Using Mechanical Testing to Validate the Implementation of Structural Health Monitoring in Composite Structures

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Abstract

This report documents the use of mechanical testing to determine the validity of the use of structural health monitoring. These results were gathered from using an impact machine to damage the composite structures. Readings were recorded to determine the amount of damage that the structure received.

Introduction

Composite structures are non-metallic high performance plastics reinforced with fibrous materials. Composite structures are used in various areas to make equipment lighter and stronger. The United States Army is currently funding an initiative for a vast weapons program known as the Future Combat Systems (FCS). In the FCS program, tanks are expected to be many times lighter and faster than they are today. One way of achieving this goal is through the implementation of composite armor into these tanks. In the battlefield, it would be nearly impossible to detect non-surface damage to these weapons systems using the techniques of today. Currently, the only way to detect this damage without further interference would be to use costly Computer Tomography (CT) scanning. This would also require the weapons system to be moved off the battlefield to a laboratory or other location. One viable solution to this problem is the implementation of Structural Health Monitoring into these systems. Structural Health Monitoring is a system devised to allow the testing for structural damage without interfering directly with the structure itself. This process is very costeffective and can be deployed on-site. There are a variety of ways to implement this technology and a vast majority only need verification to prove that they are conceivable for use in the military of the future.

Body

There are various methods that can be used for Structural Health Monitoring. One method involves the use of ceramic tiles located inside the composite armor. The composite armor consists of many fibrous layers of glass, IM 7 graphite and ceramic tiles infused with resin, and a high performance plastic. The armor is assembled with layers of IM 7 on the bottom, and ceramic tiles placed on top the IM 7. More layers of IM 7 are then placed on the ceramic tiles. Finally many glass sheets make up the final layer on the piece of armor. The armor is then infused with resin to make the piece durable.

The method of Structural Health Monitoring that was used in the experiments involves the application of conductive silver paint. Lines of the conductive silver paint were painted across a tile. The square ceramic tiles were four inches in width and a half an inch thick. This was done to several ceramic tiles. Wires were then attached to each end of the lines of silver paint by means of an adhesive known as epoxy. Once the wires were attached to the ceramic tiles, they were then wrapped in packaging tape. This prevented the tile from being shattered to pieces and was clear so the damage done to the ceramic tile would be able to be seen. The tiles were then placed in an impact tester. The impact tester drops an indenter head or a hammer head on the specimen. The purpose of the impact test is to measure the strength of the tile, the maximum load the tile can withstand, and the amount of energy the ceramic tiles can absorb before they are broken. While the ceramic tile is sitting in the impact tester the resistance (Fig. 1) across the tile is read using a multimeter. The multimeter reads the resistance while the tile is in the impact tester and continues to read resistance until after the indenter head has been dropped. When the tile is cracked or destroyed, the resistance reading should become higher, especially if the ceramic tile was destroyed.

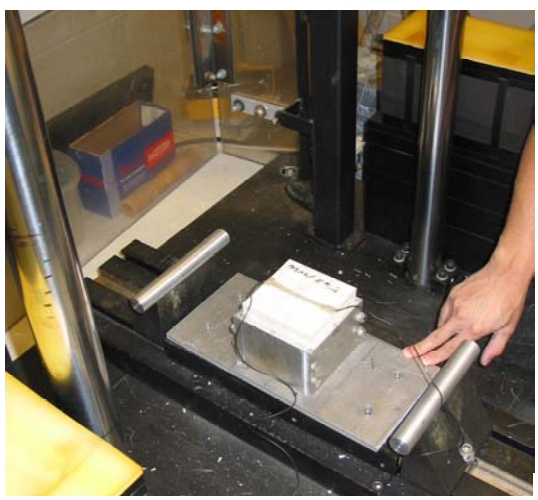

Figure 1. A ceramic tile placed in the impact tester

The main idea behind this experiment is to place the ceramic tiles with conductive silver paint and wires into the armor pieces. The wires attached to the ceramic tiles could then be attached to a computer similar to a multimeter to read the resistance across the tiles. The armor would then be placed in a weapon system. When the weapons system becomes damaged the resistance could be read to determine how much damage was received.

Several runs were performed with the impact tester on the ceramic tiles. On the first run, the amount of force needed to at least crack the tile was uncertain. The tile was placed in the smaller of the two impact testers available. The indenter head used to strike the first tile was a half an inch head and had a mass of 8.04 pounds. In the first run, the tile was struck with 24.1819 kilonewtons (Appendix 1). The first run was unsuccessful and the impact tester didn't do any damage to the ceramic tile. The resistance amount didn't change as expected because the ceramic tile didn't damage.

A second test was performed with the same impact tester and the same ceramic tile. The head was changed to a one-inch head and the indenter head now had a mass of 8.35 pounds. The indenter head was now raised as high as it could possibly be raised on the machine. In this run the tile was struck with a force of 38.1663 kilonewtons (Appendix 2). The resistance still didn't change because the piece didn't damage again. The ceramic tile proved to be stronger and more durable than was expected.

The same ceramic tile was than moved from the smaller impact tester to the larger one. This indenter head was the same size, one inch, and had a mass of 250.79 pounds. The maximum load that this impact tester could produce is fifty thousand pounds. The head was raised to about sixteen inches and dropped. The indenter head drove straight through the ceramic tile and struck the tile with a force of 54.4972 kilonewtons (Appendix 3). A good resistance reading was achieved from this run. Before the head struck the tile, the resistance was in a range from -47 ohms to -30 ohms. Once the indenter head struck the tile, the resistance reading jumped from the range that it was in to infinity, which is represented on the graph by zero (Appendix 12). The reason that the reading went to zero was because the indenter head broke the circuit that was on the wire. It was proven that if the tile is destroyed that there will be a dramatic change in the resistance readings.

On the fourth run, the second tile was put into the impact tester. The same indenter head was used as in the third run. This time the head was raised to eight inches because the purpose was not to destroy the tile, just crack it. Once the head was dropped, the same results occurred as in the third run; the indenter head completely destroyed the tile. The head struck the tile with a force of 69.5038 kilonewtons (Appendix 4). There was a huge resistance change were the resistance was at a steady reading of about -40 to -30 ohms before the drop, then after the drop, the resistance changed to infinity (Appendix 13).

One the fifth run the same indenter head was used but the head was only raised to one inch. The indenter head struck the ceramic tile with a force of 84.858 kilonewtons (Appendix 5). On the first drop, the resistance reading on the tile never changed, and the tile remained undamaged. The resistance reading remained constant between 5 and 7 ohms (Appendix 14). There were no cracks or breaks anywhere. Another run, the sixth run, was done on the same tile. The same indenter head was raised to 2 inches this time. When dropped, the head struck the tile with a force of 60.1758 kilonewtons (Appendix 6) and cracked it in numerous places. The resistance reading changed from a range of 5 to 7 ohms to infinity (Appendix 15). It was proven that a crack in the tile could give the same reading as if the tile was totally destroyed in the previous runs.

On the seventh run the idea was to crack the tile just enough to make the resistance reading change to a higher value instead of reading infinity. According to the previous run, raising the head to an inch proved to neither change the resistance reading nor do damage to the tile. The indenter head was then raised to 1 and ¼ inches. After the drop the resistance reading of about one ohm changed to a range from two and a half to three ohms (Appendix 16). This is what was trying to be achieved from the first test. The indenter head struck the tile with a force of 67.8434 kilonewtons (Appendix 7. A second run was done on this tile and the indenter head was raised to the same height, 1 and ¼ inches. When the head was dropped, it hit with a force of 55.015 kilonewtons (Appendix 8) and the resistance reading changed from 2 and ½ ohms to infinity ohms (Appendix 17). The tile was cracked in multiple places and the circuit was broken.

The ninth run was done on the fifth tile. This run used the same indenter head as in previous runs, but the head was only raised to one inch. On the first drop the resistance remained the same at about 2 ohms (Appendix 18) and the indenter head collide with the tile with a force of 57.1123 kilonewtons (Appendix 9). A second run on the same tile was repeated. The same indenter head was raised to one inch and dropped again with a force of 60.2314 kilonewtons (Appendix 10). The resistance remained the same at about 2 ohms (Appendix 19). A third test was run using the same parameters. This time the indenter head struck the tile with a force of 58.8841 kilonewtons (Appendix 11). The resistance still remained at about 2 ohms (Appendix 20). A fourth run was preformed where the same indenter head was used but the head was raised 1/8 an inch higher than the previous run to 1 and 1/8 inches. The head was dropped and the resistance readings jumped from about 2 ohms to 15 ohms. This reading of 15 ohms was only for one second and then the reading went back to about 2 ohms. The tile was considerable cracked and the resistance was back at 2 ohms. When the tile was picked up the resistance reading changed to infinity (Appendix 21). This created a problem.

There are some flaws in this process. One flaw is in the packaging tape. The packaging tape was used to hold the tile together so that it wouldn't shatter everywhere. The problem with the packaging tape was that it did its job too well. In the last run the tile was cracked and yet the resistance reading remained the same. This was because the tape held the tile so tight the circuit was still connected even thought there were cracks in the tile. Another flaw is that the epoxy wouldn't always hold the wires down that were connected to the silver paint that went across the ceramic tile. This would cause the resistance to read infinity before we would break the tile. Another flaw with the epoxy is that it isn't conductive, so if the epoxy would happen to be in-between the wire and the silver paint, the resistance would read infinity.

Conclusion

Structural Health Monitoring will prove to be an essential application to the Future Combat Systems. This process of Structural Health Monitoring has many flaws, but could result as a key process to insuring the safety of the men in the battlefield. Even though there are several flaws, the process has just begun its research and more technologies or methods could be produced from it. Right now this process appears to be crude and unsophisticated, but further study could prove it to be rather useful and very applicable.

Acknowledgements

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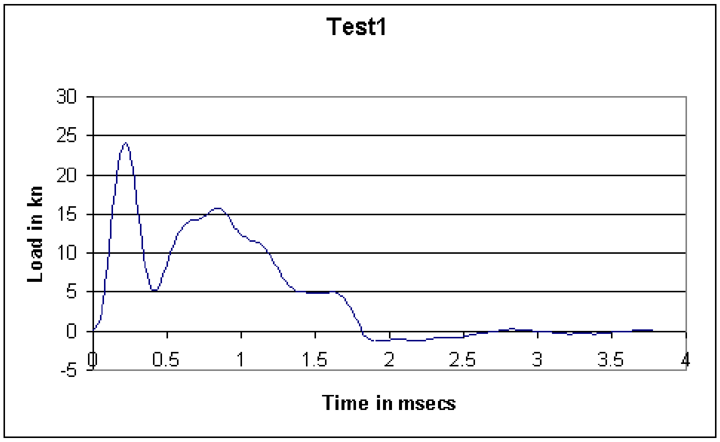
Appendix

Appendix 1



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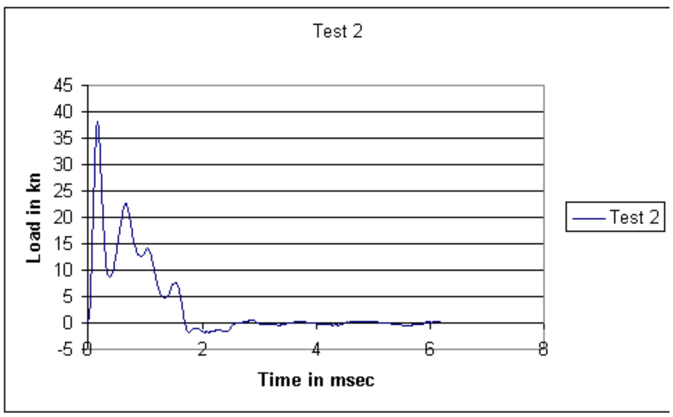

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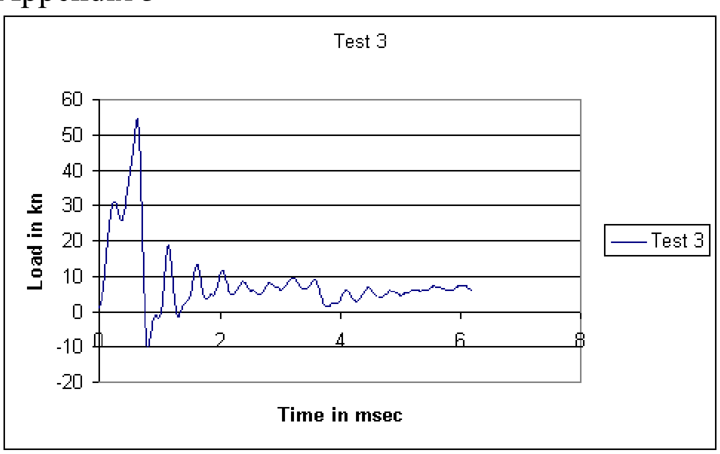

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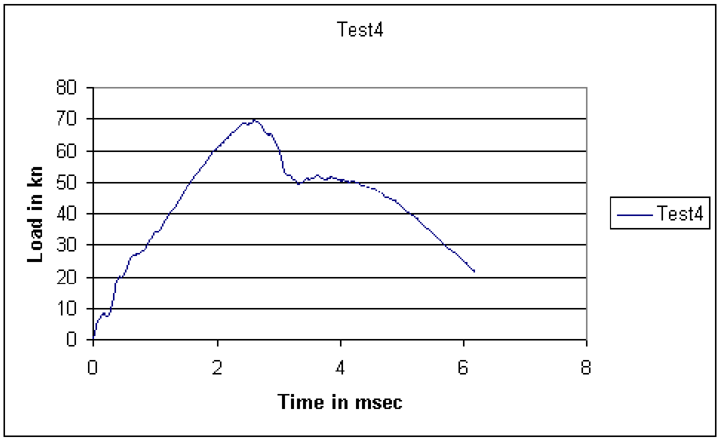

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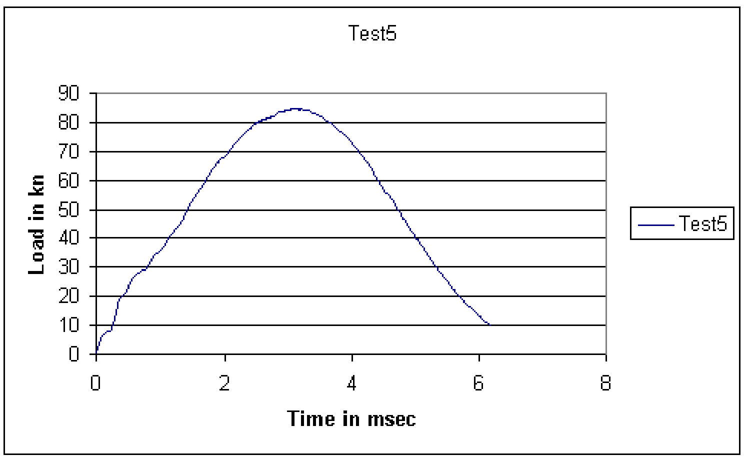

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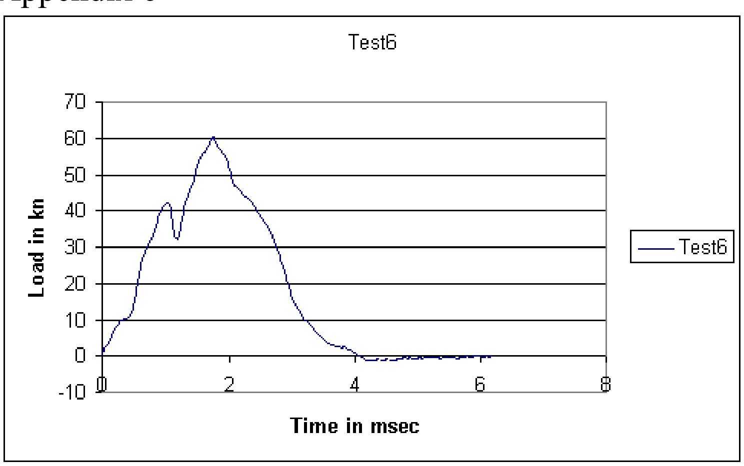

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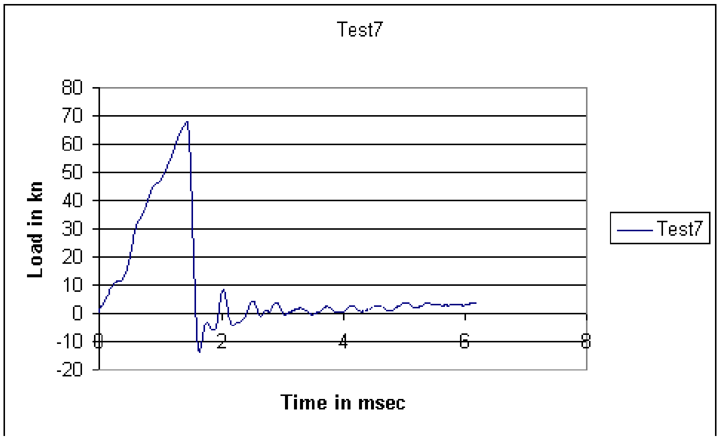

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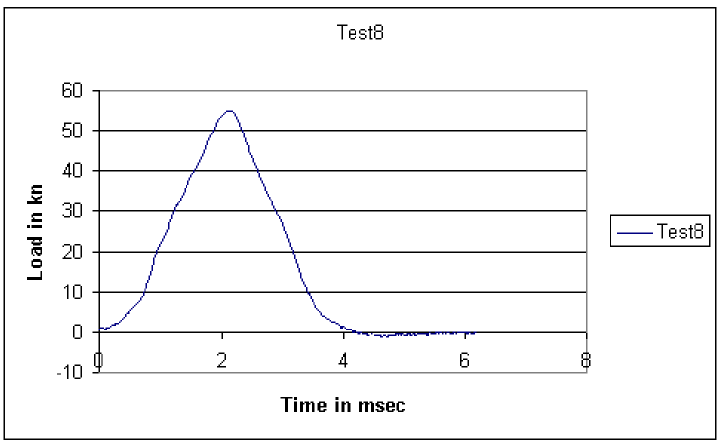

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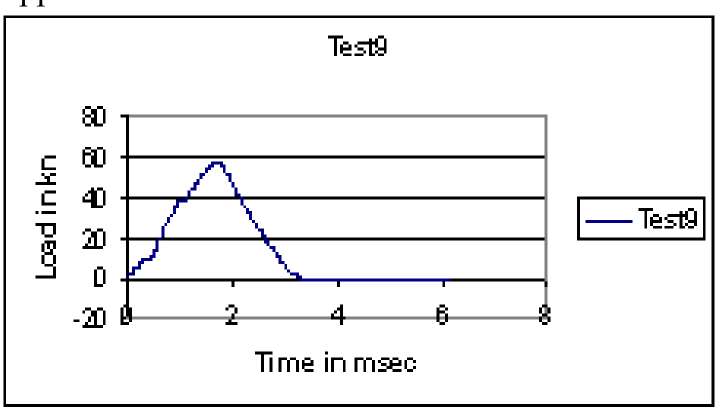

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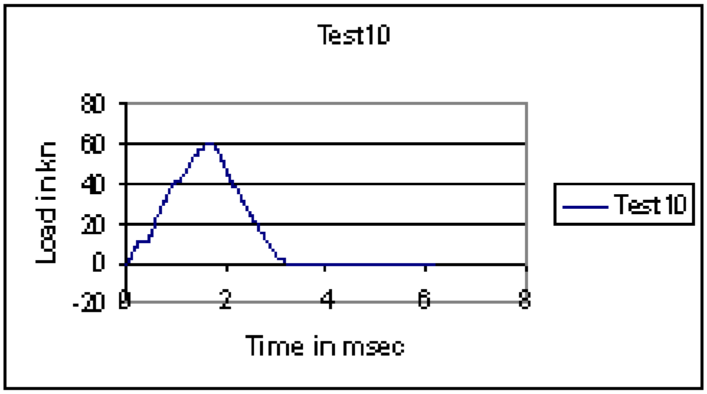

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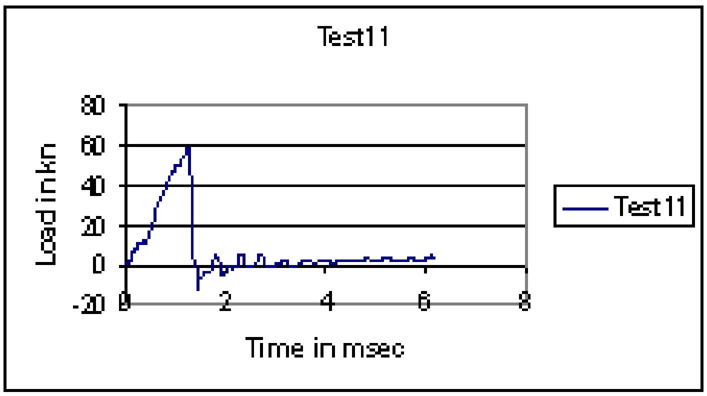

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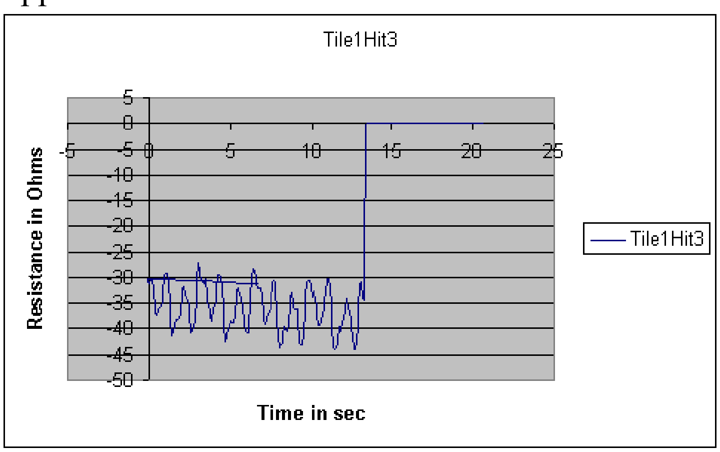

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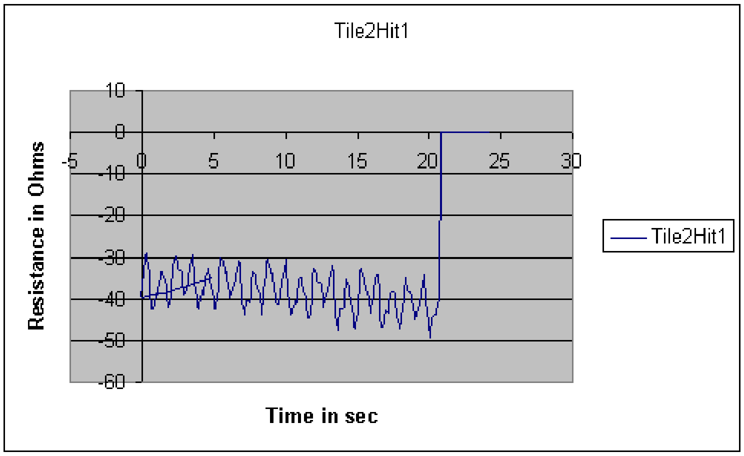

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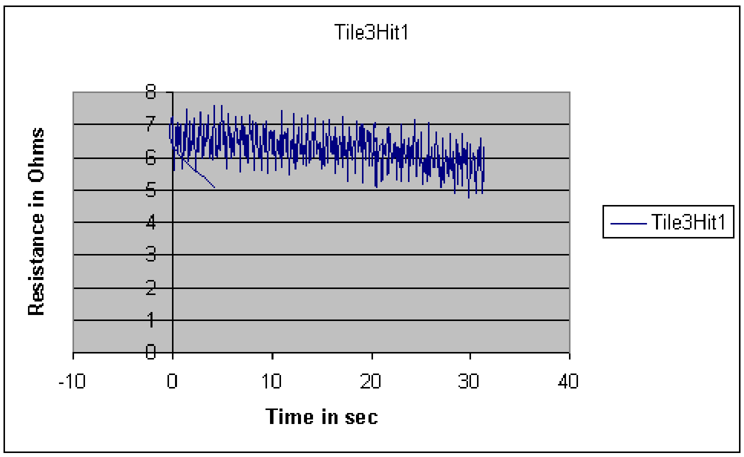

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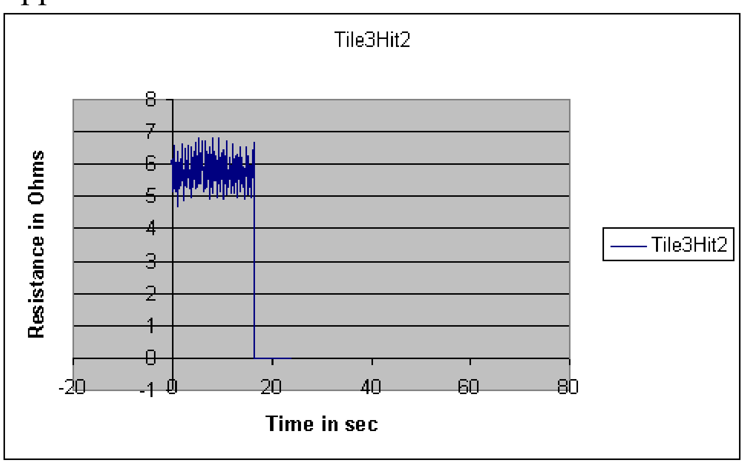

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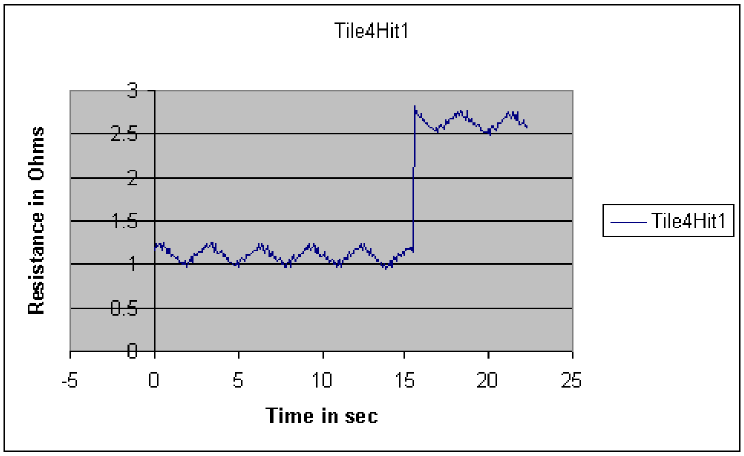

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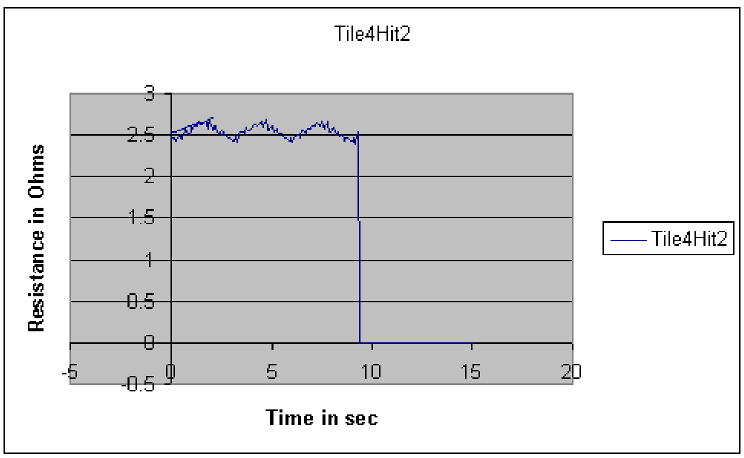

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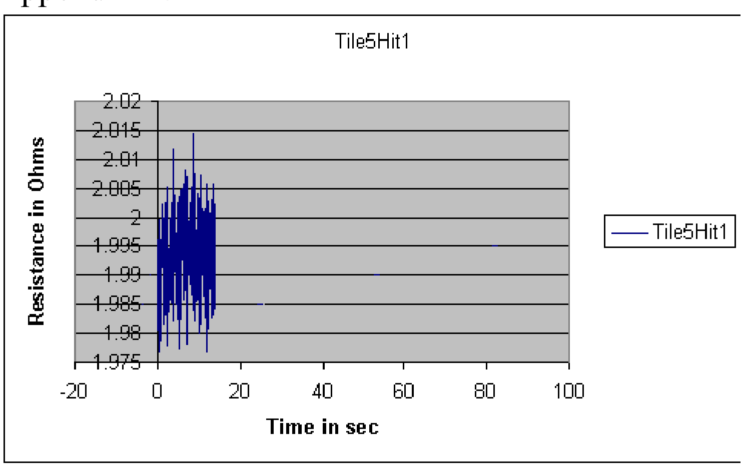

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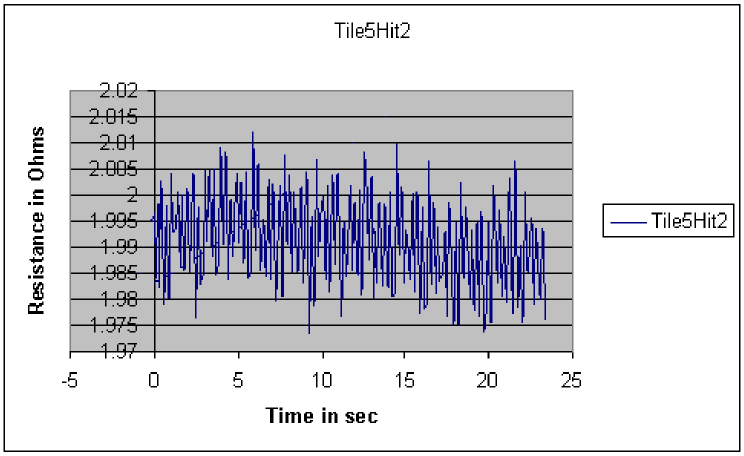

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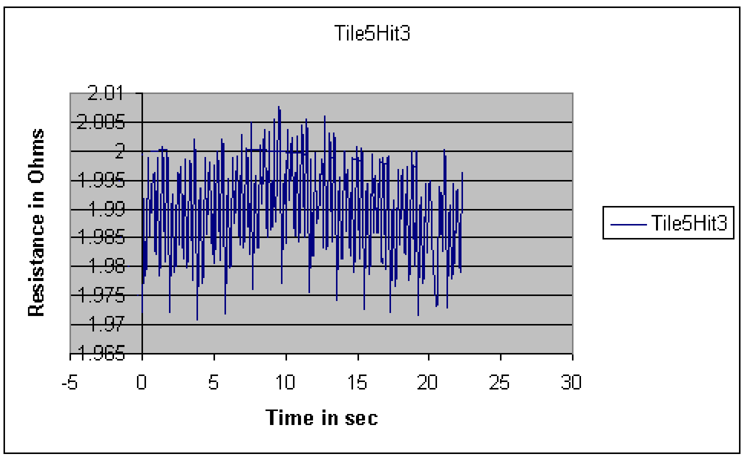

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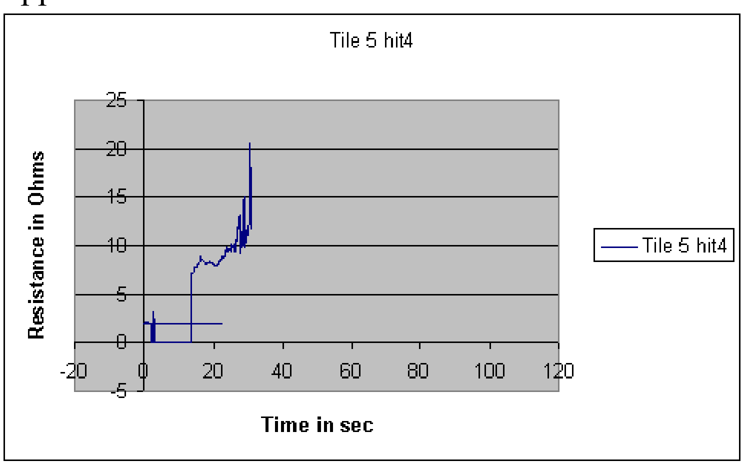

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