Numerical Simulation of a Human Body Subjected to Electrostatic Fields for Study of the Turin Shroud Body Image

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Abstract:

The Turin Shroud (TS) is the most important Relic of Christianity and one of the most studied objects from a scientific point of view because a not yet explainable body image is codified on it.
The best hypothesis to explain this image is based on a Corona Discharge related to an intense electric field.
It is here supposed a direct correlation between TS image intensity and electric field strength.
This paper compares the TS image with those obtainable by means of a numerical model of a manikin subject to different environmental conditions.
A floating manikin immersed in a vertical electrostatic field reaches the best match thus supporting the Corona Discharge hypothesis.

Keywords: Turin Shroud, body image, electrostatic field, corona discharge, numerical simulation.

List of abbreviations

E.P. = Electric Potential	F = Floating
G = Ground	TS = Turin Shroud
Z.C. = Zero Charge	1,2,3,4,5 = Case

1. Introduction

The TS[1,2] (Turin Shroud), see Fig. 1, is a fine linen fabric showing a not yet explainable[3] double body image of a scourged and crucified man stabbed on the right side. Many unsuccessful hypotheses[4] have been formulated and perhaps the most reliable is correlated to formation of Corona Discharge[5] triggered by an electric field which is possibly intensified by ambient ionization owing to radon efflux. Before to formulate specific hypotheses regarding the environmental conditions, that will be studied in the future and barely mentioned in the final discussion, the analysis focalizes the interest on the verification of the effects of such an electrostatic model on a linen sheet. Therefore, the first steps is to simulate the distribution of the electric field over a two-dimensional sheet enveloping a numerical manikin postured as the human body visible on the TS[6].

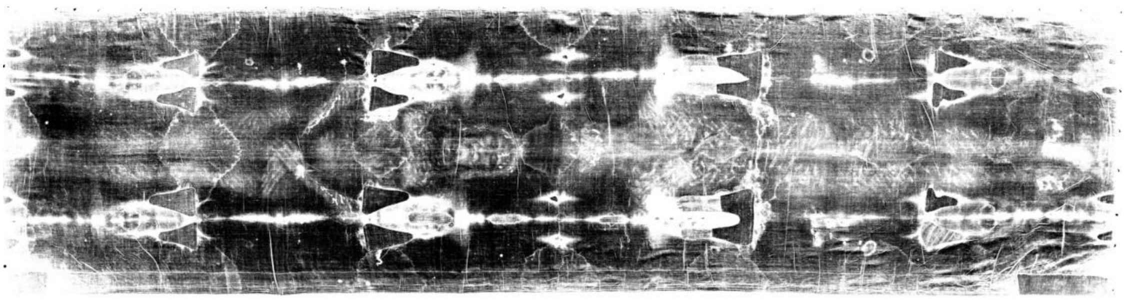

Figure 1. The Turin Shroud: negative image.

Two of the authors[7] have already performed a preliminary analysis using an unsophisticated but eloquent numerical manikin composed of 11 ellipsoids. The results of an enhanced model, in which hair, hands' fingers and some detail of face, like nose and eyes are also reproduced, are here presented and discussed.
This improvement was required because the interest on the TS image is also addressed to these details.
Starting from the hypothesis, sustained by experimental results, that the surface electrostatic -field magnitude is proportional to the image intensity codified on the linen sheet, the aim of this study is to show which is the best environmental condition, if any, from an electric point of view, that produces an image as close as possible to the TS one.
Such a comparison allows to verify from a numerical point of view which was the best condition, if any, that could have generated the TS image.
This study obviously does not consider any historical or religious aspects regarding the environment in which was posed the TS Man - a subject which can be discussed elsewhere - it only simulates the effects of some simple electric configuration to show which of them better fit with the TS image.

2. Corona Discharge

Gases, air in particular, behave as insulating media under normal conditions; however if the electric field is high enough, free charges which are always present in the environment can gain sufficient energy to ionize neutral molecules by collision, thus giving origin to an avalanche process.
In case of non-uniform field distributions this activity is confined to a small fraction of the gap, specifically where the curvature radius of the electrode is smaller. This process tends to be self-limiting, in the sense that of the two ion species being generated the one bearing the same sign of the applied voltage drifts to the opposite electrode. This moving space charge reduces the field in the region in which ionization takes place.
In principle, corona generates very short current pulses with an interval between them dictated by the time needed to sweep away the remaining charges; the situation can be very different depending on the voltage wave shape (alternating, continuous or even impulsive) due to the contribution of the space charge left in the gap.
Normally, as the voltage is increased, a situation can be reached in which the repetition frequency of the pulses is so high that the current results practically continuous.
In this case the visual appearance of the discharge is that of a faintly distributed luminosity (glow discharge); usually the acoustical noise is very low and this is the situation which is usually associated to corona. If the field is further increased, the equilibrium condition is broken and the discharge tends to concentrate, thus assuming the character of vivid filamentary discharges (streamers) and giving rise to cracking noise. This discharge mode is also polarity dependent and represents the last step before the gap breakdown.
In any case, the zone in which corona develops is a very active one because of light emission due to electron excitation/de-excitation with emitted light normally in the UV (or even vacuum UV) range. Free ions and also very reactive species (free radicals and ozone) are produced.

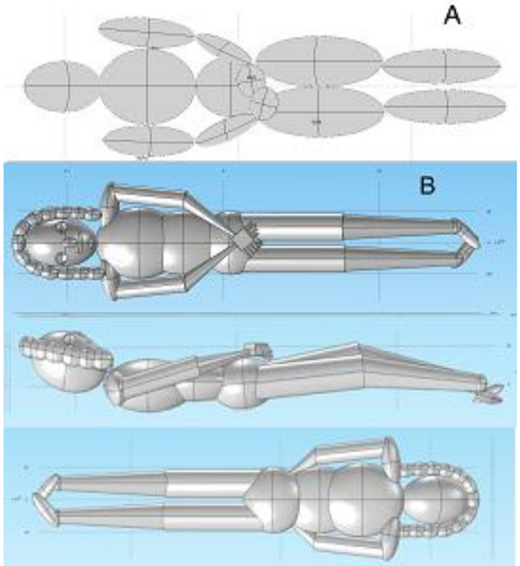

Figure 2A Numerical manikin consisting of 13 elements initially developed by Ref. 7 . **Figure 1B** Improved numerical manikin made by 46 elements used in the present analysis.

Therefore, in presence of organic materials a modification of the superficial layers can be expected due to a variety of aging processes, often exploited for industry applications (plasma treatments).

Roughly speaking, this is the process that supposedly generated the TS body image, whose various characteristics like superficiality, double superficiality[4], image concentration on overstressed points, to mention a few, confirm this hypothesis. Instead, the origin of the electric field that generated the TS image is not clear for the moment.

The matter can even become more complicated in presence of an insulating barrier in front of the electrode because the material can capture and concentrate charges, thus appreciably modifying the field; in addition the presence of different permittivities can further complicate the field distribution.

For this reason a numerical model showing the electric field distribution along a manikin seems very useful to understand which environmental condition could have generated the TS image.

3. Numerical model

An electrostatic finite element mesh using the ComsolMultiphysics® (Version 4.2a) software was built to represent an anthropomorphic manikin with its boundary conditions.

The comparison with the TS image has been repeated by a trial-and-error approach aimed at

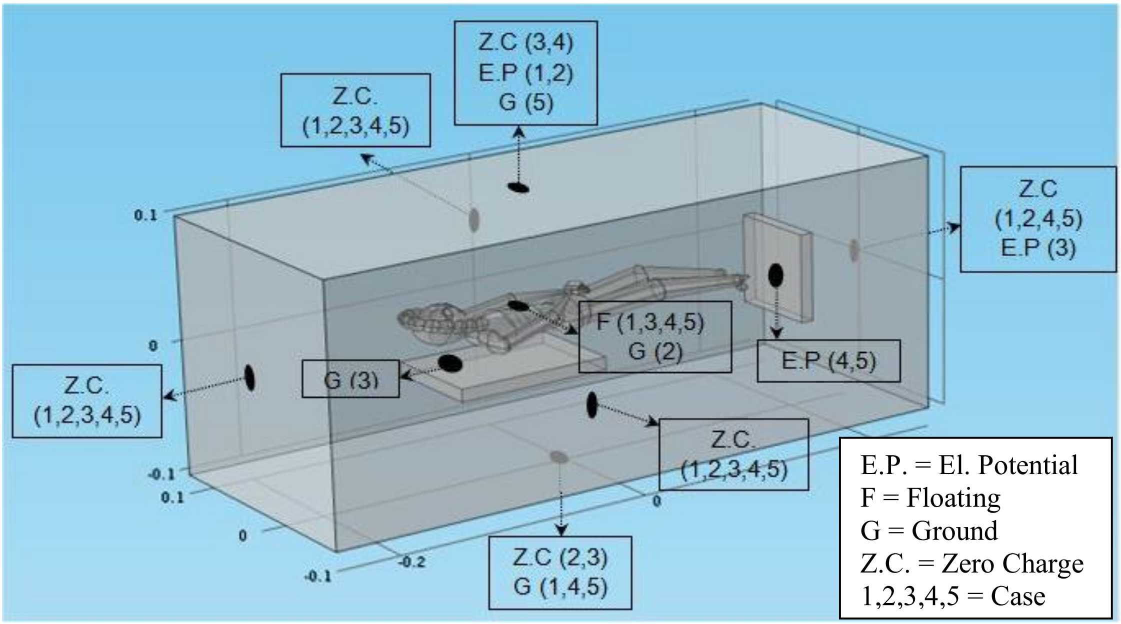

Figure 3. Scheme explaining the simulated cases. The numbers 1 to 5 correspond to individual cases simulated.

Table 1. Summary simulations with respective environmental conditions.

Case	Figure	Manikin	Upper Wall	Lower Wall	Right Wall	Three Lateral Walls	Additional Plate
1	3-4	Floating	1V	Ground	Zero Charge	Zero Charge	-
2	5	Ground	1V	Zero Charge	Zero Charge	Zero Charge	-
3	6	Floating	Zero Charge	Zero Charge	1V	Zero Charge	Ground
4	7	Floating	Zero Charge	Ground	Zero Charge	Zero Charge	1V
5	8	Floating	Ground	Ground	Zero Charge	Zero Charge	1V

attaining the pre-established degree of model sophistication. In particular, also hands, face and hair were accommodated in the model. On the contrary, the parts of the body that are less visible (or even absent) on the TS such as the feet's fingers, have been left roughly reproduced. Particular care was taken in the model smoothing in order to avoid spikes and edges producing unrealistic charge concentrations.
Starting from an initial manikin[6,7] having only 13 ellipsoids to represent the body (Figure 2A), the new articulated model (Figure 2B) is performed by 176295 degrees of freedom and composed by 46 elements of different shapes and dimensions: 26 ellipsoids, 12 cylinders, 4 cones , 2 rectangles and 2 balls.

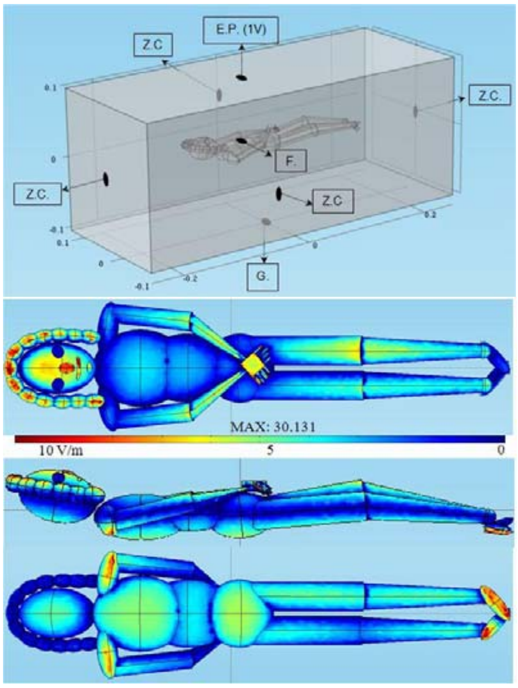

Figure 4. Environmental conditions and electrostatic field of Case 1.

The position of the limbs (arms tilted, hand position, inclination of the legs) has been implemented in the numerical model by using available data[1].
To simulate the environmental conditions around the manikin, a parallelepipedal enclosure was built up. In coherence with the previous model[7], the manikin about 0.3 m long has been put in the middle of the parallelepiped, sufficiently distant from the sides, to avoid edge effects.

The boundary conditions are dictated by the surfaces of the parallelepiped having sizes of 0.2 x0.2x0.5 m^3. The inner volume is assumed as being gas filled, thus presenting unitary relative permittivity.
During the preprocessing phase a second order interpolation in each element (tetrahedrons) composing the mesh has been adopted; the elements sizes range from 10^{-3} to 10^{-2} m.

4. Results

Based on previous studies and data given adopting a prominent hypothesis of image formation[5,7], five cases have been here simulated.

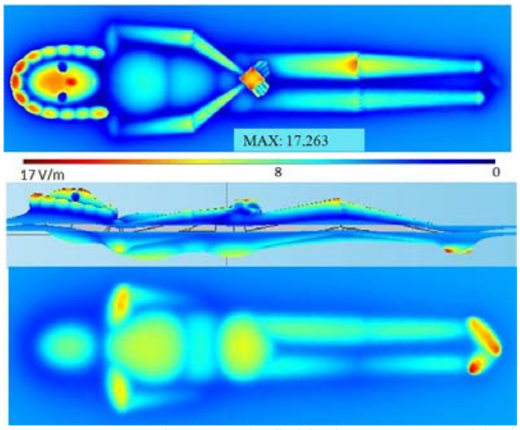

Figure 5. Electrostatic field of Case 1 on an ideal surface simulating the TS.

Figure 3 and Table 1 describe the environmental conditions in terms of distribution of electric field on the manikin.
Case 1 shows the distribution of the electric field on the surface of the numerical manikin floating in the parallelepiped having the upper plate at a potential of 1V, see Fig 4.
The higher the field strength, the more intense is the body image. This simulation shows the high concentration of electrostatic field in correspondence of tips of nose, hair and hands.
There is a difference in intensity between the chest and the back of the numerical model that is not ostensible on the TS.
Observing the lateral side of the manikin, the intensity of the electric field shows a reduction substantially consistent with the well known

cosine law expected by the theoretical floating objects.

The electric field on the manikin's surface has been evidenced with a maximum value, relative to the present simulation, of about 30 V/m, thus 6 times the unperturbed applied field of 5 V/m.

Fig.5 shows the distribution of the electric field on an ideal surface (*Isosurface*), characterized by a relative permittivity near to the unity, positioned at a certain distance from the manikin in some areas, and in contact in correspondence of other, to simulate the TS wrapping around the human body. The analogy with the intensity distribution of the TS body image is evident.

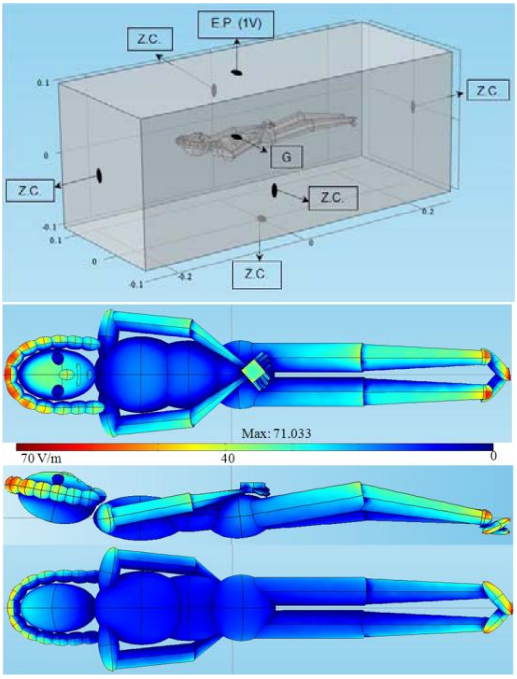

Figure 6. Environmental conditions and electrostatic field of Case 2.

<u>Case 2</u> represents the distribution of the electric field on the surface of a grounded manikin see Fig 6. A potential of 1V is on the ceiling. The electric field on the manikin's surface has a maximum value, of about 71 V/m.

This case evidences a slight field magnitude also all around a lateral band of the manikin figure, but the dorsal side is quite shielded, with the exception of the feet. This fact is in agreement with intuition based on elementary field theory considerations.

The belly is also shielded because of the close presence of the forearms with small radius of curvature.

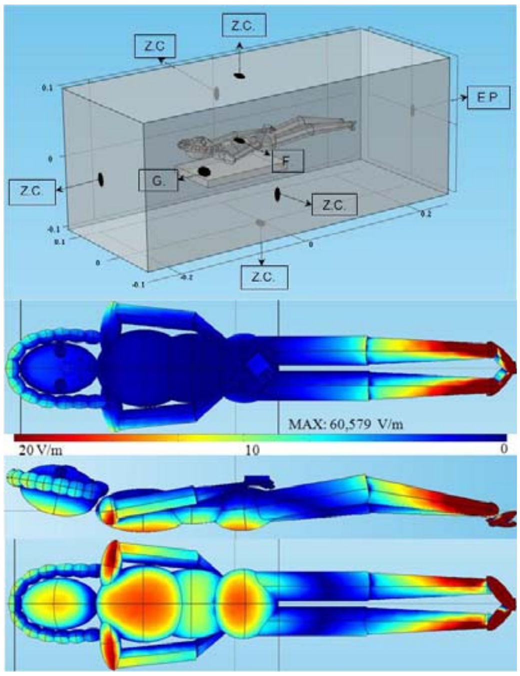

Figure 7. Environmental conditions and electrostatic field of Case 3.

<u>Case 3</u> of Fig. 7 shows a manikin charged with a potential of 1 V in correspondence of the lateral wall near the feet. The distribution of the electric field is therefore concentrated in the area of the feet. The extra plate at the back has been positioned with the aim of achieving a uniform electric field in the vicinity of the manikin. The electric field on the manikin's surface has a maximum value of about 60 V/m.

The electric field distribution of Case 3 is also similar to that of **<u>Case 4</u>**, see Fig.8 where an additional plate is put in the nearness of the feet and charged with a potential of 1 V. The electric field on the manikin's surface has a maximum value, of about 103 V/m.

<u>Case 5</u> of Fig. 9 is similar to Case 4, but the ceiling has been grounded. The field intensity is larger in correspondence of the feet than in Case 4 having a maximum value of about 125 V/m.

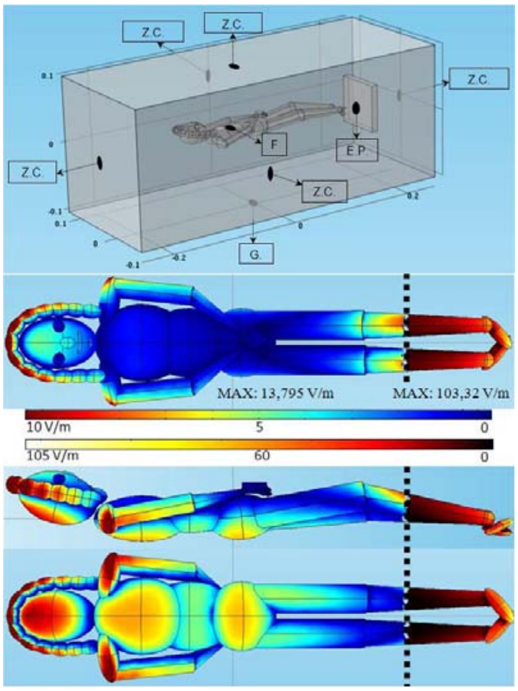

Figure 8. Environmental conditions and electrostatic field of Case 4.

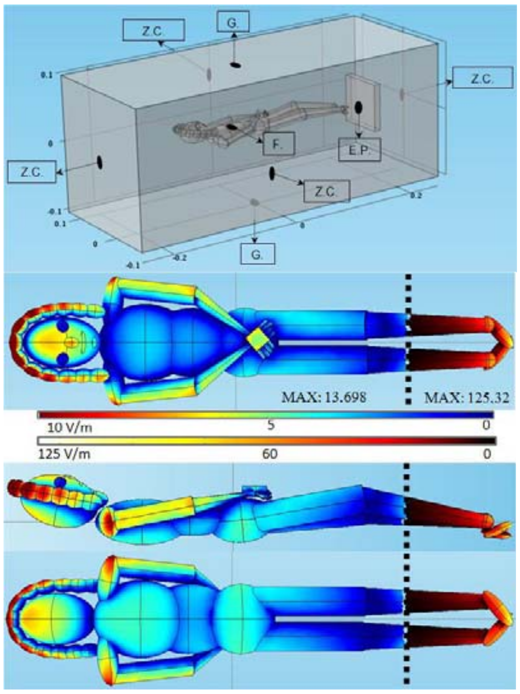

Figure 9. Environmental conditions and electrostatic field of Case 5

5. Conclusive remarks

On the basis of a previously less sophisticated multi-ellipsoid model[7], the present numerical manikin built up to widely control the surface electrostatic better satisfies the expectation of reproducing the TS body image.
Notwithstanding this, some local refinements as those shown in Figure 9 could be used in the next future. This is especially the case in the hands' palms and fingers, nose, mouth, beard and hair.
From the five cases studied, the best match with the TS image seems reached by Case 1 that simulates a manikin floating in an electric field with planar conductor positioned on the upper side of the parallelepiped.
This results are referred to the geometrical and electrical scaled model. Thanks to the linearity of the problem (for dimensions greater than some centimeters), in order to obtain a real condition, the geometrical model should be enlarged by a factor of six and the applied electrical potential should be increased by a factor of about 100000.

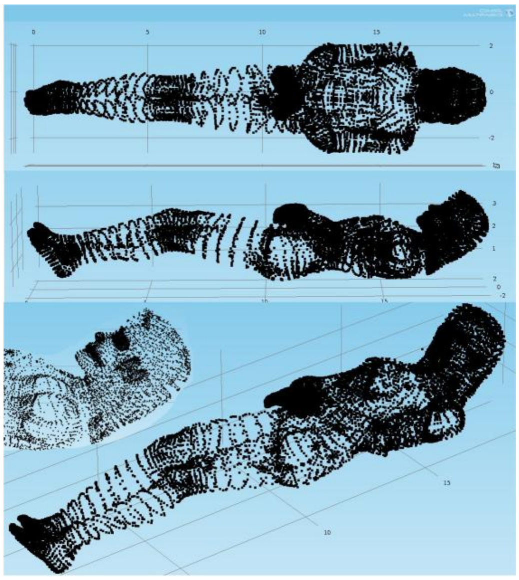

Figure 9. A new finer model of numerical manikin that can be used in the next future to study some body details of face and hands..

This result sustains the Corona Discharge hypothesis and gives further suggestions useful in the study of the environmental conditions that caused the TS image.

Also after the recent rebuttal of the 1988 radiocarbon results[8], the authors are convinced that the TS really wrapped the body of Jesus of Nazareth and therefore they are studying which kind of environment could have generated the TS body image.

In the hypothesis suggested by the Gospels that the corpse of Jesus was buried in a sepulcher excavated in the rock of Jerusalem, and externally closed by a big stone, we can formulate two initial hypotheses to explain the vertical electrostatic field suggested by Case 1.

The first one is related to the Resurrection, but this hypothesis obviously goes out of the realm of science and is therefore not discussed here.

The second one, makes reference[5,7] to an electric field generated in the sepulcher by a not yet well defined cause that could also be a (ball) lightning or the spillage of radon gas accentuated by the concomitance of a big earthquake, also mentioned in the Gospels. The radon gas would have ionized the environmental air. The consequent charge separation due the polarity-dependent ion mobility of the ionic species involved in forced transport phenomena could be a reason for existence of a background electric field. In addition corona discharge can locally have been enhanced at microscopic level by the point effect related to the single linen fibers of the TS enveloping the conducting body and by the vacuoles full of ions.

Based on the numerical results here obtained, future experiments, are just addressed to reproduce an electrostatic image on a linen fabric that will be as much as possible similar to that of the TS in the environmental conditions of Case 1. These results will hopefully help in a definition of the environment that produced the TS body image.

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