A New Method for Droplet Image Analyze of Marking Machine

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Keywords: Estimation, Tracking, Inscribed circle, Droplet image, Marketing machine.

Abstract. This paper shows the whole process of droplet image analyzing for marking machine on heavy plate produce line. The liquid droplet from marking machine is the idea sphere, but the droplet on the heavy plate shows different shapes which caused by different conditions. This paper rebuilds the droplet image to the initial liquid droplet sphere from marking machine shown as Fig.11. Based on maximum likely-hood closed convex polygon for liquid droplet image, the x-y unit length is estimated and a new x-y axis is reconstructed in this paper, which is the basis of the measurement grid. The simulation and image analyze progress give a new product-information trace method.

Introduction

The most steel mills used to make plates by hand-placing character modules and printing plates. However, there are many disadvantages in this method: marking paint effect environment, solvent endangering the health of operators, not suitable for high-temperature plates [1], unable to upload identification data for recording, statistics or management. It cannot be synchronized with the entire production line of the plate, which is the reason that rapid production process is difficult to achieve. It is also difficult to guarantee the high-quality marking.

Recently the automatic marking machine shows that the plate printing machine has the advantages of fast response, high degree of automation and low failure rate, which is the reason why it is widely used in plate mill for identification of the product. Results in the reproduction identification of plate mill.

Some technology-leading companies in the United States and United Kingdom have made remarkable achievements in the low temperature environment of the sheet metal production process. Since the steelworks' coatings and solvents are expensive and so special, only Danmark's magnemag machines can meet in the steel plant production line's bed requirements [2].

The identification is the middle process for life track of the product, identifying the product with license plate number, manufacturer, certification, etc. The other part of cycle tracking of the product life is the identification of product. By reading and identifying product identification, the transportation management and products in the next production chain are checked and identified. The trajectories of product life will provide so many information about products at distinct times and in distinct areas, and explain how to make the product perform better or improve shipping conditions. Some steel mills are beginning to focus on product life tracking.

System Constitution

Marking machine is a flexible mobile system, which can be powered not only by electricity but also by pressure air. The painting head should be regarded as the most useful component in the entire system on the car. With the movement of the car, all the marking functions and work are completed.

Device Description

The motor is controlled by the Lunze frequency converter with sensor speed control circuit, which drives the trolley to positive or negative positions with different speed. On the trolley the paint guns move from the initial position to the starting working-position, which is the beginning of the automatic marking process.
The movements of paint guns including moving up and down, turning alternative angle, returning or cleaning, which are driven by pressured air. The pressured air drives two air-pumps respectively, pumping, mixing solvents and painting. At the end of the whole process, all paint guns shall be cleaned with Cleaning agent. Otherwise, since the paint drops dry quickly and are fixed on the workpiece or paint gun, several paint guns may be blocked.

**Description of Paint Guns**

The paint guns divide into 10 lines with the matrix $10 \times 12$ which are parallel arrangement with the fixed-angle slope. Each line can be marked with a single line of characters. The paint guns can mark $10 \times 10$ liquid droplets of the character synchronously. Line 3 on the left and right which owns 12 guns can achieve special function with more liquid droplets, such as factory seal, group name, etc. [1].

**Mathematical Description**

For stationary droplets, the continuity equation of binary liquid mixtures is simplified to diffusion equation. Assume the ideal liquid droplet is spherical, we construct the Laplace transform on the diffusion equation $\mathcal{L}$ and $\phi$ in the coordinate system. The diffusion equation of matter in binary mixture droplets expressed by mass fraction is as follows.
\[
\frac{\partial Y_i}{\partial t} = D\left[ \frac{1}{r^2} \frac{\partial}{\partial r} \left( r^2 \frac{\partial Y_i}{\partial r} \right) + \frac{1}{r^2 \sin \vartheta} \frac{\partial}{\partial \vartheta} \left( \sin \vartheta \frac{\partial Y_i}{\partial \vartheta} \right) + \frac{1}{r^2 \sin^2 \vartheta} \frac{\partial^2 Y_i}{\partial \varphi^2} \right]
\]

(1)

Where \( D \) is the binary diffusion coefficient for the liquid droplet [3].

According above equation, on different conditions parameter \( i \) is different value which needs different math method. At the liquid droplet surface, the boundary conditions are \( Y_i | r = a(t) \) which means the droplet mass determined fraction. Its equation is as following

\[
- D \frac{\partial Y_i}{\partial r} - \frac{da}{dt} Y_i = \frac{m_{f,i}}{\rho_i}
\]

(2)

at \( r = a(t) \) for different times.

Where \( a(t) \) : time-dependent droplet radius;

\( \rho_i \) : liquid density;

\( m_{f,i} \) : mass flux of liquid droplet surface.

The latter may be a function of the angles \( \vartheta \) and \( \phi \), but it may be formulated as the ratio \( \frac{m_i}{A} \) of the evaporation rate of component \( i \) and the liquid droplet surface \( A \) in the case that there is no dependency on these angles[4].

And the initial condition that the mass fraction profile of substance \( i \) in the droplet at initial time \( t = 0 \) (which must also satisfy the boundary and regularity conditions, of course) be given as a function

\[
Y_i | t = 0, r = Y_{i,0}(r)
\]

(3)

for different \( r \) at initial time \( t = 0 \).

When Marking Machine works, plenty of droplets are controlled by the center computer according the content of characters. One droplet drops from painting head to the steel plate, forms the standard circle image as Fig.4. The gravity center of image is the same as the droplet from painting head. As we know, the painting head moves fast when marking characters, which is not the same process of theoretical analysis. The droplet drops to the steel plate with one fixed initial speed, which makes that in the marking process the droplet shows one beautiful parabola as Fig.4.

\[\text{Figure 4. Droplet fall progress.}\]

On one solid plane, the droplet contact angle \( \theta_e \) can be described as Young’s equation:

\[
\cos \theta_e = \frac{\gamma_{sv} - \gamma_{sl}}{\gamma_{lv}}
\]

(4)

Where \( \gamma_{sv} \) : surface tensions of solid-vapor;

\( \gamma_{sl} \) : surface tensions of solid-liquid
\( \gamma_{LV} \): surface tensions of liquid-vapor.

Assuming a liquid completely fills the depressions in the region of its contract with a rough substrate, Wenzel’s theory referred to as the “wetted surface”.

\[
\cos \theta_w^r = r \cos \theta_r
\]  

(5)

Where \( \theta_w^r \) represents the apparent contact angle on the wetted surface and \( r \) is the ratio of the actual of the rough surface to the projected area [5].

Assuming a composite surface is formed, liquid is completely lifted up by the roughness features. Cassie’s theory gives the following formulate:

\[
\cos \theta_c^r = -1 + \phi_c (\cos \theta_c + 1)
\]  

(6)

Where \( \theta_c^r \): contact angle on the composite surface;
\( \phi_c \): the area fraction of the solid surface.

The Source droplet can be controlled by the duty ratio of PWM for electromagnetic valve, and the area of droplet image is proportional of the source volume. The larger the duty ratio of PWM, the larger of droplet image area. But if the droplet source volume is out of steel plate saturation, when the droplet splash down and form with center image and several little circles as Fig.5 [6].

The splash down of droplet has several factors, like the initial height of droplet, the volume of droplet, the initial tangential speed of droplet, the mixture ratio of paint solvent and the cleanness of steel plate [9]. The splash drop makes the image process more and more difficult to study, especially for the transient process as Fig.5.

Based on the center of droplet image [7], this paper focus on the main center image assume that the complex influence works the same on center image and the little surround images, and attempt to find the droplet mirror from center image as Fig.6.
Module System

Problem: Given a vertex v of the polygon P, find the kernel position of gravity.

As Fig 7 shown, the inscribed circle and circum circle are the instead image for the droplet, which are used mostly in the industry area [8].

\( \gamma(t) \) is a one parameter family of closed convex \( C^2 \) curves; \( G(t) \) is the lamina enclosed by \( \gamma(t) \), while \( L(t) \) and \( A(t) \) are the length of \( \gamma(t) \) and the area of \( G(t) \) respectively. The position vector \( X(t, \phi) \) parameterizes the curve; \( N(t, \phi) \) is the inward pointing unit normal; and the curvature is \( \kappa(t, \phi) \). The evolution equation can now be written as

\[
X_t(t, \phi) = \kappa(t, \phi)N(t, \phi)
\]  \( (7) \)

Where the subscript denotes partial differentiation with respect to \( t \).

From Fig.8 we know that the evaluate error is proportional of the distance between the elliptical focus of inscribed or circum ellipse. The vertex of surround image directly affects the evaluating results for main center image.

Problem: Given a vertex v of the polygon P, find the least vertex set of maximum likely-hood closed convex polygon Q.

This paper gives a new vector method for searching maximum likely-hood circle between inscribed circle and circum circle.

Given three vertex v of the surround centre image \((P_{n-1}, P_n, P_{n+1})\), \( R_n \) is the center of inscribed circle pass-through the tree vertex \((P_{n-1}, P_n, P_{n+1})\); \( \vec{r}_n \) is the vertex \( P_n \) pointing to inscribed circle center \( R_n \); \( r_n \) is the module of the vector \( \vec{r}_n \); \( \theta_n \) is the average angle of vector \( \vec{r}_n \) with vector \( \overline{P_n P_{n-1}} \) and \( \overline{P_n P_{n+1}} \) shown as Fig.9.
For a convex polygon, the vector $\vec{r}_n$ points into the polygon, and the angle $\theta_n$ always is acute; but for non-convex polygon the vector $\vec{r}_n$ does not perform consistency for all polygons.

So how to recognize the “missing convex” and replace the wrong convex with one evaluated error-controlled convex, becomes the focus point of this problem. The most recognition methods need the image to be convex or expand the original image to be convex which leads losing significant information.

Problem: Given a set $v$ of the polygon $P$, how to find the maximum likely-hood circle by replacing some non-vertex elements with error-controlled method.

Given $P_{n-1}, P_n, P_{n+1}$ in one line $L$, the convex of $P_n$ descript with the distance from $P_n$ to line $L$; if $P_n \mid v < 0$ is no within convex set, the convex is negative; if $P_n \mid v = 0$ is on the line $L$, the convex is zero; if $P_n \mid v > 0$ is within convex point, the convex is positive shown as Fig.10.

![Figure 10. Maximum likely-hood circle.](image)

Based on uniform sampling, the value of $\hat{M} = \hat{r}$ and $\hat{\theta} = \angle \hat{r}$ should be the same error level at axis $x$ and $y$. Asymptotic replace $P_n$ with $P_n \mid v > 0$, the set $v$ of polygon $P$ will be convex set, and the final results is the answer of this problem.

![Figure 11. Rebuilding initial droplet sphere.](image)

Summary

This paper shows the whole process of droplet image analyzing for marking machine on heavy plate produce line. The liquid droplet from marking machine is the idea sphere, but the droplet on the heavy plate shows different shapes which caused by different conditions, such as liquid concentration, air pressure, the heavy plate surface difference, gravity or winds etc. This paper rebuilds the droplet image to the initial liquid droplet sphere from marking machine shown as Fig.11. The maximum likely-hood method is used to estimate the unit length of X-Y and reconstruct the new image, which is the basis of character recognition measurement. The result of droplet image analyze is not based on specific library, which reduces the math-training and is independence with special library.

The focus of future research is that the image recognition from steel-mills has a higher noise and region overlap, even in the case of high-quality marking, it also exists in most marking processes. The design of wavelet filter and the detection of redundancy will be the focus of the tag image processing and recognition in the future.
References

[1] Liu D L D. Marking process analyze in plate marking machine[C]//International Conference on Machine Learning & Cybernetics. IEEE, (2010).

[2] Liu D. Simulation and character recognition for Plate Marking Machine[C]//International Conference on Signal Processing Systems. IEEE, (2010).

[3] Han H D, Wu X N. Approximation of Infinite Boundary Condition and its Application to Finite Element Methods [J]. Journal of Computational Mathematics, 3(2):179-192, (1985).

[4] Velev O D, Furusawa K, Nagayama K. Assembly of Latex Particles by Using Emulsion Droplets as Templates. 1. Microstructured Hollow Spheres [J]. Langmuir, 12(10):2374-2384, (1996).

[5] Cao W. On the Error of Linear Interpolation and the Orientation, Aspect Ratio, and Internal Angles of a Triangle [M]. Society for Industrial and Applied Mathematics, (2005).

[6] Dong L, Chaudhury A, Chaudhury M K. Lateral vibration of a water drop and its motion on a vibrating surface [J]. The European Physical Journal E-Soft Matter, 21(3):231-242, (2006).

[7] He B, Patankar N A, Lee J. Multiple Equilibrium Droplet Shapes and Design Criterion for Rough Hydrophobic Surfaces [J]. Langmuir, 19(12):4999-5003, (2003).

[8] Lin Z, Granick S. Patterns Formed by Droplet Evaporation from a Restricted Geometry [J]. Journal of the American Chemical Society, 127(9):2816-2817, (2005).

[9] Cofrades S, Antoniou I, Solas M T, et al. Preparation and impact of multiple (water-in-oil-in-water) emulsions in meat systems [J]. Food Chemistry, 141(1):338-346, (2013).