Transactions of the VŠB – Technical University of Ostrava, Mechanical Series
No. 2, 2013, vol. LIX
article No. 1960

Pawel JURECZKO[*], Damian GĄSIOREK[**],
Michal BACHORZ[***], Łukasz JUSZYŃSKI[****]

THE EXERCISE DEVICE OF THE LOWER LIMBS

REHABILITAČNÍ ZAŘÍZENÍ PRO DOLNÍ KONČETINY

Abstract

In the article Authors are showing the endurance test of the prototype multifunctional device for contraction exercises of joints and strengthening muscles. The endurance test was conducted with finite element method in the Ansys Workbench program and permitted the durability of material checking, whether the structural figure of the device is safe from the side for patients.

Abstrakt

Autoři článku se zabývají pevnostním výpočtem multifunkčního prototypu, který bude sloužit pro rehabilitací kloubů a svalů. Pevnostní výpočet byl realizován v prostředí programu Ansys Workbench za účelem ověření vhodnosti použitého materálu a zda-li je konstrukční návrh bezpečný z pohledu pacienta.

Keywords

Rehabilitation, lower limb, Dynamizer.

1 INTRODUCTION

Problems in getting the full scope of the movement in the joint can result from damaging articular surfaces inside the incongruity articular and resulting from here or for reasons outside articular i.e. of contracture of contractile tissues - muscles working within the joint, contracture of unshrinkable tissues - of a synovial capsule and ligaments[1,2].

[*] PhD. Eng., Silesian University of Technology, Konarskiego 18A, 44-100 Gliwice, Poland, tel. (0-48) 32 237-28-47, e-mail: Pawel.Jureczko@polsl.pl

[**] PhD. Eng., Silesian University of Technology, Konarskiego 18A, 44-100 Gliwice, Poland, tel. (0-48) 32 237-28-47, e-mail: Damian.Gasiorek@polsl.pl

[***] MSc. Eng., Institute of Medical Technology and Equipment in Zabrze, Roosevelta 118, 41-800 Zabrze, Poland, tel. (0-48) 32 271-60-13, e-mail: michal.bachorz@itam.zabrze.pl

[****] MSc. Eng.,Institute of Medical Technology and Equipment in Zabrze, Roosevelta 118, 41-800 Zabrze, Poland, tel. (0-48) 32 271-60-13, e-mail: lukasz.juszynski@itam.zabrze.pl

They can lead injuries to the appearance of contracture - of dislocation, fracture, crushing, cutting in two including states after the surgical treatment and morbidities - an inflammatory conditions, accumulating in joints different substances (e.g. gout), immunologic illnesses (RA) and other. A universally appearing hypertrophic arthritis is the most frequent cause of injuring knee joints. Statistics are announcing, that the deviation of knee joints is the most frequent cause of visits at doctors of orthopaedists [3-5].

The treatment is covering the sharp phase - medicines, immobilizing, injections, punctures decompressive all the way to the surgical treatment inclusive and rehabilitation.

The rehabilitation and improving proceedings comprises from:

- ➢ techniques improving the scope of the movement in the joint:
- Performing exercises in lightening, active and resistance.
- Redressment exercises.
- Making the traction.
- Techniques of the mobilization and the manipulation assisting and rebuilding the articular run.
- Numerous treatments in physiotherapy mainly heating or the effect of low temperatures, massage, electrotherapy, influence of magnetic fields, ultrasound are supporting effects of motor therapy mainly by painkilling and loosening acting contraction tissues (a synovial capsule, ligaments, muscles, sinews).
- ➢ and procedures allowing to rebuild power and the endurance of muscle groups working within the injured joint:
- Exercises - according to the Loveta test - from isometric exercises for exercises resistance.
- Electrostimulations weakened muscles including modern forms of the ETS electrostimulation,
- Exercises copying activities of the everyday life and recreational administered sports disciplines [6-8].

It should be underlined that therapeutic elements from Dynamizer device are used in previous rehabilitation practice. They are:

1. Passive exercise on the dynamic splint,
2. Heat treatment
3. Traction
4. Vibration (run)
5. Active exercises resistance
6. Electrostimulation.

In Dynamizer combining techniques mentioned above is unique - placing them in appropriate sequences in the time i.e. one temporary influence of the passive movement, the heat treatment and the traction and sequential placing the passive movement, the vibration, the active movement and the electrostimulation. In this setting repeatedly synergy effect is achieved, which means strengthen the positive effect of the therapy.

Expected synergy effects:

1. The made passive movement is slow during the constant traction technology relieving articular areas what results in the elimination of pain and small change of "incongruities" of articular areas.
2. The passive movement with the traction performed is slow in the area of warmed, relaxed tissues - elimination of pain experiences limiting the effectiveness of the move, increase in the susceptibility of tissues to stretching.
3. The inclusion of vibration in the resulted extreme position causes the effect of slip joint (multiple repetition per unit time) The vibration additionally is reducing the perception of pain and is loosening stretched muscle teams.
4. Resulted "captured field" of scope of the movement is being composed by the active movement of the limb strengthened with effect of the electrostimulation without the need to leave the therapy post.

During the device design one should pay attention to the damaging influence of the temperature. Based on literature sources, has been determined that at 42 ºC, after 6 hours a cuticle is already yielding to necrosis, at 55 ºC, 3 minutes of action are enough for , and at 70 ºC - only one second. The temperature in which the white tissue is yielding to an irreversible damage is 55 ºC. Every highest temperature acting to the body surface injures the skin and deeper tissues.

Cold compresses are applicable in order to trigger local action. Locally and through the short time the acting cold is producing a vasoconstrictor effect in small, superficial blood vessels, what is reducing the blood flow in these regions by - is acting against swelling, is lowering metabolic activity of tissues, temperature, sensitivity of nerve endings - is acting analgesically.

2 GEOMETRICAL FEATURES OF THE POSITION

Scope of the changeability antrophometric they established this way so that on the device conducting rehabilitation exercises for adult women and men in scope 5 was possible ÷ 95 of the percentile of the population:

- Propping the torso and the head corresponds to the seating height: 79.8÷97 cm (100 cm),
- The width of the support corresponds to the dimension of the hip width enlarged for 30 cm: 65.8÷78.7 (70 cm),
- The depth of the seat corresponds to the dimension buttock - the knee minus 15 cm: 38.2÷49.6 cm,
- The width of the seat corresponds to the dimension of the hip width enlarged for 30 cm: 62.5÷69.2 (70 cm),
- The length of the crural segment corresponds to the dimension of the popliteal height from the base reduced by 20 cm: 48.1−20=28 cm (30 cm),
- The height of putting the seat from base corresponds to the assessment of the knee height from the base increased by 10 cm (freedom of movement) i.e. 59.5+10=69.5 cm (70 cm).

3 HARDWARE MODEL OF THE PROTOTYPE DYNAMIZER DEVICE

The hardware model of the prototype device was carried out in the environment CAD in the Inventor program. It let structural documentation of the prototype device carrying the hardware model out, simulations of the move of the device and the workmanship. The pictures below show a structural form of the proposed post was played. In GCR a checked rightness of the concept was "Repty" of structure of organising this project being an object. During therapy sessions the range of the movement gradually was increased. The applied heat treatment let limit pain during the move of the limb.

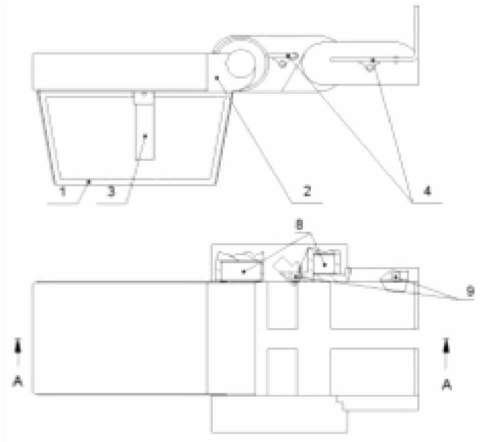


Fig. 1 View of the device

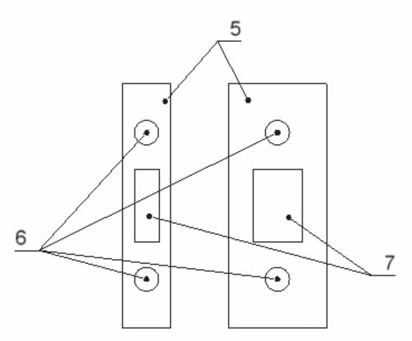


Fig. 2 The distribution of elements on the belt fastening

Drawing explanations(Fig.1,2):

1. Base of the rehabilitation armchair
2. Armchair with the moving backrest
3. Mechanism of the move of the support
4. Support of a lower limb with the mechanism of precise putting the slit of the knee joint
5. Belt of immobilizing the limb in the support
6. Electrostimulating muscles elements
7. Heating elements
8. Implementation drive of the traction move of the limb along with the sensor of the resistance put by the patient
9. Vibrator.

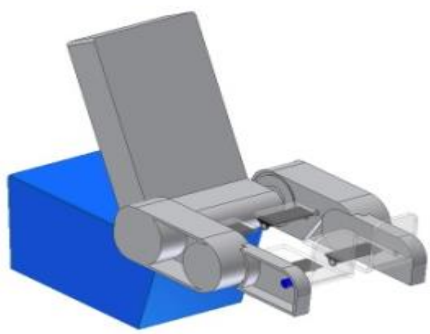


Fig. 3 The device in a sitting position

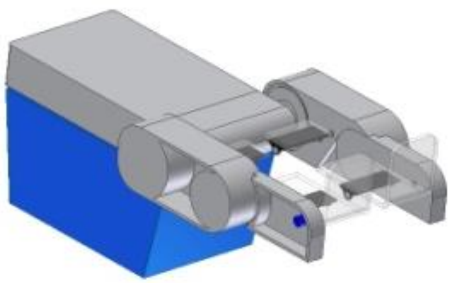


Fig. 4 The device in the supine position

4 ENDURANCE ANALYSIS ORGANISING REHABILITATION DYNAMIZER

In order to perform endurance analysis of the prototype position a hardware model of the device was drawn up and for examinations bank conditions were accepted.

Endurance analysis was conducted with finite element method in the Workbench program. For analysis of Messes bank conditions were accepted on the base [4]. A load coming from the weight of the patient with the weight of 105 kg was taken devices working on the seat, however to the support of a lower limb a load coming from the moment of muscle powers was taken at the man while straightening the limb out in the knee joint at the isometric contraction (Fig.5). The value of the 337.2 Nm moment is a mean of the moment of muscle strength of the man at straightening the limb out given in the work [4], and with being mean of the moment received by different Authors of examinations. For endurance examinations they assumed that the structure of a machine was carried out of steel immune to corrosions, which the following properties were taken for: Younga E Modulus = 210 GPa and the rate of υ Poisson = 0.3.

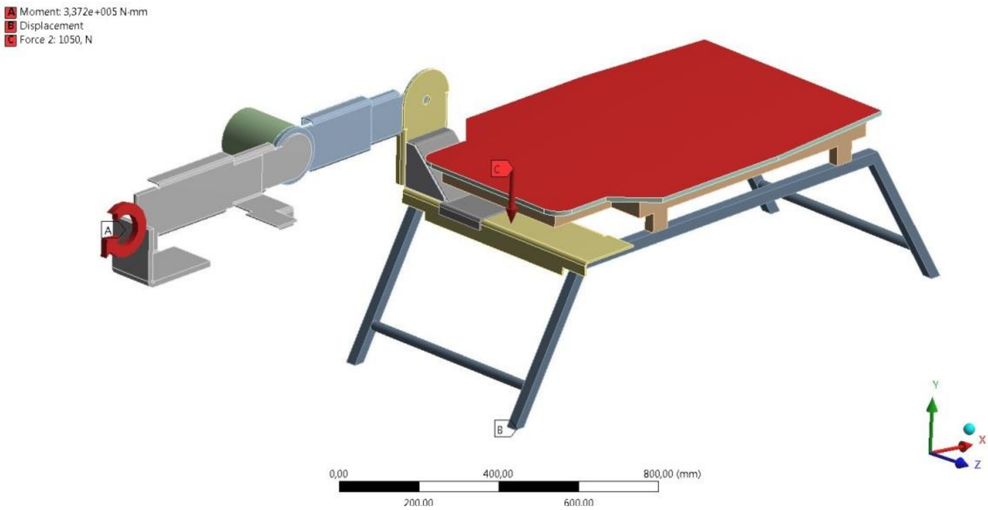


Fig. 5 Bank conditions admitted to endurance calculations

As a result of made numerical simulations maps of stresses reduced according to the Huber-Mises-Hencky'a hypothesis and summary transfers were received. In table 1 and 2 results of maximal values of stresses and transfers were compared for individual groups of devices (Fig.6,7). On the picture below vivid maps of stresses and transfers were compared.

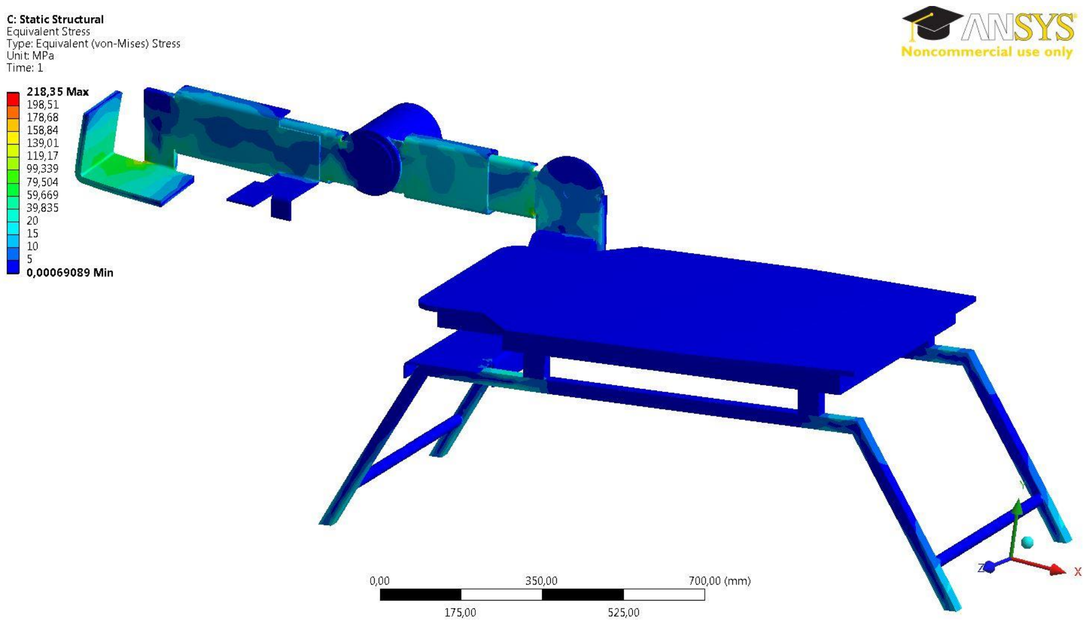


Fig. 6 Map of stresses reduced according to the Huber-Mises-Hencky hypothesis (max 218 MPa)

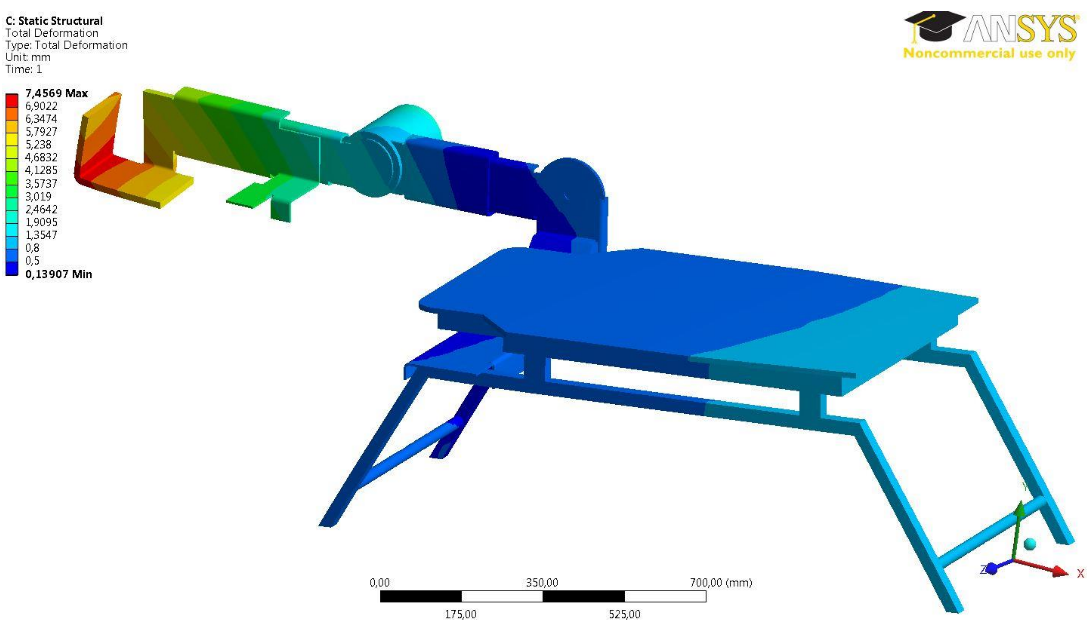
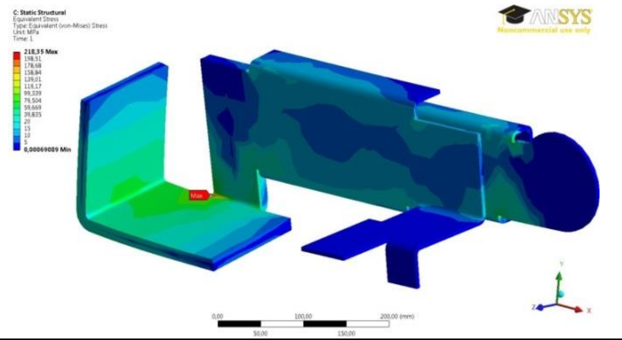
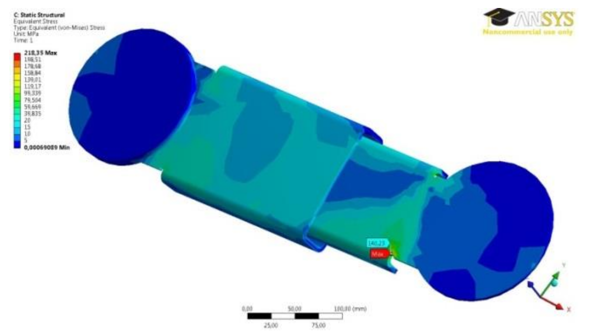
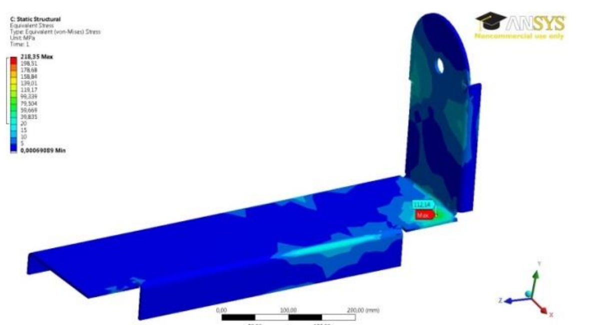
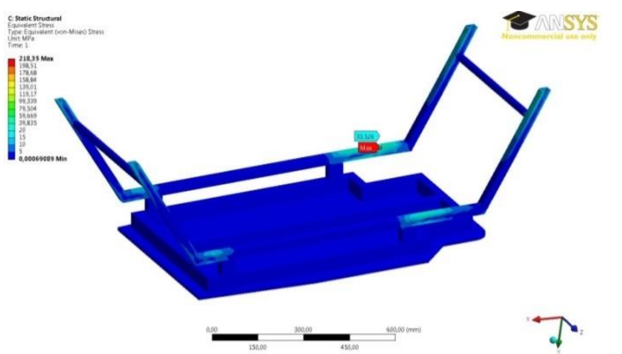
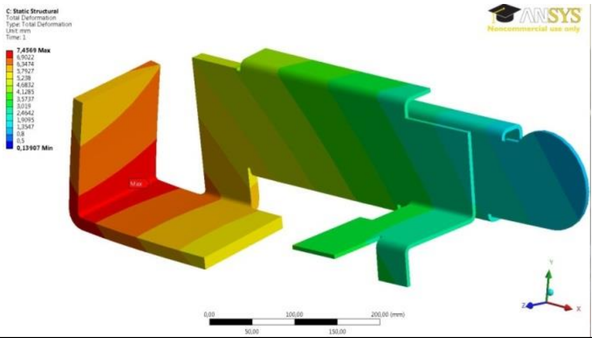
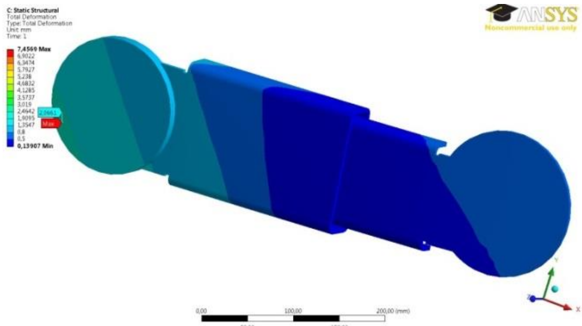
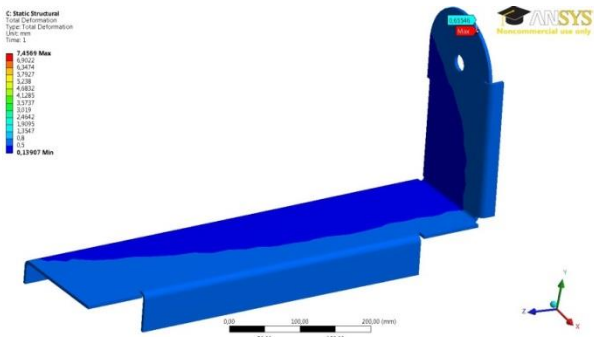
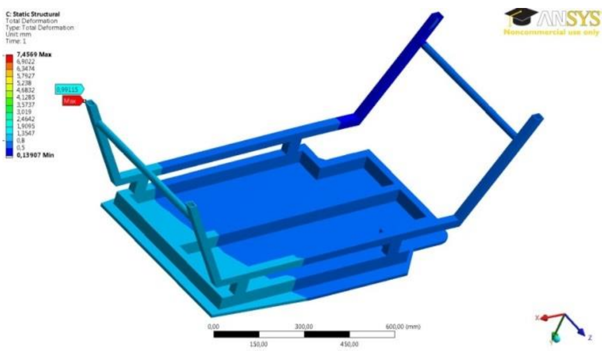


Fig. 7 Map of summary transfers (max 7.5 mm)

Tab. 1 Of maximum values of stresses reduced according to the Huber-Mises-Hencky'a hypothesis

Item number	Name of the part	Max value of stresses reduced according to the Huber-Mises-Hencky hypothesis [MPa]	Map of stresses reduced according to the Huber-Mises-Hencky hypothesis
1	Calf part of the device	218	
2	Thigh part of the device	140	
3	Support linking the thigh part with the table	112	
4	Table	33	

Tab. 2 Value of the maximum summary transfers

Item number	Name of the part	Max value of summary transfers [mm]	Map of summary transfers
1	Calf part of the device	7.5	
2	Thigh part of the device	2	
3	Support linking the thigh part with the table	0.65	
4	Table	1	

They to the structure of the device are recommending using structural corrosion-proof e.g. became X3CrTi17 according to EN 10088, for which the yield point stipulated in the contract is taking out 230 Mpa.

Fig. 8 The finished prototype rehabilitation device

5 CONCLUSIONS

From conducted endurance analysis to conclude it is possible, that the structure is stable and is transferring loads for the patient with the weight of 105 kg. The state of stress in the table is suggesting that mass of the patient can be much higher. Maximal value of reduced stresses according to. Huber-Mises-Hencky hypotheses (218 MPa) was observed in calf part devices, in the decimal place of fixing the foot to the device. It is possible to minimize stresses appearing in this part applying the greater ray of rounding the join of metal sheets off in the decimal place. Arguable steel suggested to the structure to the X3CrTi17 corrosion according to EN 10088 has yield point 230 MPa what he is determining, that the maximum stresses in the device don't exceed of the one border. It is possible to subject the device to the optimisation process for the structural figure what will allow for reducing his mass and the cheaper cost of the workmanship. However this device is a prototype device and there is no requirement of conducting such analysis which should be made before setting about to the serial production. In the paper Authors focussed at a performance for the structural figure of the prototype (Fig.8) device and for his numerical analysis, it is possible to obtain the thorough description of individual parts of the device in other papers devoted to the prototype DYNAMIZER device.

REFERENCES

[1] ALVIK I., *Generll ortopedisk kirurgi*, Olaf Norlis forlag, Oslo, 1953

[2] LEWIT K., *Manual Therapy in the rehabilitation of musculoskeletal diseases*, ZL NATURA, Kielce, 2001

[3] MACCONAILL M. A., BASMAJIAN J. F., *Muscles and Movements,* Williams and Wilkins, Baltimore, 1969

[4] TEJSZERSKA D., ŚWITOŃSKI E., GZIK M., *Biomechanics of human musculoskeletal*, WNITE-PIB, Gliwice, 2011

[5] TRAVELL & SIMONS`, *Myofascial Pain and Dysfunction*: The Trigger Point Manual and ed, Lippincott Williams & Wilkins, Philadelphia, 1999

[6] WALASZEK R., KASPERCZYK T., MAGIERA L., *Diagnosis in kinesis and massage,* Biosport, Kraków, 2007

[7] ZEMBATY A., Kinezyterapia. Tom II: *An outline of the theoretical and diagnostics kinesytherapy*, Kasper, Kraków, 2003

[8] ZEMBATY A., *Measurements of joint movement range of human*, AWF, Warszawa, 1989