Temperature analysis on wrist surface due repetitive movement tasks using Sensorial Thermography to find out a possible pathology for a CTD

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Resumen: A través de la historia se puede observar como la temperatura ha sido un indicador importante para determinar cambios importantes en los ecosistemas del planeta, en la resistencia de materiales para el diseño de nuevos productos, y también en el campo de la medicina analizando por ejemplo, fiebres ocasionadas por infecciones provocadas por nuevas enfermedades. A través de este estudio de las variaciones de temperatura corporales provocadas en los nervios del área de la muñeca generando la reducción en la habilidad muscular para realizar el trabajo debido a movimientos repetitivos, lo cual nos puede llevar a entender la patología de un Desorden de Trauma Acumulado (DTA), tomando en cuenta la termografía sensorial, ya que no es invasiva para el ser humano, que facilita la recolección y manipulación de los datos. *Objetivos:* Analizar cambios en los patrones de temperatura generados en el área de la muñeca. Mostrar la factibilidad de la aplicación de la termografía sensorial. Recabar información acerca de las variables no laborales (edad, género, peso, entre otras) y laborales (repetitividad, temperatura del área de trabajo). Desarrollar las pruebas preliminares emulando la operación ejecutada en la industria y que involucra los movimientos repetitivos. Identificar los puntos de estrés máximo alcanzados durante un periodo de operación describiendo síntomas detectados.

Delimitación del problema: Este estudio se realizó con sólo un estudiante de la Facultad de Ingeniería Ensenada de la UABC. *Metodología:* Se seleccionó a un estudiante en condiciones físicas normales, quien realizó pruebas en un laboratorio aplicando el protocolo para el experimento haciendo uso de la termografía sensorial. *Resultados:* Las temperaturas máximas alcanzadas en ambas muñecas fueron en periodos de operación en tiempos muy similares. Se detectaron molestias en el hombro derecho en el rango donde se identifican las temperaturas más altas durante el proceso de la operación para ambas muñecas. A través del ajuste de una ecuación de tercer orden fue posible explicar el comportamiento de las temperaturas. *Conclusiones:* Por medio de la termografía sensorial es posible analizar patrones de temperatura, ligarlos a una estadística creando la posible patología de un DTA y que pudieran servir en futuras investigaciones.

***Palabras clave**:* Termografía sensorial, DTA, temperatura.

Abstract: Through history we have observed how temperature has been an important factor to take in account in order to detect many several climatic changes in planet. This factor has been deeply studied in weather changes, material resistance for the designing of new products, and also, in the medicine field obtaining remarkable results studying fiber causes in multiple diseases, most of them related to infections. This research aimed at evaluating body temperature variations on wrist surface that can cause muscle disability and weakness due repetitive movement tasks. The work contributes to discover a possible Cumulative Trauma Disorder (CTD) pathology using sensorial Thermography as an innovative and dynamic tool, since this is not a non-invasive technique it means that can not cause any damage on humans. It is a powerful tool also, because allow investigators to manipulate data and import or export them to statistics programs. *Objectives:* Analyze temperature pattern changes and show up the feasibility of the sensorial thermography. Collect information about different kind of variables that may affect the study, like age, gender, weight, height, and others like repetitiveness and work area temperature. Perform preliminary test emulating an operation highly repetitive in the textile industry. Identify maximum stress points while preliminary test is taking place, and at the same moment detect key symptoms. *Methodology:* An Industrial engineering student in good shape was selected to perform the repetitive task in a lab by following the experiment protocol and using sensorial thermography.

Results: Maximum temperatures in both wrists were detected in similar periods of time. The student showed pain symptoms in right shoulder while doing the task. It was detected while the maximum temperature range was reached in both wrists. By adjusting a third order equation it was possible to explain the temperature behavior. *Conclusions:* Through sensorial thermography is possible to analyze temperature pattern and link them to statistics creating a possible CTD pathology that could help in future researches.

Keywords: Sensorial thermography, CTD, temperature.

1. INTRODUCTION

The highly repetitive activities are a disease that in nowadays affect thousands of people developing several cumulative trauma disorders. In many times this kind of disorders are confused with other kind of diseases. The cumulative trauma disorders cause damages on body tissues due to excess motion periods. It can be developed through pass of the time. Furthermore, today, the DTA'S are well known as an industrial epidemic causing a periodic disability. The experimentation was based on temperature analysis generated on wrist area of one subject, which is the area where the carpal tunnel syndrome begins. A repetitive movement simulation consisted in an operation emulated from a local textile industry. The study was taken using sensorial thermography.

The thermography is a non invasive technique without biologic hazard. It detects, measures, and converts invisible, surface body heat into visible display which is the photographed or videotaped as a permanent record. This type of thermography it is the one we call infrared thermography (Feldman al., 1991). The digital sensorial thermography it is different from the infrared one, because it is widely used to look for temperature patterns on skin surface through sensor contact (Zontak et al., 1998).

This technology was born while the submarine thermographs a long time ago were developed to measure underwater temperatures. It has many applications such as oceanography, marine ecology, industry, and many others (Lopez, 1992).

This study arose from three important questions, what is the subject temperature behavior during the motion? What is the relationship between pain symptoms and temperature data? What are the max stress points? A close examination of the literature shoes that no study has been devoted to these problems emulating a motion executed in the textile industry in order to analyze cutaneous temperatures.

However a swimming study was carried out with a professional swimmer in a pool where the swimmer practiced several swimming styles, so researchers could analyze the temperatures after each swimming style (Zaidi et al., 2007).

The Study was carried out in a closed room where the temperature was a relevant parameter. We use a home heater to try to control the temperature, because according with the literature, the most useful temperature parameter in experimentations of this kind is between 20 and 25 degrees (E.Y.K, N.G. et al., 2005).

It is advisable to specify that the present work is not a statistical study. The results obtained in this study cannot be considered to have a universal character since only one subject was taken into account for our experimentation. However we are doing many test with more subjects at the campus to make temperature behavior inferences. The objectives in this preliminary experimentation were to show the applications of the sensorial thermography on one hand, and on the other hand, to show the maximum temperature stress points.

2. OBJETIVES

This Study presents the following objectives:

- To analyze temperature pattern changes generated on wrist area.

- To show the application of sensorial thermography.
- To collect information about subject gender, age, mass and others.
- To collect information about repetitive cycles and temperature working area.
- To develop preliminary test emulating a textile industry repetitive operation.
- To identify maximum stress points during the operation period and to describe symptoms detected.

3. METHODOLOGHY

3.1 The subject

The subject taking in part in this study is a subject in good shape. The principal anthropometric characteristics of the subject are summarized in table 1.

Table 1. Anthropometric data for the subject

	Age	Height (m)	Mass (Kg)
Subject	29	1.63	60

3.2 Equipment and data analysis

All the cutaneous temperatures were taken using a sensorial thermograph Sköll with a temperature range of 0˚C – 40˚C, a precision of ±.3˚C, and a resolution of 1 degree, a microporous tape (Lopez, 1992), a laptop (COMPAQ Intel Pentium Dual Core), a home heater. Programming the thermographs was possible using a program called Akela. Also a statistical program was used for data analysis (Minitab 15) and Microsoft Excel 2007.

3.3 Protocol

Subjects were asked to refrain from intense exercise, caffeine, smoking, alcohol and smoking for 20 minutes prior to the experiment (Gold et al., 2004) and (Gold et al., 2009) because smoking

could produce a massive reduction of body temperature and alcohol a raise of body temperature. Previous studies have demonstrated that the corporal temperature stabilization takes about 20 minutes due to a reduction on body metabolism (E.Y.K NG y Sim en E.Y.NG et al., 2008).

Having the opportunity to use a home heater we warmed up the room temperature for the experiment between 20-25 degrees (E.Y.K NG et al., 2005), Once we warmed up the room, the participant was seated in an ergonomic chair with arm rest and then stick the sensorial thermographs in both wrist, close to the median nerve region. After that, the subject was asked to rest both arms in a flatbed at the ribs height (Kroemer et al., 2001) for about twenty minutes. The next step in the experiment protocol was to simulate a highly repetitive operation executed in the textile industry for about 3.5 hours, this period of time representing the longest period of the workday. The operation involved several movements like reach, take, place and many others. Several pain symptoms were identified during the experiment. Finally, the sensor thermographs were removed from both wrist and then analyze the results.

4. RESULTS

The results of all pain symptoms detected during the experiment developed are shown in table 2. These anomalies were given off by the subject while he was doing the repetitive task. It was so important to write down the hour, minute and second, so we could link this info to the temperatures.

Table 2. Anomalies detected in the operator

	Right shoulder pain	Left shoulder pain	Lower back pain	Upper back pain	Right wrist pain	Right palm pain
Preliminary 1	x					
Preliminary 2	x		x	x	x	x
Preliminary 3	x				x	
Preliminary 4	x	x		x		x

4.1 Preliminary test 1

The corresponding temperature behavior is shown in Figure 1 and 2. If we compare both figures we can see that both temperature behaviors in both wrists are very but very similar. Three similar characteristics were identified as a result:

- The temperatures in both writs (maximum stress points) were 33.44˚C and 32.921˚C, and were reached at similar periods of time, 11:41:14 and 11:49:28 (h:m:s).
- The anomalies in right shoulder started to being shown by the person at the range where were the highest temperature levels, while doing the operation using both wrists.
- The most aggressive projection of the temperature was approximately at 11:30 and 12:00 in both wrists.

In both cases the subject beated the pain symptoms on right shoulder, this happened when the most aggressive projection began to appear, approximately at 11:40. Then at the same time the temperature projection became less aggressive and began a tendency of decrease.

On the other hand, by adjusting a third order equation it was possible to explain the temperatures of the person with a coefficient of determination of 91.1% for the left hand wrist and 87.7% for the right hand wrist.

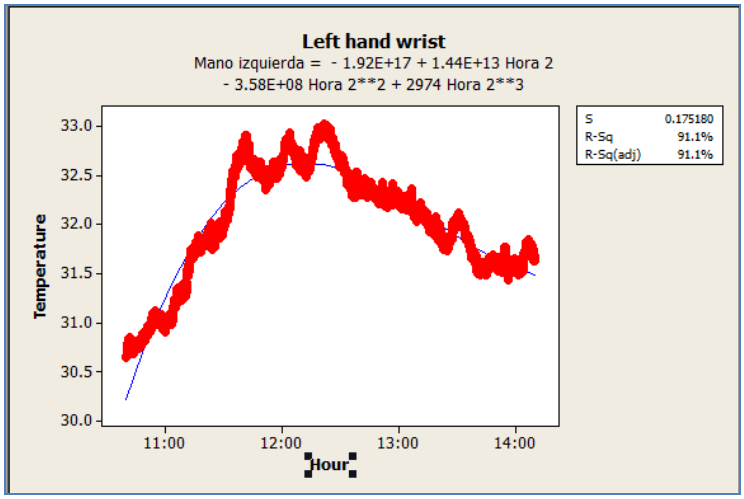

Figure 1. Adjustment of the curve of left hand wrist

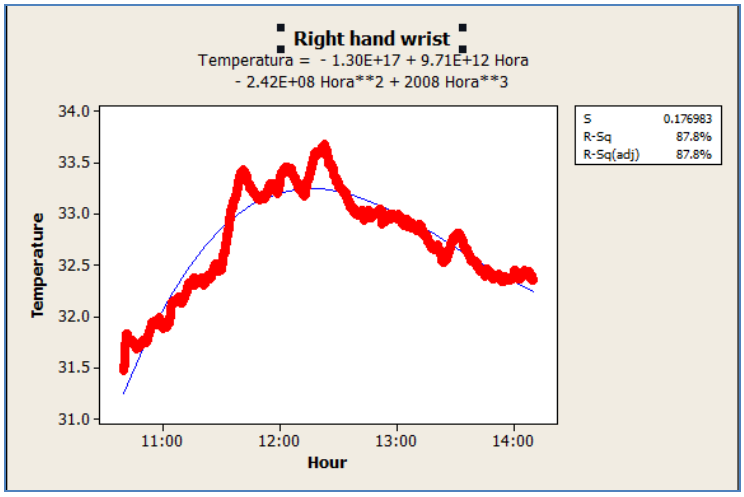

Figure 2. Adjustment of the curve of right hand wrist

4.2 Preliminary test 2

The corresponding temperature behavior is shown in Figure 3 and 4. If we compare both figures we can see that both temperature behaviors in both wrists are very similar has shown in the previous preliminary test. The maximum time of stress of the hands was to similar one from each other, and based on this we could say the following important points:

- ✓ The maximum stress points were reached in similar times in both wrists. On left hand wrist at 12:48:24 and the temperature was 34.276˚C and on right hand wrist was 12:48:39 and the temperature was 34.154˚C. Factors like temperature and time were similar.
- ✓ Many anomalies were detected on right wrist around 12:33:30 and after one hour on right palm, and at the same time on lower back.
- ✓ Anomalies on right shoulder were detected when the maximum temperature stress point was reached.

On the other hand it was possible to adjust a polinomial third order equation that represents the subject temperature behavior and as a result a coefficient of determination of 80.5% for the left hand wrist and 86.8% for right hand wrist.

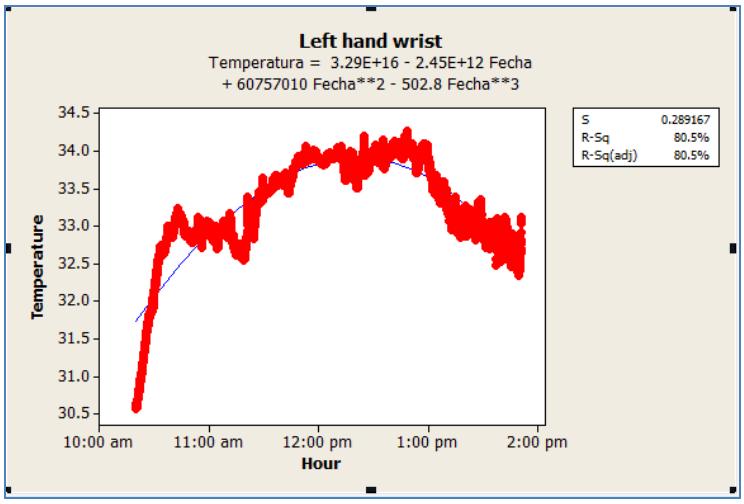

Figure 3. Adjustment of the curve of left hand wrist

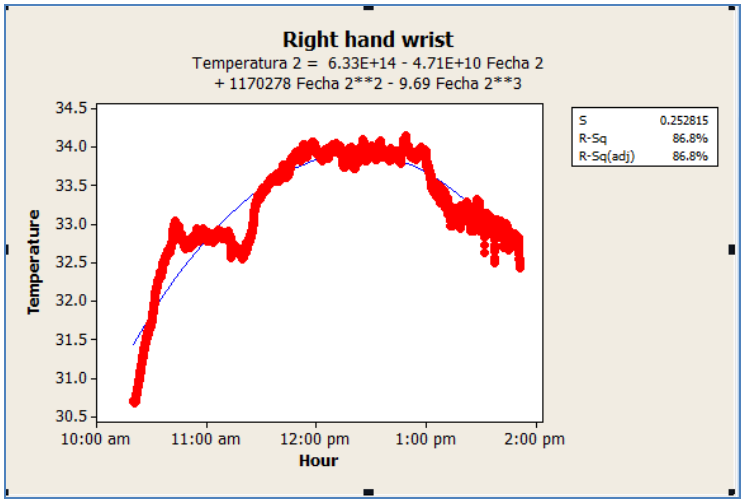

Figure 4. Adjustment of the curve of right hand wrist

4.3 Preliminary test 3

The corresponding temperature behavior is shown in Figure 5 and 6. If we compare both figures we can see that both temperature behaviors in both wrists are very similar has shown in the previous preliminary test and. The maximum time of stress of the hands was similar one from each other, and based on this we could say the following important points:

- ✓ The maximum stress points were reached in similar times in both wrists. On left hand wrist at 14:11:40 and the temperature was 33.481˚C and on right hand wrist was 14:13:22 and the temperature was 33.313 ˚C. Factors like temperature and time were similar.
- ✓ A lower back pain was identified around 12:55:35 and close to the end of the experimentation a pain on right hand wrist around 14:54:10.
- ✓ Anomalies on right shoulder were detected when the maximum temperature stress point was reached.

On the other hand it was possible to adjust a polinomial third order equation that represents the subject temperature behavior and as a result a coefficient of determination of 90.8% for the left hand wrist and 94.5% for right hand wrist.

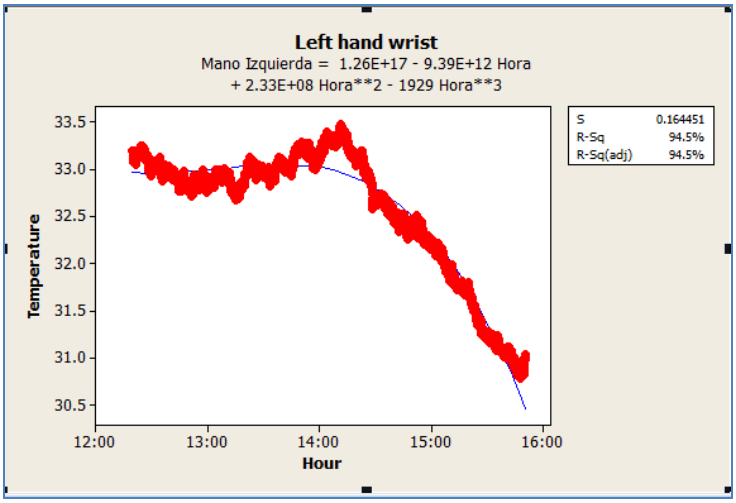

Figure 5. Adjustment of the curve of left hand wrist

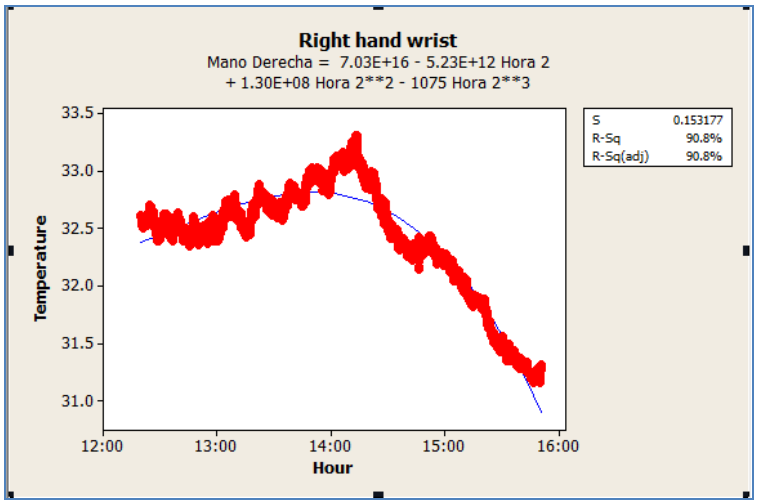

Figure 6. Adjustment of the curve of right hand wrist

4.4 Preliminary test 4

The corresponding temperature behavior is shown in Figure 7 and 8. If we compare both figures we can see that both temperature behaviors in both wrists are similar has shown in the previous preliminary test and. The maximum time of stress of the hands was to similar one from each other, and based on this we could say the following important points:

- ✓ The maximum stress points were reached in similar times in both wrists. On left hand wrist at 12:52:14 and the temperature was 33.686˚C and on right hand wrist was 13:03:53 and the temperature was 33.114˚C. Factors like temperature and time were similar.
- ✓ A lower back pain was identified around 12:55:35 and close to the end of the experimentation a pain on right hand wrist around 14:54:10.
- ✓ Anomalies on right shoulder were detected during the period when the temperature began to decrease around 13:42:52. Also a pain on right palm was identified around 14:13:43.
- ✓ At the end of the test a pain on left shoulder was identified around 3:52:40 and also the pain on right shoulder increased in a several way, this occurred around 3:56:36.
- ✓ On the other hand it was possible to adjust a polinomial third order equation that represents the subject temperature behavior and as a result a coefficient of determination of 97.3% for the left hand wrist and 95.6% for right hand wrist.

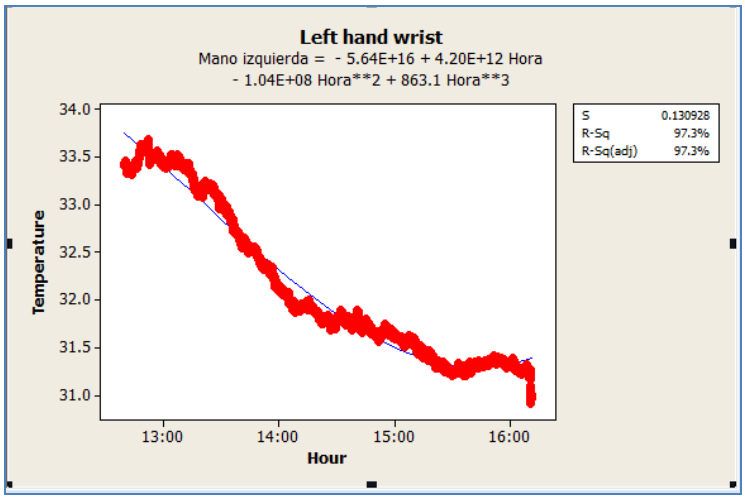

Figure 7. Adjustment of the curve of left hand wrist

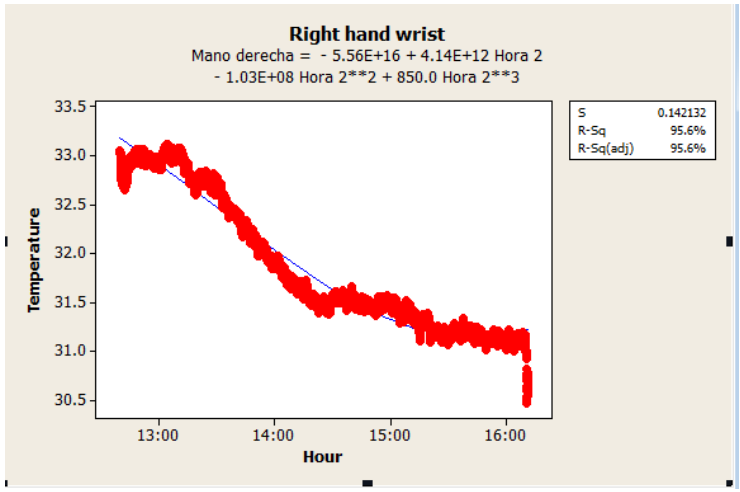

Figure 8. Adjustment of the curve of right hand wrist

4.5 Averages

Taking in account the maximum temperatures reached in the experiment stress points of all the preliminary test of both hand wrists, we obtained averages for each hand wrist, and the equation 1 shows how to calculate the averages:

$$\bar{y} = \frac{\sum_{i=1}^{n} y_i}{n} \quad (1)$$

We found out, and based on having similar temperature patterns and stress point periods that averages were similar too. The average temperature for left hand wrist was $\bar{y} = 33.72\,^{\circ}$C and $\bar{y} = 33.38\,^{\circ}$C for the right hand wrist.

5. CONCLUSIONS

A preliminary experimental test was undertaken on one hand, for studying the feasibility of using sensorial thermography on the analysis of repetitive tasks, and on the other hand to identify the maximum stress point, behavior and temperature patterns as a result of the activity. In particular, this study shows that the use of the sensorial thermography is appropriate in order to detect temperature patterns. It is remarkable to mention that in all the test the temperature patterns were very similar in both hand wrists, independently of the dominant hand of the subject. The temperature patters were similar for all the tests, but changing its behavior during the days. The same conditions were taking in account for the entire tests, including the room temperature as the main element.

On the other hand it was possible to adjust a polinomial third order equation for each test that represents the subject temperature data behavior and as a result a coefficient of determination to represent the level of the curve adjustment to data.

6. RECOMENDATIONS

One should recall to this conclusions cannot be considered as universal as far as only one subject, a subject in good shape, took part in this study. Nevertheless, the conclusions make us

think of considering a statistical study taking in part more subjects (men and women), to verify if the temperature patters of several subjects are linked in same way.

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