Izabela KRZYSZTOFIK

AUTOREFERAT
providing a description of scientific achievements

Annex No. 2

1. Name, Surname

Izabela Krzysztofik

2. Degrees:

Master of Science in Mechanical Engineering, specialism Mechanical Maintenance and Management, Faculty of Mechanical Engineering, Kielce University of Technology, 1996

Doctor of Philosophy in Mechanics, Faculty of Mechatronics and Mechanical Engineering, Kielce University of Technology, 2005. Ph.D. dissertation: „ Analysis of the interaction of weapons and gunner of light anti-aircraft missiles and small arms" supervised by professor Jan W. Osiecki

Postgraduate programmes in terms *Manager of commercialization and knowledge transfer*, Faculty of Management and Administration, Jan Kochanowski University, 2009

3. Employment:

Current workplace:

Kielce University of Technology
Faculty of Mechatronics and Mechanical Engineering (formerly Faculty of Mechanical Engineering)
Department of Applied Computer Science and Armament Engineering
Division of the Dynamics and Control of Mobile Systems
Al. Tysiąclecia Państwa Polskiego 7
25-314 Kielce

History of employment:

from 1.10.1996	assistant in Department of Internal Combustion Engines and Machines, Faculty of Mechatronics and Mechanical Engineering, Kielce University of Technology
from 1.11.1997	assistant w Department of Applied Computer Science and Armament Engineering, Faculty of Mechatronics and Mechanical Engineering, Kielce University of Technology
from 1.10.2005	to present adjunct (assistant professor) in Department of Applied Computer Science and Armament Engineering, Faculty of Mechatronics and Mechanical Engineering, Kielce University of Technology

4. Scientific achievement (according to art. 16 of the Act on Academic Degrees and Academic Title and Degrees and Title in Art of 14 March, 2003)

My scientific achievement within the meaning of art. 16 paragraph 2 of the Act on Academic Degrees and Title and on Degrees and Title in Art of 14 March, 2003, as amended, is a single-subject series of papers entitled:

"Problems of dynamics and control of systems for observation, scanning and tracking, placed on a moveable base"

The indicated single-subject series of papers consists of the following papers:

1. Dziopa Z., Krzysztofik I., Koruba Z., 2010, *An analysis of the dynamics of a launcher-missile on a moveable base*. Bulletin of the Polish Academy of Sciences – Technical Sciences, Vol. 58, No. 4, pp.645-650, ISSN 0239-7528, IF 0.945
2. Koruba Z., Krzysztofik I., Dziopa Z., 2010, *An analysis of the gyroscope dynamics of an anti-aircraft missile launched from a mobile platform*. Bulletin of the Polish Academy of Sciences – Technical Sciences, Vol. 58, No. 4, pp.651-656, ISSN 0239-7528, IF 0.945
3. Koruba Z., Dziopa Z., Krzysztofik I., 2010, *Dynamics and control of a gyroscope-stabilized platform in a self-propelled anti-aircraft system*. Journal of Theoretical and Applied Mechanics, Vol. 48, No. 1, pp.5-26, ISSN 1429-2955, IF 0.264
4. Koruba Z., Dziopa Z., Krzysztofik I., 2010, *Dynamics of a controlled anti-aircraft missile launcher mounted on a moveable base*. Journal of Theoretical and Applied Mechanics Vol. 48, No. 2, pp.279-295, ISSN 1429-2955, IF 0.264
5. Koruba Z., Krzysztofik I., 2013, *An algorithm for selecting optimal controls to determine the estimators of the coefficients of a mathematical model for the dynamics of a self-propelled anti-aircraft missile system*. Proceedings of the Institution of Mechanical Engineers, Part K: Journal of Multi-body Dynamics, Vol. 227, No. 1, pp.12-16, ISSN 1464-4193, IF 0.415
6. Krzysztofik I., Koruba Z., 2012, *Model of Dynamics and Control of Tracking-Searching Head, Palced on a Moving Object*. Journal of Automation and Information Sciences, Vol. 44, Issue 5, pp.38-47, ISSN 1064-2315, IF 0.038
7. Krzysztofik I., 2012, *The Dynamics of the Controlled Observation and Tracking Head Located on a Moving Vehicle*. Solid State Phenomena, Vol. 180, pp.313-322, Trans Tech Publications, Switzerland, ISSN 1012-0394

8. Krzysztofik I., Koruba Z., 2014, *Mathematical Model of Movement of the Observation and Tracking Head of an Unmanned Aerial Vehicle Performing Ground Target Search and Tracking*. Journal of Applied Mathematics, Vol. 2014, Article ID 934250, 11 pages, ISSN 1110-757X, IF 0.720
9. Gapinski D., Koruba Z., Krzysztofik I., 2014, *The model of dynamics and control of modified optical scanning seeker in anti-aircraft rocket missile*. Mechanical Systems and Signal Processing, Vol. 45, Issue 2, pp.433-447, IF 2.256
10. Gapiński D., Krzysztofik I., Koruba Z., 2014, *Analysis of the dynamics and control of the modified optical target seeker used in anti-aircraft rocket missiles*. Journal of Theoretical and Applied Mechanics, Vol. 52, No. 3, pp.629-639, IF 0.636
11. Krzysztofik I., Dziopa Z., Koruba Z., 2016, *The dynamics and control of a self-propelled anti-aircraft missile system with a gyroscope system for observation, scanning and tracking* (*Dynamika i sterowanie samobieżnego przeciwlotniczego zestawu rakietowego z giroskopowym układem obserwacyjnym, skanującym i śledzącym*). Monografie, Studia, Rozprawy M74, Politechnika Świętokrzyska, Kielce, s.267, PL ISSN 1897-2691

The above mentioned series of papers was sorted chronologically in the order of creation of the individual studies.

Discussion of the scientific aim of the above mentioned works and the results achieved:

Conducted research issues relate to problems of dynamics and control of anti-aircraft systems, with special emphasis on surveillance systems installed in armed modules and tracking head used in anti-aircraft missiles.

Armed conflicts of recent years have shown the importance of air defence, including the anti-aircraft defence on the battlefield. The task of anti-aircraft defence is to provide support to military units for their own activities, in the hazardous air conditions.

The technological development of missiles caused that the demands for modern anti-aircraft defence systems are getting bigger. Transmission and analysis of data from the battlefield and command of anti-aircraft defence should take minimum amount of time. Therefore, many armies are increasingly equipped with self-propelled anti-aircraft missile systems. Self-propelled systems provide defence and high mobility of military units, automating the process of detection and tracking of air targets and operational reliability in all weather conditions. They allow for a quick change of the current position. Small sizes of system enable air transport and airdrop in the target area.

Well-known, produced in the world, self-propelled rocket systems with short-range missiles include:

- SANTAL and ASPIC systems with *Mistral* missiles, developed by the French company Matra BAE Dynamics (now MBDA). SANTAL system is completely autonomous. It is equipped with six launchers and a device to detect and track air targets. A system is usually mounted on the chassis of the French three-axle armored vehicle VAB. There are also available versions that are mounted on the chassis of the Swiss conveyor Piranha, a French armored vehicle Panhard and on tracked vehicle M113. It is designed to protect troops of armored and mechanized armies against air attacks from small heights and attacks carried out by helicopters. For the purposes of the armies there was also developed a system of Mistral ASPIC, equipped with four launchers and optoelectronic sighting device, mounted on a light off-road vehicle.
- Starburst VML system (Vehicle Multiple Launcher) developed by Thales Air Defence Limited company (formerly Shorts Missile Systems Ltd) for the needs of the armed forces of the United Kingdom and for export, among others, to Canada, Kuwait and Malaysia. This system belongs to very short-range systems of VSHORAD class (Very Short Range Air Defence). It is equipped with eight launchers of *Starburst* missiles and mounted on the chassis of the light type vehicle like Land Rover.
- Starstreak SP HVM set (Self-Propelled High Velocity Missile), also produced by Thales Air Defence Ltd. The system is mounted on the tracked vehicle Alvis Stomer. It is equipped with twelve *Starstreak* missiles and a device to alert the air defence ADAD (Air Defence Alerting Device) provided by Thales Optronics, which provides the automatic detection and selection of the target in all weather conditions. However, the use of ADAD equipment requires the vehicle to stop briefly. Another version of the system is a Starstreak LML (Lightweight Multiple Launcher). It is a lightweight launcher containing three *Starstreak* missiles, able to be mounted on a light wheeled vehicle, such as Land Rover or multi-purpose vehicle HMMWV (High Mobility Multi-Purpose Wheeled Vehicle). These systems have been developed to counter air attacks from small heights and attacks carried out by helicopters.
- AVENGER system with *Stinger* missiles, developed and manufactured by Boeing Aerospace, currently used by the Army and Marine Corps of the United States. The system consists of a rotary, gyro-stabilized turret, mounted on a HMMWV multi-purpose vehicle. The turret has two launchers with eight *Stinger RMP* missiles. Also,

the system is equipped with a highly automated fire control system, an optical viewfinder, a FLIR sensor, laser rangefinder and can carry out its tasks in all weather conditions. AVENGER system provides mobile protection of ground units against maneuver missiles, unmanned aerial vehicles, low flying planes and helicopters.

- ASRAD system (Atlas Short Range Air Defence) developed for the German Army by ATLAS Elektronik GmbH, mounted on a tracked chassis Wiesel 2. Rotating turret is equipped with an IR/TV camera and laser rangefinder and is adapted for mounting of the following missiles type: Stinger, Igła 1, Mistral, Starstreak or RBS 70.
- RBS 70 system manufactured by Bofors for the Swedish armed forces, but also exported to 18 countries of the world including the Czech Republic, Germany, Finland, Australia, Brazil, Lithuania. The most famous version of the mobile system includes RBS 70 VLM (Vehicle Launched Missile) mounted on the tracked vehicle and RBS 70/VCR-AA installed on an armored vehicle Panhard VCR-AA. The system has been constantly modernized and the current version of the RBS 70 NG (New Generation) is equipped with an automatic control and aiming system, thermal camera and a new *Bolide* missile.

Given the trends and, above all, the necessity of building modern, automated defence systems, equipped with anti-aircraft short range missiles, also the Polish company PIT-RADWAR developed self-propelled anti-aircraft missile system Poprad (SAMS Poprad), equipped with missiles *Grom*. In December 2015, the Ministry of Defence signed an agreement with PIT-RADWAR, under which our army will receive seventy seven SAMS Poprad. Moreover, the company will modernize the two systems already belong to Polish army. The agreement will be implemented for four years from 2018.

Poprad is very short range anti-aircraft system and enables the detection and destruction of air targets located at low altitudes from 10 m to 3.5 km and in close distances from 500 m to 5.5 km. The main element of the system is the tracking-aiming head, which includes IR camera, daylight camera, laser rangefinder and videotracker. In addition, a system has four launchers of *Grom* missiles, identification device "IFF" and fire control, navigation and orientation systems. The use of the system requires two people, i.e. a driver and operator.

The presented construction of self-propelled anti-aircraft missile systems attest to the growing need to use this type of systems on the battlefield, and hence, the need for the production of sets of this type. Systems will be subject to constant modifications and in a presented series of papers, one can find valuable tips to improve the construction, e.g. the possibility of firing while moving the set over uneven terrain.

The basic tasks of self-propelled anti-aircraft missile system are performed by armed module. The most important elements of the module are optoelectronic, observation and tracking head, missile launcher and short range anti-aircraft missiles. An important element of the action of the system is to detect and track the detected air target, already in the process of movement of the vehicle on which the armed module is placed. Observation and tracking head allows the combat vehicle crew to make preliminary, effective recognition and to determine the location of targets for destruction. This head and the heads of homing missiles are influenced by external disturbances coming from the vehicle movement over uneven terrain and the movement of the missile on guide rail of the launcher. Thus, in the observation and tracking heads there is used a stabilizing system, which isolates the head from the vibration of base on which it is located. In addition, in order to ensure the mobility of the system, one should provide the system of space scanning in the heads of homing missile. This makes it possible to intercept the target even after firing a missile in the area of the target's likely stay.

In the anti-aircraft system, we can identify the interacting systems:

– searching and observation system in the optoelectronic observation and tracking head,
– a launcher control system, which task is to direct the missile into the area of the target's likely stay,
– scanning and tracking system of the homing head (seeker) of missile, in which a drive is a mechanical gyroscope,
– autopilot control system implementing the flight path of the missile.

There is a need to examine the resistance of the control system of observation and tracking head and homing missile system to the activities of kinematic force coming from overcoming the terrain obstacles by the vehicle. An important task is the optimum suppression of transient processes. Transient processes occur in the event of a vehicle colliding with terrain obstacle, at the time of switching of gyroscope control system from seeking state to tracking state of the detected air target and on the time of launching of missile control system when it detects the target. These are very complex issues, requiring extensive research and collaboration of research teams.

Furthermore, the proper dynamics of anti-aircraft missile system may help to increase its mobility and effectiveness on the battlefield. It is therefore necessary to choose appropriately the dynamic parameters of individual objects included in the self-propelled anti-aircraft missile system, and control systems, in order to, independently of external disturbances, be able to conduct the process of finding and tracking of the detected aim stably and reliably.

The aim of this series of papers is to carry out theoretical research and comprehensive analysis of the dynamics of anti-aircraft missile system taking into account capabilities of firing missiles during the movement of the vehicle on which the armed module is placed. Accordingly, the following operations should be conducted:

- formulate models of components of the system, i.e. movement model of vehicle, movement model of missiles launcher, model of dynamics of the controlled observation and tracking head, along with the model of the dynamics of the controlled scanning and tracking gyroscope and movement of missile;
- develop appropriate control algorithms;
- carry out studies of the dynamics of the system.

Therefore, in the present series of papers there are included appropriate considerations and theoretical, simulation and experimental analyzes.

My studies were commenced by participating in a research project of MNiSW No. O N514 001 on *The development of a methodology for research and analysis of the movement of self-propelled anti-aircraft missile system (Opracowanie metodologii badań i analiza ruchu samobieżnego przeciwlotniczego zestawu rakietowego)*, realized in Kielce University of Technology.

Considerations included in articles [1] and [2] focused on the development of the physical model and mathematical system consisting of a launcher and missile with gyroscope coordinator, and then conducting numerical analysis of the behavior of a missile set in terms of shooting a moving air target while moving set over uneven terrain.

In the article [1] there is presented a physical and mathematical model of the set of launcher-missile, of four degrees of freedom: y_v – vertical displacement of the center of mass of the turret, ϑ_v – the angle of inclination of the turret, φ_v – the angle of tilt of the turret and ξ_{pv} – straightline displacement of the center of mass of missile along the guide rail. My contribution to this work involved the development of a numerical model of the system and then performing numerical analysis of system dynamics during launching the missile and development of research results. In the article [2], there are shown the equations of motion of controlled gyroscope. Gyroscope is a drive of optoelectronic target coordinator for homing missile placed in the guide rail of the launcher. Location of gyroscope axis in space are determined by angles: ϑ_g, ψ_g – respectively, the angle of inclination and deflection of axis. Kinematic impact caused by the movement of the vehicle over uneven ground and move of missile along the guide rail cause the force of gyroscope through friction in the bearings of his frames. Since it is not possible to completely eliminate friction, therefore, jerky movements of the launcher affect the accuracy of the desired position of axis of gyroscope in space. The greater the value of the coefficient of friction in the bearings of frames, the more visible will be the drifts of gyroscope axis. In order to prevent this undesirable phenomenon, corrective control torque should be applied to the frame of gyroscope. It was proposed to use skew PD regulator. In my the part of the article, I have made a numerical analysis of the kinematic impact on the dynamics of both launcher and gyroscope. Presented in articles [1] and [2] results of studies show that bumping of the vehicle on a obstacle like "bump" and move of the missile along the guide rail of launcher adversely affect the maintenance of the axis of the gyroscope in the desired position, i.e. target tracking. The use of correction torques minimizes the movement of gyroscope axis from the specified position. Gyroscope becomes more resistant to the harmful kinematic impact of launchers as well as the movement of missile on the guide rail of the same launcher. Graduated gyroscope axis deviation from the desired position could lead to "losing" of the tracked target from the field of view of missile seeker's lens. The results confirm the correctness of the algorithm of gyroscope motion correction under active interference on the part of the launcher and missile.

The article [3] presents a concept of introduction on the pedestal of self-propelled anti-aircraft missile system an additional three-axis gyro platform, which allows isolation of the launcher from angular movements of the motor vehicle. A simplified model of motion of controlled, three-axis platform equipped with two three-degree gyroscopes was presented. Pre-programmed control of platform was carried out in an open system, and the correction control (stabilizing) was determined using the method of linear-quadratic optimization LQR. In the rest of the work contributed by me, I have presented the results of simulation studies of the behavior of the gyro platform. If the parameters of regulators are not chosen optimally, the platform after the appearance of interference over a relatively long period of time is in the process of transition. For the parameters chosen optimally, platform very quickly returns to its original position. Corrective controls clearly weaken the impact of the base on the platform. Also in the course of program moving one can see the difference in the work of the platform, depending on the control parameters. For optimized parameters, the platform very quickly and with great accuracy begins to implement the specified movement. Such a platform can be used as a stable base for the searching and tracking equipment.

In the article [4] there is presented the physical and mathematical model of the controlled antiaircraft missile launcher placed on a moveable base. Model of the launcher with missile has six degrees of freedom: y_v – vertical displacement of the center of mass of the turret, ϑ_v – the angle of inclination of the turret, φ_v – the angle of tilt of the turret ξ_{pv} – straightline displacement of the center of mass of missile along the guide rail, ψ_{pv} – the angle of deflection of the turret and ϑ_{pv} – the angle of inclination of the guide rail. My excessive contribution to this work included the preparation of complex dynamical equations of motion of the launcher and development of the numerical model. Moreover, a following concept of launcher control was created: to the launcher there are applied pre-programmed control that causes the rotation of the turret by an angle of ψ_{pv} and the guide rail of the angle of ϑ_{pv}, and thus set the longitudinal axis of the guide rail at a specific location in space. Vehicle movement over uneven terrain, the missile launching and the same controlled motion of the launcher cause adverse vibrations of the launcher. So, to keep the launcher in a given position regardless of the movements of the base and operating external interferences, it should be used in the system of automatic regulation of the launcher stabilizing control. Later in the study we investigated the behavior of the launcher after moving of a vehicle on a single bump with and without using the correction in the system of automatic control and operation of software control systems for different coefficients of the control system. The results showed that in order to avoid the negative transition process occurring at the moment of passing of the launcher over the "bump", the correction control should be used. Optimal selection of reinforcement and suppression coefficients in the control system of the launcher effectively reduces harmful vibrations caused by pre-programmed control.

The subject of the article [5] is devoted to the algorithm of selection of the optimal control impacts to determine coefficients estimators of dynamics model of missiles. Currently, it is desired to capture low-flying, maneuvering air targets not only in all weather conditions, but also when the vehicle is moving over uneven terrain. This requires the selection of such a system of stabilization and control of a missile set, that the process of target finding and tracking could occur reliably with these adverse conditions. In the work there is proposed a method of solving the problem of parametric identification of the launcher model using the optimal plan of the experiment. This is done using the least squares method with simultaneous selection of such control interactions on the object of study in order to obtain the maximum value of the determinant of the information Fisher matrix (D-optimality criterion). My contribution to this work was a preparation of the linearized model of motion of missile launchers and development of a plan for the experiment. In the final part of the work there are mentioned the comparative test results of the launcher subjected to random interference, using the control interaction with the use of D-optimality criterion and optimal LQR control. The conducted considerations suggest that the planning of D-optimal experimental identifications using the optimal control signal increases the accuracy and stability of the estimators of the coefficients of the model and enables the detection of changes in the structure and parameters of the launcher.

The conduction of described above studies of the dynamics of self-propelled anti-aircraft missile system constituted an introduction to the works of the observation and tracking heads.

The head is a technologically advanced, multi-sensor optoelectronic system including TV camera and/or infrared camera, and safe for the eye rangefinder and laser pointer. Image stability is provided by electro-mechanical gyro stability system. It is also often equipped with a navigation system GPS/IMU, so it can set and display the geographical location of the target. The head performs angular movements in the vertical plane in the typical range of 90 degrees and in the horizontal plane in the range of $n \times 360^0$. In the process of searching for an air target, the head performs specified program motion, and upon detection, it automatically switches to the state of the target tracking. Optoelectronic heads are designed for use in systems of detection, identification and observation of ground and air targets and in daylight and at night. There is known the usability of this type of heads in unmanned flying cameras and surface platforms. In many cases, heads carry out their tasks under the effect of vibration and high interference from the deck on which they are located. The problem of the stable tracking of the detected moving target in terms of the kinematic interaction of the ground is still present.

Developed general model of a following observation and tracking head, which is my original achievement, was used for the tests described in [6,7,8,11].

In the article [6] I have presented a mathematical model of observation and tracking head situated on the deck of a moving object and the concept of controlling the head. I marked programmed controls using the inverse dynamics. Corrective and tracking controls were carried out in a control closed system, in which there was used a PID controller. The amplification coefficients in the control system for both correction and tracking are selected as optimal, due to the minimum of mean square error between the predetermined and realized angular positions of the axis of the head. In the further part of the work I have conducted a simulation study of the impact of kinematic forcing on work of the head, both controlled and not controlled, and have presented its results. Kinematic forcing was adopted in the harmonic form. In the article [7], I have examined the behavior of the observation and tracking head located on the vehicle, when the vehicle runs into the "bump" with the front wheels and wheels on the left side of the vehicle. Studies carried out in articles [6,7] have shown that the kinematic forcing that act on the head from the side of the vehicle causes substantial deflection of its axis, which can contribute to losing of the target by the optical system. In addition, the head is influenced by the nonlinearity of the head movement, the friction in the bearing of the head and a technological inaccuracies. The target tracking errors are caused mainly by shifting the center of rotation to the center of mass of the head. Thus, to enter the head on a given path, one must also use stabilizing control in a closed system. The proposed control system of the head allows to set it quickly along the line of target monitoring, and optimized control parameters ensure minimizing of the dynamic effects and the fastest attenuation of transient processes.

In turn, the subject of the article [8] focuses on the use of the monitoring-tracking head on the deck of an unmanned aerial vehicle. There is presented the kinematics of mutual motion of unmanned aerial vehicle and the ground target. The device that implements the observation of the area, the search for ground target and its tracking is the controlled observation and tracking head. My big contribution to this work involved the development of a model of dynamics and control laws of the head placed on board an unmanned aerial vehicle. I have conducted a study of dynamics and control system of the head during the searching and tracking of the ground target from the deck of an unmanned flying apparatus. I have taken into account the impact of kinematic forcing and parameters controllers were chosen in an optimal way because of the minimum deviation between the desired and conducted track. The study shows that the vibration of deck of aerial vehicle adversely affect the work of the head. In the case of non-optimal selection of parameters of the controller of head axis, deviation from the predetermined position are particularly visible. For the optimized parameters there are relatively small values of angles of the head axis deviations from the nominal location. Control moments take small value.

Chapter 2 of the monograph [11] is a comprehensive summary of my research on behavior of controlled observation and tracking head placed on a deck a self-propelled missile system. I have made a review of the observation and tracking heads designed for self-propelled missile systems. I have proposed the equations of dynamics and head control algorithms. I have focused on the presentation of the fuzzy PD controller to control head in the programmed and tracking movement. In addition, I have made the analysis of the dynamics of the controlled observation and tracking head, under the influence of interference from the deck of the vehicle, using the classical PID controller and fuzzy PD controller.

Another important issue in my research were studies on the new optical scanning seeker of designed for use in anti-aircraft homing missiles [9,10]. The construction of this seeker is described in the patent PL 199721 B1 by a doctoral student, for whom I was an auxiliary supervisor (Section. 6.7).

In the article [9] there was presented in detail the construction and type of operation of designed scanning seeker and its advantages in relation to this type of devices. There were developed the control right for seeker axis and foremost the mathematical model of movement, which is my contribution to this work. There were carried out the numerical studies of dynamics and control of seeker axis, with the concurrent influence of external interference from the part of homing missile. In the article [10] I have developed the concept of control of seeker axis during the execution of the programmed movement, taking into account the process of scanning of the airspace through the optoelectronic system of the devices. There was carried out a series of numerical tests and analyzes of the selection of the appropriate speed and trajectory of seeker axis movement. The results in the articles [9,10] showed the correctness of construction assumptions of developed scanning seeker of anti-aircraft missile and its technical ability to implement. Occurrence of large accelerations of the base causes a small, thousandths of a degree, deviation of seeker axis from the pre-set position. Programmed control of the axis seeker in the search phase of airspace runs with sufficient precision and requires small values of control moments. It is possible to detect targets moving at high speed of 280 m/s.

The monograph [11] is devoted to the problems related to the dynamics and control of short-range anti-aircraft missile systems. It draws attention to the fact that an important element of today rocket systems is detection and tracking of detected air target, when the vehicle on which the launcher is located moves. Vehicle movement over uneven terrain, as well as missile motion along the guide rail, however, generate disturbances that adversely affect the observation and tracking systems. The study has formulated a mathematical and physical model of a movement of self-propelled anti-aircraft missiles system, which consists of the following models of its individual elements:

- a model of motion of the controlled missile launcher;
- a model of motion of the vehicle and excitations affecting it;
- a model of the dynamics and control of the head for observation and tracking;
- a model of motion of a homing missile;
- a model of the dynamics of the controlled gyroscope for scanning and tracking.

Numerical analysis were presented:

- movement of the launcher and missile system;
- movement of launcher and gyroscope located on it;
- target attack from a moveable launcher;
- movement and control of the observation and tracking head.

In addition, there were presented the results of polygon experimental research of the system. My big contribution to this work involved the development of Chapter 2, Subsection 4.6 and Chapter 5. In Chapter 2, I have included the findings of the study of modeling of the dynamics of controlled observation and tracking head contained in a self-propelled anti-aircraft missile system. In Subsection 4.6 I have made a numerical analysis of the process of finding, tracking and attacking of the air target by a homing missile fired from a mobile controlled launcher situated on a motor vehicle. In addition, I have developed results of polygon experimental research of missile set forth in Chapter 5.

Summing up, presented in the monograph theoretical, simulation and experimental studies have confirmed the correctness of formulated set of models. There was presented a research methodology of self-propelled systems. There were discovered the properties of the behavior of the system components. It was determined the level of interference caused by the start of the missile and the movement of the vehicle over uneven terrain.

The monograph results provide the designers with tools for effective analysis of physical phenomena accompanying the operation of a self-propelled anti-aircraft missile system with short-range missiles, considerations contained in a monograph will also allow to interpret the phenomena that may affect the lack of effectiveness of the system in combat. It should be noted that the use of formulated in the monograph movement model of the system can facilitate both the process and reduce design time and time to test the product prototype. The monograph is intended, therefore, for the constructors of weapons of a similar type, and for young researchers, especially doctoral students.

In my view, presented results of the research show that the subject matter raised in the above series of papers is up to date and has an utilitarian importance. Moreover, they can broaden knowledge in the field of dynamics and control of observation, scanning and tracking systems placed on a mobile basis.

5. Discussion of other scientific and research achievements

After undertaking a job at the Technical University of Kielce my research interests focused on issues related to armament technology. I obtained a PhD degree in April 2005. The theme of the doctoral thesis was the *Analysis of the interaction of weapons and shooter of light anti-aircraft missiles and small arms* (*Analiza współoddziaływania broni i strzelca lekkich rakiet przeciwlotniczych i broni strzeleckiej*). The supervisor was prof. zw. dr. hab. inż. Jan W. Osiecki – scientific authority in arms technology, the reviewers were prof. dr. hab. inż. Krzysztof Kędzior, Warsaw University of Technology and dr hab. inż. Dariusz Janecki, Kielce University of Technology. In the study I have conducted a discussion of biomechanics of the shooter cooperating with the mechanical subsystem, that is a weapon. The shooter was not treated as a passive system which received the impact energy of weapons, but as the active system, who reacted to the weapon operation with his reflexes. There were researched two types of weapons. The first was a light anti-aircraft missile fired from the shoulder of the shooter (like "Strzała 2M", "Grom"), the second was a personal weapon (pistol). It was prepared a complex system of equations of dynamics and methodology of analysis. Based on the experimental data, there were determined the reactions of the shooter and the analysis of movements of the limbs and body. In addition, there were formulated relevant conclusions indicating the directions of training of novice shooter.

The result of my research was the realization of grant KBN No. 0 T00B 018 26 on *Analysis of the interaction of weapons and a shooter* (*Analiza współoddziaływania broni i strzelca*), for which I was the main contractor. I have presented the results of the research at national and international conferences and published them in journals listed in Annex No. 3.

After obtaining a doctoral degree I started research on the problems of dynamics and control of antiaircraft sets, especially monitoring and tracking systems. I have considered systems in which the drive is a classic gyro system and systems based on the latest accelerometers and gyroscopes. I have concentrated on modeling and analysis of the dynamic properties of the monitoring head used in manned and unmanned ground platforms and unmanned flying cameras. I have developed the theoretical basis of the functioning of the head on the deck of a moving object. I have analyzed the problem of stable tracking by the head of the moving target in terms of external forces on the part of the platform. Developed algorithms were used in the modeling of a modified optical scanning head of homing missiles.

The results of the research have been presented at national and international conferences and published in articles. This is also confirmed by participation in a research project NCBR No. O N501 282440 on *Development and analysis of the dynamics of control and stability system of the platform for observation, searching and tracking of ground targets from deck of an unmanned aerial vehicle* (*Opracowanie i analiza dynamiki układu sterowania i stabilizacji platformy do obserwacji, poszukiwania i śledzenia obiektów naziemnych z pokładu bezzałogowego aparatu latającego*).

Conducted experimental studies have contributed to the development of the patent:
Patent PL 216422 B1, *Strain gage to measure the two force components*. Creators: Izabela Krzysztofik, Adam Rozenau, Application date: 31.12.2010, the decision to grant a patent: 18.09.2013.

In the Table 1, I have set the number of papers by their type including a division of papers before and after obtaining a doctoral degree. Information about percentages for the papers of the co-authors after obtaining a doctorate are included in Annex No. 3.

Table 1. Summary of papers

Paper type	Number of papers		
	before doctoral	post doctoral	Total
Authorship or co-authorship of articles in list A	-	9	9
Authorship or co-authorship of articles in list B	-	16	16
Patents	-	1	1
Authorship or co-authorship of articles in other journals	7	14	21
Authorship or co-authorship of monographs	-	1	1
Authorship or co-authorship of textbooks	-	1	1
Authorship or co-authorship of papers in conference proceedings	12	24	36

5.1. Total *impact factor* of scientific papers according to Journal Citation Reports (JCR)

Total *impact factor* scientific papers according to publication year is **6.483**, the IF for the Journal of Applied Mathematics at the level of 2013 was taken into account.

5.2. Citations according to Web of Science (WoS)

Number of citations according to Web of Science is **42** (without self-citations 30).

5.3. Hirsch index according to Web of Science (WoS)

H-index according to Web of Science is **5**.

Table 2 presents the comparison of indicators of papers, number of citations and h-index according to various sources.

5.4. International and national research projects

After obtaining a doctoral degree, I managed a research project and was the contractor in two national research projects funded by the MNiSW and NCBR. Information about the project is presented in Table 2.

Table 2. Summary of participation in research projects

Project title	Participation
Research project MNiSW nr O N514 001534 „Optymalizacja procesu samonaprowadzania środka napadu powietrznego na elektroenergetyczną linię przesyłową wysokiego napięcia jako obiektu emitującego pole elektromagnetyczne niskiej częstotliwości", 2008-2010	contractor
Research project MNiSW nr O N514 001 „Opracowanie metodologii badań i analiza ruchu samobieżnego przeciwlotniczego zestawu rakietowego", 2007-2011	contractor
Research project NCBR nr O N501 282440 „Opracowanie i analiza dynamiki układu sterowania i stabilizacji platformy do obserwacji, poszukiwania i śledzenia obiektów naziemnych z pokładu bezzałogowego aparatu latającego", 2011-2015	leader

Before obtaining a doctoral degree, I was the main contractor of the grant KBN nr 0 T00B 018 26 „Analiza współoddziaływania broni i strzelca", 2004-2005.

5.5. International and national awards for research or artistic achievements:

- team award II degree of Rector of Kielce University of Technology for scientific activity and promoting of the university through scientific activity, 2002
- individual award of Rector of Kielce University of Technology for scientific activity, 2005
- team award I degree of Rector of Kielce University of Technology for papers in journals from the Philadelphia list and obtained patents, 2011
- team award II degree of Rector of Kielce University of Technology for papers in significant journals and journals from the Philadelphia list, 2012

5.6. Papers of international or national thematic conferences

The results of my research were presented at the 34 thematic conferences:

[1] III Międzynarodowa Konferencja Naukowo-Techniczna „Amunicja precyzyjnego rażenia oraz układy zabezpieczająco-wykonawacze i zasilające", 21-22 września 2000, Skarżysko-Kamienna

[2] III Międzynarodowa Konferencja Uzbrojeniowa „Naukowe aspekty techniki uzbrojenia", 11-13 października 2000, Waplewo

[3] V Konferencja Naukowa „Oprzyrządowanie techniczne działalności bojowej artylerii", 2001, Toruń

[4] VI Konferencja Naukowa „Oprzyrządowanie techniczne działalności bojowej artylerii", 2002, Toruń

[5] IV Międzynarodowa Konferencja Uzbrojeniowa „Naukowe aspekty techniki uzbrojenia", 9-11 października 2002, Waplewo

[6] V Międzynarodowa Konferencja Naukowo-Techniczna „CRAAS 2003", wrzesień 2003, Tarnów-Zakopane

[7] III Konferencja Naukowa „Kierowanie ogniem systemów obrony powietrznej (przeciwlotniczej)", 25-27 maja 2004, Koszalin-Wicko Morskie

[8] V Międzynarodowa Konferencja Uzbrojeniowa „Naukowe aspekty techniki uzbrojenia", 6-8 października 2004, Waplewo

[9] IV Konferencja Naukowa „Kierowanie ogniem systemów obrony powietrznej (przeciwlotniczej)", 27-29 września 2006, Koszalin-Ustka

[10] XI Krajowa Konferencja „Automatyzacja i eksploatacja systemów sterowania i łączności", 10-12 października 2007, Władysławowo-Cetniewo

[11] XII Konferencja Naukowo-Techniczna „Automatyzacja – Nowości i Perspektywy Automation 2008", 2-4 kwietnia 2008, Warszawa

[12] 3rd International Conference on Scientific Aspects of Unmanned Aerial Vehicle, 7-9 May 2008, Kielce-Cedzyna

[13] VI Międzynarodowa Konferencja „Perspektywy i rozwój systemów ratownictwa, bezpieczeństwa i obronności w XXI wieku", 25-27 czerwca 2008, Gdańsk

[14] VI Międzynarodowa Konferencja Uzbrojeniowa „Naukowe aspekty techniki uzbrojenia i bezpieczeństwa", 8-10 października 2008, Pułtusk

[15] XIII Konferencja Naukowo-Techniczna „Automatyzacja – Nowości i Perspektywy Automation 2009", 1-3 kwietnia 2009, Warszawa

[16] XVI International Conference On Automatic Control (Automatics-2009), 22-25 September 2009, Chernivci, Ukraine

[17] XII Konferencja Automatyzacji i eksploatacji systemów sterowania i łączności, 12-14 października 2009, Jurata

[18] 4th International Conference on Scientific Aspects of Unmanned Aerial Vehicle, 5-7 May 2010, Suchedniów

[19] XIV Konferencja „Mechanika w Lotnictwie" ML-XIV 2010, 24-27 maja 2010, Kazimierz Dolny

[20] VI Konferencja Awioniki, 16-18 września 2010, Bezmiechowa

[21] VI Konferencja Naukowa „Kierowanie ogniem systemów obrony powietrznej (przeciwlotniczej)”, 21-23 września 2010, Ustka

[22] VIII Międzynarodowa Konferencja Uzbrojeniowa „Naukowe aspekty techniki uzbrojenia i bezpieczeństwa”, 6-8 października 2010, Pułtusk

[23] XVIII International Conference On Automatic Control (Automatics-2011), 28-30 September 2011, Lviv, Ukraine

[24] XIII Konferencja Automatyzacji i eksploatacji systemów sterowania i łączności ASMOR 2011, 12-14 października 2011, Jastrzębia Góra

[25] XV Konferencja „Mechanika w Lotnictwie” ML-XV 2012, 28-31 maja 2012, Kazimierz Dolny

[26] IX Międzynarodowa Konferencja Uzbrojeniowa „Naukowe aspekty techniki uzbrojenia i bezpieczeństwa”, 25-28 września 2012, Pułtusk

[27] XIX International Conference On Automatic Control (Automatics-2012), 26-28 September 2012, Kyiv, Ukraine

[28] 5th International Conference on Scientific Aspects of Unmanned Mobile Objects, 15-17 May 2013, Dęblin

[29] VIII Konferencja Naukowo-Techniczna „Kierowanie ogniem systemów obrony powietrznej (przeciwlotniczej) KOSOP 2014”, 13-16 maja 2014, Ustka

[30] XVI Konferencja „Mechanika w Lotnictwie” ML-XVI 2014, 26-29 maja 2014, Kazimierz Dolny

[31] 15th International Carpathian Control Conference (ICCC), 28-30 May 2014, Velke Karlovice, Czech Republic

[32] X Międzynarodowa Konferencja Uzbrojeniowa „Naukowe aspekty techniki uzbrojenia i bezpieczeństwa”, 15-18 września 2014, Ryn

[33] XV Konferencja Automatyzacji i eksploatacji systemów sterowania i łączności, 7-9 października 2015, Władysławowo

[34] 22nd International Conference Engineering Mechanics 2016, 9-12 May 2016, Svratka, Czech Republic

6. The achievements in the fields of education and popularization of science

6.1. Participation in the international or national scientific conferences or participation in the Organizing Committee of this conferences

[1] My considerations, analysis, and results of research were presented at the thematic conferences listed in point. 5.6 and at the scientific conferences listed in Annex No. 3, Section III.B.

[2] Secretary of Organizing Committee, 1st International Conference on Scientific Aspects of Unmanned Aerial Vehicle, 19-21 May 2004, Kielce-Cedzyna.

[3] Secretary of Organizing Committee, 2nd International Conference on Scientific Aspects of Unmanned Aerial Vehicle, 10-12 maja 2006, Kielce-Cedzyna.

[4] Secretary of Organizing Committee, 3rd International Conference on Scientific Aspects of Unmanned Aerial Vehicle, 7-9 May 2008, Kielce-Cedzyna.

[5] Secretary of Organizing Committee, 4th International Conference on Scientific Aspects of Unmanned Aerial Vehicle, 5-7 May 2010, Suchedniów.

[6] Secretary of Organizing Committee, 5th International Conference on Scientific Aspects of Unmanned Mobile Objects, 15-17 May 2013, Dęblin.

[7] Member of Organizing Committee, I Kongres Lotniczy i Kosmonautyczny, 22-24 czerwca 2016, Rzeszów.

[8] Chairman of session, IV Konferencja Naukowa „Kierowanie ogniem systemów obrony powietrznej (przeciwlotniczej)", 27-29 września 2006, Koszalin-Ustka.

[9] Chairman of session, XII Konferencja „Automatyzacja i eksploatacja systemów sterowania i łączności", 12-14 października 2009, Jurata.

[10] Chairman of session, XV Konferencja „Mechanika w Lotnictwie", 28-31 maja 2012, Kazimierz Dolny.

[11] Chairman of session, 5th International Conference on Scientific Aspects of Unmanned Mobile Objects, 15-17 May 2013, Dęblin.

[12] Member of Scientific Committee, IX Konferencja Naukowa „Kierowanie ogniem systemów obrony powietrznej (przeciwlotniczej)", 22-24 czerwca 2016, Ustka.

6.2. Prizes and awards

- Medal Brązowy za Długoletnią Służbę, 15.09.2009
- team award III degree of Rector of Kielce University of Technology for organizational activity for the faculty, 2004
- team award II degree of Rector of Kielce University of Technology for organization of the conference, 2008
- team award II degree of Rector of Kielce University of Technology for organizational and educational activity for the faculty, 2010

6.3. Participation in the Editorial Boards and Scientific Committees of journals

[1] member of Editorial Board of monograph: *Scientific Aspects of Unmanned Mobile Vehicle*, edited scientific by Zbigniew Koruba, Polish Society of Theoretical and Applied Mechanics Section of Kielce, Kielce 2010, p.605;

[2] scientific editor of monograph: *Scientific aspects of unmanned mobile objects,* edited scientific by Zbigniew Koruba, Izabela Krzysztofik and Konrad Stefański, Monografie, Studia, Rozprawy M60, Politechnika Świętokrzyska, Kielce 2014, p.175.

6.4. Participation in international and national scientific organizations and societies

From 2009 member of Polish Society of Theoretical and Applied Mechanics and collector Section of Kielce

6.5. Achievements in the fields of education and popularization of science

[1] The teaching of major and specialization courses, for full-time and part-time in the fields of *mechanical engineering, safety engineering* and *transport*, listed in detail in Annex No. 3, in Section I.

[2] Tutor of student group, 2002-2011.

[3] Proxy for the quality of education in the field of safety engineering, 2011-2012.

[4] Coordinator of the following courses (also, I have elaborated the syllabuses)

- Mechatronic systems for detection and tracking of targets (lecture, laboratory) – first cycle programmes in the field of mechanical engineering
- Basis of mechatronic systems in armament (lecture, laboratory) – first cycle programmes in the field of mechanical engineering
- Detection and cracking of targets (lecture, class, laboratory) – second cycle programmes in the field of mechanical engineering
- Automatic control of the observation and tracking systems (lecture, laboratory) – first cycle programmes in the field of automation and robotics
- Gyroscopic mechatronics systems (lecture, class, project) – second cycle programmes in the field of automation and robotics

[5] Textbook: Krzysztofik I., Osiecki J. W., *Wykrywanie i śledzenie celów*. Skrypt Nr 430, Politechnika Świętokrzyska, Kielce 2008, s.216.

[6] I have built two laboratory stand for testing of the optical systems of a seeker and I have elaborated instructions.

[7] I have elaborated instructions on operating Mathcad 13 and Delphi to laboratory of Fundamentals of Computer Science and Information Technology.

6.6. Scientific assistance for students

Supervisor of 7 master thesis, 3 engineering thesis and 2 engineering projects.

6.7. Scientific assistance for doctoral students as advisor or auxiliary supervisor

Auxiliary supervisor of Ph.D. dissertation of Daniel Gapiński titled *Zmodyfikowana optyczna głowica skanująco-śledząca jaklo układ do poszukiwania, identyfikacji i śledzenia celów powietrznych*, 2013-2016.

Dissertation defended with distinction on 17 March 2016 at the Faculty of Mechatronics and Mechanical Engineering, Kielce University of Technology.

6.8. Internships

Eight-month internship within project „Świętokrzyski Transfer Wiedzy – biznes dla nauki – nauka dla biznesu” at MESKO SA, from 1 April 2014 to 30 November 2014.

6.9. Reviewing of papers in international and national journals

[1] review of paper in *Theoretical&Applied Mechanics Letters*, 2012

[2] reviews of four papers in monograph *Mechanika w Lotnictwie*, 2012

[3] reviews of two papers in *Problemy mechatroniki:. Uzbrojenie, lotnictwo, Inżynieria bezpieczeństwa*, 2014, 2016

[4] review of paper in *Advances in Military Technology*, 2015

[5] review of paper in *Advances in Research*, 2015

[6] review of paper in *British Journal of Applied Science & Technology*, 2015

[7] review of paper in *Advances in Mechanical Engineering*, 2016

6.10. Participation in additional training courses

[1] Training seminar in the field of protection of intellectual and industrial property, Kielce 2007

[2] Seminar „Ochrona własności intelektualnej w Polsce i Unii Europejskiej”, Kielce 2009

[3] Training in the field of ADM701: Adams Basic Full Simulation, certificate, Kraków 2011

[4] Training „Rejestracja i analiza zjawisk szybkozmiennych”, certificate, Kraków 2012

[5] Forum jakości „Nowe wyzwania w zapewnieniu i ocenie jakości kształcenia”. Warsztaty: Projektowanie wewnętrznego systemu zapewnienia jakości kształcenia. Budowanie planów studiów w oparciu o efekty kształcenia, Gdynia 2012

[6] Training „Zarządzanie własnością intelektualną praktyce. Strategie komercjalizacji”, certificate, Kielce 2013

[7] Conference „Krajowe ramy kwalifikacji – zmiana dla edukacji i rynku pracy”, Kielce 2013

[8] The Bologna Seminar „Budowanie kultury jakości niezbędnym warunkiem efektywnego funkcjonowania wewnętrznego systemu zapewnienia jakości kształcenia”, Kraków 2013

[9] Seminar „Potwierdzanie efektów uczenia się w szkolnictwie wyższym”, Kielce 2015

7. Organizational activity

[1] Vice Dean for Students and Education of Faculty of Mechatronics and Mechanical Engineering of Kielce University of Technology, 2012-2016 and Vice Dean-elect, 2016-2020

[2] Head of the Laboratory of Technology Armament, Department of Applied Computer Science and Armament Engineering, Faculty of Mechatronics and Mechanical Engineering from 1.05.2012

[3] Member of collegiate organ:

- member of the Board of Faculty of Mechatronics and Mechanical Engineering, 2008-2012 and 2012-2016
- member of the Selection Committee of Faculty, 2007/2008 and 2008/2009
- member of the Selection Committee of University, 2009/2010, 2010/2011, 2011/2012, 2012/2013, 2013/2014, 2014/2015, 2015/2016
- member of Education Quality Assurance System at Kielce University of Technology from 20 June 2012
- member of the Quality Assurance Committee of Faculty, 2012/2013
- member of the Committee for Students and Education of Senate from 26 September 2012
- member of the Education Committee of Faculty, 2012-2016
- chairman of Scholarship Committee of Faculty, 4.03.2013-3.03.2014, 5.03.2014-30.09.2014, 1.10.2014-30.06.2015 and 1.10.2015-30.06.2016
- member of the team preparing the self-evaluation report in the field of mechanical engineering – 2010
- member of the team for opinion of report in the field of automation and robotics – 2012
- member of the team for opinion of report in the field of transport – 2014
- member of the team to develop of educational building B, 2011-2012

Izabela Krzysztofik

Kielce, June 6th, 2016 …………………………………
signature