Assessment of occupational risks in the aircraft industry

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Abstract. The aircraft industry of Russia is one of the most important high-tech and knowledge-intensive branches of machine building. About 150 thousand employees work at aircraft manufacturing enterprises. Their working conditions do not meet sanitary and hygienic requirements. The research purpose is to compare professional risks for workers of the aircraft industry on the example of the aircraft plant in Ulan-Ude (Buryatia). The research object is Ulan-Ude Aviation Plant, which is the largest enterprise in the Republic of Buryatia. It is part of the Russian Helicopters Company belonging to the RosTech Company. The risk of occupational diseases is determined by chemical factors, severity of the labor process, industrial noise. All the professions are at risk. For gluemens, locksmiths, and riveters, the level of an occupational risk is high. For sealants and tightness testers, the risk is low. To reduce the professional risk, it is necessary to modernize production, replace obsolete equipment, and implement modern technologies.

1. Introduction
According to experts of the International Labor Organization (ILO) and the WHO, there are more than 150 occupational risks, of which about 100 ones are sources of constant danger to workers of 2,000 professions. Identification and assessment of occupational risks in various sectors of the national economy are relevant issues [1-10]. Researchers study methods of assessment of occupational risks in the construction industry [1, 2, 7], the aluminum industry [3], the coal industry [4, 8], and the oil production industry [10].

The aircraft industry of Russia belongs to a large branch of the Russian engineering industry, which develops and produces aviation equipment. The Russian aircraft industry produces fighters, bombers, military and passenger aircrafts, transport and military helicopters [11]. The main manufacturers are public holdings “United Aircraft Corporation” and “Russian Helicopters”. On the territory of Russia, there are more than 20 large enterprises, four companies of pilot and experimental aircraft production, aircraft plants repairing equipment and producing various units. The main production sites of the Russian aircraft industry are aircraft engine manufacturing enterprises (Perm, Samara, Kazan, Moscow, Omsk); aircraft manufacturing enterprises (Irkutsk, Novosibirsk, Voronezh, Ulyanovsk); enterprises manufacturing helicopters (Moscow, Kazan, Rostov, Ulan-Ude) [12].

About 150 thousand employees work at aircraft manufacturing enterprises. Their working conditions often do not meet sanitary and hygienic requirements. Depending on their professional affiliation, there are many factors that can cause injuries and occupational morbidity of workers. Thus, an analysis of official data of the State Statistics on injuries showed that among all the leading economic activities, the leading position is occupied by manufacturing industries (including the
aviation one). For example, in 2018, the level of injuries, including fatal ones, exceeded the level of injuries in other industries 4.3-10 times. The share of new occupational diseases was 27.32%. The main causes of chronic occupational diseases were imperfect technological processes and design flaws of labor means.

The purpose of this article is to compare occupational risks in the aircraft industry on the example of Ulan-Ude aircraft plant (Buryatia).

2. Materials and methods
The research object is Ulan-Ude Aviation Plant (U-UAZ), which is the largest enterprise in the Republic of Buryatia. It is part of the holding company “Russian Helicopters” of the state corporation Rostech. The plant manufactures Mi-8 helicopters. Developments of Moscow Helicopter Plant named after M.L. Mil are civilian models Mi-8AMT and Mi-171, military models Mi-8AMTSh and Mi-171Sh, units and spare parts. In 2018, the production of Ka-226T multi-purpose helicopters was launched [11].

The structure of the enterprise includes various structural divisions, including 4 large plants, workshops of production preparation, 11 workshops of main production, as well as auxiliary divisions. In this work, attention will be paid only to the workshops of main production, where aircrafts are manufactured.

The aggregate assembly plant (ZAS-133) is the main link. The main professions are a riveter-assembler, a sealant, an aircraft assembly fitter, and a riveting operator. The mechanical assembly plant (MSZ-146) is one of the workshops of main production, where parts are manufactured and tested. The blanking and stamping plant (ZShZ-123) deals with blanking, stamping and welding. In the non-metal workshop (workshop-36), rubber products, organic glass products, and various sewing products are manufactured. The main working professions are assemblers of fiberglass products, workers producing glass mats, fiberglass, workers assembling products from organic glass and vulcanizers. The control and testing shop (Shop-055) controls quality of supplied purchased component parts (PKI), manufactured products, units and assemblies.

Assessment of occupational risks can be carried out using various methods. GOST R ISO / IEC 31010-2011 describes 31 methods for assessing occupational risks. It is worth noting that new methods are being developed. Therefore, there is no universal method for assessing occupational risks. Each of the methods has its pros and cons. They are all aimed at improving working conditions, preserving life and health of employees [13-20].

We used two most informative and frequently used methods for assessing occupational risks [21]. The first one is the method for calculating retrospective occupational risks. It is based on statistical information on occupational injuries and occupational morbidity of employees. Based on statistical information on occupational injuries, indicators that show frequency and severity of accidents and the level of occupational morbidity were identified. These include the accident rate frequency coefficient (Kf); the severity coefficient (Ks); the loss coefficient (Kl); the fatal accident rate coefficient (Kcm); the coefficient of generalized labor losses (Kg).

Based on the values of frequency and severity of accidents, the organization calculates probability of safe operation $P(0)$ and the risk of injury $R$ [21].

The second method is used to determine prognostic occupational risks using materials of special assessment of working conditions. In accordance with this method, the classes of working conditions for all the professions under consideration were converted into conditional points. Using their values, the relative level of safety and the risk of occupational diseases were calculated. The calculated values of the level of occupational risks for each workplace must be compared with the maximum allowable risk. This comparison is required to rank the risks that require early intervention and adjustment.

3. Results and discussion
Calculation and assessment of retrospective occupational risks. Occupational risks were assessed for 5 years (from 2014 to 2018). For the analyzed period, 60 accidents, including one fatal one, were
registered. During the period under review, 13 accidents happened in the workshops of main production.

According to standard formulas of the method [21], statistical indicators that reflect frequency and severity of accidents were calculated. Based on the obtained values of these indicators, probability of safe operation and the risk of injury were evaluated. The calculation results are presented in Table 1.

Thus, the greatest risk of injury to one person during one year was recorded at AAP-133. It was 0.993; in workshop 036 and ZShZ-123, the risk was 0.950. The lowest risk was in workshop 055.

During the working experience (25 years), the highest injury risk level was calculated for workshop 036 and ZShZ-123, where the risk values were 0.401 and 0.117, respectively.

Table 1. Indicators of industrial injuries at U-UAZ.

| Department | Frequency coefficient, $K_f$ | Severity coefficient, $K_s$ | Loss coefficient, $K_l$ | Coefficient of generalized labor losses, $K_{gl}$ | Probability of safe working conditions During one year | Injury risk During the working experience (25 years) |
|------------|-----------------------------|----------------------------|-------------------------|-----------------------------------------------|-----------------------------------------------|--------------------------------------------------|
| AAP-133    | 10,712                      | 0.141                      | 1,51                    | 1.51                                           | 0.007                                         | 0.963 0.037                                      |
| Workshop 36| 21,429                      | 0.957                      | 20,510                  | 20.51                                          | 0.050                                         | 0.599 0.401                                      |
| MSZ-146    | 3,530                       | 0.051                      | 0.18                    | 0.18                                           | 0.135                                         | 0.995 0.865                                      |
| ZShZ-123   | 5,894                       | 0.843                      | 4.968                   | 4.97                                           | 0.050                                         | 0.883 0.950                                      |
| Workshop 55| 11,905                      | 0.286                      | 3.401                   | 3.40                                           | 0.368                                         | 0.918 0.632                                      |

Occupational risks were assessed for the main professions of AAP-133 and workshop-036 using the forecast method.

Calculation and assessment of occupational risks using the forecast method. Assessment of predicted occupational risks is carried out on the basis of results of special assessment of working conditions obtained in 2015-2018.

In the non-metal workshop (036), the main harmful production factors are an increased noise level, severity of the labor process, and harmful substances in the air. For the workplace of a glueman of power fittings and soft tanks, the highest final subclass of working conditions was 3.3 (harmful working conditions). Harmful working conditions are due to excessive harmful substances. For workplaces of the aggregate assembly plant (AAAp-133), the final subclass of working conditions is 3.2. The leading harmful factors were increased levels of noise and vibration, harmful substances in the air, and severity of labor conditions (Table 1).

In general, an analysis of working conditions showed that 86% of professions correspond to the “harmful” class of work. Therefore, urgent measures are required to improve working conditions.

In accordance with the prognostic assessment of occupational risks, the classes of working conditions were converted into conditional scores whose values were used to calculate the relative level of safety and the risk of occupational diseases. The calculation results are given in Table 2. The ranking of occupational risks was carried out on a scale of deviation of the actual risk level from the maximum allowable one [21]. The evaluation results are presented in Figures 1 and 2.

Thus, for such professions as a glueman, a locksmith and a riveter-assembler, the “highest” level of occupational risks was determined. Consequently, it is necessary to take priority actions to reduce or eliminate occupational risks. The workplaces of sealants and leak testers are characterized by the lowest risk level. For other jobs, the risk level is “medium”.
To reduce the levels of occupational risk, it is necessary to modernize production, replace obsolete equipment, and implement modern technologies. In particular, for a glueman and a locksmith, it is necessary to install an effective system of supply and exhaust ventilation, repair floors, replace hazardous substances with less hazardous ones, use modern personal respiratory protection. For a riveter-assembler, it is necessary to use "active" anti-noise headphones (such as ZM Peltor Optim), perform hydraulic procedures, repair remote control cranes, implement extended regulated breaks, use goggles, and replace obsolete pneumatic tools with new ones.

### Table 2. Results of professional risk assessment at UA-UAZ.

| Name of the workplace | Final class of working conditions | Generalized risk level | Maximum Allowed Risk Level | Deviation of the actual level of an occupational risk from the maximum allowable one, % | Risk level |
|-----------------------|----------------------------------|------------------------|---------------------------|----------------------------------------------------------------------------------|------------|
| Painter               | 3.2                              | 0.714                  | 0.614                     | 16,304                                                                           | Medium     |
| Glue-boiler-spreader  | 3.2                              | 0.714                  | 0.610                     | 17,067                                                                           | Medium     |
| Glueman               | 3.3                              | 0.874                  | 0.651                     | 34,190                                                                           | High       |
| Screenman             | 2                                | 0.525                  | 0.475                     | 10,711                                                                           | Medium     |
| Glass mat producer    | 2                                | 0.606                  | 0.506                     | 19,782                                                                           | Medium     |
| Locksmith             | 3.1                              | 0.691                  | 0.521                     | 32,582                                                                           | High       |
| Assembler             | 3.2                              | 0.722                  | 0.602                     | 19,925                                                                           | Medium     |
| Presser               | 3.2                              | 0.828                  | 0.702                     | 17,953                                                                           | Medium     |
| Aggregat Assembly Plant (AAP-133) |                    |                        |                           |                                                                                    |            |
| Sealant               | 3.3                              | 0.852                  | 0.811                     | 5,039                                                                            | Low        |
| Leak tester           | 3.2                              | 0.656                  | 0.605                     | 8,355                                                                            | Low        |
| Glue boiler           | 3.2                              | 0.808                  | 0.725                     | 11,511                                                                           | Medium     |
| Riveting Machine Operator Assembler-riveter | |                        |                           |                                                                                    |            |
| Assembler-riveter     | 3.2                              | 0.845                  | 0.605                     | 39,732                                                                           | High       |
| Locksmith-assembler   | 3.1                              | 0.538                  | 0.462                     | 16,450                                                                           | Medium     |

### 4. Conclusion

Occupational risks for employees of 14 professions of Ulan-Ude Aviation Plant were assessed. The results showed that working conditions are harmful, have a high level of an occupational risk, and require urgent corrective and preventive actions. For such professions as a glueman, a locksmith, and a riveter-assembler, the "highest" level of an occupational risk was determined. Consequently, it is necessary to take priority actions to reduce or eliminate occupational risks.

To reduce the level of an occupational risk, it is necessary to modernize production, replace obsolete equipment, and implement modern technologies. After these measures have been implemented, occupational risks should be reassessed.
**Figure 1.** Deviation of the actual level of an occupational risk from the maximum allowable one at AAP-133.

**Figure 2.** Deviation of the actual level of an occupational professional risk from the maximum allowable one in Workshop-036.

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