This paper is available online at www.praiseworthyprize.org
International Review of Aerospace Engineering (I.RE.AS.E), Vol. 15, N. 1
ISSN 1973-7459 February 2022

Technical and Legal Relations in Aviation Industry from Technology Management and Sustainability Perspective

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Abstract – *Technical and legal relations in the production concern certain actions and interactions in a company. Knowledge in this area is essential for proper risk management. In this paper, the relations occurring in the production of aircraft parts responsible for flight safety, taking into account the construction and technological requirements as well as legal aspects were analyzed. The results of the performed analysis were used in building of a system of legal relations in the production of airplane parts. Moreover, problems concerning compliance with legal regulations were analyzed. It has been shown, among others, that it is impossible to eliminate the human factor from the production process. This results in the necessity to carry out awareness, ethical and professional training of the personnel involved in the entire production chain, from the preparation of process documentation to the final product inspection. The study is interdisciplinary in nature, combining the analysis of structural, technological, organizational, and legal issues related to the production of critical aerospace parts.*

***Keywords**: Technology Management, Aviation Industry, Legal Risk, Compliance System, Sustainable Manufacturing*

I. Introduction

Knowledge of technology management relations, binding actions and interactions in a company allows for development in the field of work organization. Business models and their adaptation to the changing market are closely related to the specificity of a given industry or industrial condition [1]. The technology management relations may concern, among other issues, the supply chain [2], complex product systems [3] or the relationship between digitization and productivity [4].

The competition in technologies implies a rivalry that is associated with the rate of development in the field of research on relations between system elements [5]. A proper approach to knowledge-based strategic management requires research related to the knowledge of the relations between individual elements of the system and the functioning of the entire company [6].

The aerospace industry is specific and therefore requires a case-by-case approach to the analysis of the performance structure for the production of aerospace components. On the one hand, this is due to the high degree of sophistication of design solutions in terms of innovation, complexity, and functional properties. This requires knowledge of special part design methods as well as monitoring and control systems [7], obtained as early as in university education [8], [9]. On the other hand, the technology for manufacturing aerospace parts is subject to much stricter requirements, which are conditional on the need to meet the design requirements.

This should take into account the continuous development of manufacturing techniques, production digitalization [10], production organization [11] and the introduction of innovative construction materials [12], which often determine the complexity of technological challenges. The most complex issues are related to the so-called critical aerospace components which are responsible for flight safety [13]. The recipients of such parts require, from the manufacturers, not only the structural conformity but also the conformity of the manufacturing technology. Apart from the constructional requirements, which are the decisive factor for technological requirements, the second factor is sustainable production [14]. The production of airplane parts under sustainable manufacturing conditions requires the manufacture of a product that meets specific constructional requirements and quality standards, taking into account not only the economic factors but also environmental and social implications [15]. In this context, the impact of production regulations and legal issues affecting production profitability is often overlooked [16]. Engine makers in the aircraft engine industry have to comply with the regulations specified by certification authorities. While it is easy to identify systems for verifying product quality, supervising the production process, or determining production inputs, greater difficulties relate to the identification of legal risks and monitoring compliance in accordance to legal standards and requirements for the production of critical

Available online by February 28th, 2022 https://doi.org/10.15866/irease.v15i1.20755

parts at the factory, industry, national and international levels. These issues are all more important as the assessment of the conformity of certain effects or activities of a company also depends on the human factor. The aim of the conducted research was to analyze the relations occurring in the production of aircraft critical parts, taking into account the construction and technological requirements as well as legal aspects. The rationale of the issue was to take into account the intricacy of sustainable production of this group of parts.

The second section of the paper discusses technological requirements for the manufacturing processes of critical aerospace parts, focusing on the critical parts of aircraft engines. Not only construction requirements, but also sustainability issues were taken into account. The third section deals with the conformity assessment of critical aircraft parts and quality management systems. In Section IV a system of legal relations in the production of airplane parts is proposed.

Section V discusses problems concerning compliance with legal regulations. The work is ended with conclusions, where the most important issues from the risk management point of view are underlined. The complexity of the problem is explained and future works are mentioned.

II. Technological Requirements for the Manufacture of Critical Aerospace Parts in the Context of Sustainable Manufacturing

The production of aircraft parts involves the need to produce them with appropriate constructional requirements. Presently, it is important that the manufacturing process also takes into account aspects of sustainable production, taking into account the economic, environmental, and social implications of the production.

These requirements determine the technological approach to the manufacturing process (Fig. 1).

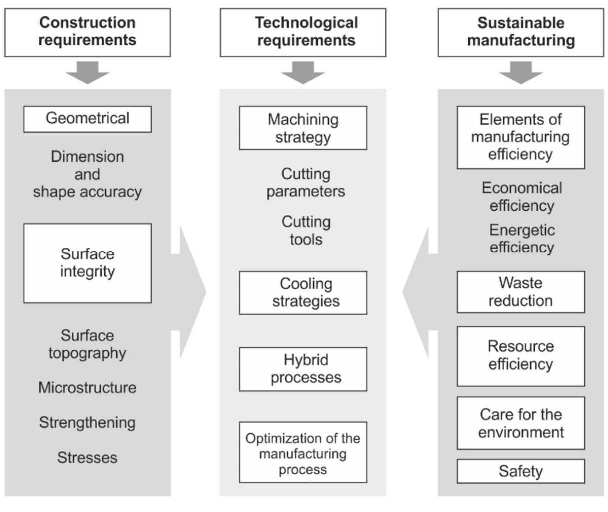

Fig. 1. Requirements for the manufacture of critical parts for aircraft engines [Source: own study]

Sustainable production is defined as the creation of products using processes that are economically justified, minimize the negative impact on the environment, save energy and natural resources, and are safe for employees as well as communities and consumers [17]. Production efficiency, including economic and energy factors, is important [18]. Together with IT integration, manufacturing efficiency is one of the most important factors determining the competitiveness of machine part manufacturers. It is essential to ensure safety at work and to reduce waste generated during production. The proper use of company resources also determines the requirements for manufacturing technology, often limiting the potential for a processing strategy. Another factor to take into account, in terms of sustainable production, is the minimization of negative environmental impacts. The following discussion presents how difficult it is to achieve sustainability in critical aircraft parts manufacturing when there are problems which cannot be solved or predicted and the only option is to involve humans to manage compliance.

The design requirements determine the functionality of the manufactured part. They are determined by the designer based on the purpose of a given part and form the basis for the development of the manufacturing technology. Manufacturing processes are design to obtain the products that meet the requirements. Machining plays a dominant role as it offers the greatest opportunities to obtain objects with the required dimensional and shape accuracy and surface topography. However, it should be noted that machining is also characterized by a significant loss of material and high energy consumption of the process, therefore has negative influence on the environment.

The critical rotating parts of an aircraft engine, responsible for flight safety, must meet high requirements not only in terms of geometry and dimensional accuracy, but also in terms of the technological state of the surface layer. This layer is limited, on the one hand, by the surface determining the shape of the workpiece after machining, and, on the other, by the depth of influence of the machining on the raw zones [19], [20]. The technological surface layer of an object is characterized by a specific topography of the surface and zones of thermal and mechanical effects which results from the cutting process [21]:

- a near-surface zone - adjacent to the surface of an object, which is characterized by the presence in its microstructure of chemical compounds created as a result of cutting under certain conditions (cutting tool, parameters, cooling method, etc.),
- A zone of orientation as a result of plastic deformation - a plastically deformed part of the technological surface layer, characterized by the orientation of the grains of the processed material;
- A zone of thermal effects in which changes in the microstructure, as a result of thermal processes, occur (e.g., recrystallization and growth of grains, phase transformation, chemical reactions).

An analysis of literature data indicates that the thickness of the technological surface layer is difficult to determine. It is assumed that the internal border of the technological surface layer, as a physical surface, does not exist. On the other hand, its thickness, depending on the material and the treatment applied, ranges from several tenths of a nanometer to tenths of a millimeter [22]. The requirements of the technological surface layer are subject to internal quality standards set by the parts customers. In this aspect, the following components of the technological surface layer can be specified [23]:

- Topography of the surface after treatment taking into account the roughness parameters and the structure of treatment marks, scratches, adhesions, chipping or cracks, etc.;
- Changes in the morphology of the microstructure;
- The occurrence of the so-called "the white layer" and grain deformations;
- The strengthening of the surface layer;
- The distribution of stress.

Roughness is the basic factor in the assessment of the quality of the surface layer of the workpiece [24]. The exact characteristics of surface roughness and topography are of paramount importance in many engineering industries, since certain functional properties of materials are often dependent on the geometric structure of the surface [25], [26]. The cutting process with tools of defined geometry and kinematics should have a defined structure of machining marks. During machining, however, some mechanisms may occur, which will affect the occurrence of some deviations in the form of scratches, adhesions, crushing or cracking [22]. Machining of titanium alloys can, in some cases, result in the so-called "white layer", especially under the cutting conditions of a worn tool or under high blade loads (Fig. 2). The term generally refers to a layer of material which is characterized by high hardness, greater than the hardness of the core material, and brittleness and is white under light microscopes. This usually occurs in combination with a plastically deformed layer as a result of the heat and stress generated during metal cutting.

Therefore so far, the exact mechanisms of its formation have not been established. It is assumed that the formation of this layer is also influenced by the large crushing action occurring in the cutting zone, which increases with the progressing tool wear [27]. This layer has an adverse effect on fatigue strength and the acceptable level of fatigue strength for critical parts of an aircraft engine is usually strictly limited.

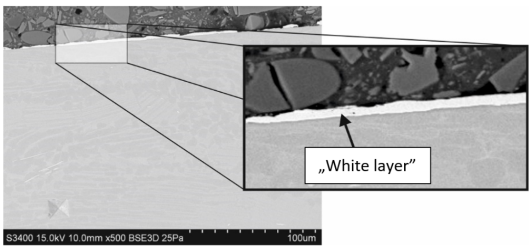

Fig. 2. Examples of a "white layer" formed after turning the alloy Ti-45Al-5Nb-0,2B-0,2C with a cutting insert made of tool ceramics

The thickness of the white layer takes values from a few to several micrometers. Its occurrence is influenced by the mechanical, thermal, and chemical properties of the material being machined and the conditions of the machining process, especially the cutting speed. The manufacture of critical parts in the aerospace industry involves a high level of reliability. The condition of the technological surface layer is one of the most important factors used to assess the quality of treated surfaces. In the case of large microstructure deformations after processing, the grain and phase boundaries may become undefined. Usually, however, the occurrence of plastic deformations and their depth can be determined by the so-called "plastic deformation". The deformation lines create a directional zone and the grain and phase boundaries are definable. The machining process may also result in a strengthening of the technological surface layer of the material depending on its physical and chemical properties. The amount of plastic deformation in the surface layer and its depth, apart from the properties of the material being machined, is also affected by the geometry of the blade, a cross-section of the cut layer, cutting speed and tool wear degree [28].

The degree of reinforcement of the surface layer has an impact on the performance of the workpieces. Increases strength properties and abrasion resistance. The depth of the reinforced zone of the layer depends on the total cutting force and properties of the material and its evaluation is made by measuring the hardness distribution as a function of distance from the machined surface [29], [30]. Plastic deformation during the cutting process leads to the formation of residual stresses in the surface layer of the workpiece. Tensile stress usually occurs in front of the cutting edge, while compressive stress usually remains in the top layer after the tool has passed. Depending on the loads on the machine parts, tensile or compressive residual stresses may be required, depending on the positive or negative effect on their durability or performance characteristics. Studies show that compressive stresses in the surface layer contribute to increasing fatigue strength. The value of residual stresses in the surface layer is an important criterion for the selection of the machined material and manufacturing technology for operation under fatigue loading. The parameters of the cutting process influence the shaping of the state of the residual stresses in the surface layer of the machined elements [31]. The creation of a compressive stress state in the surface layer of the workpiece increases creep resistance and fatigue strength and limits the formation of micro-cracks during operation [32], [33]. The examples of technological requirements for the manufacturing of critical parts of aircraft engines presented above show that quality indicators are often non-parametric (e. g. the presence of a "white layer") and difficult to assess. Therefore, the determination of conformity of a manufactured part with the design requirements and production standards, requires an objective assessment by qualified inspection personnel with the necessary knowledge and experience. Since safety issues are involved, this is a factor that carries certain legal risks associated with the choice of such a person by the organization. A significant influence on the machining process has the tribology of cutting [34].

Generally, tribological aspects are considered from a cutting tool wear perspective. A lot of scientific efforts were dedicated to understanding this phenomenon and generally is quite well known [35]. For critical parts machining, the tribology of cutting tool-chip and cutting tool-workpiece pairs has to explore a much wider spectrum of criteria, including parameters of surface integrity influencing part strength, durability and reliability. The interaction between cutting tool material, coating, cutting edge shape, coolant and additives, coolant supply system, cutting parameters and machined material and impact on the surface condition are the key tribological conditions that had to be well recognized and understood to right design, perform and control the machining process [36]. Finish machining is a major and important portion of the manufacturing process of a critical part. Cutting tribology plays a significant role in this area, helping understand the mechanism of surface defects creation (white layer, laps, gouges, tears, grain distortion, etc.) and giving a chance to eliminate or minimize the appearance of these nonconformances [37], [38]. The definition of sustainable production presented earlier does not in any way refer to the legal aspects that are very relevant to aviation production, and failure to comply with regulatory requirements may have consequences. The authors, therefore, propose the following extended definition of sustainable production to emphasize the importance of these legal aspects:
"*Sustainable manufacturing is the creation of products through economically-sound processes by motivated and well-treated employees undertaking environmentally friendly manufacturing activities in accordance with suitable external and internal standards and regulations to ensure product and community safety*".

The proposed definition refers in addition to the requirements of standards and laws and the internal rules and procedures of a particular company to ensure safety.

This is particularly important in aviation production, where the effects of processes such as the formation of tensile stresses in the surface layer of the products or the formation of a "white layer" are very important to ensure the functionality of the manufactured aircraft parts, which is discussed in detail in this section. Non-application of the rules and procedures concerning the production processes in progress can lead to nonconformities that are not detectable in non-destructive testing and therefore can be concealed by the manufacturer and the nonconforming products delivered to the customer can lead to an accident.

III. Aviation Critical Parts Compliance Assessment and Quality Management System

The production of critical parts is a specific case of aircraft production requiring a unique approach. These are parts that have characteristics which significantly affect the service life of the product and cannot be controlled on the finished product by non-destructive methods and whose failure may result in a risk to flight safety. Such products are, among others, turbine engine rotating parts, e.g.: compressor discs, turbine discs, disc seals, compressor blades, turbine blades, etc. In addition to the general requirements for aeronautical production mentioned above, additional conditions and restrictions are imposed, which has a significant impact on the manufacturing process, its supervision, implementation of changes and control of the product. This, in turn, significantly affects its manufacturing cost and price. For the above examples of parts, the critical parameter is the fatigue strength, for which destructive testing of a product, made by a defined process, is required to confirm compliance. In such cases, before the manufacturing process is approved, it is required that the part manufactured in this process be destroyed to determine whether the part reached the required fatigue strength. Additionally, e.g. metallographic research is carried out. If the conducted tests confirm compliance with defined standards (standards depend on the assessed production method), the process is presented, with the test results, to the customer for approval and after approval it is "frozen". This means that any deviation from the approved process is not acceptable and any change affecting the quality of the product (significant change) requires the customer's consent. Changes in the process defined as significant require re-performing costly destructive tests in order to verify their influence on the properties of the part defined by the characteristic parameters for the critical parts. Insignificant changes only require customer notification. Important changes include e.g. a change of cutting parameters, change of coolant, change of machine, change of tooling, change of instrumentation, displacement of a machine, etc. Thus, any change that may affect the parameters indirectly determining the fatigue strength (durability) of the product is significant. Also, production disruptions, unforeseen by the approved manufacturing technology, which may affect the durability of the product, must be reported and considered individually in terms of their impact on the requirements defined for critical parts. For example, chipping of a cutting tool edge at the middle or finish of the machining stage requires assessment of the impact on the parameters of the technological surface layer, even though no visual trace of the event would be visible in the final stage of production. Therefore, employees must be well trained to properly behave in a certain situation. Very often, in the process of manufacturing a part, there are several production methods that require approval, e.g. mechanical treatment, heat treatment, coating (plasma, galvanic, ...), which means that in order to approve the entire production process, it is sometimes required to perform destructive tests on several parts, which significantly increases implementation costs. In addition, there are situations when the test results are not acceptable the first time.

Sometimes the approval of the process requires a few or even a dozen modifications of the process (parameters, tools, equipment, machines, etc.) to achieve a positive test result. Also, the improvement of the process or its optimization requires re-approval of the process and the destruction of subsequent parts, which takes time and increases costs. People involved in the production preparation process, then the production and control process of critical parts themselves, influence many parameters and factors and interpret events in the production process (e.g. use of speed control knobs, feed, no blade change at the time indicated in the machining program, unreliable measurement result, etc.). Therefore, the reliability of these people and the awareness of the impact of their behavior on the product, the safety of its use and thus on the health and life of others is extremely important. Since it is impossible to eliminate the human factor in the production process, as well as 100% monitoring of all parameters and events, therefore, great importance is attached to awareness, ethical and professional training of the staff involved in the entire production chain from the preparation of process documentation to the final product inspection. The role and responsibility of managers and executives in shaping the attitudes of employees and supporting them in the implementation of these particularly responsible processes, as well as in eliminating all hazards and unethical or disregarding standards of production of critical parts are extremely important here. In aviation companies, there is a great deal of emphasis placed on mandatory awareness trainings, repeated at specified times, on the principles of critical parts production.

Moreover, ethical training for employees are implemented. Furthermore, it is mandatory to be familiar with alerts on detected irregularities, corrective actions and the cardinal rules applicable to each area of the company's operations, the violation of which result in disciplinary dismissal. Due to the seriousness of the problem and the related requirements as well as the constraints, the manufacture of critical parts is one of the most difficult and costly areas of aerospace parts manufacturing. Despite the high level of automation and process monitoring, the reliability and honesty of employees is still the basis and key element, especially in the area of critical parts production. When analyzing legal requirements, companies' internal standards, technological processes and control processes, it can be concluded that aviation production is one of the most demanding areas of production in terms of quality standards and ensuring product safety. International aviation supervision organizations (e.g. Federal Aviation Agency - FAA, European Union Aviation Safety Agency - EASA) as well as national aviation regulatory organizations (Civil Aviation Authority - CAA), and most of all customers, oblige aviation industry suppliers to apply recognizable standards of quality assurance of production and services. The basis for the aerospace industry is the AS/EN 9100 standard, based on ISO 9001, which addresses the requirements of the Quality Management System (QMS) for the aerospace and defense industries in design, development, manufacturing and service. Each company may implement the requirements of this standard in a different way, which it specifies in its own normative acts (e.g. procedures, instructions). In the production of aviation products, QMS implementation is connected with the necessity of meeting specific requirements and performing adequate activities connected with the following aspects:

- Planning of product production;
- Manufacturing under controlled conditions;
- Configuration management;
- Ensure identification and traceability;
- Ensuring product safety;
- Protection against counterfeit products;
- Supervision of equipment, tools and software;
- Approval of special processes;
- First piece production inspection;
- Supervising changes in the production process;
- Non-conforming product management;
- Risk management;
- Ensuring customer satisfaction;
- Analysis and evaluation;
- Management review;
- Dealing with nonconformities and implementation of corrective actions;
- Continuous improvement.

Product manufacturing planning includes the definition of the criteria for process evaluation and acceptance of the product and the determination of the resources necessary to achieve a compliant product and deliver it to the customer within a specified time. It is also necessary to maintain and store the documentation necessary to confirm the correct course of processes and demonstrate the compliance of the product and the results of critical parts control. Production under controlled conditions means the availability of production documentation and appropriate measuring equipment. Inspections shall take place at appropriate stages of the process, creating documentation to support process control and include acceptance and rejection criteria for parts. It should be possible to reconstruct the parts manufacturing history. As traceability is required for critical parts, the organization must maintain the unit identification of each product unit and maintain records for that part. The organization must establish, implement and supervise the processes necessary to ensure the safety of the product throughout its life cycle and prevent the use of falsified parts. This translates into purchases only from approved suppliers and verification of the documentation received with the delivery for authenticity. Equipment, tools and software used for production, control, monitoring and measurement of production processes must be approved before being released for production and must be supervised thereafter. Special processes, as well as changes to these processes, require approval. This involves setting review and approval criteria and persons authorized to approve such changes in production processes must be identified.

It is also required to adopt procedures for managing non-compliant products so that they are not accidentally sent to the customer and are supervised until they are physically destroyed or repaired. A separate issue is risk management by the relevant services. This requires the introduction of risk assessment criteria, communication and risk reduction measures in case of exceeding certain values for defined risk assessment criteria. The organization's management must assess the performance of the organization's quality system at fixed intervals. In addition, in the event of non-compliance, corrective action should be taken, the consequences of the non-compliance should be analyzed and the risk of recurrence taken into account. Records of non-conformity and related corrective actions must be kept. On the basis of the results of monitoring, measurement and analysis, opportunities for improvement should be identified and appropriate action is taken.

IV. Legal Relations in the Production of Aviation Parts

The activities of a company producing aerospace parts involves a higher than average legal risk as part of the activities of such an entity. The specificity of the production of machine parts, including the production of critical aerospace parts, is often characterized by an innovative approach and modern management, resulting in specific cases where legal liability may arise. The purpose of the presented legal analysis is to indicate the risk of legal liability, which translates into the operation of a protection system aimed at increasing security. A proper understanding of the relationship, in this respect, allows for an increase in risk management effectiveness.

Examples of risk factors in a modern company will be presented, as well as issues of the legal liability for selected elements of the company's operations. Due to the complexity of the issue, the main focus of the analysis will be on the topic of potential criminal liability of the collective entity for activities in the production and control area.

IV.1. Legal Risk in the Activity of an Innovative Enterprise

The aviation industry is inextricably linked to a global exposure to the legal risks generated by digitization and automation, coupled with often conflicting rights and obligations and limited enforcement capabilities. This gives corporations the opportunity to question the need to comply with all applicable laws. Although most of the typical risks in the production area are concentrated around information security, the legal risks involved in the production of safe-of-use items must also be considered. The risk management process must take into account the availability of a large amount of data in real-time, which requires adaptation of existing instruments and tools. The use of innovative technologies, including elements of digitization and automation, means taking into account an open catalog of legal risk factors [39], [40]. Among the risks which may occur in the structure of an innovative company, dealing with the production of critical parts for aviation, can be distinguished as follows [6]:

- Bodily injuries;
- Damage to property;
- Breach of contract;
- Misuse of personal data;
- Loss of control over machines;
- Violation of employees' rights;
- Risk of injury or damage;
- Infringement of intellectual property;
- Approval for use of the non-compliant part.

Determination of the likelihood of the overall occurrence of a given legal risk within the structure of a company, will depend on a number of factors, including those related to the level of technological advancement, which must be considered on a case-by-case basis.

Extensive implementation of digitization and automation involves high legal risks. It can be reduced by reducing the probability of risk for a given technology. In most cases this is possible, but requires international legislative cooperation. There are also areas of unpredictable risk, but this is the price of industrial development.

IV.2. Corporate Legal Responsibility

Among the issues related to the legal responsibility of corporations involved in the production of critical aerospace parts, a number of general cases related to the possibility of legal liability can be identified. This may include civil, administrative, labor and criminal liability, depending on the country's laws, including international regulations. An important issue in the legal responsibility related to the activities of a corporation is the theft and protection of confidential information related to the production process. Confidential information may relate to design, know-how and also other classified information related to e.g. supply chains. In the situation of modern and complex company structures, it is possible to breach international and national law in the context of the location of production facilities in different countries, and thus to be liable under different national laws. Such provisions may be different from those of the country where the head office is in fact located. In this respect, problems may also be related to the issue of a virtual factory, whose individual components may be in different countries. In such a case, the company's responsibility for meeting all the legal requirements, regardless of where it operates, should be predominant.

A problem may arise when the laws of different countries regulate certain issues in different ways. Legal issues relating to work safety, include among others, injuries (e. g. as a result of not wearing suitable protective clothing or improperly securing machines) or even the risk of injury. In this case, it is based on the law of the country where the production takes place.

Infringements of human resources are also subject to the rights and risks associated with production. For example, cases such as the employment of part-time workers to avoid the employment of full-time workers who require medical insurance, discrimination against workers on the basis of their sexual orientation or gender and unequal treatment of candidates for a particular job can be identified here. This is a violation of equal opportunity legislation in the workplace. This problem is also related to the objectives of sustainable development, i.e. reduce inequality within and among countries and achieve gender equality. In the case of companies using advanced technologies, issues related to violations of temporary ban on competition are important. This includes an agreement between the employee and the employer on where the person cannot work after leaving the current employer. This is to limit the transmission of information e.g. about the production technologies used by the prior employer to the new employer. Competition protection is designed to prevent employees from passing on relevant information, customer lists, technology or other competitive information after leaving the current company. A particularly important issue in the aerospace industry is the legal supply chain constraints, which determine the types of claims that customers can make and under which conditions. Such cases may relate, on the one hand, to damage of parts or semi-finished products during transport and, on the other, to probable scenarios for the delivery of components which may be an important part of the customer's finished product, causing potentially large damage due to untimely delivery date. A corporation may also be responsible for the manufactured product in the event of non-compliance with the design requirements. The production of such a product itself is of course not subject to criminal liability, but deliberate or inadvertent concealment of the non-compliance of such a part with the construction requirements may result in civil liability (for damages) or in the event of exposure to danger or causing dangerous consequences, even criminal liability of the entrepreneur.

If a part fails to function properly, the manufacturing company may have to pay compensation for the effects of the part malfunctioning. Therefore, many manufacturers have product liability insurance policies. However, there may be a situation where a malfunctioning part may result in exposure to danger or bring about accidents. This may result not only in liability for damages but also in criminal liability of the corporate.

IV.3. Corporate Criminal Responsibility Risk Analysis

Traditionally understood criminal law, which is focused on the responsibility of the individual, is not able to neither adequately describe nor respond to the entire criminal content of offenses committed by company employees in the performance of their duties. The natural person is often only a part of a malfunctioning system and contributes only in some extent to the evil done.

Their responsibility may have no major impact on the functioning e.g. of the company, because the penalized employee may be replaced by another. As a rule, an individual is much less financially capable, making the compensation function, which is already a permanent feature of the criminal process today, much more difficult to implement. There are many documents in the European Union that oblige countries to introduce rules on the criminal liability of legal persons into their legislation. The community's legal system contains many provisions on corporate responsibility standards. Corrupt behavior by individuals is often carried out in the name of or on behalf of legal persons. For this reason, some States, and subsequently the international community, have considered it advisable to introduce a mechanism allowing legal persons to be prosecuted for acts that are committed for their benefit by individuals. International and European Union law has adopted legal acts aimed at obliging States to adopt the relevant provisions into their domestic law. Poland also faced such a necessity in connection with its accession to the European Union (EU). The introduction of liability of legal persons into the Polish legal order was directly caused by the need to adapt Polish law to international instruments adopted in the EU, in particular the Convention on the Protection of the EC Financial Interests of 26 July 1995 and its two Additional Protocols. The Convention on the protection of the European Communities' financial interests and its Protocols expressly stress the need for Member States to adopt legislation to criminalize the managers of companies or other persons in the company who have the power to take decisive actions or to exercise control over them (i.e. of legal persons). In Poland, the national legal act currently regulating the aforementioned issues is the Act of 28 October 2002 on the liability of collective entities for acts prohibited under penalty. Currently, in Poland, it is not possible to hold a collective entity liable for an individual's crime related to exposure to danger or bringing about such danger, because the catalog of crimes for which the entity may be liable is closed. Such a solution has been repeatedly criticized and the regulations in this respect should be changed. Figure 3 shows a schematic diagram of the concept of potential criminal liability of collective entities for approval of the non-compliant critical part in the aviation industry, taking into account the compliance system within the company. According to the scheme, the existence of an appropriate legal employment relationship between the employee and the corporation/employer is required for the normative basis for the liability of the collective entity. The relationship could be:

- To act on behalf of or in the interest of the corporation/employer within the power to represent it;
- To act on behalf of or in the interest of the corporation/employer within the power to exercise internal control;
- To allow a person referred to in point 1 or 2 to act as

a result of an abuse of power or failure to comply with their obligations;
- To act on behalf of or in the interest of the collective entity; with the consent or knowledge of the person referred to in point 1 or 2;
- To be an undertaking that directly cooperates with the corporation for a common purpose.

Another condition that would have to be met in order for a collective entity to be held criminally responsible is the attribution of specific guilt to such an entity, which may result from:
- Lack of due diligence in choice;
- Lack of due diligence in supervision;
- Lack of due diligence in the organization.

Diligence in choice, the person entrusted with the performance of the activities, involves checking whether this person has sufficient professional qualifications. The diligence in making the choice should also include checking whether a given person has such predispositions and habits that may expose other people to harm. Diligence is also taking into account life and professional experience, education, physical and mental fitness and other features of the person entrusted with the performance of the activities, and providing them with the necessary guidance and instructions. On the other hand, diligence in supervision is connected with the quality of establishing the obligation to carry out supervision on the part of the supervising entity and showing the existence of a cause and effect relationship between the lack of supervision and the behavior of the supervised entity. Organizational fault consists of improper organization of the activities of a collective entity, which results in failure to ensure the required caution in the behavior of its employees.

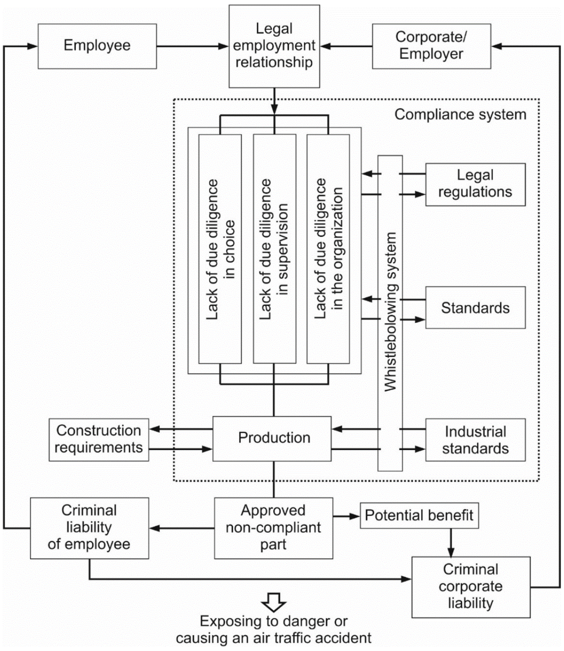

Fig. 3. A scheme of potential criminal liability of collective entities for approval of the non-compliant critical part in the aviation industry [Source: own study]

One of the reasons for the organizational guilt of the collective entity may be the situation where the functioning of a given collective entity was not based on any formal grounds. Another kind of situation may be that, while there is a certain formal framework for the functioning of a collective entity, or at least some kind of common practice, they are general enough to leave too much space for decision-making. In this context, the compliance system should play an important role in companies. This system is about ensuring compliance not only with the legal requirements but also with moral standards. An important component of the compliance system is the requirements that an organization must meet as well as those that it wants to meet. The requirements that an organization must meet include the applicable legal regulations. There is little room for maneuvers in this area. The requirements that an organization wants to meet include a variety of voluntary commitments, such as industrial or organizational standards, codes, good governance principles, as well as social and ethical standards recognized by the organization. Companies must always strive to focus their activities on relevant laws and legal interpretations.

The most important thing is to respect the law and the agreed rules in order to avoid the risk of liability under criminal and civil law for both companies and their bodies. Companies operating in the aviation production market must meet high expectations. The requirements for manufacturers and suppliers to the aviation industry include ISO 9001, EN 9100, AS/EN 9100, ICAO, EASA regulations and industry standards developed by EUROCAE. It is clear that, in the case of the aviation industry, quality control is associated with a threat to customers' life and health. In order to make the operation of the compliance system more effective, it is necessary to report irregularities taking place in the organization.

This is the purpose of the whistleblowing system. This system is used to inform and warn, in good faith, about undesirable actions, which allows for early detection and counteraction of actions against the company. With regard to the safety of products placed on the market, the main source of evidence is the companies operating within the production chain and distribution network.

The reporting of problems/infringements by whistleblowers in such companies has a high added value as they are much closer to information about possible unfair and illegal manufacturing or product control practices. The need to introduce the protection of whistleblowers is a problem that has been present in international legal traffic for several years. Directive 2019/1937 of the European Parliament and of the Council of 23 October 2019 on the protection of whistleblowers requires that Member States adopt legal solutions to prohibit retaliation against whistleblowers.

The aim of this Directive is therefore to ensure effective protection of whistleblowers and, in addition, to prevent damage and detect dangers and threats to the public interest in connection with existing abuses. The aim of these provisions is to introduce harmonized solutions for comprehensive protection of whistleblowers across the EU Member States. Currently, the Polish law does not provide solutions to the problems identified in a comprehensive manner, hence the fact that the issue is regulated deserves a positive assessment. The Member States must introduce new provisions on the protection of whistleblowers by 15 May 2021 at the latest. This is important for two reasons. The whistleblowers must be protected from retaliation by the employer. At the same time, the companies need to be protected against false accusations. Whistleblowers must be aware that intentional and unfounded accusations will not go unnoticed by the law. The production of aviation parts is based on the construction requirements and industrial standards. With regard to aviation production, only the approval of intentionally or unintentionally (through lack of inspection) of an approved non-compliant part should be criminalized. The approval of such a part gives rise to the responsibility of the natural person directly responsible for the control due to the exposure to danger or the introduction of such danger in air traffic. The fact of committing an offence by a natural person, who is in a legal employment relationship with a collective entity (corporate), to whom a specific type of fault can be attributed in the supervision, selection or organization are necessary elements of the responsibility of such entity.

Furthermore, the possibility of a collective entity obtaining a potential benefit, even of a non-pecuniary nature, is indicated as a necessary condition for liability.

The fact of obtaining a financial benefit may be related not only directly to the price of a given part, but also to the costs and damages related to the supply chain.

V. Analysis of Problems Related to Compliance with Legal Regulations

In every manufacturing enterprise, there is a specific system of relationships that defines the causes and effects of a specific conduct. However, many companies are not even aware that such a relationship system exists. In this work, the implementation system in a manufacturing company from the aviation industry was analyzed. The potential causes and potential effects of a given procedure in connection with the legal consequences were analyzed. The developed system of relations is shown schematically in Fig. 4. The legal requirements in force within the country, created on the basis of EU regulations, are the basis for the company's functioning in the aviation industry. The company may also accept certain standards for use. This is the basis for creating internal rules and standards applicable to the production company. Company employees are trained in and committed to comply with applicable internal regulations.

The work of employees is also supervised according to internally established rules. Ineffective training or supervision can lead to situations of non-compliance.

Such situations may also occur where the employee has made a mistake. Employee's errors may be due to many reasons, however, internal procedures should prevent such errors. Therefore, when an error occurs, internal procedures should be improved, situations that provoke such errors should be eliminated or other necessary actions should be taken.

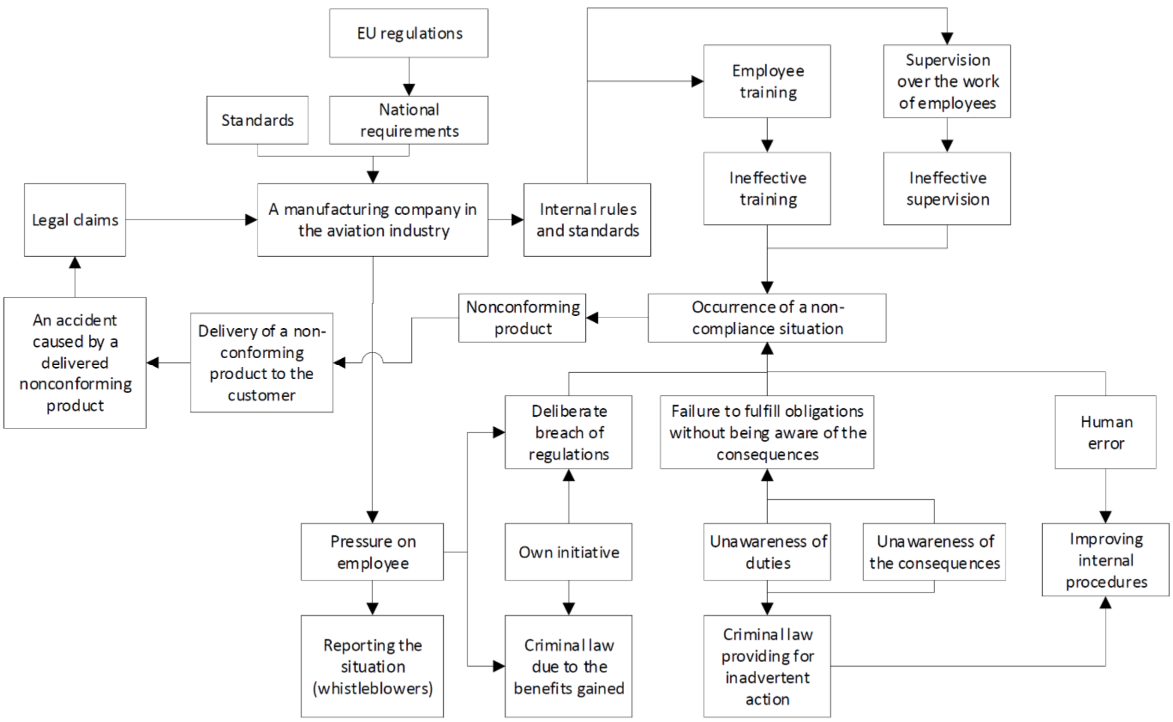

Fig. 4. System of relations in a production company [Source: own study]

The employees should be motivated to identify the situations that provoke a mistake as well as to propose preventive actions. The solutions implemented based on employees proposals are more readily accepted by employees. The companies should build a system to motivate employees to propose improvements [41]. Non-compliance can also be caused by ignorance of obligations or consequences of non-compliance. The consequences in question relate to the appearance of non-compliant products. Consequences may also arise for the employee. These will be based on the criminal law provisions governing liability for mismanagement of acts and omissions. Non-compliance can also be caused by deliberate actions taken by an employee who breaks the rules on his or her own initiative or by pressure on the employee, for example from supervisors. In this situation, an employee may be liable to criminal prosecution because of his or her benefits, or because of the possibility of benefits in others or in the company.

The effect of not following the rules may be to deliver non-compliant products to the customer. Non-compliant products may be delivered to the customer and not identified by the customer as non-compliant and therefore accepted. These may be non-compliant critical parts, which will then be built into the finished product by the customer. Incompatible products may cause an airplane accident, resulting in legal claims against the manufacturer who supplied the non-compliant products.

In the event of pressure on an employee to deliberately break legal provisions, it is possible to apply EU whistleblower rules (Directive 2019/1937). According to the Directive, an employee reporting intentional violations of the law, will be protected against the negative consequences of reporting. It is necessary to precisely define in what situations the employee should make a report, in what form and to whom, in order to avoid abuse and to prevent slander. In order to avoid undesirable situations, one should also work on the organizational culture, increase employees' awareness, create not only legal norms, but also shape moral norms.

VI. Conclusion

The analysis of the technical and legal relations in the production of critical parts in the aerospace industry has led to the formulation of fundamental conclusions in this respect:

- The technological requirements for the manufacturing process of critical aero-engine parts demonstrate the complexity of assessing the conformity of the manufactured part with design requirements and production standards. Consideration shall be given to the relevance of the human factor, which translates into knowledge and experience requirements for control staff;
- Special requirements for critical parts, the failure of which results in a threat to flight safety, are related to the necessity of destructive testing, which translates into production costs and special production procedures and compliance control. Any deviation from the approved process is not acceptable and any change affecting the quality of the product requires the customer's consent. This limits the possibilities for technology development, as it requires reapproval of procedures after subsequent testing, which significantly increases the time of process implementation or change as well as costs;
- The inability to eliminate the human factor in the production process translates into the necessity to carry out awareness, ethical and professional training of the personnel involved in the entire production chain, from the preparation of process documentation to the final product inspection;
- Manufacturers of critical aero-engine parts are subject to recognized quality assurance standards for production and service, including in particular AS/EN 9100, which addresses quality management system requirements for aerospace and defense in design, development, manufacturing and service. The companies may implement the requirements of standards in various ways, which they specify in the internal documentation (procedures, instructions, etc.);
- Risk management requires the introduction of risk assessment criteria, communication and risk reduction measures if the defined risk assessment criteria are exceeded. In the event of non-compliance, corrective actions should be taken, the consequences of the non-compliance should be analyzed and the risk of recurrence should be taken into account. It is recommended to involve employees in the development of mistake-proofing solutions. The knowledge of relations in this area allows for increasing the effectiveness of risk management taking into account the issue of legal liability for selected elements of the company's operations;
- Criminal liability in the field of aircraft parts production should only cover the approval of intentionally or inadvertently (through lack of control) of the non-compliant part responsible for flight safety. The approval of such a part gives rise to the responsibility of the natural person directly responsible for the control, on account of exposure to danger or the introduction of danger in air traffic. Committing a crime by a natural person who is in a legal employment relationship with a collective entity (enterprise) to which a specific type of fault in supervision, selection or organization can be attributed to are necessary elements of the legal liability of such entity;
- The development and analysis of a system of relations, which determines the causes and effects of a specific conduct in a production company, determining the potential causes and effects of a specific conduct in connection with the legal consequences, is the basis for effective management. Given the specificities of critical aerospace parts production, such a system is particularly complex and

the technical issues are even more clearly linked to the potential criminal liability of an individual or company.

The presented study is interdisciplinary in nature, combining the analysis of structural, technological, organizational and legal issues related to the production of critical aerospace parts, what has not yet been presented in literature. The paper proposes an extended definition of sustainable development that takes into account the legal aspects that are particularly important for ensuring safety not only in aviation production. The developed system of relations in a production company, which is applicable not only to companies from the aviation industry, makes people aware of the occurrence of threats from the human factor and their consequences for the company and individual employees. The presented work can be useful in understanding the complexity of risk management in aviation companies, and not only, to identify the factors which influence the risk and its consequences. Usually, the problem is analyzed from only a few points of view. The most important are clients' requirements as well as costs and then, employees and environment protection. Therefore, the manufacturing technology and relations with suppliers are in focus. Despite the fact that usually the management system, as indicated in the work, takes into account all important aspects, employees of individual areas of the enterprise focus on a fragment of the whole.

Presenting the issue as it was done in this paper shows that, for example, technological details are very important, as shown in the example of the so-called "white layer", but even the best developed technology will not bring the expected results if the human factor fails. Likewise, carrying out expensive destructive testing and developing perfect procedures will not be sufficient if error-provoking situations arise and workers are not involved in identifying these situations and presenting proposals to prevent them. This work presents the problem from different points of view. The reader may get the impression that the individual issues analyzed are very far from each other. The point, however, is to notice that apparently different issues are interdependent. In future studies, the authors plan to analyze the practical implementation of the compliance system in selected companies from the aviation industry.

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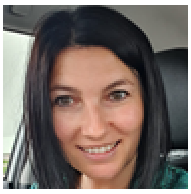

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