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Study of the Spray Gun Trajectory for Inner Hull Block Structures

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Abstract: Manual spray painting application has limitations and problems causing irregular film thickness coverage that reworking process must be repeated until the quality requirements are fully satisfied. This problem directly impacts with the service life of the ship. It has been concluded that the painting automation is the definite solution to solve the problem, because it can provide with consistent performance of paint film thickness.

In this paper, an effective spray gun trajectory generation minimizing the relative film thickness variations, calculating method of optimizing the number of painting strokes, confined area corner painting method considering the dynamics effects of the painting system, and maximizing the production rates are discussed.

1. INTRODUCTION

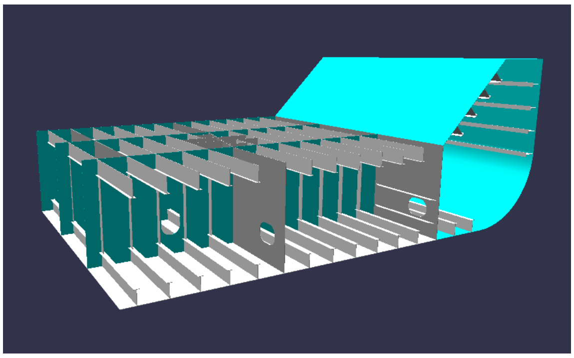

Fig. 1. Structures of a double hull block

The water ballast tanks of a modern ship are constructed with double hull block structures. Since the tanks are filled with sea water, protecting the structure with sufficient thickness of protective paint is very important. Airless spray painting is the most widely used method of painting application. In manual spray painting process, it is almost impossible to maintain a constant spray depth, painting speed, and orthogonal angle to the painted surface, while those are the key factors in spray painting application. Furthermore, there are many cases where requiring difficult ergonomic postures to paint certain structure areas. Due to these inconsistencies and difficulties, manual spray painting produces irregular coverage of paint. The quality of paint coats may not be sufficient for some areas lacking rust protecting performances, while excessive coats may cause cracks of paint coats along the weld joined seams. Therefore, painting automation has been one of the most important issues

2. PATTERN OF A SPRAY FILM THICKNESS PROFILE

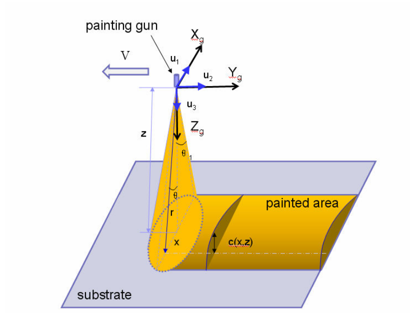

Fig. 2. Pattern of a spray film thickness profile

Fig. 2 shows the schematic view of a spray film thickness profile. Due to the paint flow flux of the spray mechanism, the density of paint at the mid range is higher than the circumference of the spray cone profile causing lower film thickness builds. This is also affected by the spray depth and the painting speed. By adopting the painting automation and properly controlling those parameters, the effectiveness can be benefited.

3. EVALUATION OF SPRAY TRAJECTORY PATTERNS

3.1 Analysis of the effectiveness of the trajectory pattern

Due to the fact that the spray film thickness profile is not even, some portion of the painted area must be overlapped by some amount. The optimum overlapping distances are determined at the points where the film thicknesses of the two spray profiles are halves of the maximum thickness, such that the accumulated thickness at that point becomes equal to

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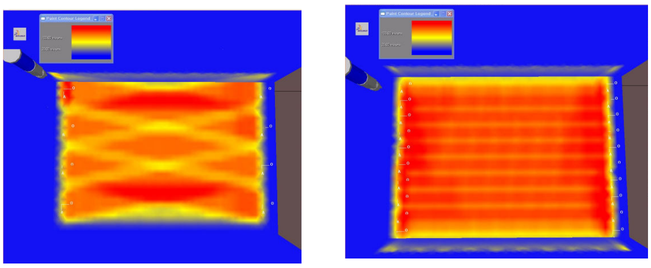
the maximum thickness of a single profile. This method results the relative thickness variations of 24% when applied with full film thickness. The relative film thickness is calculated by dividing the thickness variation by the average film thickness. This variation can be decreased to 20% when the painting speed is doubled that the film thickness is deposited with double layers of thin coats.



(a) pattern by zigzag strokes *(b) pattern by single strokes*

Fig. 3. Comparison of different spray trajectory patterns

The zigzag trajectory pattern is the combination of the two sets of single strokes offset by an angle. Each stroke speed must be doubled to paint with the desired film thickness. The relative film thickness variation created by the zigzag trajectory is 17%. However, this trajectory pattern requires insufficiently overlapped area below and above the targeted area which is not suitable for confined area application.

3.2 Determination of the number of painting strokes

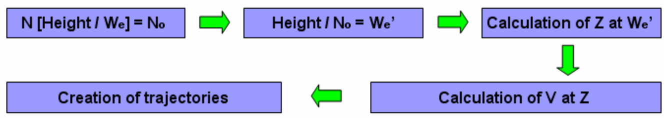


Fig. 4. Process of calculating the optimum number of strokes

Fig. 4 shows the calculating process of determining the optimum number of strokes (N_o). The number of optimum strokes can be determined by dividing the height of the area to be painted by the effective spray width (W_e), but the number may not come up with an integer that the spray depth (Z) must be adjusted to paint with a new effective spray width (W_e'), and the nozzle speed (V) must be adjusted accordingly.

3.3 Nozzle tilting motion and dynamics considerations at the start and end of each stroke

Since, the inner hull block structures are confined areas, the painting gun cannot start or move to the far end of each stroke while maintaining an orthogonal angle that the nozzle must be tilted to paint the corners to avoid collisions with the surfaces. During this process, the distance between the spray target point and the spray nozzle must be maintained to apply with a consistent spray width. Another consideration is the dynamics of the robot motion. Since the area is confined, the painting system must go through the acceleration and deceleration periods. One possible solution is to move the paint gun in the direction of painting motion to accommodate the speed varying dynamics effects.

3.4 Maximizing the production rate

The production rate is defined by dividing the painted area by the total operation time. It directly depends on the paint flow rate or the number of paint guns used. Supposing a single nozzle application process, the spray gun-off time must be minimized to increase the productivity. Intermittent painting motion requires non-painting relocation periods that painting sequence and the start-end position of each trajectory must be connected close to each other to process with the least non-productive motions.

CONCLUSION

The relative film thickness variance has been used to evaluate different spray trajectory patterns. The single stroke trajectory pattern shows relatively reasonable film thickness variations and is suitable for confined area application. There are geometric restrictions in the confined area spray painting application that the optimum number of strokes is determined from the size of the targeted area, and the nozzle tilting motion must be designed while considering the dynamic behaviour of the painting robot. To maximize the productivity, the non-productive gun-off time must be minimized by designing the work sequence in a continuous motion.

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