Six Sigma Program Helps Solve Explosive and Grenade Production Problems

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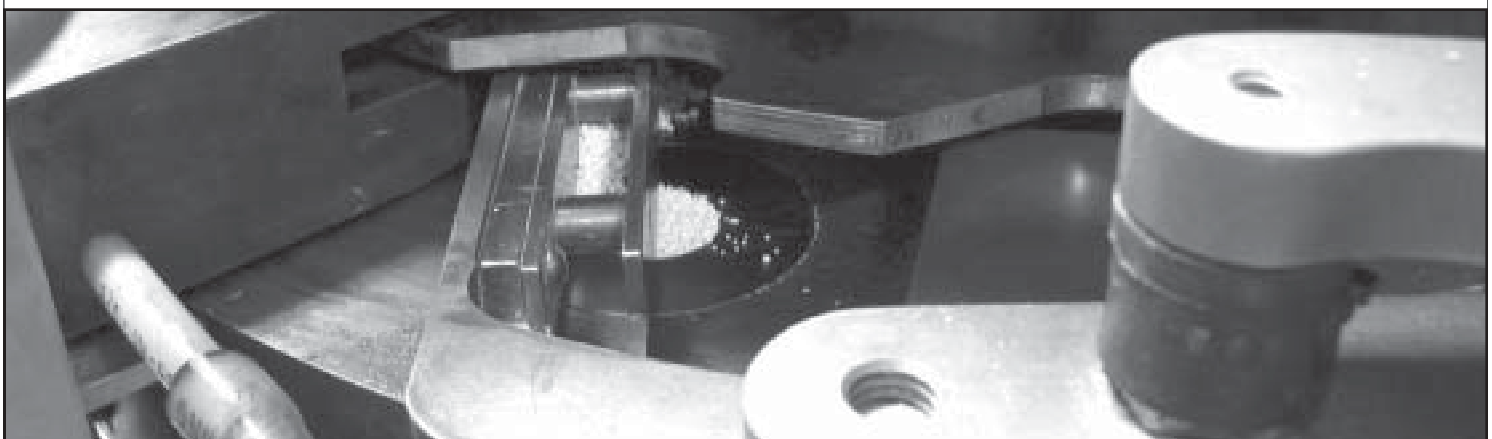
BEST BUSINESS PRACTICES

The Project Manager for Combat Ammunition Systems (PM CAS) and the U.S. Army Tank-automotive and Armaments Command's Armament Research, Development and Engineering Center (TACOM-ARDEC) have been working with VSE Corp. since 2000 to implement Six Sigma. This article highlights the extraordinary customer-supplier teamwork at Picatinny Arsenal, NJ, and details Six Sigma as a proven, effective strategy for applying rigorous controls to design, production and business processes and activities. More specifically, this article demonstrates the importance of focusing on increasing productivity, reducing cost and using Six Sigma tools to solve the problem of manufacturing Picatinny Arsenal Explosive-2A (PAX-2A) — an insensitive munition (IM) that users want — into M77 and M80 grenades.



Background

The M915 105mm Dual-Purpose Improved Conventional Munition (DPICM) is an extended-range projectile with an improved anti-personnel, anti-materiel capability. The 105mm DPICM cartridges are being developed primarily for use in the M119A1 howitzer to leverage its greater range capability. The projectiles contain a submunition payload of 42 dual-purpose M80 grenades. The M80 is a 1.22-inch diameter fragmentation/shaped charge submunition.

To increase safety to soldiers in the field and follow recommended DOD policy for incorporating IM technology, the M915 Developmental Project Officer decided to replace the Comp A5 explosive with a Type II insensitive material PAX-2A explosive.

PAX-2A was developed in the late 1980s as a less sensitive, high-explosive replacement for use in main charge conventional munition warhead applications. Initial specifications for PAX-2A were developed to mimic Comp A5 specifications. Small mixes of the material were fabricated and successfully loaded at Lone Star Army Ammunition Plant (LSAAP), Texarkana, TX. Grenades loaded with this material were successfully tested per IM requirements (sympathetic detonation, bullet impact and slow cook-off). Based on these results, the M915 Developmental Project Officer decided to enter full-rate production and field the M915 105mm projectile with PAX-2A.

Accordingly, the M915 program contracted Alliant Techsystems Inc. (ATK) for a total delivery of 18,800 pounds of PAX-2A. ATK subcontracted Thiokol Corp. to manufacture the PAX-2A. For this effort, Thiokol intended to scale-up the manufacturing process from a research and development (R&D) 50-gallon mixer to a 600-gallon production mixer to supply the contract quantity for M915. It became evident that delivery of this large quantity of PAX-2A would be difficult within the available resources. Thiokol could not meet the specifications in large quantities and the prime contractor could not use the material from its subcontractor. Thiokol requested a “termination for convenience,” which would conservatively cost both sides more than $500,000 each in technical preparation for the case, legal fees and bad feelings, and put a “black-mark” against a good subcontractor. At this juncture, Thiokol requested PM CAS assistance in solving the current PAX-2A production and loading problems.

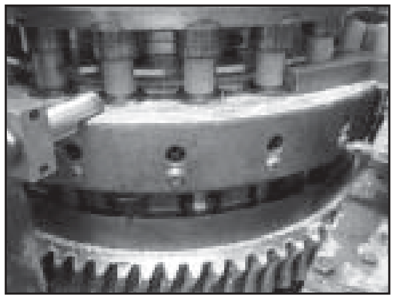
During the initial evaluation of PAX-2A loading in the M80 grenades, there was no record of excessive dusting or spillage of explosive material on the press. However, sticking of the explosive material to the powder guides, punches and rotary die face was observed during the loading of the Multiple Launch Rocket System (MLRS) M77 grenade under a TACOM-ARDEC Logistics R&D IM program.

Initial M77 grenade loading of this mix from the 600-gallon mixer did not prove successful. Heavy spillage was observed during loading. The grenade-loading presses at both LSAAP and Kansas Army Ammunition Plant (KSAAP), Parsons, KS, required intensive cleaning after short product runs, which proved essentially cost-prohibitive for full-scale production. The impact of this spillage problem became a major issue. The spillage created a safety problem and greatly reduced production rate and efficiency. Only 500 grenades could be loaded between maintenance on the standard high-rate production Day & Zimmermann rotary press. With Comp A5, the number is much higher and is about 60,000 parts in run-time between maintenance cycles (two 10-hour shifts). The same result was found in the M915 M80 grenade loading during a quick rotary press evaluation.

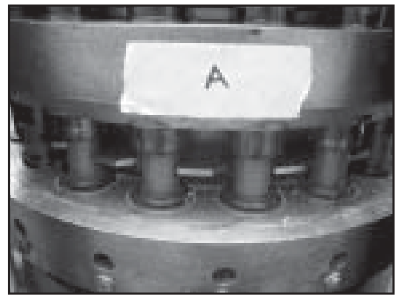
PAX-2A Explosive Build-up

Feed shoe and die cavity before Six Sigma

Feed shoe and die cavity after Six Sigma



Press before Six Sigma



Press after Six Sigma

Six Sigma Program

Successfully loading PAX-2A Type II into M80 grenades required the use of the following Six Sigma tools:

- Quality Function Deployment (QFD). This caused the team to re-evaluate the requirements and focus on the key system-level requirements.
- Brainstorming. This permitted the joint collection of ideas and concepts that could be evaluated in an open format. This included weekly status telephone conference calls to maintain team member coordination.
- Process Maps — Walking the Line. By actually walking the process, we determined a number of areas that were not initially stated in the process map. The process also identified potential problem areas that needed to be addressed and those that could be either optimized or eliminated.
- Failure Modes and Effects Analysis (FMEA). All team members contributed to formulating a failure effects analysis and provided recommendations for reducing individual and overall process risks.
- Design of Experiments (DOEs). This is where we would get small samples of the material’s different sizes and try to load them. When we found one or more sizes that could actually be loaded, the experiment was repeated to ensure that there were no additional variables influencing our observations.

• Validation Process. When we found a mix that could work in small quantities, we expanded on that load to verify that we were on the correct path.

By using Six Sigma tools, the team was able to identify the critical parameters and concentrate on actual failure modes. As a result of applying Six Sigma tools such as DOE, brainstorming, FMEA and process maps, the subcontractor was able to produce material that could be manufactured at economical yield rates and used by the prime contractor to load M77 and M80 grenades.

The focus on main system requirements using QFD included penetration requirements, IM properties and low cost. In this process, the team was able to step back and look at the main system requirements and determine the four main problem areas:

• Not being able to efficiently load PAX-2A at an acceptable rate with normal maintenance intervals with the current hopper and feed shoe.
• Explosive smearing on the powder guides (nests) leaving a hard residue that requires extensive cleaning of nests and punches.
• The possibility of segregation where the larger particles will settle on the container's bottom and smaller particles will go to its top. Particle size uniformity is extremely important.
• Ability to fully use product from the 600-gallon mixer and reduce unnecessary post-processing of powder.

Through production line studies at LSAAP and Thiokol, soliciting the services of material flow experts and conducting numerous DOEs, the following conditions were identified:

• The segregation problem was addressed by the design, fabrication and installation of a new blender, hopper and feed shoe for PAX-2A Type II.
• The addition of an acceptable flow agent provides solutions to address loading and explosive smearing problems.
• The U.S. Standard Sieve Number (USSS#) 6-30 particle size band is the best compromise between maximizing product from the 600-gallon mixer and feeding powder to the rotary press that can be loaded with minimal press spillage.

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The above statements were documented and validated with two separate runs of PAX-2A Type II in different mixes to determine the correct particle size. Verification was documented with two small runs of PAX-2A Type II. A sustained run of a 3,000-pound mix of USSS#6-30 proved to be the most efficient material from both a manufacturing process and a loading process. With the 3,000 pounds, we were able to successfully load 69,120 M80 grenades and 1,991 M77 grenades within normal maintenance intervals. Prior to adding a flow additive and the new particle distribution requirement, we could load fewer than 300 M80 grenades with PAX-2A before it became a safety issue, forcing loading press stoppage and intense cleaning. This type of production cycle is not acceptable for high-volume grenade loading. After completing Phase One of the Six Sigma program, we saw a 400:1 improvement in run times between maintenance cycles (two 10-hour shifts). Before LSAAP applied Six Sigma, consolidation press loading with PAX-2A particle distribution USSS#20-80 without an additive resulted in 3-minute run times. With Six Sigma application, particle distribution USSS#6-30 using an additive resulted in 1,200-minute run times.

This project has demonstrated the benefits of applying Six Sigma tools and techniques for achieving Army munitions goals and objectives. It also demonstrated the importance of customer-supplier teamwork for cost-effectively developing and producing explosives.

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