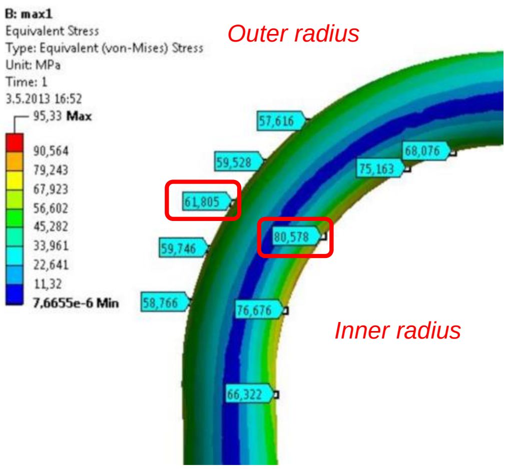


Fig. 10 Detail of von Mises stress distribution for position 1 variant A

In each position, the highest value of stress is found on both inner and outer radius as is shown in Fig. 10 for variant A position 1. This is done for two hypotheses, the von Mises and the Guest. The highest results are highlighted in red rectangles. Figures 11 and 12 show von Mises result of stress for position 3 and position 5. Figures 13, 14 and 15 show this result for variant B position 1 to 3.

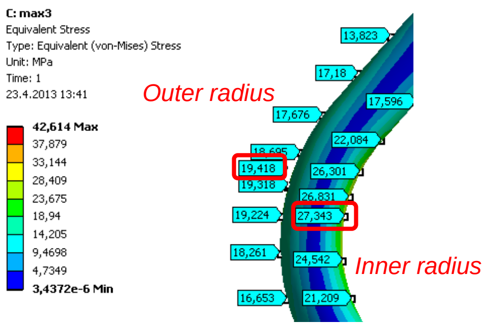


Fig. 11 Detail of von Mises stress distribution for position 2 variant A

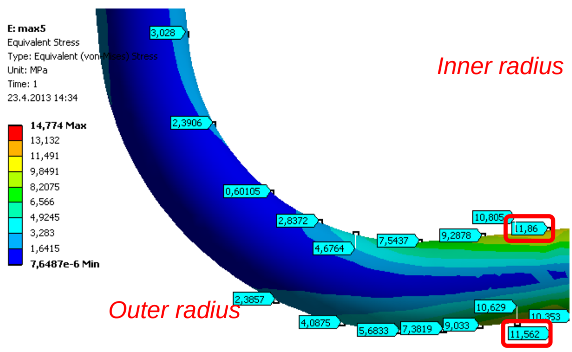


Fig. 12 Detail of von Mises stress distribution for position 3 variant A

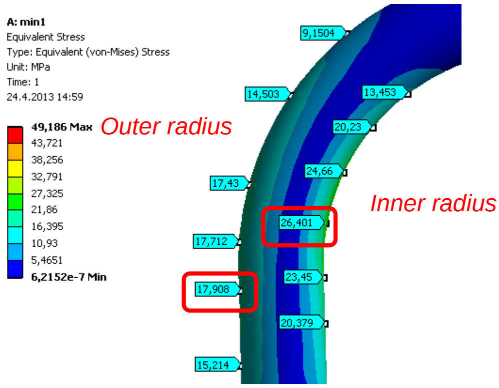


Fig. 13 Detail of von Mises stress distribution for position 1 variant B

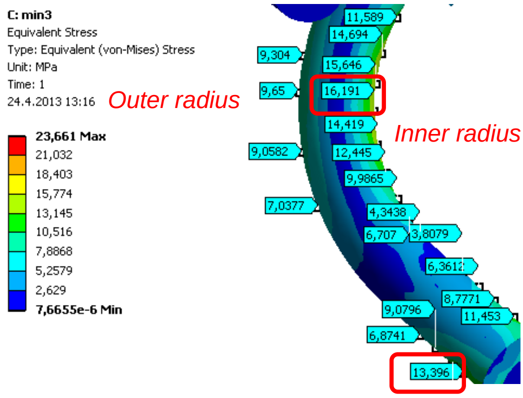


Fig. 14 Detail of von Mises stress distribution for position 2 variant B

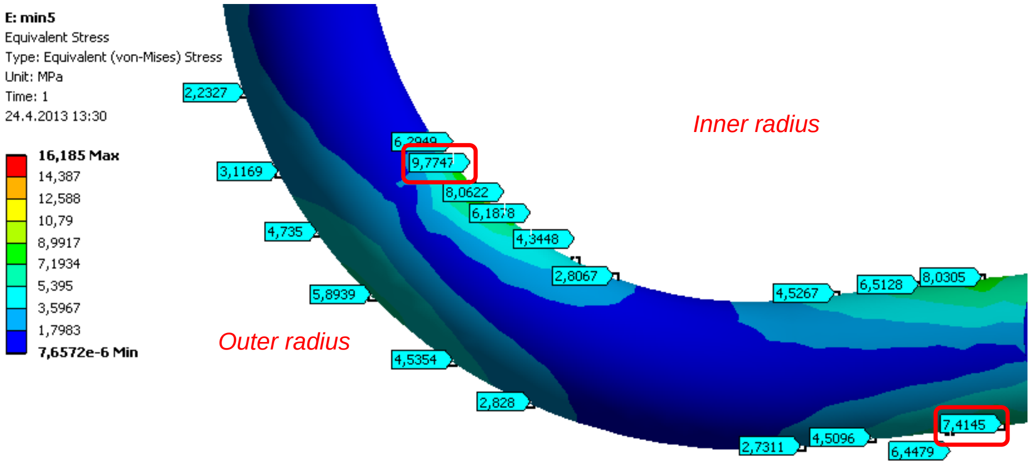
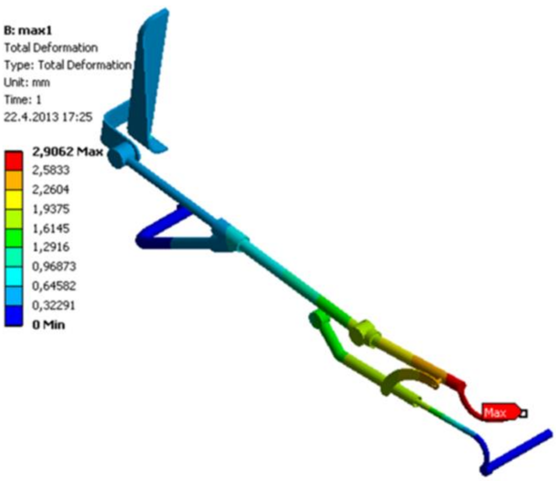
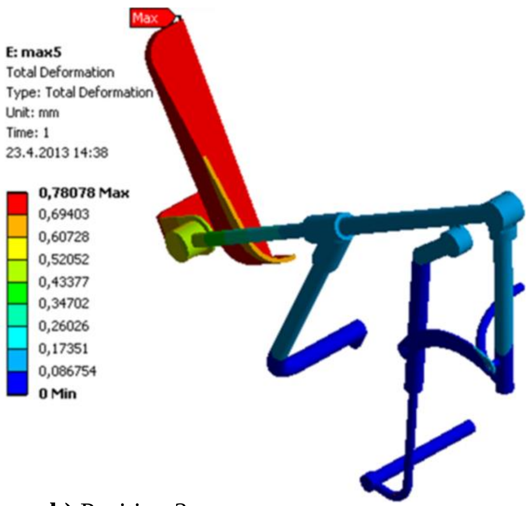


Fig. 15 Detail of von Mises stress distribution for position 3 variant B



a) Position 1

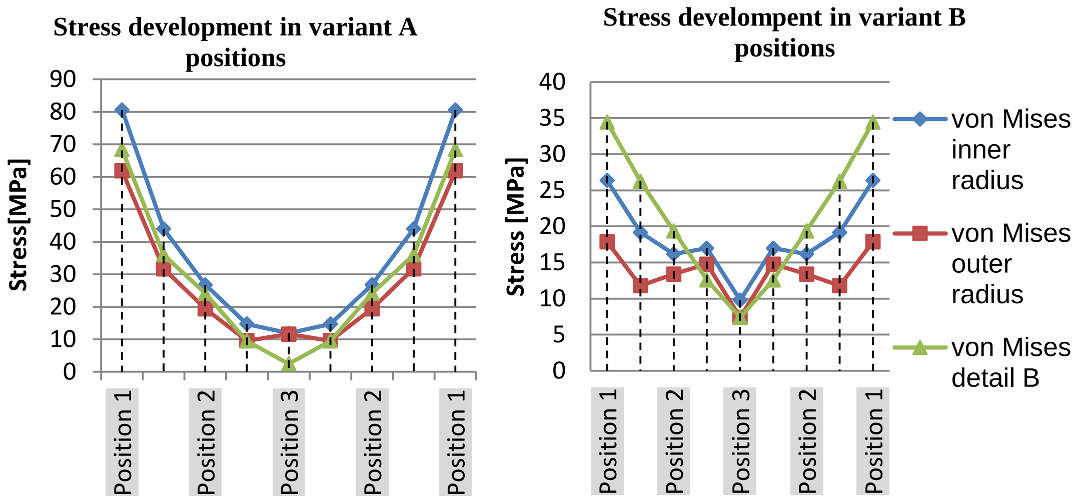


b) Position 3

Fig. 16 Highest deformation in position 1 and 3 for variant A

The maximum deformation (total displacement) result changes with positions. The highest result in position 1 variant A is under the thigh and the highest result in position 3 is under the foot as is shown in Fig. 16a and Fig. 16b.

The changes of the highest stresses changes for variant A over all positions are shown in Fig. 17a. The graph includes the stress result of detail B. In Fig 17b are shown the same results for variant B. The deformation is compared for each corresponding position of both variants as the maximum deformation moves from under the thigh to a foot region. Deformation in corresponding positions is on the same place of the model. Deformation results are shown in Fig. 18.



a) **b)**

Fig. 17 Stress development for variant A and for variant B

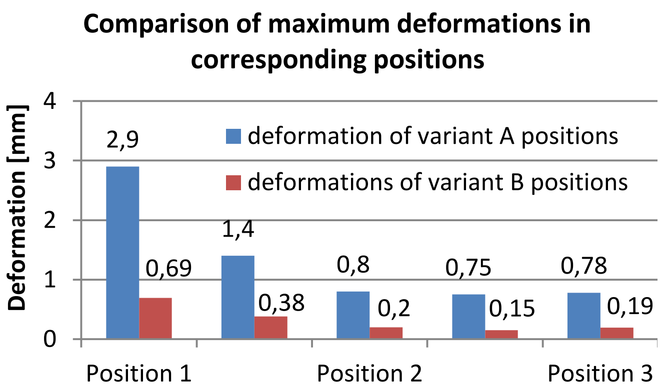


Fig. 18 Deformation comparison

4 CONCLUSION

Continuous passive motion splint "Artromot K1 Comfort", used in traumatology orthopaedics and rehabilitation for treatment of patients, was solved in this article. Multibody system theory (ADAMS sw) and FEM (ANSYS sw) were applied for the solution of dynamical and strength analyses. All results will be applied for design of a new passive motion splint, see [5].

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