The study on the factors influencing the quality of paint and varnish coating when repairing the car body

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Abstract. The article presents the main results of the studies on the factors influencing the quality of paint and varnish coating of the car body while performing the emergency recovery repair. The relevance of scientific observations in the presented work is that the issues connected with the quality assessment of applying and drying of paint and varnish coating of the body are not studied to the full extent. It especially concerns the cars that need recovery repair after road accidents. The data presented in the article can be applied while assessing the technical state of the cars, injured as a result of break-down incidents; when training specialists in the automotive industry; with the color selection of paints and varnishes and further application on the body. The scientific work provides the contribution to the improvement of the efficiency indicators of the cars operation on the basis of defects testing of decorative protective coating of the body and the definition of the factors influencing the quality of paint and varnish coating during repair application. The scientific novelty of the article consists in obtaining the identification results of the most significant factors affecting the quality of the paint and varnish coating applied while repairing, aimed at the restoration of the critical state of the car body resulting from the traffic accident.

1. Introduction

The high level of modern automobilization leads to a number of issues connected with vehicles operation. This is especially true for cars as the most numerous among the transport-technological machines.

Lately disputes between the quality of the repair coloring of the car body and the factory covering are observed on the market of the autotechnical examination. The clients of the service stations are not satisfied by the reconstructive options for coloring in terms of its thickness, gloss, structure and other parameters.

These divergences can occur owing to the non-compliance with the technology of the preparation and the repair coloring of the body surface, the use of paints and varnishes of various brands, the use of human abilities while coloring, but not the robotic line of coating, etc. In this regard it is necessary to develop the number of actions directed to the solution of the above problems.

The study on factors influencing the quality of paint and varnish coating when repairing the car body is one of the tasks solved within the improvement of the technological process of control and the protective decorative coating. The general scheme of the study is represented in figure 1. Some tasks were solved earlier; the main results of these works were published in the scientific papers [1-3].
2. Methods
The study on factors influencing the quality of paint and varnish coating was carried out with the use of a priori ranging method.

Ranging assumes a certain arrangement of factors on the expected extent of their influence on the optimization parameter.

It is recommended to invite more experts when ranging the factors to reduce the subjectivity of the rank estimates.

The ranging results are presented in the form of matrixes for the convenience of the subsequent calculations (Table 1).
Table 1. Matrix of the ranks.

| Experts | 1   | 2   | ... | i   | ... | k   |
|---------|-----|-----|-----|-----|-----|-----|
|         | $a_{11}$ | $a_{12}$ | ... | $a_i$ | ... | $a_{ik}$ |
|         | $a_{21}$ | $a_{22}$ | ... | $a_{2j}$ | ... | $a_{2k}$ |
|         | ... | ... | ... | ... | ... | ... |
|         | $a_{i1}$ | ... | ... | $a_{ji}$ | ... | $a_{ik}$ |
|         | ... | ... | ... | ... | ... | ... |
|         | $a_{m1}$ | $a_{m2}$ | ... | $a_{m}$ | ... | $a_{mk}$ |

Summarizing the matrix columns (table 1) we determine the sum of the ranks according to the factors

$$T = \frac{\sum_{i=1}^{k} \sum_{j=1}^{m} a_{ij}}{k},$$

(1)

where $m$ – a number of experts.

The difference between the ranks sum of i-factor and the average sum of the ranks is:

$$\Delta i = \sum_{j=1}^{m} a_{ij} - \frac{\sum_{i=1}^{k} \sum_{j=1}^{m} a_{ij}}{k} = \sum_{j=1}^{m} a_{ij} - T,$$

(2)

Then we calculate the sum of squared differences ($S$) by formula 3:

$$S = \sum_{i=1}^{k} (\Delta i)^2$$

(3)

For the calculation of the value of the concordance coefficient ($W$) we use formula 4:

$$W = \frac{12S}{m^2(k^3-k)}.$$

(4)

It is possible to use the concordance coefficient after the assessment of its importance. For the assessment of the concordance coefficient importance we can use the $\chi^2$ distribution at $f = k - 1$ of the degree of freedom: $\chi^2 = W \cdot m \cdot (k-1)$.

The $\chi^2$ value depending on the expression for the $W$ calculation will be determined by formula 5:

For the identification of the factors influencing the quality of paint and varnish coating we studied and analysed the characteristic defects of paint and varnish coatings of a body (Table 2) and the reasons for their occurrence [4].

3. Results and discussion

A priori ranging of the factors influencing the quality of paint and varnish coating of a body was carried out in the study. There was an expert survey with the ranks distribution from 1 to 10 on the specified factors of influence on the coating quality. 10 painters of the Orenburg service stations acted as experts.
| Sketch | Coating defects | Reasons for occurrence |
|--------|----------------|------------------------|
| 1      | Unsatisfactory adhesion (the film of paints and varnishes does not keep on a substrate or an underlying layer) | Unsatisfactory preparation of the surface: the presence of wax, oil, water, rust. Compressed air on the dispersion is polluted. The inappropriate solvent for the dispersion is used. The material is applied on hot or too cold surface. The coating is too thick. There is an unsatisfactory grinding of primer. |
| 2      | Dirtiness of coating | There is an unsatisfactory wiping out after grinding. Pollution appears during the application. There is an unsatisfactory cleanliness of the room and the equipment. The container with paints and varnishes has litter. There is an unsatisfactory filtration of material. |
| 3      | Dry spraying | The solvent has low boiling temperature. The ratio of paints and varnishes and air is incorrectly regulated. The distance from the colored surface to the nozzle is long. There is too much air pressure on spraying. The presence of draft in the painting camera. The flow is insufficient when coloring by the method of electrostatic spraying. |
| 4      | “Shagreen” | The reasons of this defect are that the liquid paint applied on the surface by means of the dispersion has no sufficient ability to "pouring" for the formation of the smooth film. In practice the coating applied by the dispersion (especially electrostatic) has usually some shagreen after drying. This results from the fact that the majority of paints has to be suitable for applying on vertical surfaces, i.e. have not so high fluidity, otherwise the coating will have flows. |
| 5      | Cracking coating | The coating is applied on the old cracked coating. The coating with small elasticity is used. The excessively thick layer of the final coating is applied. The solvent which is not corresponding to paint is used. The additional blowing of wet film by air is used to drying acceleration of the coating. The material is insufficiently mixed (the ratio a pigment - binding is broken). |
| 6      | Drips (flows) | The coating is applied on the dirty surface (oil, wax, etc.) or on the film which is a little decomposed and will give the chance to the top layer to flow down. There is a large amount of the slowly evaporating solvent. The enamel layer is too thick and is also put with small viscosity. The shape of the dispersion torch is incorrect. There is low air pressure for spraying. |
### Table 2. Continuation

| Water spots | There is water on the painted surface during the application of the subsequent layer in the painting camera or after the final coloring in the drying camera |
|-------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Wrinkling.  | The coating is too thick. There is fast hardening of the top layer. The surrounding temperature is high, there is siccative surplus                                                                 |
| Formation of "pockmarks", "craters". | It is impossible to expect the tendency of paints and varnishes to the formation of "pockmarks" and to eliminate this defect is very difficult. Some of the reasons are the excess of some silicones in paints and varnishes or the metal surface is polluted by it; the existence of polishing structures containing silicone or wax on the surface |
| Bubbles formation. | There was moisture between metal and primer or between the layers. Compressed air contains oil, water. The material supply at the electrostatic dispersion is too small |
| Coating slipping from the surface | Cold paints and varnishes or solvent are used. The material is insufficiently mixed. The solvent with small dissolving ability is used. The coagulated material is used. The material is overheated at hot dispersion |
Table 2. Continuation

| Coating inflation | The primary applied layers dissolve in final layer due to unsatisfactory drying. Incompatible paints and varnishes and the active solvents at final coloring are used. The old coating is not completely removed, the first layer is applied to the non-greasy surface |

The calculation of the key indicators was made in the Exel program with the observance of the necessary requirements to a priori ranging (the concordance coefficient $W = 0.52$, and $\chi^2 > 14.1$). The results of a priori ranging of the factors are presented in Table 3.

Table 3. The results of a priori ranging of the factors.

| Parameters | Sum of the ranks $\sum_{j=1}^{m} a_{ij}$ | Deviation $\Delta_i$ of the sum of the ranks from the average sum of the ranks | Squares of deviations, $\Delta_i^2$ | Weight Factor | Place |
|------------|--------------------------------------|-------------------------------------------------|--------------------------------|----------------|-------|
| The distance discrepancy from the nozzle to the colored surface (X1) | 76 | 21 | 441 | 0.048 | 10 |
| The application of paints and varnishes on badly prepared surface (X2) | 28 | -27 | 729 | 0.105 | 4 |
| Insufficient mixing of paints and varnishes (X3) | 34 | -21 | 441 | 0.086 | 6 |
| The mismatched viscosity of paints and varnishes (X4) | 19 | -36 | 1296 | 0.114 | 3 |
| Unsatisfactory cleanliness of the room of the painting and drying chamber (X5) | 30 | -25 | 625 | 0.095 | 5 |
| Pollution of compressed air and paints and varnishes (X6) | 15 | -40 | 1600 | 0.124 | 2 |
| The use of inappropriate paints and varnishes or the solvent (X7) | 13 | -42 | 1764 | 0.133 | 1 |
| The mismatch of material supplying when coloring (X8) | 73 | 18 | 324 | 0.067 | 8 |
| Insufficient amount of paints and varnishes in the nozzle tank (X9) | 87 | 32 | 1024 | 0.029 | 12 |
| The application of an excessive layer of paint and varnish coating (X10) | 78 | 23 | 529 | 0.038 | 11 |
| Misadjustment of the spray torch (X11) | 75 | 20 | 400 | 0.057 | 9 |
| Inappropriate air temperature in the camera when applying paints and varnishes (X12) | 88 | 33 | 1089 | 0.019 | 13 |
| The mismatch of compressed air pressure during spraying (X13) | 65 | 10 | 100 | 0.076 | 7 |
| Inappropriate air humidity in the camera when applying paints and varnishes (X14) | 95 | 40 | 1600 | 0.01 | 14 |
| Total | 776 | - | 11962 | 1.0 | - |
Proceeding from the received results a priori graph of the ranks has been constructed (figure 2). This graph has allowed to reveal the most significant factors influencing the quality of paint and varnish coating (factors: X7, X6, X4, X2, X5, X3, X13, X8) when repairing the car body.

**Figure 2.** A priori graph of the ranks: X1 – the distance discrepancy from the nozzle to the colored surface; X2 – the application of paints and varnishes on badly prepared surface; X3 – insufficient mixing of paints and varnishes; X4 – the mismatched viscosity of paints and varnishes; X5 – unsatisfactory cleanliness of the room of the painting and drying chamber; X6 – pollution of compressed air and paints and varnishes; X7 – the use of inappropriate paints and varnishes or the solvent; X8 – the mismatch of material supplying when coloring; X9 – insufficient amount of paints and varnishes in the nozzle tank; X10 – the application of an excessive layer of paint and varnish coating; X11 – misadjustment of the spray torch; X12 – inappropriate air temperature in the camera when applying paints and varnishes; X13 – the mismatch of compressed air pressure during spraying; X14 – inappropriate air humidity in the camera when applying paints and varnishes

### 4. Summary

The analysis of the defects when applying paint and varnish coating on the details of the car body has shown that the main reasons are the technology factors connected with the modes of the material application and with the purity degree of enamel, compressed air, the repaired surface and the painting and drying camera.

A priori ranging of the factors influencing the quality of paint and varnish coating of the car body has revealed the most significant factors: X7 – the use of inappropriate paints and varnishes or the solvent; X6 – pollution of compressed air and paints and varnishes; X4 – the mismatched viscosity of paints and varnishes; X2 – paints and varnishes application on badly prepared surface; X5 – unsatisfactory cleanliness of the room of the painting and drying chamber; X3 – insufficient mixing of paints and varnishes; X13 – the mismatch of compressed air pressure when spraying; X8 – the mismatch of the material supplying when coloring.

When controlling paint and varnish coating it is necessary to make the comparison of the repair values of paint and varnish coating thickness with the factory values; the divergence has to be no more than 10-15% [5].
5. Conclusions
The obtained scientific data can be used for the quality control of the preparatory and painting work on the car body and its details while conducting reconstruction influence arising from the traffic accidents.

The study’s results promote the positive efficiency of the cars operation due to the improvement of the technological process of controlling and applying paint and varnish coatings that will allow to increase the parameters of environmental safety of the process, to reduce the labor input of the volume of repair works and to increase the efficiency of the service station functioning, to improve the quality of the provided services in body repair at the service stations.

The developed statement will allow us to use the data of the scientific article for the efficiency increasing in the damage determination arising from the traffic accidents for the value accounting of fair tear and wear of the cars body and also for the training experts/automotive technicians, bachelors and masters. Their future profession is connected with the operation of transport technological machines and complexes.

The main results of the study are published in the collections and materials of scientific works and conferences of various levels [6-12].

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