Improvement Model of Double Base Propellant Production Process Simulation Capacity 1.5 Ton/Year for Domestic Small Caliber Ammunition

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Abstract— The production of fully operational munitions in the country is currently only capable of producing small caliber with a production capacity of 120 million rounds per year and will be 290 million, nearly 300 million rounds per year with the addition of new machines. The production, which has almost penetrated 300 million rounds per year, has not been able to meet all the needs of TNI munitions. This study aims to simulate the production process system of PT Dahana's propellant mini plant in Subang for a capacity of 1.5 tons/year in producing small caliber munitions (MKK) to meet the needs of the TNI and the defense industry. The research was conducted using quantitative methods using HYSYS simulation. The simulation results show that the propellant produced is 0.194 kg/hour or 4.646 kg/day or if it runs in one year the product is 1.5 tons/year. The optimal process simulation proposed is the Warren L Plunket Process using a mixed acid process, namely HNO3 and an acid catalyst H2SO4 because it has advantages in a short time, high temperature relatively not too high and the resulting yield is greater. This product can be used to support the needs of small caliber TNI munitions, especially for blank ammunition which requires little propellant.

Keywords— mini plant, small caliber ammunition, propellant, process simulation.

I. INTRODUCTION

Komite Kebijakan Industri Pertahanan (KKIP) compiles a Road Map for the development of Defense and Security Equipment (Alpalhankam) products. One of the main priorities for the independence of the defense industry is the development of propellant technology. Propellant technology is a key technology that must be mastered for the development of ammunition, rockets and missile defenses (Iskandar, 2018). Mastery of propellant technology is also carried out to support the acceleration of the development of the propellant industry.

The production of propellant that has been operating at PT Pindad has only penetrated 300 million grains per year and has not been able to meet all the needs of TNI munitions. TNI needs up to 500 million items per year (Yayat, 2021). So that there are still around 200 million rounds or 40% of the munitions needs that have not been met and must be imported to fulfill them. In the need for 500 million MKK items, 25% are MKK needs (Eddy et al, 2016).

The defense industry engaged in the development of propellants, namely PT. Dahana which focuses on single base and double base propellants. Currently PT Dahana has built a miniplant that produces single base propellant with a maximum production capacity of 5 kg/day. The capacity is adjusted to the capacity of the machines and equipment that support the process. In addition, the capacity is adjusted to the operating hours of employees, which consists of two system shifts where each shift runs for eight hours. PT Dahana's mini plant is used to produce laboratory-scale propellant to test whether the propellant has met the expected performance or not to proceed to industrial-scale production process (Anwar, 2015).

PT. Dahana as an industry that produces explosives, one of which is propellant, must be able to meet all these needs in accordance with the specifications of user needs. Research on the production capability of PT. Dahana needs to be done in order to know the effectiveness and efficiency of its production. Effective and efficient is obtained by minimizing the raw materials used as well as production costs and obtaining the optimum operating conditions formulation. Optimum operating conditions resulting in efficient operation are measured by saving resources in propellant production which results in high conversion of propellant base products (D Xu et al, 2016).

This study aims to simulate the production process system of PT Dahana's miniplant propellant for a capacity of 1.5 tons/year with parameters of temperature, pressure and material phase. In addition, this study also aims to provide suggestions for improving the production process system at a strategic process stage by proposing an efficient simulation model by minimizing the raw materials used and production costs and obtaining the optimum operating conditions formulation. With this research, it is hoped that it can support and optimize the propellant production process by the domestic industry through strengthening the industrial structure and self-development.

II. RESEARCH METHOD

The method used by the researcher is a quantitative approach to obtain the main data through observation and literature study in obtaining supporting data in simulating the production process system using HYSYS software. This study uses flowsheet simulation data such as raw material specifications, feed ratio of raw materials, equipment specifications, process conditions (temperature, pressure, fluid phase), and production flow diagrams.

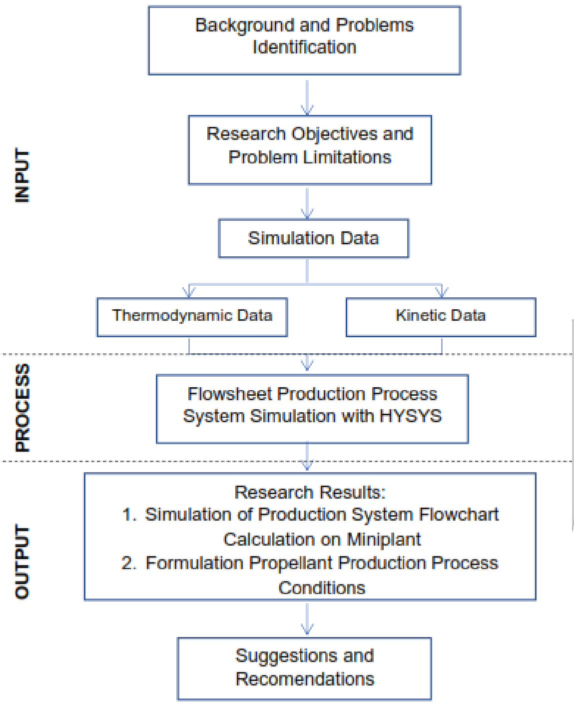

Figure 1. *Flowchart of Research Framework*
Source: processed by researcher, 2022

III. RESULT AND DISCUSSION

Selection of Production Capacity and Specification Raw Materials

In the simulation of the propellant production system at PT Dahana's mini plant, it is designed with a capacity of 1.5 tons per year or 4.11 kg/day or a maximum of 5 kg/day adjusted to the capacity and capability of the available machines (Angga, 2022). To make double base propellant, raw materials such as nitrocellulose, nitroglycerin, ammonium nitrate, sodium nitrate, sodium chloride, talc, graphite and glycol are needed (Urbanski, 1964). For nitroglycerin raw material itself, PT Dahana has been able to produce its own nitroglycerin material with a plant capable of producing 200 tons/year, but for nitrocellulose raw material it cannot be produced alone and domestic producers are still very limited so that to fulfill it, imports can be carried out, namely come from China, Finland, South Africa. As for other supporting materials such as nitric acid. PT Dahana has also been able to produce its own with a capacity of 3750 tons/year and sulfuric acid with a capacity of 3750 tons/year (Budi Antono, 2020). In more detail, the following are the physical and chemical properties of the main raw materials and catalysts in the manufacture of double base propellants.

Table 1. *Physical and Chemical Properties of Main Raw Materials*

Properties	Nitrocellulose	Nitroglycerine	Nitric Acid	Sulfuric Acid
Purity	13,35 %N	99%	98,50 %	98,85 %
Molecul Weight (g/mol)	526,5	227,1	63	98,1
Phase	Cair	Cair	Cair	Cair
Boiling Point (^{0}C)	170	218	86	340
Melting Point (^{0}C)	160	14	-42	10,35
Density (g/cm^3)	1,6	1,6	1,5	1,8

Source: Ulmann's, 2006

Process Equipment and Operating Conditions

After the raw materials and their properties are known, the selection of equipment is carried out in accordance with the operating process. This data is used to find equipment specifications. Based on the results of the study, the equipment data along with the operating conditions of the propellant production process were obtained as follows.

Table 2. *Process Equipment and Operating Conditions*

Equipment	Function	Temperature (^{0}C)	Pressure (bar)	Phase
Tank 2	Storage of NAC	60	1	Liquid
Tank 3	Storage of SAC	60	1	Liquid
Tank 4	Storage of NG	60	1	Liquid
Mixer 1	Mixing of NAC +NG	60	1	Liquid
Continous Stirred Tank	Making lacquer	165	1	Liquid
Tank 1	Mixing lacquer+NC	165	1	Liquid
Cooler 1	Lowering temperature	115	1	Solid

	and pressure of lacquer			
Jet Cutting	Making graining from lacquer	120	1,5	Solid
Compressor	Harding graining	125	3	Solid
Rotavapor	Coating graining with coating/glazing material	120	1	Solid
Cooler 2	Lowering temperature graining	80	1	Solid
Rolling mill	Filtering graining	85	1	Solid
Sieve Unit	Reducing graining sizes that exceed the caliber	90	1,5	Solid
Air Cooler	Lowering temperature of the propellant evenly	35	1	Solid
Baghouse Filter	Coating propellant with anti static agent	35	1	Solid

Source: PT Dahana, 2021 and Brownell & Young, 1959

Simulation Results Using HYSYS Sofrware

After obtaining the above data, then a simulation is carried out using HYSYS software to obtain a mass balance in the propellant production process for the double base type at the PT Dahana miniplant. The simulation results are visualized in the following image.

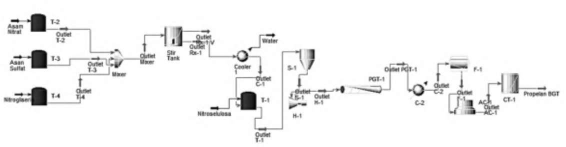

Figure 2. *Process Simulation Results Using HYSYS*
Source: processed by researcher, 2022

The raw materials for nitroglycerin and nitric acid with a feed ratio of 1:3 flow with a sulfuric acid catalyst and flow from the storage tank to the mixer for the mixing process and the formation of the lacquer phase. After the lacquer is formed, it is impregnated in tank 1 with nitrocellulose as raw material and the grain size is formed in the graining machine.

Comparison of feed ratio between nitrocellulose and nitroglycerin 3:7. In the existing double base propellant production system, there is a mixer for the mixing process, graining for the size formation process before hardening. When the raw propellant granules come out of the graining machine, they are sent to the hardening machine to reduce the liquid content contained. After hardening, it goes to the phlegmatizer machine for coating to make it easy to shape and fit the caliber size of 5.56 mm.

After the coating process, the propellant grains go to the sieving process to carry out a sieving process to filter the propellant that does not match the caliber size. The propellant that passes is then milled in a rolling machine.

Milling aims to eliminate voids that may be present in the propellant structure. Propellant products that are still at high temperature are lowered by using a cooler to the ambient temperature. The appropriate output product is then stored in the product storage area.

After the simulation, the propellant product produced is 0.194 kg/hour or 4.646 kg/day or if it runs in one year the product is 1.5 tons/year. This product can be used to support the needs of domestic small caliber munitions propellant.

Analysis of Strategic Process Stage

Determining the production system to be more efficient will choose a strategic process in the system that will most influence the success of production as a whole. The double base propellant production process can be seen as follows.

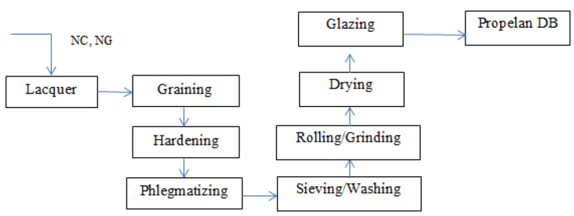

Figure 3. *Stage Diagram of the Double Base Propellant Manufacturing Process*
Source: processed by researcher, 2022

From the series of process flows, the strategic process stage that requires attention and improvement and determines the next stage of the process is at the stage of forming the lacquer (Angga, 2022).

Process Improvement Model

In this research, the model is made by finding relevant reference sources in the process of making lacquer through literature study (Cho et al, 2016). Here are some descriptions of the lacquer making process:

Table 3. *Comparison of Lacquer Manufacturing Process*

Parameter	Proses Warren L Plunket	Proses Charles dan Everette	Proses William C. Ramsey
Raw material	Nitrocellulose, Nitroglycerine	Nitrocellulose, Nitroglycerine	Nitrocellulose, Nitroglycerine
Solvent	HNO_3	HNO_3	HNO_3
Catalyst	H_2SO_4	$Mg(NO_3)_2$	H_3PO_4
Feed ratio	1:4	1:6	1:5
Operation conditions	T= 165C	T=150C	T= 180C
	P= 1 atm	P= 1 atm	P= 1 atm
	Times = 30 minutes	Times = 60 minutes	Times = 60 minutes
Yield	70-80%	40%	60-86%

Source: processed by researcher, 2022

From the literature data, a simulation model can be made with changing variables, namely the ratio of raw materials, temperature and yield of the resulting product. In general, with the same raw materials and solvents but different catalysts will affect the conversion and yield produced. Then the proposed model is as follows.

Table 4. *Variable Process Improvement Model*

Parameter	Model 1	Model 2	Model 3
Feed ratio (in 60 minutes)	1:4	1:5	1:5
Operation conditions	T= 165C	T=150C	T= 180C
	P= 1 atm	P= 1 atm	P= 1 atm
	Time = 30 minutes	Time = 60 minutes	Time = 60 minutes
Yield	70-80%	40%	60-86%

Source: processed by researcher, 2022

Result Process Improvement Models

Table 5. *Comparison of Simulation Output and Improvement Model*

Trial to	Real System Output (gram/days)	Output Model 1 (gram/days)	Output Model 2 (gram/hari)	Output Model 3 (gram/days)
1	4647	4790	4383	4790
2	4760	4818	4240	4818
3	4678	4110	4415	4110
4	4598	4000	4240	4056
5	4732	4014	4324	4098
6	4601	4516	4384	4902
7	4718	4296	4274	4110
8	4673	4328	4296	4042
9	4634	4902	4184	4070
10	4655	4107	4168	4906
Total	46696	43881	42908	43902
Average	4669,6	4388,1	4290,8	4390,2

Source: processed by researcher, 2022

Based on the simulation with different parameters of feed ratio, temperature and conversion, it can be concluded that there is a difference between the real simulation and simulation models 1, 2, and 3. and proposed is the Warren L Plunket Process using mixed acid, a mixture of nitric acid as a nitrating agent and sulfuric acid as a dehydrating agent, with the following reasons:

1. Time reaction shorter

From a technical point of view, the length of reaction time has an effect on determining whether the continuous or batch process will take place. Selected a faster time so that the reaction continues so that the process conditions and the resulting product are more constant (Shreve, 1977). In addition, the continuous process is suitable for large production capacities. From an economical point of view, the reaction time will affect the determination of the dimensions of the tool used. A longer time requires a larger volume of tools, of course with larger tools the purchase costs will be even greater. Then choose a fast reaction time in order to reduce investment costs.

2. Higher yield generated

From a technical point of view, yield is related to the separation or purification process. Large yields produce more products and less impurities, so that the separation or purification process becomes easier and faster (Ulrich et al, 2000). From an economic point of view, yield is related to conversion. Big yields come from big conversions. To produce the same product capacity, with a large conversion requires less raw materials, so it will be profitable from an economic point of view.

3. Temperature Reaction

From a technical point of view, high temperatures will affect the safety of employees because there are greater risks, such as if there is a tank leak or even the tank explodes due to overheating.

Then the reaction temperature is chosen which is close to room temperature or not too high. From an economical point of view, high temperatures require additional tools such as heaters and low temperatures require coolers, with the addition of these tools the investment costs will be even greater (Smith et al, 1996).

Therefore, a system improvement model was obtained in order to obtain an efficient production process as follows.

Table 6. *Operating Conditions of Production System Improvement*

Parameter	Real Process	Proses Warren L Plunket (Model 1)
Raw materials	Nitrocellulose, Nitroglycerine	Nitrocellulose, Nitroglycerine
Solvent	HNO_3	HNO_3
Catalyst	$H2SO_4$	H_2SO_4
Feed ratio (in 60 minutes)	3:7	1:4
Operation conditions	T= 165C	T= 165C
	P= 1 atm	P= 1 atm
	Time= 60 minutes	Time= 30 minutes
Yield	70-75%	70-80%

Source: processed by researcher, 2022.

IV. CONCLUSION

Simulation using HYSYS with nitroglycerin and nitric acid as raw materials with a feed ratio of 1:3 flowing with sulfuric acid catalyst flowing from the storage tank to the mixer for the mixing process and the formation of the lacquer phase.

After the lacquer is formed, it is impregnated in tank 1 with nitrocellulose as raw material and the grain size is formed in the graining machine.

Comparison of feed ratio between nitrocellulose and nitroglycerin 3:7. The propellant product produced is 0.194 kg/hour or 4.646 kg/day or if it runs in one year the product is 1.5 tons/year.

The optimal and proposed process simulation is the Warren L Plunket Process using a mixed acid process, namely HNO_3 and H_2SO_4 acid catalyst because it has advantages in a short time, relatively low temperature and higher yield.

This research can be used as a reference and development related to the production of double base propellant in order to support the needs of the defense industry and the TNI.

Further research is needed, in order to provide even more efficient operating conditions with actual conditions in the field.

REFERENCES

[1] Iskandar, M. A. (2018). Strategic Policy in the Development and Development of the Defense Industry. Defense University September 25 2018: Defense Industry Policy Committee.

[2] Yayat Ruyat. (2021). Ammunition and Explosion System (Production). AEPP Course Armament Technology Study Program, Faculty of Defense Technology, RI University of Defense.

[3] Eddy Kustriyanto, Ishardita Pambuditama, Yudy Surya Irawan. (2016). Improvement of the Layout of the Munitions Longsong Production Machine Using the Systematic Layout Planning and Blocplan Method (Case Study: Munitions Division - Pt. Pindad (Persero). Journal of Mechanical Engineering Vol.7, No.3 of 2016: 103-112.

[4] Anwar, S. (2015). Mastery of Defense Technology by HR. Defense, 22 volume 5 number 1.

[5] D.Xu, B.H. Han, Z.G. Cheng, W.H. Hey. (2016). Research Status and Development Trend of Automatic Quantitative Technology of Small-Calibre Gun Propellant. Mechanical Engineering College, Shijiazhuang, China : 4th International Conference on Mechanical Materials and Manufacturing Engineering.

[6] Urbanski, T., (1964), Chemistry and Technology of Explosives, Vol 3., Pergamon Press, Tokyo.

[7] Budi Antono. (2021). Value Chain and Ecosystem of the Propellant Industry and Risk Management of the Emulsion Cartridge Supply Chain (CE). Domestic Work Lecture Seminar (KKDN) Faculty of Defense Technology RI Defense University.

[8] Ullmann's. (2006). Chemical Properties Handbook, Encyclopedia of Industrial Chemistry. McGraw Hill Companies. New York.

[9] Brownell & Young, EH., 1959. Process Equipment Design,. John Wiley & Sons Inc, New York.

[10] Cho, S et al. (2016). Optimal Operating Condition of Fluidized Bed Propellant Incinerator Considering Fluidization Effect and Reaction of the Particles. Proceedings of the 26th European Symposium on Computer Aided Process Engineering (p. 1). Portorož, Slovenia: Elsevier B.

[11] Shreve, R.N. (1977). The Chemical Process Industries, second ed. McGraw Hill Book Company. Inc. New York.

[12] Ulrich, Karl T. and Stephen D. Eppinger. (2000). Product Design and Development, 2nd. Edition, McGraw-Hill Inc, New York.

[13] Smith, J.M., Van Ness, H.C., and Abbott, M.M. (1996). Introduction to Chemical Engineering Thermodynamics. Singapore:McGraw-Hill.