ELECTRO-MUSCULAR DISRUPTION DEVICES

Jeehyun LEE [1] , Jin Keun SEO [1] and Eung Je WOO [2]

1) *Department of Mathematics, Yonsei University, Korea.*

2) *College of Electronics and Information, Kyung Hee University, Korea.*

Corresponding Author : Jeehyun LEE, ezhyun@yonsei.ac.kr

ABSTRACT

Electro-muscular disruption (EMD) devices such as TASER M26 and X26 have been used as a less-than-lethal weapon. Such EMD devices shoot a pair of darts toward an intended target to generate an incapacitating electrical shock. In the use of the EMD device, there have been controversial questions about its safety and effectiveness. To address these questions, we need to investigate the distribution of the current density $\mathbf{J}$ inside the target produced by the EMD device. One approach is to develop a computational model providing a quantitative and reliable analysis about the distribution of $\mathbf{J}$. In this paper, we set up a mathematical model of a typical EMD shock, bearing in mind that we are aiming to compute the current density distribution inside the human body with a pair of inserted darts. The safety issue of TASER is directly related to the magnitude of $|\mathbf{J}|$ at the region of the darts where the current density $\mathbf{J}$ is highly concentrated. Hence, fine computation of $\mathbf{J}$ near the dart is essential. For such numerical simulations, serious computational difficulties are encountered in dealing with the darts having two different very sharp corners, tip of needle and tip of barb. The boundary of a small fishhook-shaped dart inside a large computational domain and the presence of corner singularities require a very fine mesh leading to a formidable amount of numerical computations. To circumvent these difficulties, we developed a multiple point source method of computing $\mathbf{J}$. It has a potential to provide effective analysis and more accurate estimate of $\mathbf{J}$ near fishhook-shaped darts. Numerical experiments show that the MPSM is just fit for the study of EMD shocks.

INTRODUCTION

Electro-muscular disruption (EMD) devices such as TASER M26 and X26 are being used as a less-than-lethal weapon [8]. These devices generate a powerful electrical shock to completely override the central nervous system of a victim and directly control a large amount of skeletal muscles. It shoots a pair of fishhook-shaped darts attached to 15-feet wires toward an intended target. When the darts are inserted in the victims's skin or clothing, the device generates a debilitating electrical shock. Although these devices are intended to reduce the probability of fatality or permanent injury compared with other lethal weapons, there are ongoing controversial arguments over its safety as the number of death increases with more frequent uses of such EMD devices. See [4,6,7]. Numerous investigations on the implications of EMD shocks are, therefore, requested to create a guidance that helps device users to minimize the risk of injury or fatality of victims.

When the pair of darts strike a victim and an electrical circuit is formed, a current density $\mathbf{J} = (J_x, J_y, J_z)$ is established inside the body. The distribution of $\mathbf{J}$ is influenced by several factors such as the shape and location of darts, distance between darts, geometry of the body, and its conductivity distribution. The knowledge of **J** is necessary for the investigation of the risk of ventricular fibrilation (VF), seizure, skin burn, and so on.

In this paper, we suggest a basic study to undertake a three-dimensional numerical modelling of an EMD shock as a way to assess its biophysical implications. We setup a mathematical model of the EMD shock that can correctly simulate the real situation. Accurate computation of **J** near the dart is required to properly assess the risk of skin burn injury and VF in the worst case. In numerical computations of **J** using such a model, however, there are serious difficulties in dealing with the region of the fishhook-shaped dart since **J** is highly concentrated there. The dart is not axially symmetric and the inserted dart creates a three-dimensional computational domain with two different corners, tip of needle and tip of barb, where singularities of $|\mathbf{J}|$ occur. Therefore, dealing with these corners requires a very fine mesh to get enough numerical accuracy, and it may lead to a formidable amount of numerical computations and memory space. To circumvent these difficulties, we develop a multiple point source method (MPSM) of computing **J**, that provides an analytical representation formula for the potential distribution near the fishhook-shaped dart. Eliminating the requirement of a very fine mesh, the MPSM seems to be an ideal method for us to model EMD shocks using a conventional PC. In this paper, we try to explain the whole process of the current density imaging during EMD shocks; motivation, mathematical medelling, computational method, and a future study of experimental validation using animal subjects. We hope that the proposed computer model to simulate the effect of shocks help examine competing claims about the benefits and risks of TASERs.

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