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Metal Rubber Blank Automatic Laying Obstacle Avoidance Strategy

Jiaxiong Xu[1, *], Baotong Lu[1, a], Ergang Ma[1, b], Ruina Jin[2, c], Xueheng Cui[3, d] and Jianhui Tian[1, e]

[1]PLA 66395, Shijiazhuang 050000, China
[2]People's Liberation Army 980 Hospital, PLA 66395, Shijiazhuang 050000, China
[3]PLA 66222, Shijiazhuang 050000, China

*Corresponding author email: 747545950@qq.com, [a]964585485@qq.com,
[b]378535946@qqcom, [c]66276422@qq.com, [d]1072876527@qq.com,
[e]765878437@qq.com

Abstract. The new metal rubber blank automatic laying equipment solves the technical problem of preparing large-sized metal rubber sheet components and metal rubber component blanks with complicated configurations such as holes. Based on the automatic laying process of metal rubber, the metal rubber components are divided into simple configuration and complex configuration, and a new method for judging the feasible laying path of metal rubber is proposed. Based on matlab, a new type of rapid metal rubber blank laying obstacle avoidance strategy was designed, which realized the identification and positioning of the feasible path of metal rubber blank automatic laying, which provided technical support for path planning and automatic laying.

1. Introduction

Metal rubber is a kind of elastic porous functional structural material, which is manufactured by cold stamping process of various grades of wire. The inside of the metal rubber is a spatial network structure in which the wires are interlaced and intertwined, and has characteristics of high elasticity and large damping. At the same time, metal rubber has the advantages of non-volatile in vacuum, no fear of radiation environment, high/low temperature resistance, corrosion resistance, long fatigue life, long-term preservation and high reliability, and is widely used in cutting-edge weapons and equipment and industrial production [1-4].

The general process flow for the preparation of metal rubber components is: selecting the material (grade) and diameter of the wire, winding the spiral, preparing the blank, cold stamping, and post-processing. The preparation process of the metal rubber blank plays a key role in the performance of the metal rubber. The preparation method of the metal rubber blank mainly consists of manual paving blanks, spiral wound blanks, armor blanks and the like. The Russian National Samara Aerospace University [5] has done a lot of work on the traditional hand-laid blanking process, and has designed many creative processes for the structure and performance of different metal rubber components. Xia Yuhong [6] studied that when other performance indexes are the same, when the inclination angle of the spiral coil is different, the rigidity, load bearing capacity and energy dissipation performance of the

obtained metal rubber component are also different, and the preparation process of the metal rubber component is further improved. It laid the foundation for the wide application of metal rubber. Wang Fengming [7] designed three kinds of spiral winding methods, such as ring overlap net, well type laying and cross-hook netting, which improved the bite degree of spiral helium in metal rubber material and improved the uniformity of material. Li Mingsen [8] uses two different winding methods: fine needle positioning and pressure line positioning, and relies on an automatic spiral roll laying platform to prepare metal rubber blanks. And the advantages and disadvantages of the two laying methods are compared and analyzed. The needle mold is suitable for the components with small laying size and high performance requirements, and the simple barrel mold is suitable for the components with large size and relatively loose performance requirements. Chen Hui [9] designed the winding device according to the metal rubber winding principle by using the fine needle positioning method. The device not only realizes the control of the winding motion, but also the device can display and adjust the parameters of the component. Zhu Yuquan [10] based on the fine needle positioning, further studied the metal rubber spiral winding winding laying method, and designed the experimental prototype to verify the correctness of the motion principle. Li Tuo [11] used a circular weft knitting machine to weave the metal wire into a net sleeve, then press the groove and wind the net sleeve, and finally stamped and formed into a braided-stitched metal rubber to solve the small density and small rigidity metal. Rubber molding problems.

For large-sized metal rubber sheet components and metal rubber components with complex configurations such as holes, it is not suitable for the preparation of blanks by spiral winding process. Generally, the traditional manual paving technology is adopted, which is time-consuming and labor-intensive, and the production efficiency is not high. The path is basically based on experience, and the structural size and performance consistency of the product are difficult to guarantee, and cannot meet the needs of large-scale production of modern defense industry. This metal rubber research center has developed a CNC blank laying equipment based on PMAC multi-axis control technology. The process is that the spiral coil after the constant pitch stretching is laid into a mesh-like structure to support the blank according to a certain laying trajectory, and the process can plan and accurately control the spiral winding trajectory. The automatic blank laying equipment realizes the three-dimensional laying of the metal rubber blank, which lays a technical foundation for the automation and flexibility of the blank laying. Huang Kai [12-14] fully expounded the automatic laying equipment and process flow of metal rubber blanks, and made in-depth research on the planning of feasible path identification and laying route.

Based on the automatic laying process of metal rubber blanks, this paper proposes a new type of fast metal rubber blank laying obstacle avoidance strategy based on matlab, which is based on matlab. This strategy further facilitates engineering application.

2. Locating Pin coding and Two-dimensional Coordinate

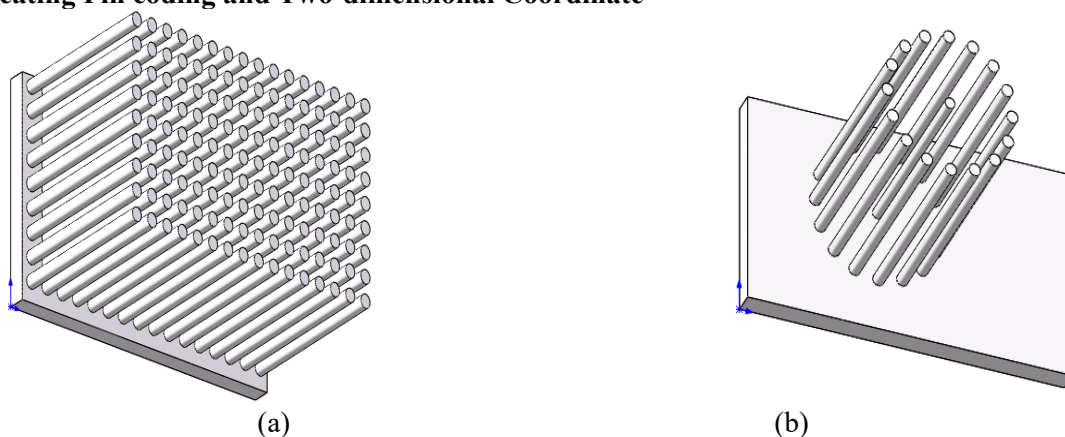(a)   (b)

Figure 1. Sketch map of laying platform.

The laying platform comprises a supporting plate and a paving setting device, and the paving setting device is composed of a detachable positioning pin and a fixing plate (as shown in Fig. 1), and is used for positioning the wire spiral winding wire in the laying process to determine the laying of the blank. Outline. The positioning pin can be placed at any position in the laying area, and the position of the positioning pin in the laying area does not affect the research content of this paper. In order to simplify the description of the problem, this paper selects the laying platform where the positioning pin is arranged regularly (Fig. 1a).

In order to quantify the collision properties between the paving path and the obstacle, the coordinate origin is selected on the laying platform plane to establish a plane rectangular coordinate system. Simplify the high-precision trajectory robot and the locating pin to a point, encode all the locating pins, and accurately position each locating pin.

3. Barriers in the Automatic Laying of Metal Rubber Blanks
Metal rubber components are also available in a variety of configurations due to the complex and diverse environment in which metal rubber is used. The spiral roll is simplified into a line-to-point connection, that is, the laying path of the spiral roll is converted into a line between the positioning pins. In the automatic laying of metal rubber blanks, the non-laying area is regarded as an obstacle. The obstacle avoidance problem is to determine whether the connection between any two positioning pins is a feasible laying path.

3.1. Classification of Metal Rubber Roughcast Configuration
According to the complexity of common metal rubber component configuration, it is divided into simple configuration and complex configuration in automatic metal rubber blank laying process.

(1)   Simple configuration means that there is no non-paving area. For example, the configuration of metal rubber elements is circular, elliptical, triangular and other convex polygons (as shown in Figure 2). Shadows in the figure are paving areas. For metal rubber components without non-laying area, the line between any two locating pins is the feasible path, so there is no problem of identifying the feasible path.
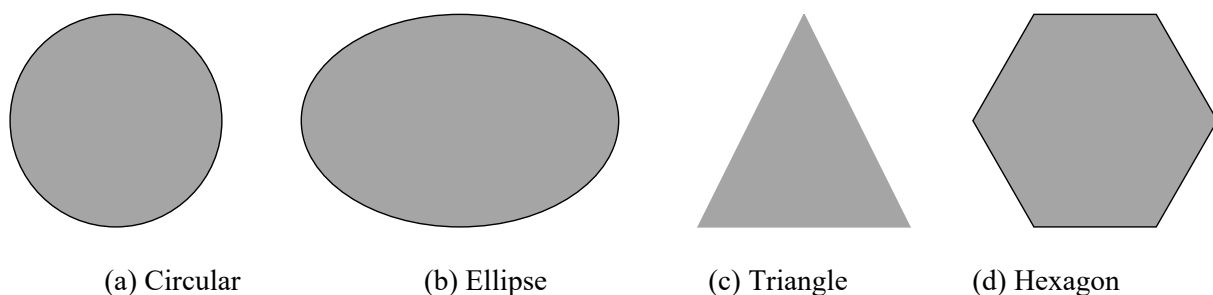

(a) Circular   (b) Ellipse   (c) Triangle   (d) Hexagon

Figure 2. Schematic diagram of simple configuration.

(2)   Complex configurations include non-paving areas, such as metal rubber components with circular, elliptical, polygonal and convex polygons (as shown in Figure 3). Shadows in the figure are paving areas and blank areas are non-paving areas. In this type of metal rubber components, first of all, it is necessary to distinguish whether the connection between locating pins passes through the non-paved area.
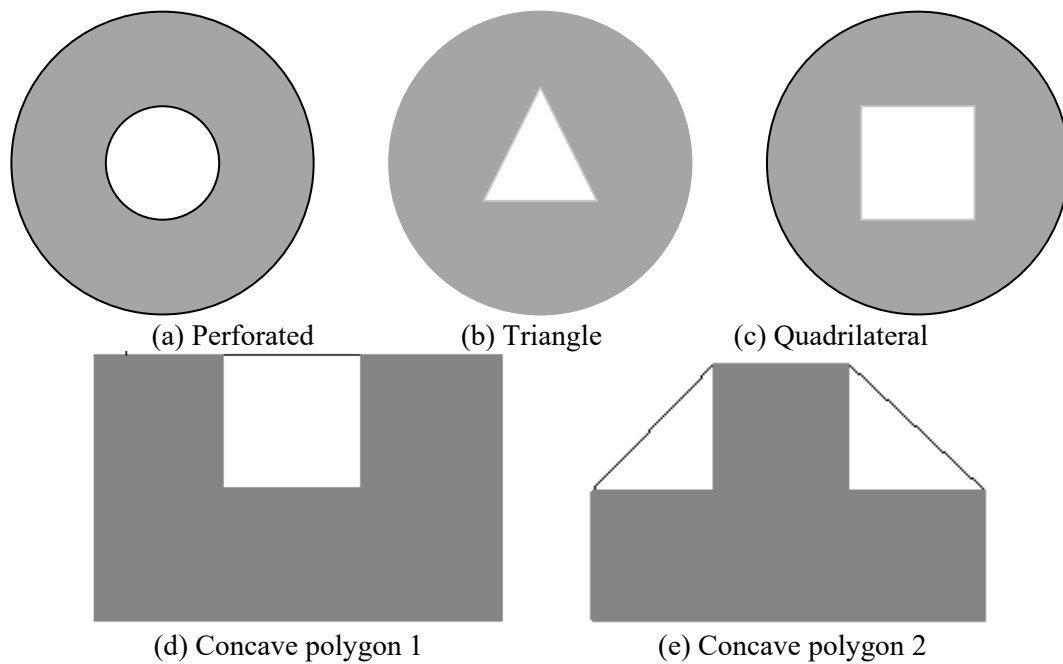
(a) Perforated   (b) Triangle   (c) Quadrilateral

(d) Concave polygon 1   (e) Concave polygon 2

Figure 3. Complex configurations of metal rubber components.

3.2. The Theoretical Basis of Feasible Path Discrimination

The feasible path of metal rubber paving is the connection between positioning pins which do not pass through non-paved areas. Using the established Cartesian coordinate system, we can distinguish whether the line between the two locating pins passes through the non-paved area or not.

(1)   Equation of connection between locating pins:

For any two locating pins n (x1, y1) and m (x2, y2), the equation is established as follows:

$$Ax + By + C = 0 \tag{1}$$

Formula A, B and C are parameters of linear equation.

(2)   Parametric representation of non-paved areas:

The non-paved area is circular, the coordinates of the center of the circle are (a, b), the radius length is r, and the parameterization equation is as follows:

$$(x - a)^2 + (y - b)^2 = r^2 \tag{2}$$

The non-paved area is a convex polygon. According to the coordinates of each vertex of the polygon, the equation of each side of the polygon is established, and the range of its horizontal and vertical values is limited. For example, three vertex coordinates of a triangle are A (1, 2), B (2, 3), C (3, 2), and their parameterization equations are as follows:

$$\begin{cases} x - y + 1 = 0\,(1 \le x \le 2) \\ x + y - 5 = 0\,(2 \le x \le 3) \\ y = 2\,(1 \le x \le 3) \end{cases} \tag{3}$$

3.3. Discrimination of Feasible Paths

The equation of pin connection and the equation of non-paved area are solved in conjunction. The results are as follows: first, there is no real solution or unique solution to the equation system. As shown in Fig. 4a, the spiral coil will not pass through the paved area, which is a feasible path; second, two different solutions of the equation system, as shown in Fig. 4b, the spiral coil may pass through the non-paved area. It may not pass through the paving area. In this case, by observing the geometric relationship between the intersection point (solution of the equations) and the two locating pins, we can know that the distance between any intersection point and the two locating pins is D1 and d2, respectively. If Max {d1, d2} is less than the distance d between the two locating pins, the spiral coil passes through the non-laying area, which is infeasible. Route. If Max {d1, d2} is greater than the distance d between the two locating pins, the spiral coil will not pass through the non-paved area, which is a feasible path. Third, there are numerous solutions to the equations. As shown in Fig. 4c, the spiral coil will not pass through the paved area, which is a feasible path.
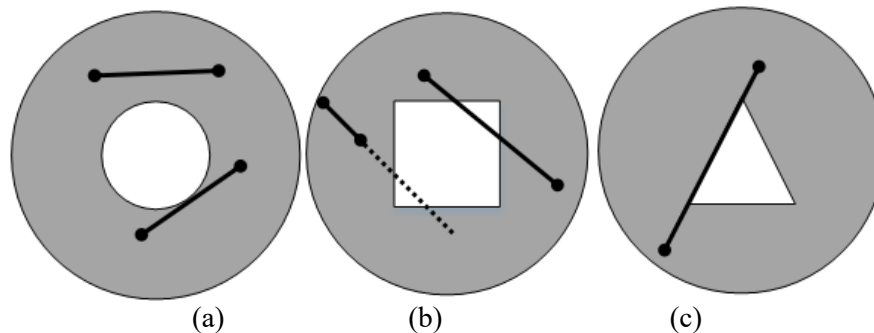

(a)   (b)   (c)

Figure 4. Relationship between laying track and non-paved area.

4. Obstacle Avoidance Strategy Based on MATLAB

Before metal rubber paving path planning, it is necessary to determine whether the paving path is feasible. The obstacle avoidance theory is compiled into the corresponding matlab language, and the feasible path is displayed in the form of images. By using the xlswrite function in matlab, the coordinates of the locating pin that composes the feasible path can be quickly identified and located, which provides technical support for the planning and path planning of the locating pin. (Note: All paths are connections between any two locating pins)

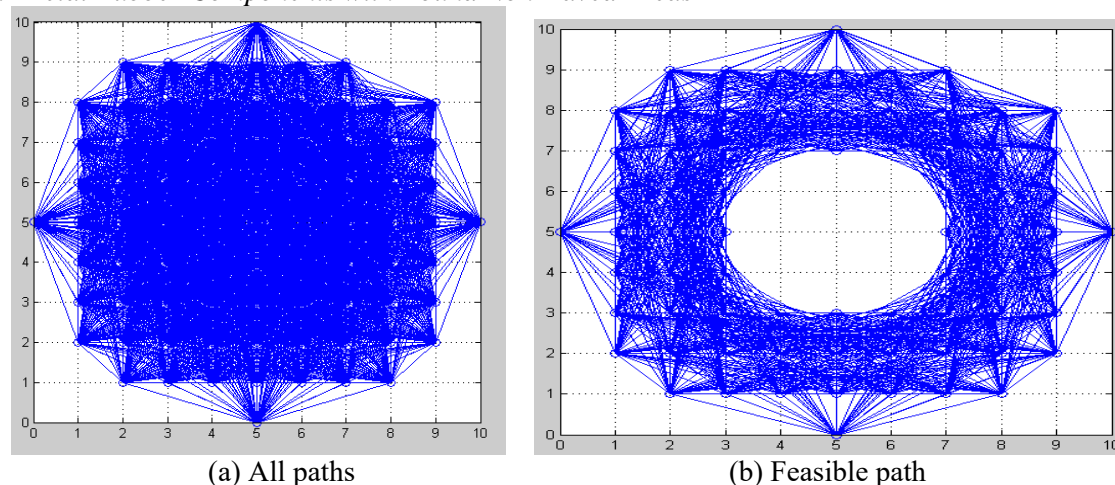*4.1. Metal Rubber Components with Round Non-Paved Areas*

(a) All paths   (b) Feasible path

Figure 5. Non-paved area is a circular contrast map.

4.2. Metal Rubber Components with Polygonal Non-Paved Areas
The number of laying paths before screening, the number of laying paths after screening and the reduction rate of workload are drawn as table 1. (Note: Workload Reduction Rate = (Number of All Laying Paths - Number of Feasible Laying Paths) / Number of All Laying Paths * 100%)

By analyzing Fig. 5, Fig. 6 and Fig. 7, and comparing the complexity of paving path before and after screening, we can preliminarily determine the importance of judging feasible path to reduce the workload of automatic paving path planning for metal rubber. The reduction rate of workload in Table 1 further confirms this view. From Table 1, we can know that the feasible paths for non-paved areas are 1047 rounds, 1719 triangles and 995 squares. At the same time, it can locate all feasible paths quickly. With the above method, all feasible paths can be identified quickly after locating pin position is determined, which provides technical support for path planning.
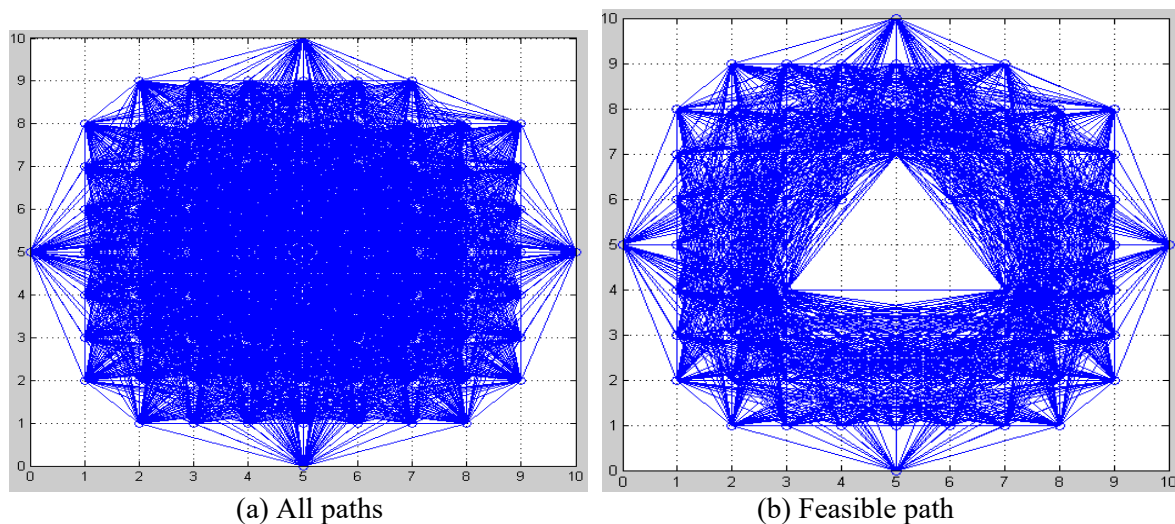(1) The non-paved area is a triangle.

(a) All paths   (b) Feasible path

Figure 6. Non-laying area for the triangle comparison chart.

(2) Non-paved area is square

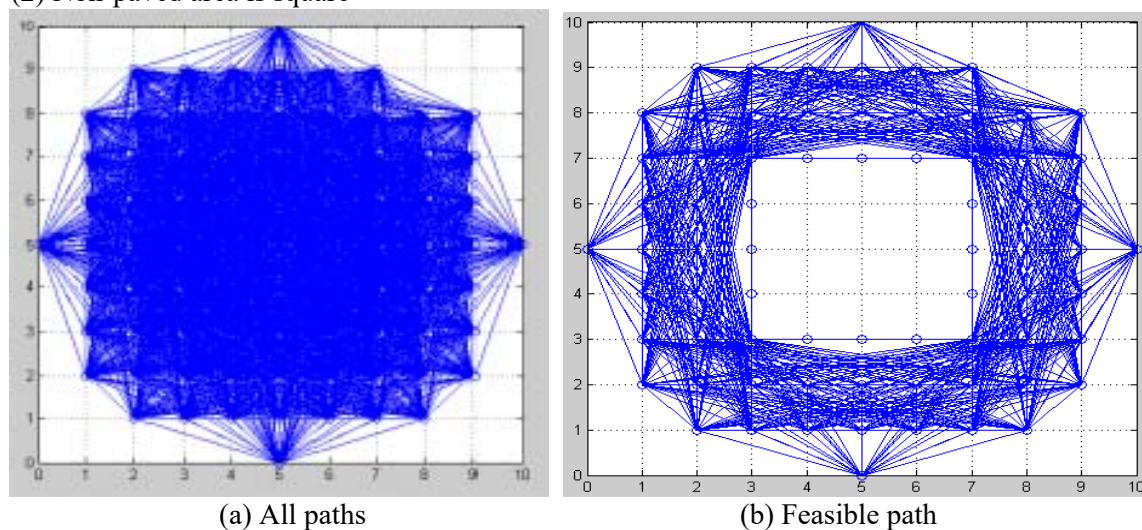(a) All paths   (b) Feasible path

Figure 7. Non-laying area for the square contrast chart.

Table 1. Laying path information.

Laying Path Information	Circle square	Triangle,	Square
Number of total paving paths	2485	2628	2485
Number of feasible paving paths	1047	1719	995
Workload reduction rate 3	57.9%	34.6%	60.0%

5. Conclusion

Based on the automatic laying process of metal rubber, the metal rubber components are divided into simple configuration and complex configuration. The positioning pin of the paving platform is coded and coordinated in two dimensions. A new method for judging the feasible paving path of metal rubber is proposed. Based on matlab, a new fast obstacle avoidance strategy for metal rubber blank laying is proposed. It realizes the fast identification and positioning of feasible path for automatic laying of metal rubber blank, and provides technical support for path planning and automatic laying. It improves the production efficiency and lays a foundation for the industrial production of metal rubber.

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