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Modelling and Simulation Flight Dynamic Terminal Air Defense Missile

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Abstract
This paper is an academic study that discusses how to design air defense missile modelling and simulation, as a missile development strategy for the Indonesian National Army. Flight dynamics modelling and simulation is a way to determine the reliability of the Missile system in which there are aerodynamics, guidance systems and control systems that are integrated with each other, in order to produce a precise and accurate missile to the target. The success of developing a rocket that has reached the level 7 technology readiness level (Protoype Tested), can be a start to seriously initiate the development of Indonesian Missiles. The initial design process was based on the specifications of the 122 mm calibre defense rocket, the length of 2810 mm, the weight of the 60.8 kg rocket and the 15 kg warhead with an overall range of 30.5 km that would be adjusted to the initial configuration of the air defense missile. Modelling and flight dynamics testing will be conducted on Matlab software which is focused on the Matlab Simulink section. This development strategy can optimize the rocket products that have been successfully developed by Indonesia, because the sustainability of the rocket mastery will be very useful to be used as a basis for missile development, specifically in terminal air defense missiles, which is the weak point of Indonesia's air defense today.

Keywords: *Initial design, Missile, Modelling and Simulation.*

I. INTRODUCTION

Indonesian National Army as a tool of national defense, based on Law no. 34 of 2004 concerning the Indonesian National Armed Forces article 7 paragraph 1 states that the Indonesian National Armed Forces are tasked with carrying out national defense policies to uphold national sovereignty, maintain territorial integrity, and protect national security, carry out military operations for war and military operations other than war, and participate actively in the task of maintaining regional and international peace. Currently various countries in the world continue to compete to display the strength of their country's defense in order to bring out the deterrence effect for other countries. As for the defense force of the country, in addition to the composition of military personnel, which is the strength of the country's defense is the strength of the main tool of its weapons system, commonly referred to as the defense equipment. In fulfilling its weapons, Indonesia has begun to make its own weapons systems such as the Assault Rifle, Anoa Panzer which is produced by PT. Pindad.

However, it must also be realized that still many military defense equipment held through overseas spending. Although there are still rules listed in Law Number 16 of 2012 concerning the Defense Industry that every procurement of defense equipment must involve the defense industry. This relates to the existence of The Local Content, Offset, and Counter-Trade. If

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Indonesia wants to optimize its country's defense strength, then what must be done is to realize the independence of the defense industry. This has already begun to be implemented by the Indonesian government through technological developments in the defense sector. The Ministry of Defense has seven priority programs in the development of the defense industry, namely jet fighters, submarines, propellants, rockets, missiles, radars, and medium tanks.

Furthermore, the development programs implemented by the Government of Indonesia through the Ministry of Defense is 122mm calibre national rocket, which is a ballistic rocket with the role of surface to surface shots. The success of the National Rocket Consortium in developing 122mm calibre rocket has reached the stage of technology readiness level 7 (TRL 7) [3]. The use of the rocket itself has different functions according to its purpose, in the case of 122mm calibre rocket its use is intended to paralyze enemy tactical and combat vehicle that are at a far reach. On the other hand, the success of developing 122mm calibre national rocket would be a good idea if it became the forerunner to build a self-defense missile based on independence [9].

A. Identification of Problems

Modeling is a very important thing to do in the process of making missiles, bearing in mind that problems will often arise before the missile is ready for use. Modelling has a very important role, where researchers or missile developers do not need to conduct experiments directly to test the tool. Tests can be done through modelling. Modelling will be very helpful in identifying problems so that costs can be reduced. After modelling, of course the next stage is to conduct simulations, both of which are interrelated systems to optimize the missile design, especially in the initial phases. There are several problems identified in the process of developing this missile defense, such as how to determine the missile configuration and optimal aerodynamic design so that it can produce optimal surface-to-air missile flying dynamics, and how to determine the control system so that the missile can destroy moving targets.

B. Dimension Detail Data

The 122mm caliber national rocket is a national strategic project focused on rocket development. For the research and development missiles based on 122mm caliber rocket, the basic specifications of 122mm caliber rocket data will be assumed by synthesizing data obtained in generalto get research results.

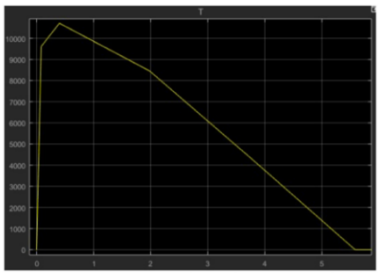

Figure 1. Results of Propulsion Synthesis

The results of the synthesis of propulsion are obtained from general information obtained, namely the distance from the rocket as far as 30Km, but of course the problem faced by researchers is knowing about the value of the structure used and other details. Therefore, the writer analyzes by means of the rocket mass and acceleration due to gravity used as a constant. Likewise, with the research on the development of defense rockets into air defense missiles, details will be assumed with synthesis in order to get results that are close to the detailed specifications of the 122mm calibre national rocket.

II. LITERATURE REVIEW

A. The 122mm Calibre National Rocket

The 122mm caliber national rocket developed by LAPAN which was acquired by the Ministry of Defense became part of a national strategic program for the independence of Indonesian defense equipment.The 122mm calibre national rocket was developed starting in 2014 at a state budget and driven by a national rocket consortium consisting of the Ministry of Defense, the Ministry of Research, Technology and Higher Education, LAPAN, PT. DI, PT. Pindad, PT. Dahana, PT. Krakatau Steel, ITB and ITS [8]. A rocket is a vehicle that has an energy conversion

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engine that can move according to the thrust generated by changing the chemical energy of the fuel into heat energy burning the fuel in space burn a rocket motor. Furthermore, this heat energy will produce pressure that can cause thrust through the rocket nozzle, so that the rocket can move in the opposite direction to the thrust direction, and then kinetic energy is produced in the form of rocket motion sliding towards its target, both targets on land, in the air and in the waters.

B. Missile

Missile are guided weapons systems with self-propelled guided weapons systems [5]. Based on these definitions, the main parameters that bind the missile are the independent propulsion system and the guidance system it has. In general, the missiles consist of a number of subsystems, namely: seeker, guidance, autopilot, control, fuzing and arming, blow-up, propulsion and airframe. Figure 2

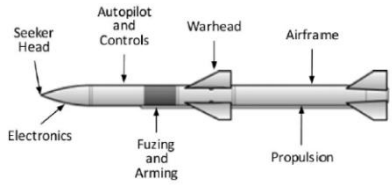

Figure 2. Main part of missile [13]

Certain missiles do not adopt the entire subsystem to adjust the function and performance that is needed. There are two types of missiles, namely ballistic missiles, which are missiles that use trajectory trajectories and rely on gravity as they reach the target, in other words, this type of missile is controlled only during the launch period or can be said as a fire and forget missile. While other missiles are cruise missiles that use wings as propulsion that rely on aerodynamic systems and use jets as propulsion. This type of missile can reach supersonic speeds and can use an automatic control system and fly at low altitude to avoid radar.

C. Terminal Air Defense Missiles

Based on the capability of the main air defense weapon system, the air defense system is structured as follows Point Air Defense, Terminal Air Defense, and Area Air Defense. The areas of air defense operations can be illustrated through the image below:

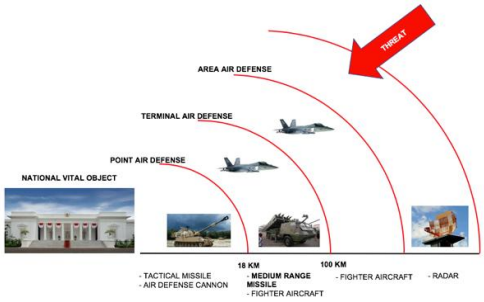

Figure 3. Air Defense Operation Areas [6]

D. Modelling and Simulation

Modelling and simulation is the use of physical or logical representations of a given system to produce data and help determine decisions or make predictions about the system. Modeling and simulation are widely used in social and physical sciences, engineering, manufacturing, and product development, among many other fields [7]. An accurate mathematical model of the dynamics of missile flying must identify and account for major influences even when ignoring the less important ones. Equation of motion serves as the basis of modeling that describes the translational movement and missile rotation (three degrees of freedom, 3DoF).

E. Dynamics of Missile Flying

Mastery of the dynamics of missile flying is needed to determine the characteristics of the missile. This flight dynamics is represented as a mathematical model in the form of equation of motion (EOM) with six degrees of freedom (six degrees of freedom - 6DoF) in the time domain. Equation of motion has a very important role in the development of a vehicle, because through this equation of motion can be known physical characteristics in the analysis of flight parameters. The relationship of the equation of motion with other flight parameters is illustrated in figure 5. In this initial design phase, the formulation of flight dynamics and flight guidance is carried out with the assumption of mass point points (point mass dynamics) in the

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context of proof of concept. The dynamics of missile flying based on guidance to the direction and motion of the vector from the target.

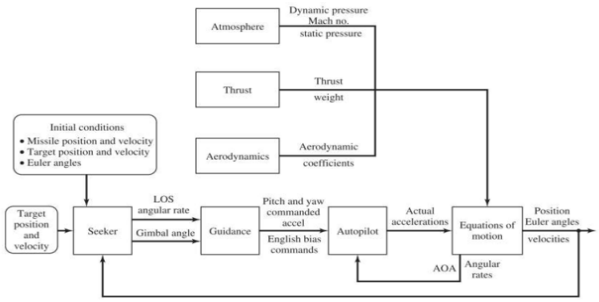

Figure 4. Data flow equation of missile motion

The engagement geometry between missiles and air targets can be expressed in 2-dimensional cartesian coordinates. With the mass point flying dynamics approach, the missiles in positions (xM, yM) that move at constant speed (VM, VM) to the target position (xT, yT) that move at constant speed (VT, VT). Changes in missile trajectories are generated by acceleration or aM guidance commands and changes can be observed through the angle M missile crossing angle. The relationship between missiles and targets is expressed by the distance parameter RTM and the line-of-sight (LOS) σTM. Equation of Motion in this study, both for missiles and targets, is assumed to be a mass point expressed in an inertial coordinate system. In this mass point analysis, the forces that affect the missile are propulsion and gravity. This equation of motion is derived from Newton's Law II.

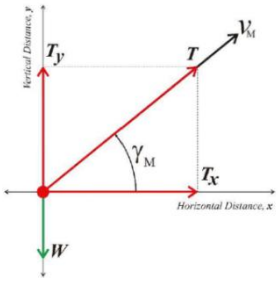

Figure 5. Equilibrium of forces in missiles.

The total amount of force F acting on the missile based on Newton's Law II is expressed as the product of mass antara and acceleration $\boldsymbol{a}$ follows:

$$\sum \mathrm{F} = \mathrm{m}\,\boldsymbol{a} \tag{2.1}$$

By deriving equation (2.1) based on the force equilibrium in figure 5, the equation of missile motion for the two components of acceleration in the Cartesian coordinates can be expressed [illegible] (2.2) following equation:

$$\boldsymbol{a}_x = \frac{T\,\cos\gamma}{\mathrm{m}} \tag{2.3}$$

$$\boldsymbol{a}_y = \frac{T\,\sin\gamma - \mathrm{mg}}{\mathrm{m}}$$

Where g is the gravitational acceleration constant with a value of 9.8 m/s^2. Furthermore, the acceleration and velocity parameters can be known through one and two integration of equation (2.2), respectively. Integration solutions are generated through ordinary differential equation (ODE) solutions using the Rungge-Kutta (RK4) method [13].

III. RESEARCH METHODOLOGY

In this study using the literature study method in which the data obtained is processed and then the problem formulation is carried out and linked to the needs of Indonesia for missiles and solving problems in the form of suggestions in order to become a design literature that can be applied in the future. Literature study is research that is only based on written works, including research results that have been or have not been published [4]. Although it is a research, research with literature study does not have to go to the field and meet with respondents. The data needed in research can be obtained from library sources or documents. In library research, library research is not only for the initial steps of preparing a research framework but also utilizing library resources to obtain research data [14].

IV.DETERMINATION OF MODELLING AND SIMULATION

In making the dynamics of rocket flying basically consists of 5 parts, namely the characteristics of the rocket, flight conditions, control and navigation systems, completion of

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equations of motion, and visualization of motion. The first part is determining the characteristics of rocket geometry, rocket dynamics or inertia and rocket aerodynamics that are usually given in stability derivatives such as CI, Cd, Cm and so on. Determination of aerodynamic characteristics is done using CFD such as Autodesk Airflow and Experimental in wind tunnels and flight tests. After the rocket characteristics are obtained, and the flying conditions and the control and navigation system are determined, all of them become input for the settlement unit of the rocket motion equation, which can be represented both in 3 degrees of freedom (3DoF). The software used is MATLAB to resolve nonlinear differential equations on the basis of the Runga-Kutta method. The last part is the visualization of the results of the rocket motion which is model using the Simulink 3DoF animation block in the Aerospace blockset [2]. The dynamics of rocket flying are basically moving in a ballistic manner and will lead to stationary targets.

V. SOFTWARE INSTRUMENTS

Research instrument is a tool used to collect data or information that is useful to answer research problems. This tool must be selected according to the type of data desired in the study. The instrument functions as a tool at the time of research using a method. The instrument can also be defined as a tool that meets academic requirements, so that it can be used as a tool to measure a measuring object or collect data about a variable. Research instruments are tools that are chosen and used by researchers in conducting their activities to collect data so that these activities become systematic and made easier by them [1]. In the research process later, researchers suggest the use of relevant software to produce graphs and sketches of defense missiles in order to determine the shape, dynamics of flying and dimensions of defense missiles. Below is the software used by researchers to obtain research results:

A. MATLAB Software

MATLAB is short for Matrix Laboratory because every data in MATLAB uses a matrix basis. MATLAB is a high, closed, and case sensitive programming language in a numerical computing environment developed by MathWorks.

B. MATLAB Simulink

Simulink is a superior feature available on MATLAB which distinguishes MATLAB from other matrix-based applications such as FreeMat. Simulink is a facility contained in MATLAB which is used as a simulation of various models, starting from signal processing to image processing. With Simulink researchers can make block diagrams based on the system to be made. This simulation serves to reduce the risk of failure of the system to be made. It also can do an earlier analysis of the system to be made. In figure 7 and figure 8 results can be seen in the form of graphics and 2D surface-to-air missile animations produced by MATLAB Simulink software.

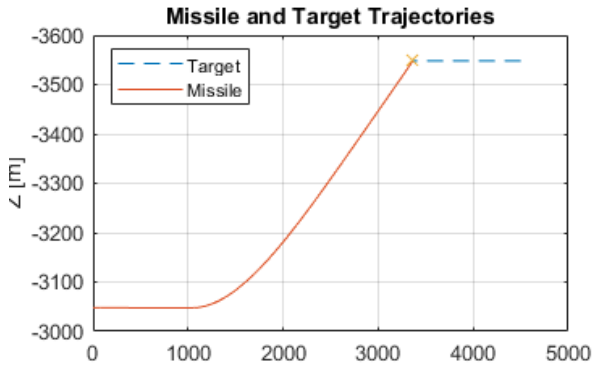

Figure 6. Surface-to-Air Missile Trajectory.

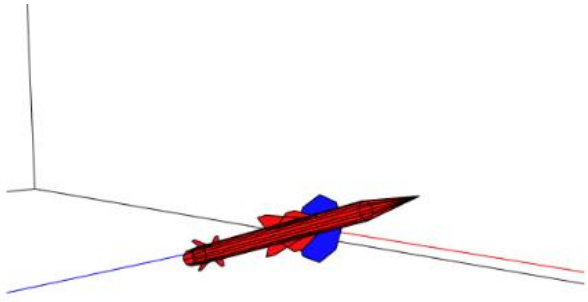

Figure 7. 2D Animation of Surface-to-Air Missiles

VI. CONCLUSION

A literature study that discusses how to do modeling and simulation on rocket affiliated

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missiles. It has been done and suggested that modeling and simulation be done on matlab software, especially on simulinkmatlab with input in the form of characteristics and aerodynamic coefficients input on the block diagram user interface. In the final stage the results will be obtained in the form of graphs and tables that illustrate the characteristics of optimal flight dynamics.

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