Design and spraying of deformed Disruptive pattern camouflage

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Abstract. This paper introduces the technical indicators related to the deformed disruptive pattern camouflage in China's national military standards, and discusses the expansion and supplement of the existing national military standard from the development of reconnaissance technology. It is recommended to increase the content of anti-military reconnaissance in the optical camouflage index; it is suggested that the speckle size shape technical index gives quantitative provisions based on the characteristic values such as area, perimeter and elongation; it is recommended to establish the relevant technical indicators of optical camouflage.

1. Introduction

Disruptive pattern camouflage is a camouflage implemented using paints, dyes, and other materials to change targets, obstacles, and background colors and speckle patterns [1]. Disruptive pattern camouflage can be divided into three categories: protective camouflage, deformed camouflage and counterfeit camouflage. The deformed camouflage is a multi-color camouflage composed of several irregularly shaped large spots, which are mainly used for camouflage military vehicles and other moving targets.

The deformed camouflage is composed of irregularly shaped multi-colored spots or stripes, and its irregularity and multi-color characteristics distorted the enemy's visual laws and satisfied the camouflage effect of the moving target [2].

After years of development, the deformed disruptive pattern camouflage has formed a relatively complete technical index system. This paper starts from the requirements of China's military standards, introduces the technical indicators of deformation camouflage, and designs and sprays the deformed disruptive pattern camouflage according to literature research and experimental data. The discussion and some suggestions for the technical indicators of the deformed camouflage.

2. Technical requirements of Chinese military standard for deformation camouflage

The requirements of the national military standard for deformed camouflage are: color selection, spot size calculation, spot shape and configuration.
2.1. Colour selection
GJB453 deprecates three and four colour, two colours; and GJB4004 deprecates four-color, two-colour camouflage, using three-color deformation camouflage. Spot colour is selected according to GJB798, GJB1082 or by contract. The main requirements for colour selection are as follows:

1. The intermediate colour of the deformed camouflage spot is selected from the dominant background colour according to the requirement of the background average brightness coefficient.
2. The contrast between the bright and dark differential colours and the intermediate colours in the deformed camouflage pattern should be no less than 0.4, and the camouflage spots maintain a sharp contrast with each other, which is good for distorting the target shape.
3. The brightness contrast between each colour in the deformed camouflage pattern and the similar colour in the background is less than 0.2.

2.2. Spot size calculation
In order to prevent spatial colour mixing of various colour spots, the size of the camouflage spot must be visible at a predetermined viewing distance. According to the contrast of the brightness of the spots, GJB453 gives the formula for calculating the visible size of the spots:

\[ \text{When } \frac{K}{D} \geq 0.4, A > \frac{(2.5 - 3)D}{3400} \]  
\[ \text{When } 0.2 \leq \frac{K}{D} \leq 0.4, A > \frac{(3 - 4)D}{3400} \]

Where: K is the spot brightness contrast; A is the spot visible size; D is Observe the distance [3].

2.3. The principles of spot shape and configuration are mainly:
1. The shape of the deformed camouflage spot is composed of an irregular curved outline.
2. Spots of the same color should be of different shapes and sizes.
3. Intermediate color spots and contrasting color spots should be staggered in equipment.
4. Deformed camouflage spots should not be symmetrically configured.
5. The spots should not be terminated at the edge of the equipment outline and should extend to the other surface. When extending, the long diameter of the spots and the ridges of the equipment should intersect at an acute angle.
6. Dark spots should be placed on the equipment projections, and bright spots should be placed on the recesses; the center of the spots should not coincide with the apex of the protrusions or recesses.
7. The top of the equipment should be equipped with dark spots, and the dark side should be configured with more bright spots and dark spots.
8. Dark spots should be placed at the orifice of the equipment, but the contour of the orifice should not be repeated.

3. Experimental process of deformed disruptive pattern camouflage design

3.1. Determine the background
We must choose the appropriate background for the experiment.

3.2. Determination of three-color deformation camouflage
Composition: The color consists of an intermediate color and a bright and dark color that is significantly different from the intermediate color.

3.2.1. The principles of spot shape and configuration are mainly. The intermediate colour of the three-color deformed camouflage can be determined by the method of protecting camouflage for the average brightness coefficient. Table 1 shows area distribution and color characteristics of background spots.
\[ r (\text{average luminance coefficient}) = \frac{(0.123 \times 16 + 0.366 \times 3 + 0.153 \times 40 + 0.179 \times 8 + 0.087 \times 21 + 0.231 \times 5 + 0.137 \times 6 + 0.280 \times 2)}{100} = 0.1514. \]

This value is similar to trees. The brightness factor (0.153), so you can select the colour of the tree (the 13th colour sample on the colour standard) as the middle colour of the deformed camouflage spot.

### Table 1. Area distribution and color characteristics of background spots.

| Numbles | Background name | Spot area% | The visible brightness coefficient | Color sample number |
|---------|-----------------|------------|-----------------------------------|---------------------|
| 1       | Roof            | 16         | 0.123                             | 20                  |
| 2       | Wall            | 3          | 0.366                             | 24                  |
| 3       | Trees           | 40         | 0.153                             | 13                  |
| 4       | Flower          | 8          | 0.179                             | 37                  |
| 5       | Bush            | 21         | 0.087                             | 1                   |
| 6       | Semi-wild       | 5          | 0.231                             | 14                  |
| 7       | Brick road      | 6          | 0.137                             | 27                  |
| 8       | Cement road     | 2          | 0.280                             | 40                  |

3.2.2. **Principle of determining the bright colour.** The brightness coefficient of the bright colour is \( r_1 \). From \((r_1 - r)/r_1 = (0.1514 - 0.1514)/0.1514 \geq 0.4\), \( r_1 \geq 0.252 \) is selected. The 29th colour sample \( (r_1 = 0.203) \) with the brightness coefficient is selected as the bright colour of the deformed camouflage spot.

3.2.3. **Principle of determining the bright colour.** The brightness coefficient of dark colour is \( r_2 \). \((r - r_2)/r_1 = (0.1514 - 0.093)/0.1514 \geq 0.4\), \( r_2 \leq 0.0908 \). Select the 21st colour sample \( (r_2 = 0.093) \) with similar brightness coefficient as the dark colour of the deformed camouflage spot.

![Bright color](image1.png) ![Intermediate color](image2.png) ![Dark color](image3.png)

**Figure 1.** Three-colour deformation camouflage

3.2.4. **Three-colour deformation camouflage design parameters (Fig. 1 and Table 2).**

### Table 2. Design parameters for three-color deformation camouflage

| Numbles | Deformed camouflage spot name | Visible light brightness coefficient | Color sample number | area |
|---------|--------------------------------|-------------------------------------|---------------------|------|
| 1       | Bright color                   | 0.203                               | 29                  | 20%  |
| 2       | Intermediate color             | 0.153                               | 13                  | 40%  |
| 3       | Dark color                     | 0.093                               | 21                  | 40%  |
3.3. Determination of three-color deformation camouflage

When observed with the naked eye, and the brightness contrast between the spots satisfies $K \geq 0.4$, there is $d \geq (2.5-3)D/3438$.

The distance $D$ we observed this time is 50 meters, so $d=0.036-0.043$ meters.

The observation distance $D$ in the equation only considers the enemy's observation of the distance between the ground and the air, because targets such as artillery, tanks, and cars, due to their small size, can only be found at a closer viewing distance [4].

3.3.1. The shape of the spot. In order to distort the original contour of the target, the deformed camouflage spots are irregularly shaped, and the sizes of the convex and concave portions are unequal. The minimum size of the concave portion is larger than the maximum size of the concave portion of 0.5.

3.3.2. Analysis of spot size and shape indicators. Due to the uncertainty of the enemy reconnaissance distance, the researchers proposed the idea of multi-structure small spot camouflage. When viewed at close range, this is a multi-color small spotted camouflage. As the observation distance increases, adjacent small spots merge into several large spots due to the color mixing effect, but the implementation of this idea faces some difficulties.

The regulations on the shape and configuration of deformed camouflage spots in China's military standards are a summary of long-term research and application experience. GJB4004 gives the typical deformed disruptive pattern camouflage pattern of the Army, but it has no ready-made camouflage pattern reference for camouflage obstacles, special equipment, new equipment, etc. and the uniform camouflage pattern of all equipment is not conducive to camouflage. Designing new camouflage patterns is also a very important task under the premise of following the national military standard [5].

Yueguo Shen [6] proposed that the deformed camouflage spot should resemble the shape of a natural background spot, that is, an irregular pattern composed of a plurality of convex and concave irregular curves, and the size of the convex and concave portions should be unequal. However, the size of the convex and concave portions must not be greater than $A/2$. And through orthogonal experiments, the influence of the survivability on the position is the shape factor $> \text{spot size} > \text{brightness difference}$ (the three levels of brightness difference are 0.10, 0.15, 0.20), that is, in the disruptive pattern camouflage technology, the shape system is the most important. However, the article does not give a calculation method for the spot shape coefficient.

How to more scientifically and more detailedly define the shape of the deformed camouflage spot is a problem that needs further study.

4. Implementation of deformed camouflage

(1) Determining experimental spraying equipment. Camouflage spray trucks are generally used.

(2) Design deformation camouflage sketch. According to the design principle of the deformed camouflage, the five sides of the target. The deformed camouflage sketch of the design target on the map, the sketch should show the colour, size, shape configuration and pigment usage of the camouflage spots on each side of the target.

(3) Blending deformed camouflage dye. Adjust the disruptive pattern camouflage colour with artificial colour matching or computer colour matching technology.

(4) Calculate the amount of paint used. Calculate the amount of paint used in the deformed camouflage according to the target area of the activity and the consumption standard of the paint [7].

(5) Colouring on the target. Applying colour to the target can be done as follows: According to the speckle pattern of the deformed camouflage sketch, the chalk is used to start the spot on the target. According to the calculated pigment and adhesive compounding paint, adjust the concentration of the paint, and stir frequently to keep the pigment particles evenly distributed. Colour the target with the colouring tool according to the starting point[8].

(6) After the implementation of the deformed camouflage, the field camouflage effect test should be carried out. The comparison of the experimental results is shown in Fig. 2.
5. Conclusion

(1) China's military standards for disruptive pattern camouflage are the accumulation of long-term research work, and the deformation disruptive pattern camouflage should meet its technical indicators; but the development of reconnaissance technology forces the national military standard to be expanded and supplemented.

(2) From the perspective of optical camouflage indicators, it is recommended that the national military standard should be added to the corresponding confrontation indicators on the basis of assessing the high enemy military reconnaissance threats.

(3) In the deformation camouflage spot size and shape design, the relevant regulations can be refined, and the quantitative technical indicators are used to standardize the design work of the camouflage pattern.

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References

[1] Jianchun Zhang. Disruptive pattern camouflage camouflage technology [M]. Beijing: China Textile Press, 2002:35.

[2] Zhou L, Shao J Z, et al. Study on the Camouflage-Protective and Dyeing Properties of Natural Dye Indigo[J]. Journal of Donghua University: English Edition, 2010, 26(1):46-51.

[3] Jianghua Hu. Camouflage camouflage technology [M]. Beijing: National Defence Industry Press, 2012, 4.

[4] Christopher F. Foss. UK Armoured Vehicles Get Thermal Imaging[J]. Jane’s Defence Weekly, 2005,42(1):11.

[5] Frode Berg Olsen. Methods for Evaluating Thermal Camouflage[R]. ADA456649, 2005:12.

[6] Dorum O H, Gnedin M. Bezier curves for advanced driver assistance system applications: US, US8725474[P]. 2014.

[7] Yueguo Shen, Xiaoqiang Huo, Xiaqi Li. Design and optimization of camouflage camouflage for engineering machinery [J]. EngineeringMachinery, 2006, (8): 29–33.

[8] Yang F, Lin Y, Hu X, et al. Design and implementation of personal blog system based on MVC mode[J]. Computer Era, 2014.