



A Numerical Modelling Investigation of The Effects of Foil Geometry on Exploding Foil Initiator Performance

Author: Fergus Russell

1810348

Supervisor: Mark Broadhead

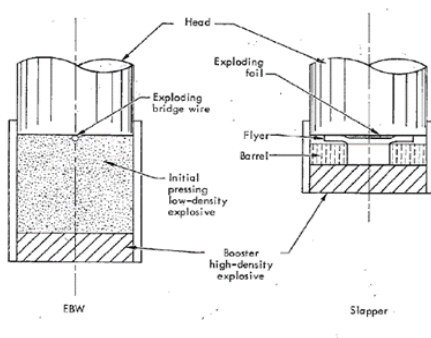
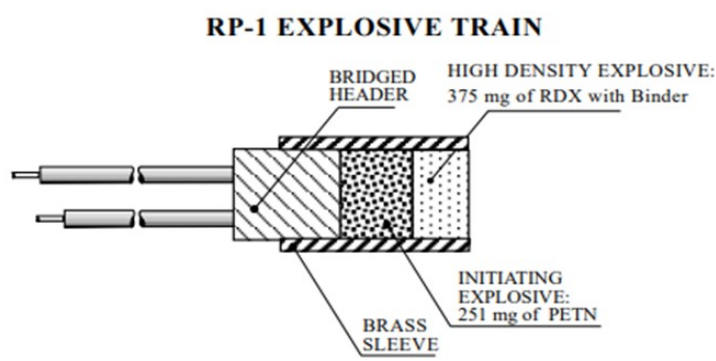
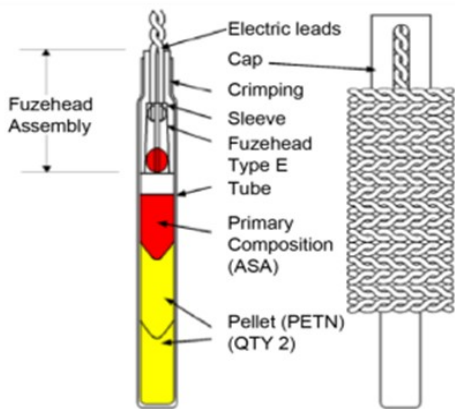


Prifysgol Cymru
Y Drindod Dewi Sant
University of Wales
Trinity Saint David

BSc (Hons) Ordnance, Munitions and Explosives Engineering
Technical Research & Development

INTRODUCTION

Detonators are energetic devices designed to convert one form of stimulus, be it electrical, mechanical or chemical, and convert it to a detonative energy output capable of initiating a larger amount of a less sensitive explosive material. Detonators can be split into two main families, Electric and Non Electric. Within the Electric family there are two sub families, Low Voltage and High Voltage. Low Voltage detonators make use of primary compositions which are easy to initiate and can provide high output however they are susceptible to damage by stray currents [1]. The Exploding Bridge Wire (EBW) detonator is an example of a high voltage detonator which has the advantage of being



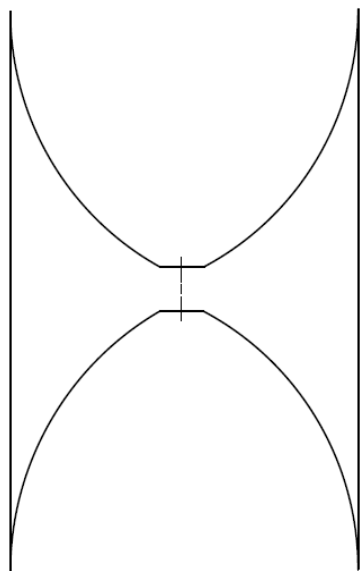
L-R: L2A2 Detonator [1], RP Detonator [2], EFI Detonator [3]

less susceptible to damage by stray electrical sources by requiring higher voltages to initiate [2]. EBW detonators were first developed for the Manhattan Project and have proven to be safe and reliable in operation. An evolution of the EBW is the Exploding Foil Initiator (EFI). EFIs have the advantage of having increased reliability, increased precision, and require significantly higher voltages than EBWs to function. Additional safety is provided by the separation between the electrical component and the explosive material [3].

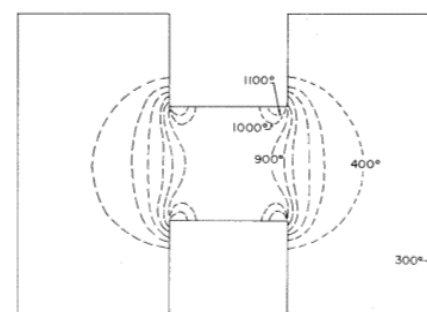
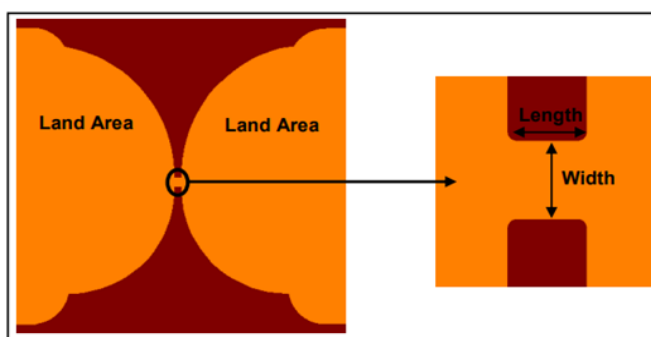
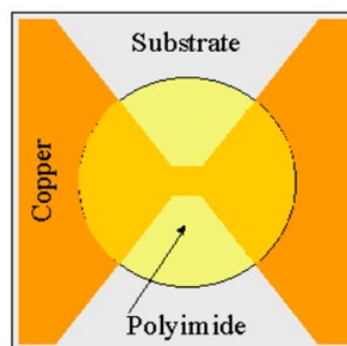
WHY INVESTIGATE FOIL GEOMETRY?

Part of an EFI is the foil itself. Several foil shapes have been identified in literature which are of interest . The first is the “Bowtie” shape which has been utilised in a design described in a paper by Neyer et al [4]. The second is a “Butterfly” shape which has been utilised in a design described in a paper by Yilmaz [5]. The final design found in literature is an “H” shape pattern disclosed in a paper by Logan et al [6]. The reason as to why one design has been chosen over another is not disclosed in the papers that have been reviewed . One additional design has been designed for investigation and has been called the “Halfpipe” design.

The aim of the project is to investigate the effect the foil geometry will have on the performance of Exploding Foil Initiators and to determine if one design offers a significant advantage over another.



Halfpipe Foil Design

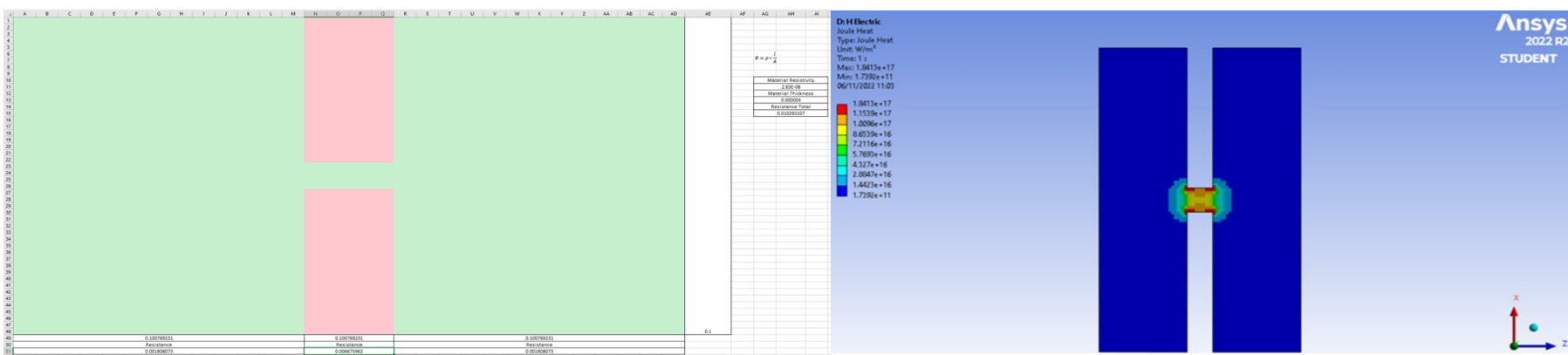


Foil Geometry From Literature: Bowtie [4], Butterfly [5], “H” [6]

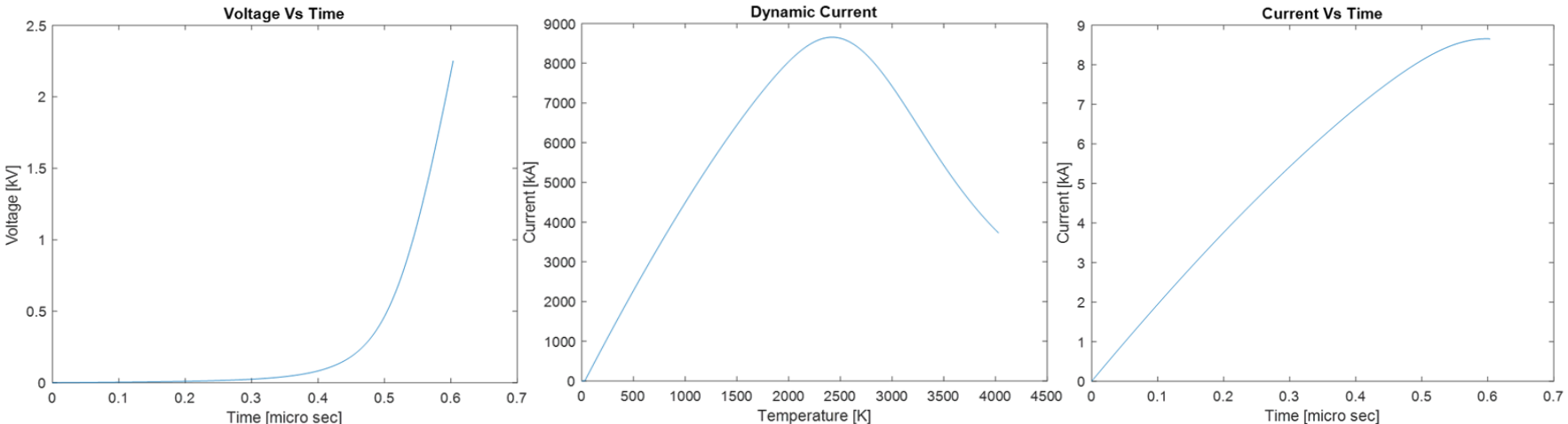
MODELLING OF EFIS

The original plan of the project was to carry out modelling and physical tests side by side however due to delays brought on by current world factors this has not been achievable.

In order to advance the project a multitude of modelling activities have been carried out in order to determine how foil geometry affects EFI performance. Initial modelling was carried out in Excel to determine resistance of the foil. Additional modelling was performed using ANSYS to determine heating build up and current build up. Finally the Excel data was inserted into a MATLAB model developed in a paper by Ghosh [7]. From the Ghosh model a number of parameters for each foil can be determined such as flyer velocity, burst current and burst time.



EXCEL Model (L) and ANSYS Thermal Build Up Model (R)



Graphical Results from Ghosh Model: L-R: Voltage Vs Time, Current Vs Temperature, Current Vs Time

FINDINGS & RECOMMENDATIONS

From the project it was found that geometry of the foil has an effect on the resistance of the foil. This resistance can have an effect on flyer velocity and burst current of the EFI design with the Bowtie design offering the highest burst current with the lowest flyer velocity and the “H” Shape foil offering the highest flyer velocity with the lowest burst current. A number of other basic parameters were found as to which factors can increase performance and which factors can increase safety.

Current ongoing works are being carried out to continue with physical testing of the design and components are currently being manufactured to achieve this as well as increased fidelity modelling using Magnetohydrodynamics software which may assist in seeing how the flyer impacts explosive material prior to physical tests.

From the project a number of recommendations were drawn up and include higher fidelity modelling of resistances of the foils to obtain more representative values, development of modelling capability using additional modelling packages in ANSYS or other suitable software and improvements to be made to the Ghosh model relating to the resistivity model utilised.

REFERENCES

- [1] Ministry of Defence, Services Textbook of Explosives, London: Ministry of Defence, 2020.
- [2] P. W. Cooper and S. R. Kurowski, Introduction to the Technology of Explosives, New Jersey: John Wiley & Sons, 1996.
- [3] J. R. Stroud, “A New Kind of Detonator-The Slapper,” in Annual Meeting of the Fuze Section, Ammunition Technology Division, American Defense Preparedness Association, April 6-7, 1976, Eglin Air Force Base, Florida , Eglin Air Force Base, 1976.
- [4] B. T. Neyer, J. T. Adams, J. C. Edwards, T. L. Stoutenborough and R. J. Tomasoski, “A Low Cost, Reliable, Hermetically Sealed, Chip Slapper Detonator Suitable for Various Aerospace Applications,” in Proceedings of 35th Joint Propulsion Conference, Los Angeles, CA, 1999.
- [5] M. Y. Yilmaz, “Design and Analysis of High Voltage Exploding Foil Initiator for Missile Systems,” The Graduate School of Natural and Applied Science of Middle East Technical University , Ankara, 2013.
- [6] J. D. Logan, R. S. Lee and R. C. Weingart, “Calculation of heating and burst phenomena in electrically exploded foils,” Journal of Applied Physics, vol. 48, no. 621, 1977.
- [7] A. Ghosh, “Modelling and Simulation of Burst Phenomenon in Electrically Exploded Foils,” School of Mechanical, Material and Enegy Engineering, Indian Institute of Technology Ropar, Ropar.