Operating behavior of initiators based on the exploding foil and bridge-wire

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1 Introduction

An initiator is a small pyrotechnic device used as heat source to operate igniter or as a pressure cartridge to move pyro-device. Aerospace and defense industries utilize it often as a one-shot device due to its advantages in rapid response, small volume and high-reliability. The most widely used initiator is a bridge-wire initiator which uses electrically heated wire to ignite charges inside. A main charge of initiator is boron potassium nitrate (BPN) due to its high-energy density and stability. A heat transfer rate from wire to charge, however, is not enough to initiate the BPN directly thus zirconium potassium perchlorate (ZPP) is adopted between wire and BPP for the faster response. A ZPP is a very sensitive material especially for the static electricity or friction. Bridge-wire initiator thus has a safety design features such as spark gap and boron nitrate shield around ZPP. A bridge-wire initiator should be handled with care as working voltage is under 20 V.

A initiator with different initiating mechanism, which directly ignite BPN, is a good solution since it reduces many risks without ZPP. Additional advatage is when using the high-voltage mechanism that is safe from the accidental ignition. This work adopted amd compared initiating mechanisms of exploding foil initaitor (EFI) and exploding bridge-wire initiator (EBW) to BPN directly. These two mechanism works only at high voltage (>1000V) and originally designed to detonate the explosive charge. Both uses shock energy to start the detonation. BPN has no detonation characteristics but only defragration. However, it is possible to initiate the reaction of BPN by shock or impact since it eventually trasnformed into the heat energy.

This work tested BPN initiator with EFI and EBW mechanism to show the feasibility of shock ignition of BPN. Closed bomb test measures pressure vs time which represents the ignition and combustion behaiviors of BPN.

2 EFI, EBW based initiator

EFI and EBW has different working mechanism. Fig. 1 describes two different initiators using sole BPN charge but has exploding foil and exploding bridge-wire, respectively. EFI uses impact shock from the high-speed flyer. EFI feeds high voltage to the cupper bridge as a result it generates plasma. Because the cupper bridge is enclosed with the polyimide layer, plasma between the cupper and polyimide layer

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tears and pushes the layer rapidly. A piece of a layer, which has a form and size similar to the cupper bridge, become a flyer directly flying towards a charge.

On the other hands, EBW has much simple design. Its configuration is similar to the electrically heated bridge-wire initiator but the difference is the material and thickness of the wire. Electrically heated wire uses relatively thick and high-resistance material while EBW is vice versa. A fine and low-resistance wire explode with the high-voltage input. This local explosion could initiate the charge above.

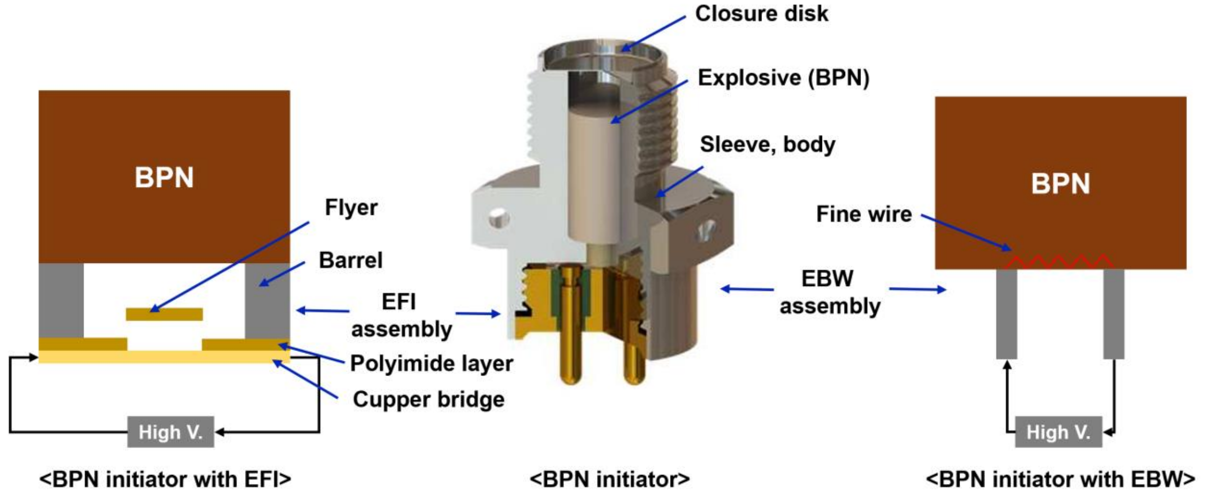

Figure 1: Schematics of BPN initiator using exploding foil and exploding bridge-wire initiating mechanism.

3 A closed bomb test

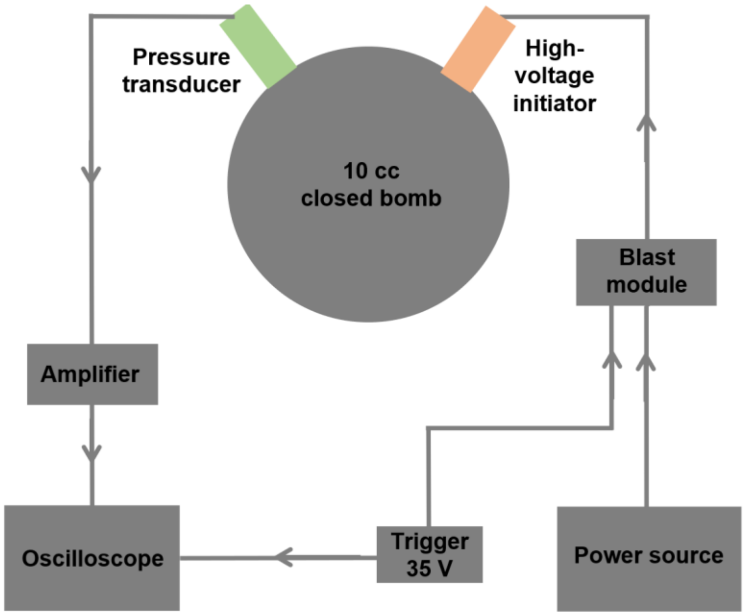

Figure 2: Schematics of closed bomb test configuration

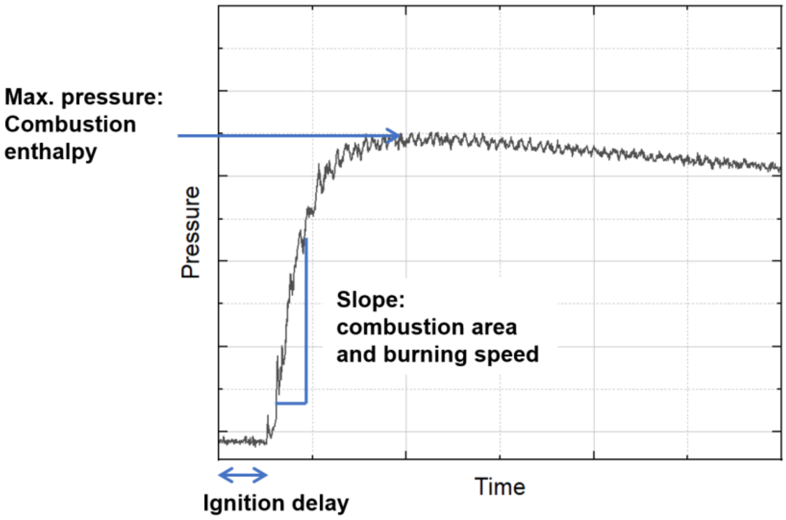

Figure 3: Typical result of CBT and combustion performance factors

Fig. 2 and 3 shows experimental configuration of the CBT to evaluate performances of high-voltage initiators. It measures pressure histories evoked by the combustion of BPN inside a closed vessel. In case of initiator with electrically heated bridge-wire, pressure histories are measured like figure 3. It shows a short period of ignition delay less than 5 ms and starts rise sharply. Its slope is coupled results of burning are and burning rate of BPN granules. Also, its maximum pressure denotes the total released energy to the vessel.

4 CBT results of EFI and EBW initiators

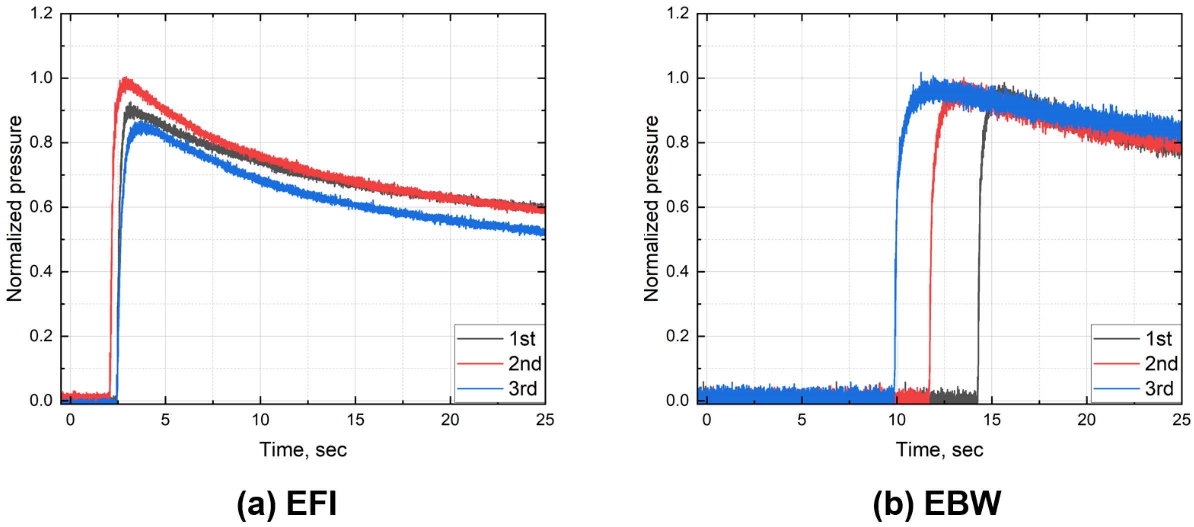

Figure 4: Measured pressure vs time curves of (a) EFI and (b) EBW initiators

CBTs with three samples are performed to evaluate the performances of each initiators with EFI and EBW. A pressure is normalized to the maximum pressure of each group. Fig. 4 compares the results of each initiators. Both initiators have a small deviation in the maximum pressure, and shape of curves, which also represents unintended combustion delay, are similar. However, ignition delay shows a great difference as EFI has ignition delay of 2.0~2.4 ms while EBW has that of 9.9~14.2 ms.

5 Conclusion

BPN initiators with EFI and EBW initiating mechanism are tested and compared using CBT. Both initiators show similar combustion behavior after the ignition of BPN, but characteristics of ignition delay was different. A difference of ignition delay is related to the order of energy concentration. In terms of system, both initiators transform high-voltage electric energy into kinetic energy and finally to the heat energy at BPN surface. EFI generates plasma in a small cupper bridge and concentrate its energy to the same area of flyer. On the contrary, EBW directly transfers the heat energy to the BPN with long, narrow area (fine wire of EBW). As a result, EFI has more concentrated heat transfer at local BPN surface which resulted in superior ignition characteristic. Although EBW has its advantages in terms of simple design and low manufacturing cost, using EFI are better choice to initiate BPN directly considering operation reliability.