International Journal of Chemical, Materials and Biomolecular Sciences
ISSN: 2415-6620
Vol:5, No:6, 2011

Improving TNT curing process by using Infrared camera

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***Abstract*—** Among the chemicals used for ammunition production, TNT (Trinitrotoluene) play a significant role since World War I and II. Various types of military weapon utilize TNT in casting process. However, the TNT casting process for warhead is difficult to control the cooling rate of the liquid TNT. This problem occurs because the casting process lacks the equipment to detect the temperature during the casting procedure This study presents the temperature detected by infrared camera to illustrate the cooling rate and cooling zone of curing, and demonstrates the optimization of TNT condition to reduce the risk of air gap occurred in the warhead which can result in the destruction afterward. Premature initiation of explosive-filled projectiles in response to set-back forces during gun-firing cause by casting defects. Finally the study can help improving the process of the TNT casting. The operators can control the curing of TNT inside the case by rising up the heating rod at the proper time. Consequently this can reduce tremendous time of rework if the air gaps occur and increase strength to lower elastic modulus. Therefore, it can be clearly concluded that the use of Infrared Cameras in this process is another method to improve the casting procedure.

***Keywords*—** Infrared camera, TNT casting, warhead, curing

I. INTRODUCTION

Military applications and activities globally used millions of tons of nitro aromatic explosives which leading to accidental release of energetic material over the last 150 years. The most widely used explosive for military application is 2, 4, 6-trinitrotoluene (TNT). This is synthesized from toluene by a nitration process and consists of a benzene ring with nitro groups on position 2, 4, 6 and a methyl group [1] (Figure1)

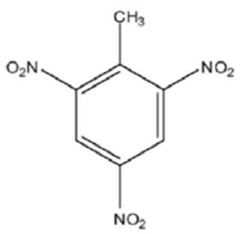

Fig. 1. 2, 4, 6-Trinitrotolyene

The warhead casting process sets by flowing the 85°C liquid TNT into the case that heat until the temperature reaches 90°C. Finally, the last procedure uses water to cool down. The preferable condition for the operation is the case cool down from the bottom to the top in order to make the air gaps float up to the surface of liquid TNT. The best condition is that the entire air gap evaporates out of the warhead after curing TNT. This condition is very difficult to control the cooling rate. Casting defects such as base-gaps, cracks and void have been held responsible for premature initiation of explosive-filled projectiles in response to set-back forces during gun-firing **[2]**. Several methods such as adding mixtures of:Alkyd resins, sorbitan monostearate, pyrogallicacid, anthracene, naphthalene and tetryl to a number of other TNT-based compositions help to reduce the defect from casting. This paper studies the use of infrared camera to detect the cooling rate temperature during the TNT casting in order to address the problems above.

The rest of the paper is organized as follows. Section II gives overview of the experiment. Section III provides the result of the experiment. Finally, conclusions and recommendations are provided in section IV.

II. EXPERIMENT

A. Experimental and configuration

This experiment uses the ratio between TNT and RDX at RDX 40: TNT 60. The process starts by liquefying TNT using heat from the boiler at the temperature around 80-90°C for 45 min.

Table1. Physical properties of TNT

Physicochemical properties of TNT (adapted from Ek[104])

CAS number	118-96-7
Chemical formula	$C_7H_5N_3O_6$
Molecular weight	227.13
Melting point	80.1°C
Boiling point	240°C
Water solubility at 20°C	$130 mgL^{-1}$
Solubility in acetonitrile at 20°C	100g/100g
Solubility in acetone at 20°C	109g/109
Vapor pressure	$1.99x10^{-4}$ mmHg
Log K_{ow}	1.6
Log K_{oc}	3.2
Henry's law constant (20°C)	$4.57x10^{-7}$ atm-m^3/mol

B. TNT casting

TNT then flows into the extremely complex melt casting process. [3] The melting point of pure TNT is 80.1°C. [4] The TNT casting process starts by utilizing the heat form boiler connecting to the TNT casting machine. After that, the liquid

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TNT combines with RDX to increase the viscosity of TNT to ease the TNT casting process. [5]

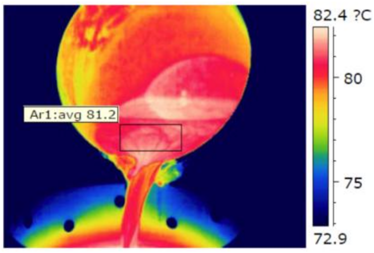

Figure 3 TNT casting in warhead case after TNT melted

C. TNT curing

The cooling procedure begins after TNT completely casted in the case. The cool down process start from the bottom to the top of the case to eliminate the air bubbles. In order to maintain this condition, the traditional method uses water to cool the bottom of the case then put heating rod in to increase the temperature of liquid TNT from the bottom up. However, it is difficult for the operator to detect the temperature of TNT in lower part of cooling case and to control the condition inside the case. This precedure requires expert operator with many years of experience in the cooling process. This process consists of 3 steps with the specific time as in Figure 4. The whole prcedure takes 4 hour and 30 minutes. To address the problem of uncontrollable condtion of cooling process, this study uses the infrared camera to detect the cooling rate inside the warhead.

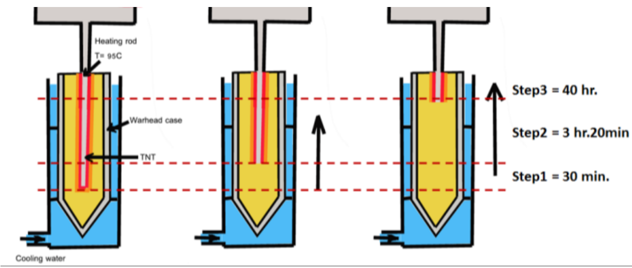

Figure 4 The entire traditional TNT casting process time is 4hr 30min.

This study uses the infrared camera to detect the temperature on the top surface of warhead. The infrared camera present the different temperature display of the warhead case. The color of each zone illustrates the temperature as in Figure 5. The heating rod showed in red indicates that the temperatute in this area is higher than surrounding in yellow, green and blue.

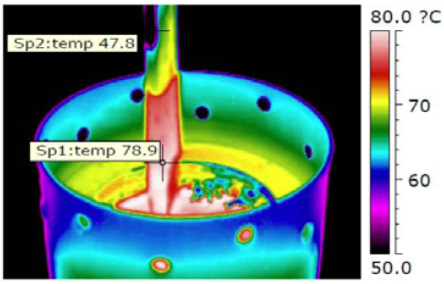

Figure 5 The illustration of the highest temperature of the heating rod

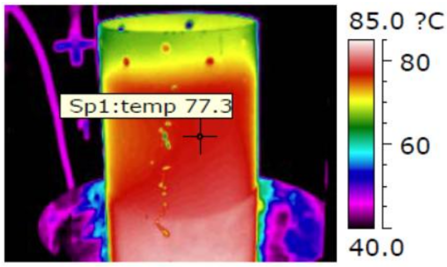

Figure 6 The illustration of high temperaute in the middle of the case resulting from heating rod

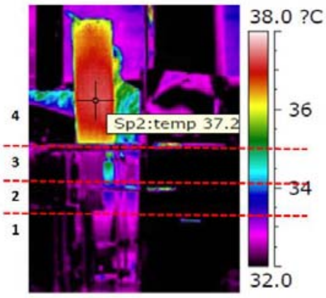

Figure 7 The illustration of the temperture after casting process.

III. RESULT

During the casting process, the infrared camera detects the temperature while the TNT is cooling down to study the cooling rate and temperature in each zone. Figure 5 illustrates the high temperature of the heating rod which is close to the melting point of TNT to maintain the liquid condition of TNT surrounding the heating rod. The temperature during casting is 77.3°C as in Figure 6. When the liquid TNT starts to cure, the heating rod begins ascending until the TNT at the surface of the case is completely cured. Finally the charging warhead from the casting process is cooling down by air. Figure 7 presents the 4 steps of temperature in the cooling process from the infrared camera.

After 1 hour, the temperature drops from 70 - 80°C to 50 - 60°C as in Figure 8. Then the temperature remains constant at 50°C until the casting finish. This shows that TNT starts to cure at 50 - 60°C then the heating rod begin to rise up.

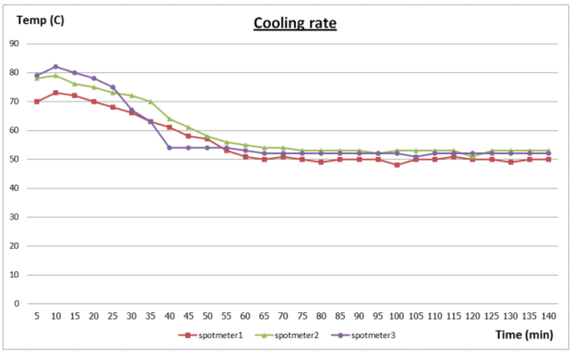

Figure 8 The cooling rate of warhead at each interval

IV. Conclusion and Recommendation

Conclusion From the experiment, it is undubtedly that the infrared camera help improving the TNT casting process tremendouly. By using the display from infrared camera, the operator can properly control the level of heating rod corresponding to the condition of the cooling rate. As a result, the cooling condtion perfectly start from bottom up which redue the arining of air bubble in TNT.

Recommendation This paper propose the new design of TNT cooling water system based on the result form the experiment. The new design can help impoving the quality and reduce the time of TNT casting procedure. The new cooling water system desing illustrated in Figure 8 shows that this system can decrease the process time by modifying the rate of heating rod ascending.

The constant rate of heating rod ascending depends on the relation of the increasing level of cooling water and level of heating rod. The operator can collect the temperature in the casting process.

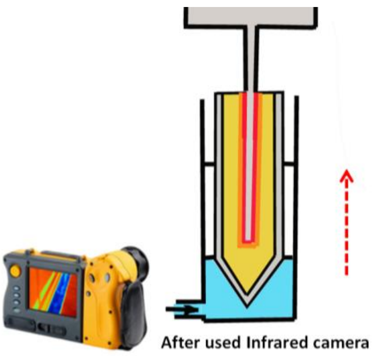

Figure 8 New design of cooling water system

The next experiment can represent the new casting procedure by improving the cooling process from the developed cooling water system. The test consist of 2 parts: the quality of TNT and the time of the process by using X-ray and split shell case.

Acknowledgment

This work was supported in part by the Defence Technology Institute (Public Organization),Bangkok,Thailand. The financial support is gratefully acknowledged.

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