Potential Problems with a Cloth Collapse Hypothesis for Image Formation on the Shroud of Turin

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Abstract

Images of the front and back of a naked crucified man can be seen on the Shroud of Turin. Evidence indicates these images were caused by radiation. The cloth collapse hypothesis holds that the disappearance of the body from within the Shroud of Turin created the conditions for the cloth to rapidly collapse into the region previously occupied by the body, where it encountered radiation that discolored the fibers thus forming the high-resolution front and back images on the Shroud. Potential problems with this hypothesis include: 1) difficulty in forming the front and back images without side images by collapse of the Shroud under the forces of gravity and air pressure difference, 2) the speed of radiation is so much faster than the speed of the cloth that cloth movement becomes irrelevant, and 3) the cloth would not start to collapse until about 99.9% of the radiation had already gone through the cloth, again making cloth movement irrelevant to the image formation. The last two problems can be avoided by assuming that the body becomes mechanically transparent when it starts to disappear. The vertical radiation hypothesis is preferred over the cloth collapse hypothesis due to the latter's difficulty in explaining why there are no side images. An equation is derived for the distance that the cloth collapses as a function of time after the disappearance of the body.

1. Introduction

Scientific examination of the image on the Shroud indicates that it is a negative image that contains 3D information, that the discoloration that forms the image is only on the top one or two layers of fibers in a thread and is only on the extreme outer surface of each fiber, and that the discoloration is not due to pigment, a liquid, contact with a hot object, or a photographic process. The discoloration of the fibers that cause the image results from single electron bonds in the carbon atoms in the cellulose molecules of the flax fibers being changed into double electron bonds. These changes in the electron bonding of the carbon atoms had to be made in a pattern to produce the image of a crucified man. These characteristics indicate that the Shroud could not be the product of an artist or forger in any era, so that the image must have been created in some way by the body that was wrapped in the Shroud.

The mechanism that discolored the fibers in the image required information to control which fibers would be discolored and the length of discoloration on each fiber. In discoloring the fibers, this information was encoded into the pattern of discolored fibers that make up the image, which is why we can see the image on the cloth. The information required to form the image was that which defined the appearance of a naked crucified man, which was only inherent to the body. The only option to carry this information from the body to the Shroud is radiation, so that the image on the Shroud must be a radiation burn created by radiation emitted from within the body that was wrapped within the Shroud (Ref. 1 and 2). This radiation must have been emitted in a very brief burst to discolor only the top two layers of fibers. Radiation emitted over a longer period will discolor the fibers to a greater depth, as indicated by Paolo Di Lazzaro's laser experiments (Ref. 7 to 11). In all our historical records, the only person suggested that might emit such a burst of radiation from his dead crucified body is Jesus. To solve how such radiation could be emitted, it is usually assumed that this burst of radiation occurred during the body's disappearance from within the Shroud (John 20:1-10). It is also usually recognized that the body's disappearance was not an instantaneous event ($\Delta T = 0.0$). If the radiation was emitted in a very brief burst, as indicated above, and if the radiation was emitted during the disappearance of the body, then the body must have disappeared very quickly – in a very small fraction of a second. This is the usual assumption, but the disappearance of the body is sometimes assumed to have disappeared over a much longer period.

To form the high-resolution images that are on the Shroud, a vertical one-to-one correspondence must have existed between each point on the image and a vertical line from that point through the body. If this one-to-one vertical relationship did not exist, then only a blur could be formed on the cloth because each point on the cloth would be affected by multiple points in the body. Two options for what caused this verticality relationship have been suggested:

- Cloth collapse hypothesis: The cloth vertically collapses into the region previously occupied by the body due to gravity and air pressure difference, and
- Vertical radiation hypothesis: The radiation that was emitted within the body was emitted in vertically up and down directions.

Both options depend on radiation to form the image. The first option assumes very short-range radiation that is only encountered when the Shroud collapses into the previous body volume, and the second option assumes a longer range for the radiation so that a significant fraction of the radiation exits the body to hit the cloth. If the disappearance of the body from within the Shroud was an extremely rapid event as is usually assumed, the disappearing body would leave behind a vacuum and the only air remaining inside the Shroud would be the air that was previously in the body-to-cloth gaps. This would create a significant pressure difference between the remaining air inside the Shroud and the normal air pressure outside the Shroud. While there would be some leakage of air through the linen cloth which would reduce this air pressure difference, the primary effect of interest is that this air pressure difference would cause the cloth to collapse into the volume previously occupied by the body. And with the body gone, the top of the Shroud would also fall due to gravity. Thus, in the cloth collapse hypothesis, these two forces (gravity and air pressure difference) cause the cloth to collapse into the volume where the body had been. In some cloth collapse hypotheses, this volume defined by the outer perimeter of the body is referred to as the "radiant region", because radiation is emitted from this region as the body disappears. It is also sometimes assumed that the body becomes "mechanically transparent" so that the cloth can collapse into this radiant region during the time that the body is disappearing. The different cloth collapse hypotheses can utilize somewhat different assumptions and phraseology, but in any case, the forces acting on the cloth are gravity and air pressure difference. Gravity, since it is only a downward force, could act on the section of the Shroud above the body to pull it down into the radiant region, but could not act on the section of the Shroud below the body to force it up into the radiant region. The force on the cloth due to the air pressure difference would not act vertically but would act perpendicular to the cloth as it wrapped the body, so that it would tend to force the sides to collapse in as well as the top and bottom of the Shroud. And the force on the bottom of the Shroud due to air pressure difference would be somewhat restricted because the bottom of the Shroud would have been laying on the limestone bench in the tomb.

Examples of cloth collapse hypotheses are in Ref. 3 to 6. In any cloth collapse hypothesis, as the cloth moves into the body's previous volume, it encounters radiation which causes the cloth to discolor. Some believe that the radiation that formed the image was primarily photons of ultraviolet light whereas others believe that it was primarily charged particles such as protons. Both options should be considered since both are based on experimental evidence (Ref. 7 to 13) and both may be significant. But depending on the details of the hypothesis, a cloth collapse hypothesis can have one or more of the following problems.

2. Potential Problems with a Cloth Collapse Hypothesis

1. On the Shroud, there are images of both the front and back of the body. This means that the sections of the cloth that were both above and below the body must move into the radiant region for both images to be encoded onto the Shroud by this mechanism. The cloth that was above the body must move down into the radiant region and the cloth that was below the body must move up into the radiant region, if the same mechanism is hypothesized to cause both the front and back images. Gravity and air pressure difference will work together to cause the section of the cloth that was above the body to move down into the radiant region, but gravity will oppose the effect of the air pressure difference to cause the bottom cloth to move up into the radiant region. In a very rapid disappearance of the body, the force due to gravity probably would have been insignificant compared to the force due to the air pressure difference. And the Shroud does not contain images of the sides of the body or the top of the head, so according to this hypothesis, the section of the Shroud corresponding to the sides of the body and the top of the head would not have entered the radiant region.

   If the disappearance of the body was rapid, then the air pressure difference would have caused the cloth covering the sides of the body and the top of the head to move into the radiant region so that their images would have been encoded onto the cloth, contrary to the evidence on the Shroud. Vertical collapse of the cloth could also cause significant wrinkling of the cloth, which would cause significant distortion of the images, contrary to the high-resolution images that exist on the Shroud. Another problem with the assumption of a rapid disappearance of the body is that the cloth that was under the body was laying on the limestone bench. The presence of this limestone surface under the bottom cloth would have impeded the flow of air to fill in under the cloth as it moved up into the radiant region. Unfortunately, the details and legitimacy of these concerns would require calculations using a finite-difference computer code to resolve.

   To avoid the above problems that arise for a rapid disappearance of the body, it is sometimes assumed that the disappearance of the body is slow enough that the air pressure difference becomes insignificant due to air leakage through the cloth. Without the air pressure difference, there is no force to cause the cloth at the sides of the body to collapse inward, thus avoiding images of the sides of the body. The only remaining force is then gravity, but gravity will not cause the bottom cloth to move up into the radiant region. So the disappearance of the body can be neither rapid nor slow, nor anywhere in between because of the same problems. We are left with no option that works.

2. The cloth collapse hypothesis assumes that the cloth enters the radiant region, defined as where the body had been, where it encounters radiation which causes the discoloration. But radiation is not a static (unmoving) thing. Radiation moves very rapidly. As stated above, electromagnetic radiation, such as photons of ultraviolet light, travels at the speed of light (3.0×10^8 meters per second or about 186,000 miles per second in a vacuum), whereas particle radiation such as protons and electrons travel much slower. But even if protons or electrons are not emitted with any additional energy but are simply left behind with a kinetic energy in equilibrium with their surroundings, i.e. at a thermal energy [0.0253 eV (electron volts)], their speed at the peak of the energy distribution would be 2200 m/s (meters per second), which is equal to 7218 feet per second = 1.37 miles/second. So radiation emitted from within the volume of the body would very quickly move out from that volume and through the cloth. If the process involved in the disappearance of the body is what caused the radiation to be emitted from within the volume of the body, as is usually assumed, then once the body has fully disappeared, there would be no additional radiation emitted. So once the body has entirely disappeared, it would take at most about 0.00005 seconds [10 cm body half-thickness / (2200 m/s x 100 cm/m)] for the slowest radiation (protons at thermal energy) to exit the volume of the body. After this 0.00005 seconds, there would be no additional radiation for a collapsing cloth to encounter, i.e. there would not be a radiant region. Under the forces of gravity and air pressure difference, the cloth could not move significantly in only 0.00005 seconds. Thus, under the assumption of a very rapid disappearance of the body, in this brief amount of time of only 0.00005 seconds, most of the cloth could not even fall through the vertical distance of the previous body-to-cloth gap to enter the previous volume of the body.

3. This third objection is related to when the cloth would begin to collapse. In what follows, it is assumed that the body disappears uniformly, so that every cubic centimeter in the body reaches zero density at the same instant. Other options are not considered, such as the body disappearing from the outside in, or from the inside out, or from the top down, or from the bottom up. For simplicity, consider only the section of the cloth that is above the body. Prior to the disappearance of the body, the cloth cannot collapse because it is supported by the body. For most of the time period during which the body is disappearing, there will be sufficient remaining body material to prevent the cloth from collapsing. The cloth will only begin to collapse when the downward force on the cloth due to gravity plus the external air pressure is greater than the upward force on the cloth due to the remaining material inside the Shroud. Air at standard temperature (0 C) and pressure (one atmosphere) produces a pressure of 14.696 pounds-force per square inch (PSI). The areal density (mass per unit area) of the Shroud is about 0.0229 g/cm^2 (Ref. 14) which converts to 0.0229 (g/cm^2) x (2.54 cm/inch)^2 / 453.6 (g/pound) = 0.000325 pounds per square inch. Comparing 0.000325 lbs/in^2 with 14.7 lbs/in^2 indicates that, if the collapse of the cloth is rapid so that the air leakage through the cloth can be ignored, the effect of gravity is insignificant relative to the force due to the air pressure difference, and so can be ignored.

   Consideration of the upward force on the cloth due to the material in the body can be done in various ways. As an initial simplifying assumption, assume that the atoms in the body have no attraction to each other in the molecules so that they act as a gas. Then as the disappearance of the body progresses, the remaining atom density of the body will decrease until it reaches zero. Under this assumption, the cloth will begin to move downward when the atom density within the outer perimeter of the body decreases below the atom density of the air outside the cloth.

Atom densities for the air and body were calculated for the model used in the MCNP nuclear analysis computer calculations reported at the Shroud conference in St. Louis (Ref. 15) in October 2014 and in Pasco, WA, in July 2017. The total atom density for air at 10 C (50.1 F), 50% humidity, and an elevation of 760 meters for Jerusalem, is 4.73 x 10^{19} atoms/cm^3. And the total atom density for an average human body is 9.5 x 10^{22} atoms/cm^3. This means that the fraction of the body density remaining when the atom densities are the same inside and outside the cloth is (4.73 x 10^{19} atoms/cm^3) / (9.5 x 10^{22} atoms/$cm^{3)}$ = 0.0005, which to a first approximation is also the point at which the cloth could start to collapse. So the process of the disappearance of the body must be 99.95% complete before the cloth could begin to collapse. And since it is most reasonable to assume that the radiation is emitted by the process involved in the disappearance of the body, 99.95% of the total radiation would be emitted by the time that the cloth starts to collapse. And since radiation moves so much faster than the movement of the cloth, this means that approximately 99.95% of the total radiation that would ultimately go through the cloth will have gone through the cloth by the time that it starts to collapse. And since it is the radiation that carries the energy and the information that is necessary to cause the image, 99.95% of the effect would have been accomplished by the time that the cloth starts to collapse. This means that whether the cloth collapses or not is irrelevant to the formation of the image on the Shroud.

The above assumes that the cloth can start to collapse when the atom density (atoms/cm^3) inside the cloth decreases to less than the atom density outside of the cloth. A similar result is obtained if it is assumed that the cloth can start to collapse when the physical density (g/cm^3) inside the cloth decreases to less that the physical density outside of the cloth. The physical density of the air around the Shroud under the above conditions is 0.00114 g/cm^3. The physical density of a human body is about 0.99 g/cm^3 because a human body will usually float in water. This means that the fraction of the body density remaining when the physical densities are the same inside and outside the cloth is (0.00114 g/cm^3) / (0.99 g/cm^3) = 0.0012, so that 99.88% of the total radiation that would ultimately go through the cloth will have gone through the cloth by the time that it starts to collapse. The conclusion is the same - the collapse of the cloth is unnecessary to the formation of the image. Notice that these arguments do not depend on how fast or slow the body disappears.

Both above analyses ignore the structural strength of the body. Under this assumption, both of the above analyses indicate that about 99.9% of the radiation would pass through the cloth before the cloth would start to collapse. But there would have been structural strength to the body due to the mutual attraction of atoms in the molecules that make up the body. If this structural strength is also included in the analysis, then there probably was additional support for the cloth, so that the cloth would start to collapse even later. This means that something greater than 99.9% of the radiation (99.9+ %) would have passed through the cloth before the cloth started to collapse. This additional amount would only strengthen the argument that a collapse of the cloth is irrelevant, i.e. it doesn’t matter whether the cloth collapses or not. Now it must be admitted that the cloth is expected to collapse after the body disappears, but the vast majority of the radiation (99.9+ %) would have already hit the cloth by the time that the cloth started to collapse. Thus, any additional radiation that hits the cloth after it starts to collapse could not have a significant effect on the discoloration of the fibers that make up the image.

4. Problems #2 and #3 discussed above can be avoided if it is assumed in the cloth collapse hypothesis that when the body starts to disappear it becomes "mechanically transparent". This assumption means that the cloth can collapse into the volume of the body, unimpeded by the atoms remaining in the body, from the time that the body starts to disappear. Evidently, the cloth would then collapse due to the external air pressure unimpeded by the remaining atoms in the body. Under normal conditions, according to the laws of physics as we currently understand them, the remaining atoms and molecules in the body as it disappears would support the cloth as in #3 above. But in assuming that the body disappears, we are already beyond or outside of our current understanding of the laws of physics, so this additional assumption warrants consideration, for there are images on the Shroud that were formed in some way. The assumptions for the cloth collapse hypotheses then become the following:

- The body disappears from within the Shroud.
- As the body disappears, it emits radiation.
- When the body starts to disappear, it becomes mechanically transparent so that the cloth can collapse into the body region over the entire time that the body is disappearing.

3. Comparison to the Vertical Radiation Hypothesis

In considering the cloth collapse hypothesis, it should be compared to the alternative hypothesis where the radiation is vertically collimated. In this hypothesis, the radiation that is emitted from within the body during the disappearance of the body is emitted vertically up and down. The radiation that is directed vertically up forms the front image on the Shroud, and the radiation that is directed vertically down forms the back or dorsal image on the Shroud. This makes it very easy to understand why there would be no image of the side of the body or the top of the head. The assumptions for this hypothesis are the following:

- The body disappears from within the Shroud.
- As the body disappears, it emits radiation.
- The initial direction of this radiation is vertical, i.e. it is vertically collimated up and down.

The first two assumptions are identical for the two options – the cloth collapse hypothesis and the vertical radiation hypothesis. It is only the third assumption that is different. In our current understanding of the laws of physics, radiation emitted from an atom is usually emitted randomly in any direction, though there are special conditions where radiation is emitted in a particular direction. For example, radiation emitted by a beam of rapidly moving atoms will be collimated along the direction of the beam, in the laboratory frame of reference. The degree of collimation depends on the velocity of atoms. For relativistic velocities, almost all the radiation will be emitted in a narrow cone along the beam. But for our purposes, it can be accepted that the assumption that the radiation is vertically collimated up and down is beyond or outside of our current understanding of the laws of physics. Notice that both options, the cloth collapse hypothesis and the vertical radiation hypothesis, employ three assumptions that are beyond or outside of our current understanding of the laws of physics. Since both options employ three assumptions, neither option should be favored over the other based on the number of assumptions, i.e. Occam's razor.

4. Calculated Cloth Movement in the Cloth Collapse

If the collapse of the cloth is rapid enough, then leakage of air through the cloth can be ignored. This is an assumption that the cloth is an ideal membrane, defined as having no weight or inertia and allowing no passage atoms through the membrane. If we also ignore the effect of any remaining fraction of the body as it disappears, ignore the air in the body-to-cloth gaps, and assume that the body leaves behind a vacuum when it disappears, then the acceleration, velocity, and distance that the cloth moves as a function of time can be derived as follows.

$A = F / M$, from the classic equation $F = M * A$
$V = (F/M) * t$, by integration of the above equation with $V = 0$ at $t = 0$
$D = [F/(2*M)] * t^2$, by integration of the above equation with $D = 0$ at $t = 0$

Where A = acceleration (m/s^2) of the cloth in response to the forces on it
V = velocity (m/s) of the cloth as it collapses
D = distance (m) that the cloth collapses
F = force on the cloth in units of Newtons (N)
M = mass of one m^2 of the cloth
$= 0.0229 \text{ gram/cm}^2 \times 10^4 \text{ cm}^2/\text{m}^2 \times 1 \text{ m}^2 \times 10^{-3} \text{ kg/g} = 0.229 \text{ kg}$
t = time (seconds) after the cloth starts to move

To evaluate the above equations, the standard SI (International System) units in terms of kg-meters-seconds will be used. In this system, the unit of force is the Newton which is defined as the force that will accelerate a mass of 1.0 kilogram at a rate of 1.0 meter per second per second (m/s^2), consistent with the formula $F = M * A$. Thus, 1.0 Newton = 1.0 kg-m/s^2. For the average force of gravity at the surface of the earth, ignoring the effect of air resistance, an object of any mass will accelerate at 9.807 m/s^2. Under these assumptions, 1.0 m^2 of the cloth weighing 0.229 kg will accelerate at 9.807 m/s^2 due to gravity, which means that the force on it due to gravity must be $F = M * A = 0.229 \text{ kg} * 9.807 \text{ m/s}^2 = 2.25 \text{ kg-m/s}^2 = 2.25$ Newtons. And under these assumptions, the air pressure on this same 1.0 m^2 of cloth due to the air outside of the cloth, at an estimated temperature of 10.1 C = 50.1 F and an elevation for the old city of Jerusalem of 760 m is 92.5 kPa (kilo-pascals) = 9.25×10^4 Pa (Pascals) where a pressure of one Pascal is defined as a force of one newton per square meter [1.0 Pa = 1.0 N/m^2 = 1.0 (kg-m/s^2)/m^2 = 1.0 kg/(m-s^2)], so that 9.25×10^4 Pa = 9.25×10^4 N/ m^2. The force on 1.0 m^2 of cloth can be calculated as follows:

Force (Newtons) = Pressure (Newtons/m^2) x Area (m^2)

$$= 9.25 \times 10^4 \text{ N/ m}^2 * 1.0 \text{ m}^2 = 9.25 \times 10^4 \text{ N}$$

The force due to gravity (2.25 Newtons) is much less than the force due to the air pressure difference (9.25×10^4 Newtons) and so can be ignored. The distance that the cloth moves as a function of time, ignoring gravity and assuming no air leakage through the cloth, is then:

$$D = [F/(2*M)] * t^2 = [9.25 \times 10^4 \text{ N}/(2 * 0.229 \text{ kg})] * t^2 = (2.02 \times 10^5 \text{ N/kg}) * t^2$$

But since one N = one kg m/s^2, then:

$D = (2.02 \times 10^5 \text{ m/s}^2) * t^2$, so that the values in Table 1 can be calculated.

Time in Seconds	Distance Cloth Will Move: Meters	Distance Cloth Will Move: cm
1.00E-09	2.0 E-13	2.0 E-11
1.00E-08	2.0 E-11	2.0 E-09
1.00E-07	2.0 E-09	2.0 E-07
1.00E-06	2.0 E-07	2.0 E-05
1.00E-05	2.0 E-05	2.0 E-03
5.00E-05	5.0 E-04	5.0 E-02
1.00E-04	2.0 E-03	2.0 E-01
1.00E-03	2.0 E-01	2.0 E+01

Table 1. Maximum Cloth Movement After Disappearance of the Body

Table 1 applies to both the top and sides of the Shroud, assuming both are free to collapse. The bottom of the cloth would move less than indicated by the values in the Table 1 because the limestone shelf on which the cloth was resting would impede the flow of air outside of the bottom cloth. This table shows that under the assumed conditions, the top and sides of the Shroud would completely collapse in about 0.001 second, that it would only move about 0.2 cm in 0.0001 second, and that it would only move about 0.05 cm in 0.00005 seconds. This last value is of significance because of the above conclusion (#2 on page 4) that "once the body has entirely disappeared, it would take at most about 0.00005 seconds … for the slowest radiation (protons at thermal energy) to exit the volume of the body". This means that under the most conservative conditions (no air leakage through the cloth, no support from the body, no air in the body-to-cloth gap, and a vacuum left by the disappearing body), the cloth can only collapse an additional half a millimeter (0.05 cm) from the time that the body has completely disappeared to the time that all of the radiation, even the slowest of the possible radiation, would have already gone out of the "radiant region" and hit the cloth. And with the complete disappearance of the body, no additional radiation would be generated in the radiant region because it was assumed that the radiation was emitted from the body in the process of the body disappearing. Thus, 0.00005 seconds after the disappearance of the body is completed, no additional radiation would go through the cloth, except for radiation possibly reflecting off materials outside of the Shroud.

5. Conclusion

The most important factor in deciding between a cloth collapse hypothesis that uses an assumption of mechanical transparency, and the vertical radiation hypothesis, is how either hypothesis explains the fact that the Shroud contains high-resolution images of the front and back of the body but does not contain images of the side of the body or the top of the head. Both options can explain the front image on the Shroud. The cloth collapse hypothesis has problems in explaining the back image on the Shroud whereas the vertical radiation hypothesis does not. But of greatest significance is that on the Shroud there are no images of the side of the body or the top of the head. The vertical radiation hypothesis explains this very easily, but the cloth collapse hypothesis appears to predict that the cloth should not only collapse vertically but also collapse in from the sides of the body and the top of the head, so that these images should be present on the Shroud. In view of these considerations, the vertical radiation hypothesis should be preferred at this time.

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Biography

Robert (Bob) A. Rucker earned an MS degree in nuclear engineering from the University of Michigan and worked in the nuclear industry for 38 years. He organized the International Conference on the Shroud of Turin (ICST-2017) held July 19-22, 2017, in Pasco, Washington, His website is www.shroudresearch.net . Send comments, questions, or corrections to robertarucker@yahoo.com .