TEXTILE SENSORS FOR ECG AND RESPIRATORY FREQUENCY ON SWIMSUITS

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ABSTRACT

Swimming constitutes one of the most demanding sports regarding technique. Years of training are necessary to master each one of the four styles. An important improvement and help for trainers would be a swimsuit that could provide information during training. This paper presents the research undertaken to develop textile sensors that will be used in a swimsuit. This paper will address ECG and respiratory frequency sensors and respective signals. The behaviour of the proposed sensors in different conditions (dry and wet environments) will be presented and discussed. The influence of movement on the signal quality and further interpretation, both by the muscular electrical signals as well as by the displacement of the electrodes, will be addressed. Other very important issue in swimming is drag. One approach that can reduce total drag consists in using compression. However, compressed fabrics will most likely modify the textile sensors' response. This problem is also addressed in order to successfully integrate the electrodes in the swimsuit

1. INTRODUCTION

The improvement of performance in sports is closely related with training methodology combined with the well-being and health status of the athlete. Trainers make a constant effort to improve the movements and training rhythm of the athletes, especially in highly technical, rhythmic and cyclic sports such as swimming or athletics, as described, for example, by Clarys et al (1996) and Gonçalves et al (2006). In this project, a swimsuit integrating sensors to measure biometric signals during exercise is being developed. The environment in which this measurement system will operate poses several specific issues, such as electric isolation, data transmission, protection from water, among others. This paper presents an overview of some results obtained using the textile electrodes and sensors developed by this team for ECG measurement and respiratory activity. The outcomes of this project should in principle be easily used in other sports and applications, such as health monitoring in leisure sports, for the elderly, patients with cardiac disease, etc.

2. BACKGROUND

2.1. ECG Measurement with Textile Electrodes

Several authors have reported work on measurement of ECG signals using textile or textile-integrated electrodes. Xu et al (2008) give a comprehensive overview about the subject. Mühlsteff et al (2004) and Linti et al (2006) proposed the use of dry rubber electrodes, either as detachable electrodes made of conductive rubber, or printing rubber electrodes on the fabric, deposing silver particles on them to become electrically conductive. In other researchs, the electrodes were produced with textile materials, but separately from the suit/vest in which they would be integrated by sewing or another joining process (Catrysse et al 2003 and 2004, Ottenbacher 2004).

Finally, some researchers such as Hertleer et al (2004) and Coosemans et al (2006) knitted the electrodes into the fabric itself, thus achieving a total integration with the textile. Integrated textile electrodes present clear advantages in terms of sensor integration and user's comfort, when compared to traditional gel electrodes. There are, however, two main drawbacks: an increase of the skin-electrode impedance, making measurement noisier and producing lower signal amplitudes, and the increase of motion artifacts in signals, since the electrodes are not kept in place (Xu 2008). From the electrical point of view, textile electrodes should be woven or knitted with metallic wires, which present high electrical conductivity and would result in lower skin-electrode impedance. However, besides being somewhat uncomfortable, they are also generally difficult to process, since most conductive yarns are quite stiff and . Currently and after years of developments, the market offers several conductive yarns with properties very close to normal textile yarns, which can be easily processed in standard textile machines. These can roughly be divided in normal textile yarns with conductive materials deposited on their surface (e.g ELITEX®), and staple yarn spun with a blend of normal textile fibres and conductive metallic fibres (e.g.: BEKINTEX®).

2.2. Specific factors of ECG measurement in a swimsuit

The first factor that has to be considered is that swimsuits, especially racing swimsuits, are worn very tight, with the fabric compressed against the body. Although this can be considered an advantage, since the contact between the electrode and skin is improved, this also means that the electrode will also be stretched, which will possibly have a negative influence on the skin-electrode contact. Another obvious aspect is the presence of water, which will predictably have two main effects on the ECG measurement:

- It reduces the skin-electrode resistance, because it wets the electrode resulting in a similar effect as an electrolyte gel, which is normally applied on conventional electrodes;
- When the swimmer is under water, the pool water, acting as electric conductor, will be connected in parallel to the input of the amplifier, thus reducing the resulting amplitude of the ECG signal. This means that the textile electrodes have at least to be isolated from the outside.

2.3. Measurement of Respiratory Movement

According to Tarrant et al (1997), "…there are two main techniques for monitoring respiration: direct airflow (oral, nasal, or both oral and nasal airflow being monitored) and some type of measurement related to changes in inflation of the lung, often called respiratory effort (focuses on movements of chest and abdomen, accessories to respiration)…". Several authors have developed work regarding the integration of sensors for respiratory movement detection based on the second method. Catrysse et al (2004), for instance, have developed a baby pyjama with integrated textile extension sensors that indicate respiratory movement. This kind of textile extension sensors, based on a piezoresistive effect (change of electrical resistance with extension) has also been used by other authors, such as Paradiso et al (2005) and Lorussi et al (2004) for measurement of respiratory movement and posture sensing by extension. They are based either on textile materials knitted from electrically conductive yarns, or by knitted fabrics coated with electrically conductive materials such as Carbon Loaded Rubber or Polypyrole which exhibit piezoresistive properties.

In this work, we have chosen to evaluate the possibility of using knitted extension sensors for the measurement. The use of a seamless knitting machine would allow a straightforward production and integration of the sensors into the swimsuit. In previous work we have been able to obtain interesting results using piezoelectric films integrated into textile accessories (Abreu et al, 2007), but the use of textile extension sensors would result in a much higher level of integration.

3. EXPERIMENTAL SET-UP

3.1. Acquisition Hardware and Software

The electrodes were connected to signal conditioning hardware based on an instrumentation amplifier, followed by a second amplifying stage and anti-aliasing filter. A National Instruments NI-USB 6259 Multifunction data acquisition board was used to acquire the signals. Sampling frequency was set at 10kHz. This is a quite high frequency for ECG signals, but it allows the evaluation of noise and motion/muscular signal artefacts present in the signals, normally located at higher frequencies. An application for data acquisition and processing was developed in National Instruments LabVIEW. It provides continuous acquisition and data streaming to file and a set of configurable digital filtering functions to allow the study of the ideal processing conditions. A simple peak detection function was used to detect the R-wave (main peak of the ECG signal) with the purpose of computing heart beat rate and arrhythmia. This function is based on the computation of the first and second derivatives and the definition of a minimum detection threshold to reduce false detections.

3.2. ECG measurement

3.2.1.Textile Electrodes

The textile electrodes developed are based on a single face knitted fabric, a jersey structure – A structure - , and a structure similar to rib – B structure. In a first approach, the electrodes were knitted on a circular knitting machine from Bekintex yarn (400 dTex) and bare elastane (78 dTex). They were produced under repeatable conditions, with the most important factors involving knitting process, such as the yarn input tension and the covering factor, expressed here as loop length, accurately controlled. The second structure – B, was produced with the purpose of improving skin-electrode contact. It has a more complex surface structure, which was hoped to improve contact, especially when stretched. The first test was the comparison of the electrodes produced with commercially available textile electrodes. For this purpose, the electrodes were cut in 2x2cm squares and compared with equally sized electrodes cut from fabrics based on silver-coated yarns, available from Textronics© – C structure, used in this case as a reference. The electrodes were placed on the subject's body using adhesive tape. This initial evaluation showed that there were no significant differences between the signals obtained from the fabric made in the laboratory A, B and the one used as reference, C, apart from a slightly higher noise level in structures A and B electrodes that can easily be removed by filtering.

3. 2.2. Experimental Plan

The experiment serves as a preliminary study of several factors influencing ECG measurement during swimming. Its objective was to provide a qualitative overview of the relative influence of these intervening factors. It also helped the tuning of the amplifier and the processing software.

The situations under analysis were the following:

- Different structures: Structures A and B;
- Influence of moisture: Electrode dry, wet and under water;
- Effect of stretching the electrode: Electrode in relaxed and stretched condition;
- Effect of muscular contraction in ECG signal;
- Influence of arm movement.

The experiment was performed in a laboratorial environment, and it should be noted that no official procedure was considered, rather than an internal procedure was followed. The electrodes were always placed at the same positions on the subject's body. The subject is a 25-year old, 1.80m, 85 kg male. Wet and submerged states were produced by submerging the subject in water (submerged state) and after leaving water (wet state). The relaxed electrodes were placed on the subject's body with adhesive tape. To stretch the electrodes, they were sewn onto a tight-fitting knitted fabric tube. This situation is similar to the final one, in which the electrode will be embedded in the fabric. Acquisitions were performed with the subject in three different situations:

- Relaxed and breathing normally;
- In a static state and contracting the pectoral and abdominal muscles;
- Moving the arms intensely.

3.3. Respiratory Rate Measurement

3.3.1. Production of the textile sensors and experimental plan

Previous work in our group had already shown that knitted yarns have limited performance as extension sensor (Abreu et al, 2009). In these experiments, the electrical resistance as a function of extension was found, in the best case, typically the behaviour shown in Figure 1

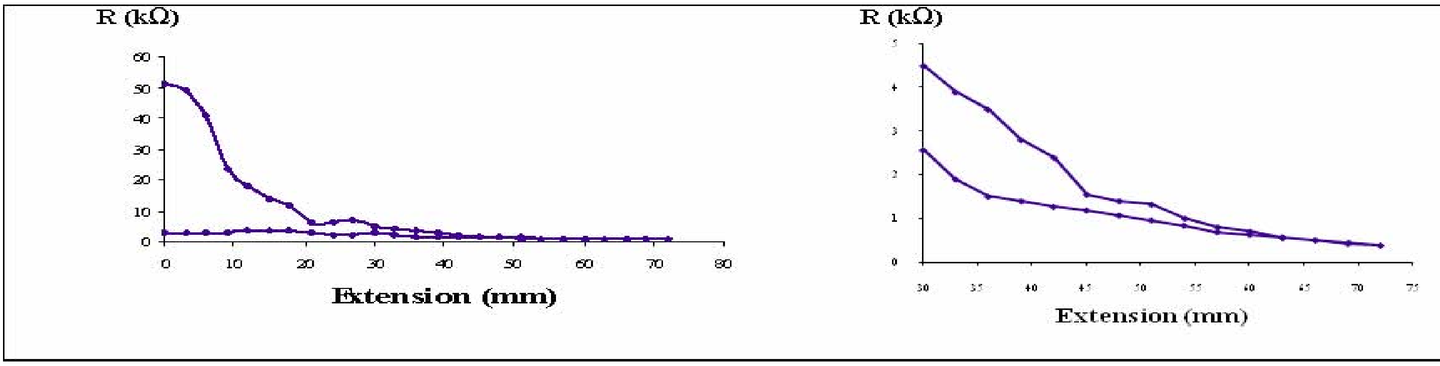


Figure 1. Typical behaviour of resistance versus extension in a knitted textile sensor.

Since the graph suggests that the proposed sensor behaves quite well and linearly in a range of extension (above 60 mm, in this case), a new experimental plan was devised to test the possibility of using these extension sensors by means of applying some pre-tension. A sample tubular knitting machine was used to knit samples of jersey fabric using Bekitex® yarn. At both sides of the samples, nonconductive, non-elastic fabric was sewn to serve as the physical interface between the dynamometer's jaws and the sensor. The samples were then electrically connected with two metallic clips, as shown in Figure 2. After this, the samples were pre-tensioned and a cyclic extension cycle was executed, with extension amplitudes similar to those expected during intensive breathing.

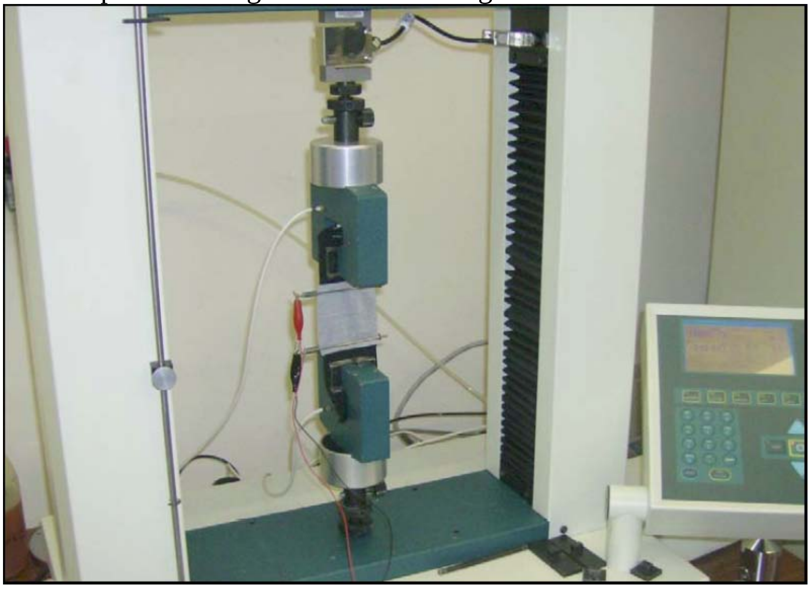


Figure 2. : Setup for test of the textile extension sensors.

The samples were knitted and tested varying the following parameters: 1-Sample length and width; 2-Thickness of the elastane used; 3- Bekitex 50/1 and Bekitex 50/2 yarn; 4 -Extension in the wale or course direction.

4. RESULTS

4.1. ECG Measurement

In the next sections an overview of the most important results is given for dry, wet and submerged states, considering relaxed electrode, stretched electrode, muscular and limb activity.

4.1.1 Relaxed Electrode

The electrode in relaxed state can be understood as the situation where the knitted fabric is washed and then dried at standard atmosphere. The resulting waveforms for the three states under study are depicted in Figure 3, Figure 4 and Figure 5.

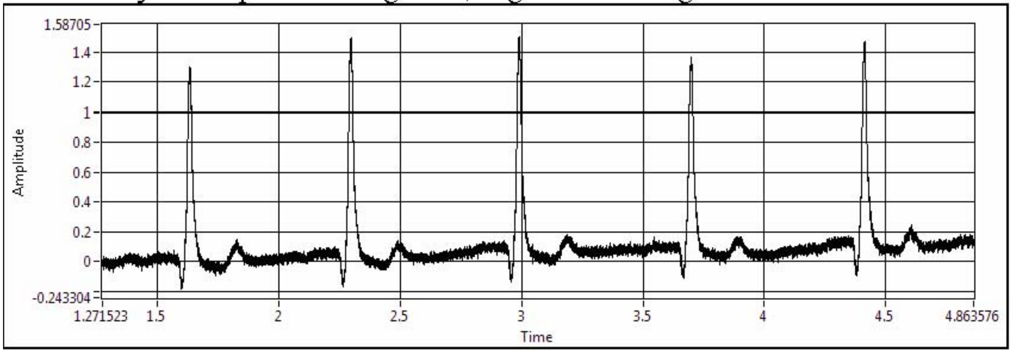
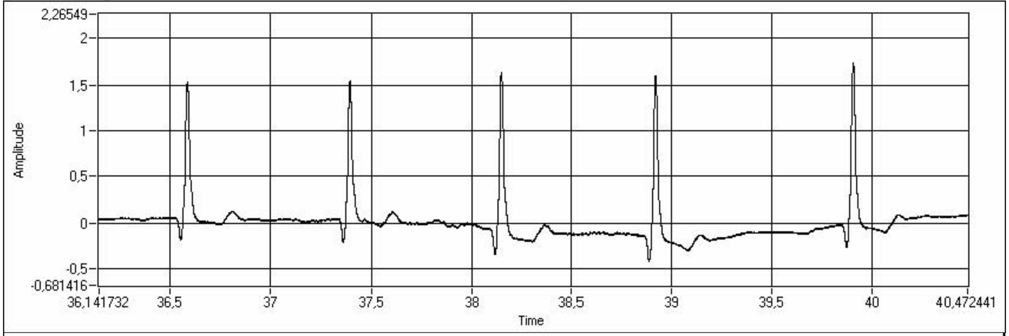


Figure 3. ECG signal picked up with a dry, relaxed electrode and subject relaxed. Figure 4. ECG signal picked up with a wet, relaxed electrode and subject relaxed.



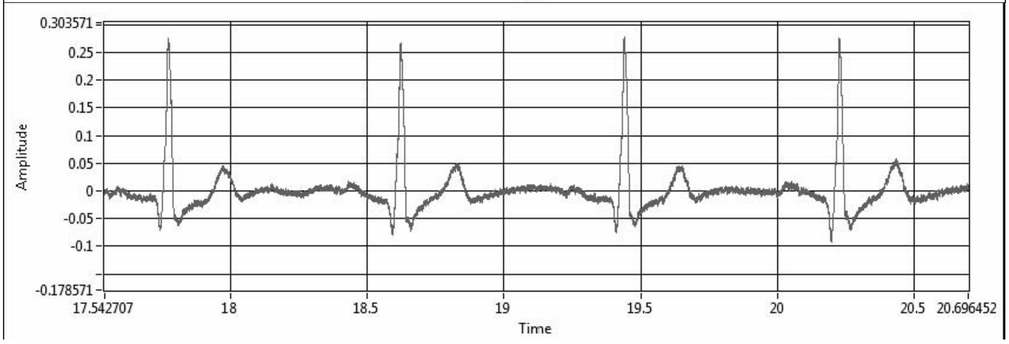


Figure 5. ECG signal picked up with a submerged, relaxed electrode and subject relaxed.

The comparison of the performance of the electrodes delivered the expected results. In all cases, clear ECG signals with well-defined QRST are picked up. Wetting the electrodes produces a better signal, as expected and previously discussed. The amplitude is higher and the signal is less noisy. The submersion of the electrodes results in a significant reduction in signal amplitude, as predicted. Nevertheless, the signal is clean when the subject is relaxed.

4.1.2. Stretched Electrode

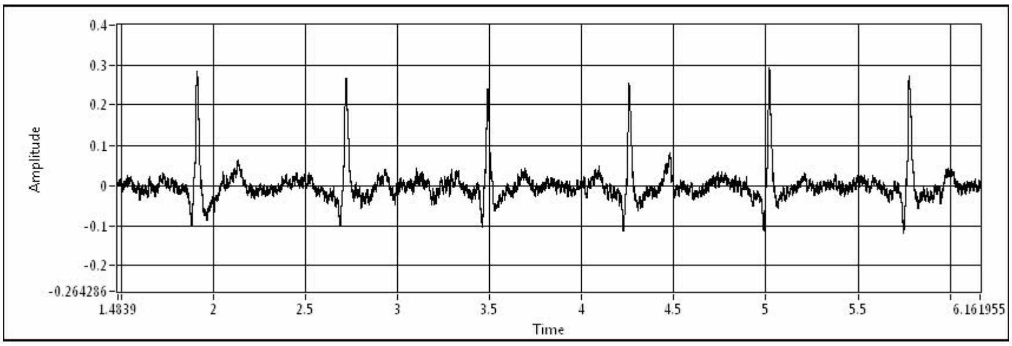
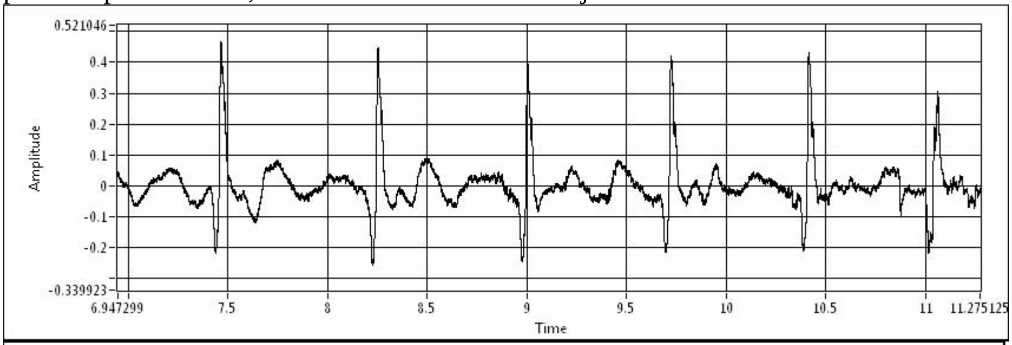


Figure 6. ECG signal picked up with a dry, stretched electrode and subject relaxed. Figure 7. ECG signal picked up with a wet, stretched electrode and subject relaxed.



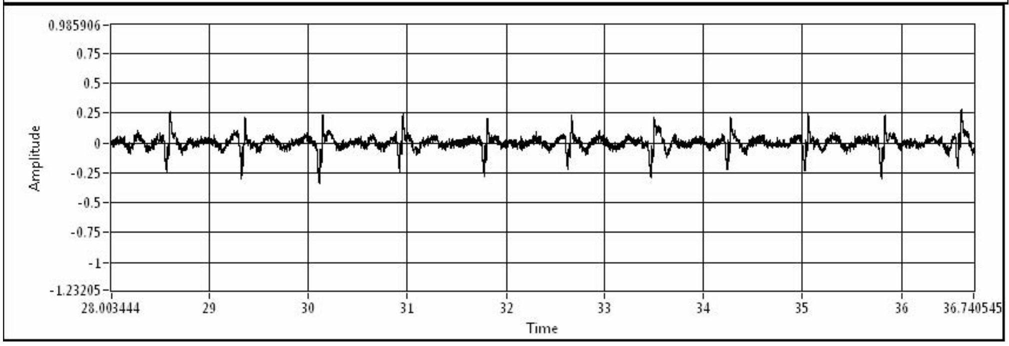


Figure 8. ECG signal picked up with a submerged, stretched electrode and subject relaxed.

Stretching the electrodes degrades the signal, with a reduction in amplitude and an increase in noise. This can be explained by the increase of both the skin-electrode and electrode inner resistance, since electrical contact inside the fabric is reduced by the stretching effect. The comparison between dry, wet and submerged electrodes can be interpreted as giving the same results previously obtained when the electrode was considered in a relaxed state.

4.1.3. Type of Structure

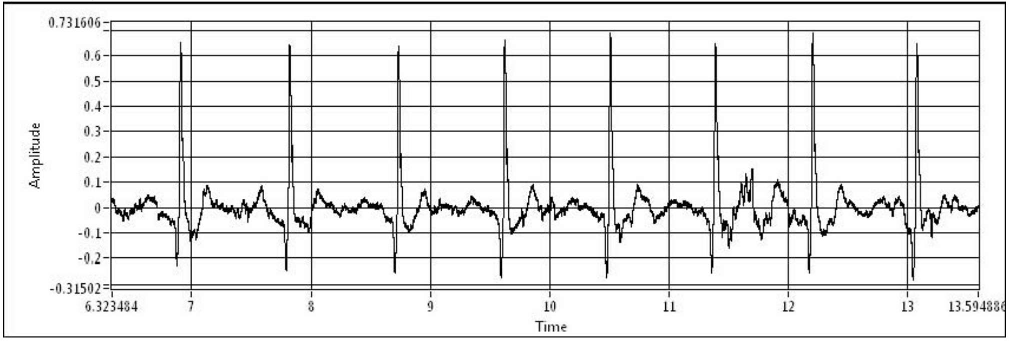


Figure 9. ECG signal picked up with a wet, stretched electrode type B, subject relaxed.

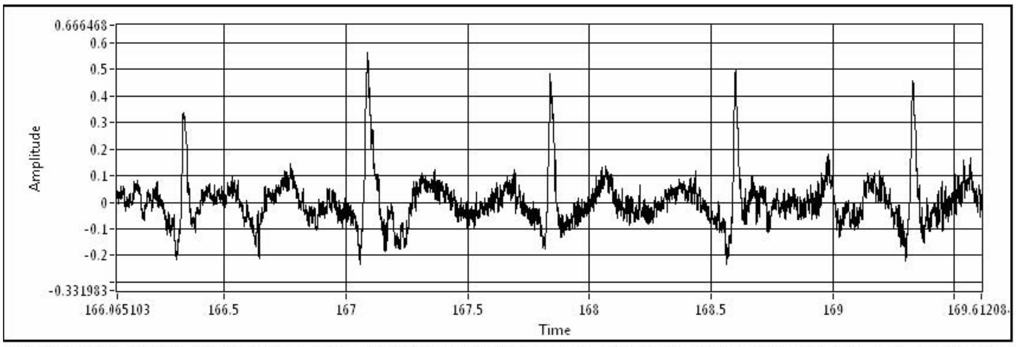


Figure 10. ECG signal picked up with a submerged, stretched electrode type B, subject relaxed.

The use of structure B produces a very interesting result. In fact, it is possible to observe that the resulting waveforms present higher amplitude (Figure 7 versus Figure 9). This result encourages the design and test of alternative structures to promote the skin-electrode contact, particularly when the electrodes are compressed against the skin and stretched, as is the case.

4.1.4. Muscular Contraction

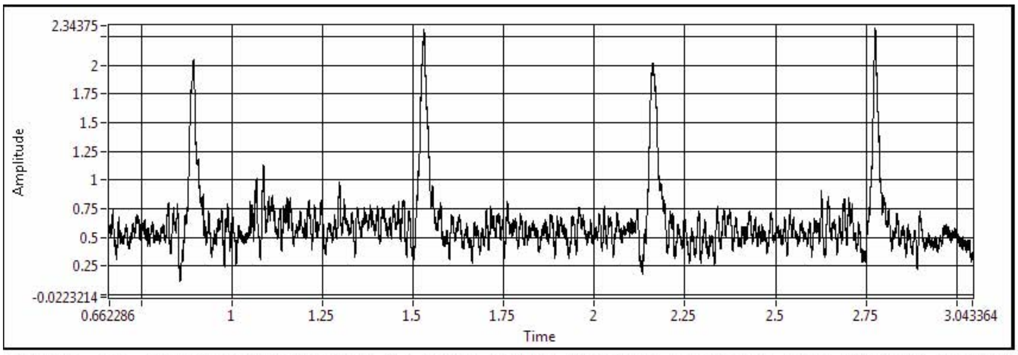


Figure 11. ECG signal picked up with a dry, relaxed electrode and subject contracting pectoral and abdominal muscles.

As expected, muscle contraction results in a signal containing significant noise, with the muscular activity masking the waveform of interest. Although heart beat rate is still well depicted, muscular activity masks off the Q and ST-waves, as expected. Although it may seem somewhat difficult, it may be possible to recover these signal features using further signal processing, since EMG signals are considered to be on a different frequency band than ECG.

4.1.5. Arm Movement

Figure 12 presents a signal in which the effect of arm movement is depicted. The software filtering tools were used to remove the fluctuation and motion artefacts. The filters eliminate the bands between 0 and 3 Hz and all above 150 Hz. After this operation the detection of the R-wave is quite straightforward, but the remaining waves have been masked off. Future experiments will show if the extraction of these values is possible on the unfiltered signal, after the detection of the exact locations of the R-wave, as illustrated in Figure 12.

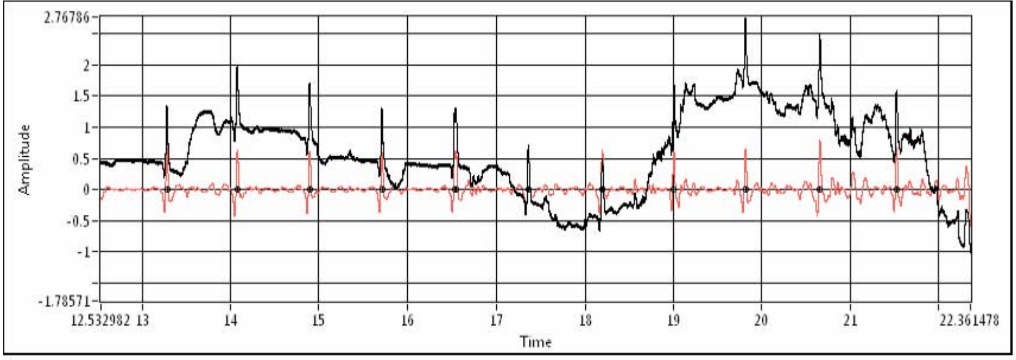
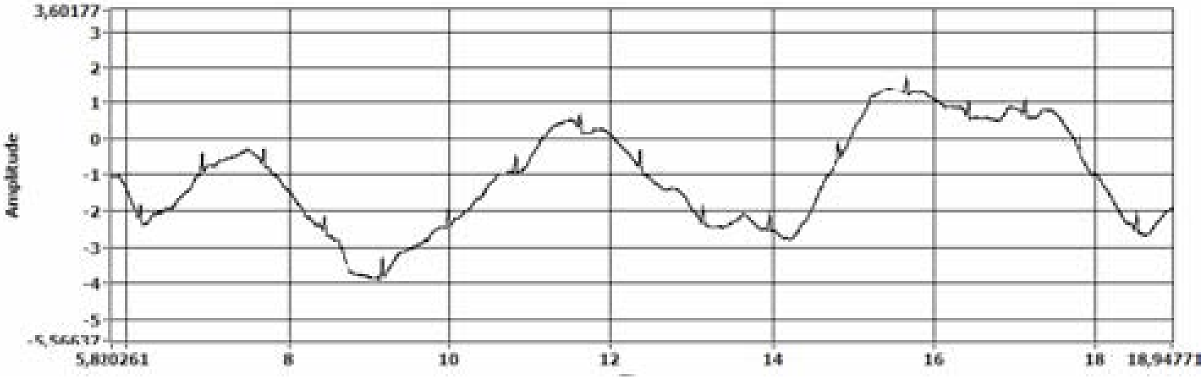


Figure 12. ECG signal picked up with arm movement, before and after filtering. Black dots identify the location of the R-Wave, automatically detected.

4.2.Respiratory Rate measurement

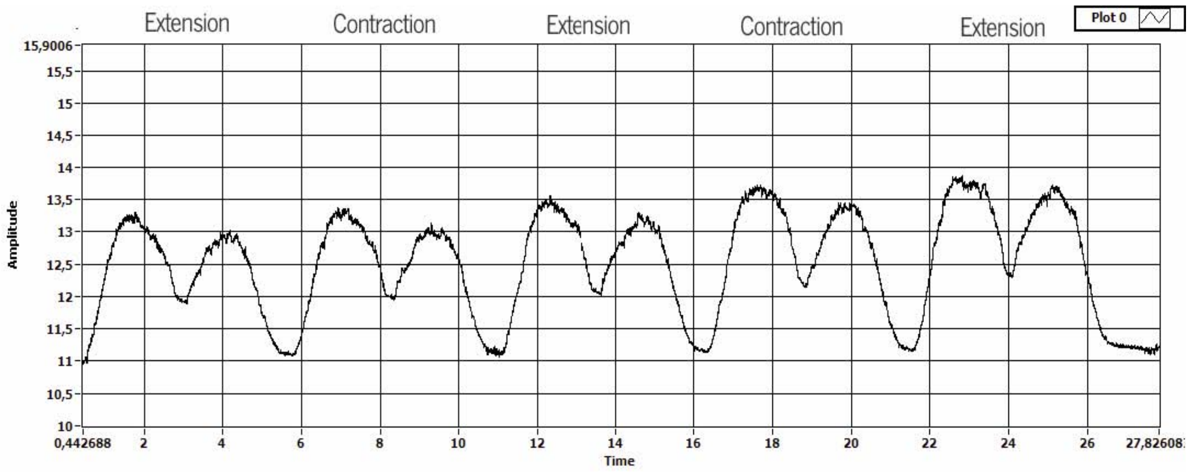
Before presenting the results obtained with the textile sensors, it is interesting to note that the respiration signal can be found on the signals obtained during ECG measurement. Figure 13 shows an example of ECG acquisition without high-pass filtering:



The presence of the respiration signal results from one or both of the two following effects: 1. the respiratory motion shifts the electrode-skin relative position and stretches the electrode, causing signal fluctuations in proportion to the movement; 2. the body's impedance changes with the expansion and contraction of the chest (the principle of respiration measurement by impedance plethysmography).

Although this method may be viable in the case of subjects at rest, in the case of swimming, the added motion artefacts will probably turn the ECG signal too much unclear and very difficult to extract any useful information if the waveform is not filtered.

The tests performed with the textile extension sensors have unfortunately not added any new useful information. The different samples have produced different results from each other; however, none of them shows a consistent, repeatable behaviour over a useful range of extension. Moreover, behaviour varies from cycle to cycle, after washing and fabric relaxing. Figure 14 shows one of the signal outputs of the measurement system during one test showing a particularly odd result:



Although at first glance the result appears to be quite interesting, a further analysis unveils the fact that the sensor exhibits a non-monotonic behaviour during a single extension or contraction movement, that is, the output signal shows increase and decrease during movement in only one direction, where it should be either increasing or decreasing.

4. CONCLUSIONS

This paper presents some results obtained from the research under development involving textile sensors which are intended to be used in a swimsuit. The behaviour of the proposed sensors in different conditions - dry and wet environments - was presented and discussed. It was also considered the effect of the electrode when in a relaxed state and under stress. It was observed that the resulting ECG waveform allow the extraction of the most important information in dry state, being quite excellent when the electrodes are wet, similar to having a conductive gel. The stress effect in the electrodes results in an addiction of artefacts, being possible to recover the most important part of the information, though. It was also observed that a different structure can improve the resulting ECG waveform, fact that is under further development. The muscle contraction together with limb movement, in this case the arm, also introduces additional artefacts that seem to turn very difficult the recovery of the entire waveform. However, there are parts that can be extracted with further processing, such as the heart beat. Regarding respiratory movement, the proposed sensors are able to reproduce the thoracic movement; however it seems to give a reproducible result. Nevertheless, further research needs to be conducted in order to better understand if these sensors can be improved regarding this reproducibility.

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Conference Programme

Thursday 12 November, 2009

08H00– 09H00 Registration & Breakfast

09H00 –09H15 Conference Opening, **Mohamed LAHLOU**, ESITH, Casablanca, Morocco, **Vladan KONCAR**, ENSAIT, Roubaix, France

09H15–10H00 **Plenary Session 1**
CREATING INTELLIGENT TEXTILES BY FUNCTIONAL FINISHING WITH RESPONSIVE POLYMERIC SYSTEMS
Prof. Dragan JOCIC
Engineering of Fibrous Smart Materials (EFSM), Faculty of Engineering Technology (CTW), University of Twente, Enschede, The Netherlands

10H00 – 10H45 **Plenary Session 2**
TEXTILE COMPOSITE
Prof. Xavier LEGRAND[1,2]
[1]University Lille Nord de France, 59100 Lille, France
[2]GEMTEX, ENSAIT, 2 allée Louis et Victor Champier, 59056 Roubaix, France

10H45 – 11H15 Coffee break

Session 1, Intelligent Textiles, Room A 11H15 – 12H45	**Session 2**, Mass Customisation, Room B 11H15 – 12H45

12H45 – 14H00 Lunch break

14H00 – 15H00 Poster Session

Session 3, Intelligent Textiles, Room A 15H00 – 16H00	**Session 4**, Mass Customisation, Room B 15H00 – 16H00

16H00 – 16H30 Coffee break

Session 5, Intelligent Textiles, Room A 16H30 – 17H30	**Session 6**, Mass Customisation, Room B 16H30 – 17H45

Friday 13 November, 2009

08H30 – 9H15 **Plenary Session 3**
"SYSTEX PROJECT" FP 7
Prof. Dr. ir. Lieva Van LANGENHOVE, dr.h.c.
Universiteit Gent, Vakgroep Textielkunde, Technologiepark 907, 9052, Zwijnaarde, Belgium

09H15 – 10H00 **Plenary Session 4**
THE UATRS: PLATFORM OF ANALYSIS TO THE SERVICES OF THE RESEARCH AND THE TEXTILE INDUSTRY
Prof. S. GMOUH
Plateforme Chimie Moléculaire, UATRS, CNRST, Rabat, Maroc

10H00 – 10H30 Coffee break

Session 7, Intelligent Textiles, Room A 10H30 – 12H00	**Session 8**, Bio Textile, Room B 10H30 – 12H00

12H00 – 13H30 Lunch break

14H00 – 18H00 Visit of the Mosque Hassan 2 and Casablanca sightseeing

21H00 – 24H00 Conference Dinner

Saturday 14 November, 2009

09H00 – 09H30 **Plenary Session 5**
YARN JOINING SOLUTIONS & LABORATORY QC EQUIPMENT
Prof. D Lalevic
Mesdan S.p.A.
Via Masserino, Puegnago del Garda (BS) Italy

09H30 – 10H00 Coffee break

10H00–10H30 **Plenary Session 6**
TECHNICAL TEXTILE IN MEDITERANEAN, IVEST IN MED PROGRAMME
Prof. F. TAMARELLE
TEXTECHMED PROJECT, FRANCE

Session 9, Intelligent Textiles, Room A 10H30 – 11H30	**Session 10**, Composite Textile et Bio Textile, Room B 10H30 – 11H30
Session 11, Intelligent Textiles, Room A 11H30 – 13H00	**Session 12**, Intelligent Textiles, Room B 11H30 – 13H00

13H00 – 14H30 Lunch break

14H30 – 15H30 Poster Session

15H30 ITMC Conference closing

Parallel Sessions Oral Presentations

Thursday 12 November, 2009

Session 1, Intelligent Textiles, Room A, 11H15 – 12H45, Chairman : V. KONCAR

TEXTILE ANTENNAS FOR OFF-BODY COMMUNICATION : INFLUENCE OF HUMIDITY, **C. HERTLEER**, L. Van Langenhove, H. Rogier Ghent University, Dept. of Textiles – Technologiepark , Zwijnaarde, Belgium

AN INVESTIGATION OF THE FRICTION PROPERTY OF WOVEN FABRICS IN MULTI-DIRECTION, A. Haeri, **Ali A.A. JEDDI**, S. Saharkhiz Department of Textile Engineering, Amirkabir, University of Technology, Tehran-Iran.

INTEREST OF ELASTIC COMPRESSION STOCKING FOR PROTECTING LEG VEINS DURING HIGH ACCELERATIONS, **Ph. ARBEILLE**, V BOUGAULT, R KASPRANSKY. UMPS Unit Med Physiol Spatiale – Univ CHU Trousseau– Tours – France

PROCESSING OF A TEMPERATURE SENSOR BASED ON TWO DIFFERENT BIPHASIC POLYMER SYSTEMS FILLED WITH CARBON NANOTUBES: ELECTRICAL, RHEOLOGICAL AND MORPHOLOGICAL CARACTERIZATION, **Aurélie CAYLA**[1,2], Christine CAMPAGNE[1,2], Maryline ROCHERY[1,2], Eric DEVAUX[1,2], [1] Univ. Lille Nord de France, Lille, France ; [2] ENSAIT, GEMTEX, Roubaix, France.

Session 2, Mass Customisation, Room B, 11H15 – 12H45, Chairman : X. FLAMBARD

INFLUENCE OF THE HUMAN BODY DEFORMATION ON GARMENT MASS CUSTOMIZATION PROCESS, **A. CICHOCKA**, P. Bruniaux Ecole Nationale Supérieure des Arts et Industries Textile, Roubaix, France

AUTOMATED TEXTILE PREFORMING OF SEMI-FINISHED FABRICS FOR THE MASS PRODUCTION OF FIBRE-REINFORCED PLASTIC COMPONENTS, **Andreas SCHNABEL**, Felix Kruse, Thomas Gries, RWTH Aachen, Institut für Textiltechnik

SIMSANO PROJECT- A NEW APPROACH ON THE RAPYD PROTOTYPING FOR THERAPEUTIC FOOTWEAR, **Aura MIHAI**, Doina GIURMA, Sabina SARULEANU, Gherghe Asachi Technical University of Iasi, Romania

AUTOMATED GENERATION OF HUMAN MODELS FROM SCAN DATA IN DIFFERENT, ANATOMICALLY CORRECT POSTURES FOR RAPID DEVELOPMENT OF CLOSE-FITTING, FUNCTIONAL GARMENTS, **Christine MEIXNER**, Sybille Krzywinski, Hartmut Rödel TU Dresden (D), Dresden University of Technology, Dresden, Germany

Session 3, Intelligent Textiles, Room A, 15H00 – 16H00, Chairman : X. LEGRAND

STUDY OF RESIN PROPERTIES TO OBTAIN MONOLITHIC FORM OF POLYMER, **I. LYASHENKO**[1], E. Bozileva[2], N. Mihailova[3], J. Novinkina[4], K.Shalma[5] and A. Lusis[6], [1,2,3,4] Scientific Research Laboratory of Biotextile Materials, Riga Technical University, Riga, Latvia, [5] Riga Biomaterial Innovation and Development Centre, Riga Technical University, Riga, Latvia, [6] Institute of Solid State Physics, University of Latvia,

USAGE OF ULTRASOUND IN TEXTILE FINISHING, **Aysegul E. KORLU**[1], M. Ibrahim Bahtiyari[1], Alenka Majcen Le Marechal[2], Simona Vajnhandl[2], Kerim Duran[1], Seher Perincek[3] , [1]Ege University, Faculty of Engineering, Department of Textile Engineering, Bornova, Izmir, Turkey, [2]University of Maribor, Faculty of Mechanical Engineering,Institute for Textile Materials and Design, Smetanova, Maribor, [3]Ege University, Emel Akın Vocational Training School, Bornova, İzmir,

DESIGNING A MARKETING STRATEGY FOR INTELLIGENT TEXTILES, **Fatna Hassani BOUGHOUFALA,** Ecole Supérieure des Industries du Textile et de l'habillement, Casablanca, Morocco Fatna Hassani

Session 4, Mass Customisation, Room B, 15H00 – 16H00, Chairman : A.M. GRANCARIC

ELABORATION OF THE PHYSIOLOGICAL COMFORT INDEX, **Małgorzata MATUSIAK,** Textile Research Institute, Lodz, Poland

DEVELOPMENT OF VIRTUAL PARAMETRIC FEMALE BODIES FOR THE 3D DESIGN OF TIGHT FITTING GARMENTS, J. Siegmund, **S.KRZYWINSKI,** Dresden University of Technology, Dresden, Germany

ADVANCED E-RETAILING OF GARMENTS, **Xiaoguang DENG**[1,2], Agnieszka Cichocka[1,2], Pascal Bruniaux[1,2], [1]Univ Lille Nord de France, Lille, France ; [2]ENSAIT, GEMTEX, Roubaix, France

FRANCHISE CUSTOMIZATION (CUSTOM'FRANCHISE) A PROPOSAL FOR A NEW GENERATION OF NETWORKS, **S.LAHRACHE,** Ecole Supérieure des Industries du Textile et de l'habillement, Casablanca, Morocco

Session 5, Intelligent Textiles, Room A, 16H30 – 17H30, Chairman : M. DE ARAUJO

NANOTECHNOLOGY IN TEXTILE - SEWABILITY OF COTTON KNITTED FABRIC TREATED WITH NATURAL ZEOLITE NANOPARTICLES, Darko Ujević, **Ana Marija Grancarić**, Anita TARBUK, Blaženka Brlobašić Šajatović, University of Zagreb, Faculty of Textile Technology, Zagreb

ELECTRICALLY CONDUCTIVE TEXTILE YARNS AND THEIR CONTACT BEHAVIOUR, **Savvas VASSILIADIS**[1], Maria Rangoussi[1], Dimitris Meimaris[2], Kleanthis Prekas[1] and Christopher Provatidis[2] , [1]Department of Electronics, Technological Education Institute of Piraeus, Greece, [2]School of Mechanical Engineering, National Technical University of Athens, Greece

NEURAL MODEL OF WOVEN FABRIC SURFACE MODIFICATION BY ATMOSPHERIC AIR- PLASMA, **Radhia ABD JELIL**[1, 2], Xianyi ZENG[1, 2], Ludovic KOEHL[1, 2] and Anne PERWUELZ[1, 2]**,** [1]Univ Lille Nord de France, F-59000 Lille, France, [2] ENSAIT, GEMTEX, F-59000 Roubaix, France

Session 6, Mass Customisation, Room B, 16H30 – 17H45, Chairman : O. CHERKAOUI

RESEARCH AND DEVELOPMENT OF SPORTS T-SHIRTS: EXPERIMENTAL AND SUBJECTIVE EVALUATION OF MULTIFUNCTIONAL KNITTED FABRICS, Manuela NEVES, Neil Lima FILHO, **Jorge NEVES,** Department of Textile Engineering, University of Minho, Portugal

DESIGNING A NEW SURGICAL GOWN USING SUBJECTIVE AND OBJECTIVE EVALUATION METHODS, **Maria José ABREU**, Iara BRAGA, University of Minho, Textile Engineering Department, Campus de Azurém, Portugal

EVALUATION OF E-TRADE IMPLEMENTATIONS IN THE MARKET PROCESS IN RESPECT OF ACTIVITY FIELDS OF READY WEAR ENTERPRISES IN TURKEY, Nurgül KILINÇ, **Meral İŞLER,** Educational Department of Clothing Industry and Clothing Arts, Vocational Education Faculty, University,TURKEY

MASS CUSTOMIZATION FOR PERSONS WITH SPECIAL NEEDS, **A.Curteza**[1], F. Kalaoğlu[2], Y. Heinen-Foudeh[3], [1]"Gheorghe Asachi" Technical University of Iasi, B-dul. D. Mangeron Nr. 67, 700050, ROMANIA, [2]Istanbul Technical University Turkey , [3]Marketing and Communications Director Europe Gerber Technology - A Gerber Scientific Company

Friday 13 November, 2009

Session 7, Intelligent Textiles, Room A, 10H30 – 12H00, Chairman : M. BLAGA

UV PROTECTION OF SUMMER CLOTHING BY NATURAL ZEOLITE TREATED COTTON – THE INFULENCE ON FABRIC HAND, **Ana Marija GRANCARIĆ[1]**, Anita TARBUK[1] & Mário LIMA[2], [1] University of Zagreb, Faculty of Textile Technology, Zagreb,Croatia, [2] University of Minho, Engineering School, Guimaraes, Portugal

INVESTIGATION OF THE PERFORMANCE OF BREATHABLE LAMINATED FABRIC STRUCTURES, **Hale KARAKAŞ**, Osman G. ARMAĞAN, Demet TEYMUR, Dilek ÖZTÜRK, Seda ULUTAş, S. Erman TARIM, Istanbul Technical University, Textile Technologies and Design Faculty, Gumussuyu, Taksim, Istanbul, Turkey

NUTRIWEAR – AN INTELLIGENT SYSTEM FOR THE MONITORING OF BODY COMPOSITION BASED ON TEXTILE ELECTRODES, **N. JUNGBECKER[1]**, L. BECKMANN[2], S. KIM[2], T. GRIES[1], S. LEONHARDT[2], [1]Institut für Textiltechnik, [2]Chair of Medical Information Technology RWTH Aachen University Aachen, Germany

TEXTILE SENSORS FOR ECG AND RESPIRATORY FREQUENCY ON SWIMSUITS
Gianni MONTAGNA[1], M. MARTINS[4], André CATARINO[2], Helder CARVALHO[2], Ana Maria ROCHA[2], J. L. MONTEIRO[3],
[1] Faculty of Architecture, Technical University of Lisbon, Department of Art and Design, Lisboa, Portugal, [2] University of Minho, Department of Textile Engineering, Guimarães,Portugal, [3] University of Minho, Department of Industrial Electronics Engineering, Guimarães, Portugal ,
[4] University of Minho, Centre for Textile Science and Technology, Guimarães, Portugal

Session 8, Bio Textile, Room B, 10H30 – 12H00, Chairman : L. VANLANGENHOVE

EXPERIMENTAL STUDY AND MODELLING OF THE MECHANICAL BEHAVIOUR OF COTTON CORE SPUN YARN WITH ELASTANE AND COTTON RING AND ROTOR YARNS, **F. BOUHJAR**, M. SAHNOUN and M. CHEIKHROUHOU, Textile Research Unit, ISET of Ksar Hellal, Tunisia

APPLICATION OF SERICIN TO MODIFY TEXTILE SUPPORTS, Imen BELHAJ KHALIFA[1], **Neji LADHARI**[2], Mustapha TOUAY[3]
[1] National School of Engineering, Department of Textile Engineering, Monastir, Tunisia, [2]Textile Research Unit of ISET Ksar Hellal, Ksar Hellal, Tunisia, [3]Tunisian-Korean project of sericiculture, Tabarka, Tunisia

STUDY OF MECHANICAL AND PHYSICAL CHARACTERIZATION OF FIBRES EXTRACTED FROM MOROCCAN ALFA PLANT, **Youssef BENYOUSSIF,** Research and Development Laboratory, Ecole Supérieure des Industries du Textiles et de l'Habillement, Casablanca, Morocco

STUDY OF ANTIBACTERIAL EFFECTS OF EUCALYPTUS LEAF EXTRACTS APPLIED ON TEXTILE FABRICS
Imen BELHAJ KHALIFA[1], **Neji LADHARI** [2], Mustapha TOUAY[3], [1] Textile Research Unit, ISET of Ksar Hellal, Tunisia, [2] Laboratory of Medical Matter, University of Pharmacy, Monastir, Tunisia, [3] Laboratory of Microbiology, University of Pharmacy, Monastir, Tunisia

Saturday 14 November, 2009

Session 9, Intelligent Textiles, Room A, 10H30 – 11H30, Chairman : D. JOCIC

ANALYZING THE STRUCTURE OF PANTS SEWING LINE IN APPAREL MANUFACTURING BY SIMULATION
Senem KURSUN, Fatma KALAOGLU, Istanbul Technical University, Textile Technologies and Design Faculty, Istanbul-Turkey

A COMPARISON OF EXPERIMENTAL EXTENSION BEHAVIOR WITH THEORETICAL MODEL OF PLAIN KNITTED FABRIC
H. R. KARIMI[1], Ali A.A. JEDDI[2], A. RASTGOO[3] , [1]Département of Engineering, Islamic Azad University, Arak Branch, Arak, Iran, [2]Department of Textile Engineering, Amirkabir University of Technology, Tehran-Iran, [3]Mechanical Engineering departement University of Tehran, Iran

DEVELOPMENT THE TEXTILE CULTURE OF THE EGYPTIAN CHILD THROUGH PUPPETS INTERACTIVE THEATRE MEDIAS,
S.TEMRAZ[1], **N. FARGHALY[2]**, [1]Alexandria University, Egypt, [2]Helwan University, Egypt

Session 10, Composite Textile et Bio Textile, Room B, 10H30 – 11H30, Chairman : A. M. GRANCARIC

BEHAVIOUR OF WARP INTERLOCKS STRUCTURE UNDER A IEDS ATTACK, **Marie LEFEBVRE[2]**, Benjamin PROVOST [2], François BOUSSU [1,2]**,** [1] Univ. Lille Nord de France, F-59000 Lille, France, [2] ENSAIT, GEMTEX, F-59100 Roubaix, France

EFFECT OF 3D-WEAVE ARCHITECTURE ON STRENGTH TRANSFER FROM TOW TO TEXTILE COMPOSITE, **Saad NAUMAN[1, 2]**, François BOUSSU[1, 2], Irina CRISTIAN[3], Vladan KONCAR[1, 2], [1] Univ. Lille North of France, F-59000, Lille, France, [2]ENSAIT, GEMTEX, F-59100 Roubaix, France, [3]Technical University "Gh. Asachi" Iasi, Romania

FLAME RETARDANCY OF NARROW COTTON FABRICS FOR APPLICATION ON PROTECTIVE CLOTHING, Vaida KLIMAVICIUTE, **Ana Marija GRANCARIC**, Anita TARBUK; University of Zagreb, Faculty of Textile Technology, Zagreb, Croatia

Session 11, Intelligent Textiles, Room A, 11H30 – 13H00, Chairman : S. CHOUKRI

DERMAL ELECTROSPUN NANOFIBRE FABRICS, **Mijović, B.**[1], Agić, A.[2], [1]Faculty of Textile Technology, [2]Faculty of Chemical Engineering and Technology University of Zagreb, 10 000 Zagreb, Croatia

STUDYING OF THE SPECIFIC CONDITIONS TO CONTROL THE MECHANICAL BEHAVIOUR OF THE DORLASTAN CORE SPUN YARN, **Helali HOUDA**, Amel BABAY DHOUIB, Slah MSAHLI, Morched CHEIKHROUHOU, Textile Research Unit of Ksar-Hellal, Tunisia

SMART CLOTHING FOR FIREFIGHTER PROTECTION, **Semra PEKSOZ**[1], Huiju PARK[1], Su Kyoung AN[1] and Huantian CAO[2]
[1]Oklahoma State University USA, [2]University of Delaware USA

EFFECT OF SWELLING RATIO ON FABRIC MASS TRANSFER, **S. BENLTOUFA**, F. FAYALA and S. Ben NASRALLAH,
Laboratoire d'Etudes des Systèmes Thermiques et Energétiques,E.N.I.M., Monastir, Tunisia

Session 12, Intelligent Textiles, Room B, 11H30 – 13H00, Chairman : O. CHERKAOUI

MAGNETICALLY DETECTABLE PRINTS FOR MARKING AND IDENTIFICATION OF TEXTILES, **Benešovský PETR,** Vaclavska Brno, Czech Republic

EFFECT OF WEAVABILITY SATURATION INDEX AND FABRIC PORE SIZE ON AIR PERMEABILITY OF POLYESTER PLAIN WOVEN FABRICS FOR TECHNICAL USES, **Mohamed DALAL[1]**, Jean Yves DREAN[2] , [1]Ecole Supérieure des Industries du Textile et de l'Habillement, Casablanca, Maroc, [2]Ecole Nationale Supérieure d'Ingénieurs Sud Alsace, - ENSISA, Mulhouse, France

BILLBOARD ADVERTISING : INNOVATION WITH INTELLIGENT MATERIALS, **Mesquita, FRANCISCO**[1] & NEVES, Jorge[2], [1] Fernando Pessoa University, [2]Minho University, Portugal

MODELLING THERMAL COMFORT INDEX BY USING DESIRABILITY FUNCTIONS, **A.HADJ TAIEB**, S. MSAHLI, F. SAKLI
Textile Research Unit, Tunisia

IDENTIFICATION OF TYPICAL MORPHOTYPES IN A SAMPLE OF POPULATION, **S. THOMASSEY** S.[1,2] – P. BRUNIAUX [1,2]
[1] Univ. Lille Nord de France, Lille, France, [2] ENSAIT, GEMTEX, Roubaix, France

Session: Poster Presentations

(*)Thursday 12 November & (**)Saturday 14 November, 2009
Poster session : (*)14H0 – 15H00, (**)14H30 – 15H30, Poster Hall
A COMPARATIVE STUDY ON OXIDATION OF INDIGO DYE BY ELECTROCHEMICAL PROCESSES: INDIRECT OXIDATION, ELECTRO-COAGULATION AND ELECTRO-FENTON, Wafa MILED, Ayoub HAJ SAID and Sadok Roudesli Laboratoire des Polymères, Biopolymères et Matériaux Organiques, Faculté des sciences de Monastir, Boulevard de l'environnement, 5000 Monastir, Tunisia
DETERMINATION OF WEAVING COEFFICIENT AS PARAMETER FOR EXPLAINING AND PREDICTING STRENGTH OF FABRICS, Mohamed DALAL, SALBY Latifa, MESSNAOUI Redouane, Ecole Supérieure des Industries du Textile et de l'habillement, Casablanca, Morocco
SYNTHESIS OF HIGH PERFORMANCE POLYAMIDE 6 FIBERS USING C- SUBSTITUTED CAPROLACTAM, O. KHALIL[1] K. BOUGRIN[1] O. CHERKAOUI[2] and A. LALLAM[3], [1]Département de Chimie, Université Mohammed V-Agdal, Rabat, Maroc, [2]Research and Development Laboratory, ESITH, Casablanca-Maroc, [3]Laboratoire de Physique & Mécanique Textiles, CNRS/UHA, Mulhouse- France
EFFECT OF ELONGATION RATE ON A TEXTILE STRAIN SENSOR, C. COCHRANE[1,2,] V. KONCAR[1,2] and M. LEWANDOWSKI[1,2], [1]Univ Lille Nord de France, F-59000 Lille, France, [2]ENSAIT, GEMTEX, F-59100 Roubaix, France
ELASTIC BEHAVIOR OF TEXTILE MATERIALS FOR MEDICAL USE IN TREATING VENOUS ULCERS, B. CHEMANI[1], R. HALFAOUI[2], [1,2]Laboratory of Treatment and Working of Polymers. Faculty of Science of the Engineer, University M' Hamed BOUGARA of Boumerdes- Algeria
ETUDES DES PROPRIETES DU NANOCOMPOSITE PMMA/ZnO, Fatiha LAKHDARI, Nassira BENHARRATS, LPPMCA, Faculté des Sciences, Université des Sciences et de la Technologie, Oran, Algérie.
FEASIBILITY STUDY TO DEVELOP INTELLIGENT GARMENT BY USING CONDUCTIVE THREAD, Arman SHAFI, Laurence SCHACHER, Dominique ADOLPHE, Jean-Yves DREAN, ENSISA, Laboratoire de Physique et Mécanique Textiles (LPMT), EAC 7189 CNRS-UHA, Mulhouse, France
INFLUENCE OF THE WORKPLACE ON THE BODY MORPHOLOGY OF THE EMPLOYEES IN THE CLOTHING INDUSTRY, Darko UJEVIĆ; Žaklina DOMJANIĆ & Beti ROGINA-CAR, Faculty of Textile Technology, University of Zagreb, Croatia
PROPERTIES OF NEW BENZTHIAZOL DYE ON BLOCKING PROPERTIES OF DYEING WOOL AND PA FIBRES AGEINST UV-RAYS, Đurđica PARAC-OSTERMAN[1], Vesna TRALIĆ KULENOVIĆ[2], Ana SUTLOVIĆ[1], Livio RACANE[2], Vedran ĐURAŠEVIĆ, [1]University of Zagreb, Faculty of Textile Technology, Department of Textile Chemistry and Ecology, Savska c.16, Croatia [2] University of Zagreb, Faculty of Textile Technology, Department of Applied Chemistry, Baruna Filipovića 128 a, Croatia
REMOVAL OF ACID DYE FROM AQUEOUS SOLUTIONS USING MODIFIED COTTON FIBERS LOADED WITH COPPER IONS: ADSORPTION ON A FIXED-BED COLUMN, Amel El GHALI[1], Mohamed HASSEN V BAOUAB[2], Mohamed Sadok ROUDESLI[1], [1] Laboratoire des Polymères-Biopolymères Matériaux Organiques (LPBMO), Faculté des Sciences de Monastir, Bd. de l'environnement, 5019 Monastir, Tunisia [2] Institut Préparatoire aux Etudes d'Ingénieurs de Monastir, 5019 Monastir, Tunisia
THERMAL COMFORT PROPERTIES OF BLENDED YARNS KNITTED FABRICS, Arzu MARMARALI[1], Mirela BLAGA[2], Tuba BEDEZ UTE[1], Gozde DAMCI[1], [1] Ege University, Faculty of Engineering, Department of Textile Engineering, Bornova, Izmir, Turkey, [2] Gheorghe Asachi Technical University, Faculty of Textiles–Leather Engineering and Industrial Management Iasi, Romania
USE OF COPPER (II)/DIETHYLENETRIAMINE-COTTON COMPLEX FOR THE REMOVAL OF PESTICIDE FROM EFFLUENT, Amel El GHALI1, Mohamed HASSEN V BAOUAB2, Mohamed Sadok ROUDESLI[1], [1]Laboratoire des Polymères-Biopolymères Matériaux Organiques (LPBMO), Faculté des Sciences de Monastir, [2]Institut Préparatoire aux Etudes d'Ingénieurs de Monastir, Tunisia
STUDY OF THERMAL, MECHANICAL AND DIELECTRICAL BEHAVIORS OF A COMPOSITE MATERIAL FLEXIBILISED BY CTBN, R. ZIRAOUI*, M. GRICH, H. MEGHRAOUI, N. RAMI, M. ELGOURI, A. MOUADA, S. FETOUAKI, A. ELHARFI E.L.C.O.M - Department of Chemistry - IBN TOFAIL UNIVERSITY - BP 133 -14000 - KENITRA / Morocco
DAMAGE OF COMPOSITE SYSTEMS WITH CORRELATED PARTS: APPLICATIONS TO UNIDIRECTIONAL TEXTILE COMPOSITE MATERIALS, M. Chahid, M. Benhamou, A. Maârouf, Université Hassan II, Faculté des sciences Ben M'Sik, Casablanca, Morocco
COMPOSITE MATERIAL PRECURSOR AND REACTIVE FLAME RETARDANT FOR EPOXY RESIN MATERIALS, M. EL GOURI*, A EL BACHIRI, SE HEGAZI, R. ZIRAOUI, M RAFIK, A EL HARFI, Laboratory of Macromolecular & Organic Chemistry, Department of Chemistry, Faculty of Sciences, Kenitra, Morocco
ELABORATION OF NEW GEOTEXTILE BASED ON ALFATO FIGHT EROSION, H. OUTIKI, Y. BENYOUSSIF, O. CHERKAOUI, Research and Development Laboratory, Ecole Supérieure des Industries du Textiles et de l'Habillement, Casablanca, Morocco