American Journal of Applied Science and Technology

VOLUME Vol.05 Issue 05 2025
PAGE NO. 5-9
DOI 10.37547/ajast/Volume05Issue05-02

Automatic Approximation of The Surface Model of The Final Distillation of Vegetable Oil Miscella

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Received: 08 March 2025; **Accepted:** 05 April 2025; **Published:** 07 May 2025

Abstract: The present study investigates the geometric modelling and surface construction process applied to the optimisation of the apparatus used in the final distillation stage of vegetable oil miscella. The surface is conceptualised as the geometric locus of points representing individual miscella particles, allowing for a more precise simulation of phase interactions during distillation. A key feature of the proposed approach is the generation of surfaces based on predefined sets of curves, through which the structure of the miscella flow can be interpreted and analysed. By employing geometric transformations and interpolation functions, the paper proposes a methodological framework for constructing complex technical forms that reflect the dynamic behaviour of miscella particles. The study also introduces a discrete spatial model using basic geometric primitives, such as planes, polynomials, and second-order curves, to approximate the evolving surface during distillation. The results of this modelling approach can significantly enhance control mechanisms and design efficiency in distillation equipment, providing a mathematically grounded basis for engineering improvements.

Keywords: Orthogonal projection, interactive learning, Flutter, geometric modeling, projection matrix.

Introduction:

Systems analysis is a scientific method of cognition, which is a sequence of actions to establish structural relationships of variables or constant elements of the system under study. It is based on a set of general scientific, experimental, natural science, strategic, and mathematical methods. Systems analysis arose in the era of computer modelling and CAD development. Its success in applying it to solving multiparameter problems in an automated mode, i.e. in CAD or computer modelling, is largely determined by modern capabilities of automated technology or information technology [1]. Systems analysis based on system thinking of an object makes it possible to study the process of determining its input and output technological parameters, and in an automated mode, to establish relationships between them, as well as when using mathematical modelling to determine a logical solution. By implementing systems analysis as a CAD in the subsystems of the SAE process, one can determine its input and output parameters, i.e. a multiparameter function in En space (where n is the number of input and output parameters) to clarify the relationship between them, i.e. the properties of the relationship between the arguments of a function of many variables are nothing more than the created subsystems of algorithmic interacting sub-processes in the form of an internal hierarchy (tension) [2].

METHODS

Systemic thinking in the analysis of the object of study, i.e. the process of final distillation of vegetable oil miscella based on multi-stage spraying as an automatic approximation of the second-order hypervolatility, can be carried out in the following sequence:

- Analysis of a complete study of the final distillation process of miscella using CAD;
- Study of the basic elements of the technological line and devices;
- research of basic principles and structures of processes;
- definition of input, input parameters as arguments of multiparameter functions in the multidimensional space of the system and processes participating in it;

Definition of the relationship (basic properties) of the indicators.

These basic properties of the parameters and the analysis of the second-order hypersurface in the general linear programming problem are used for identifying as well as solving the optimisation problem.

As a result of the study of the final distillation process of vegetable oil miscella, the proposed algorithm developed its hierarchical structure using geometric modelling as the main task of linear programming in the CAE subsystems.

The modern stage of system analysis of technological processes based on system thinking in the analysis of the object makes it possible to study the process, find its input and output technological parameters, the relationship between them, as well as the logical solution of the task set according to predetermined conditions, here the object of the study is the process of distillation of vegetable oil flowing in the apparatus as gas particles. Considering that, the geometric place of the gas particle and its transformations, the parameterisation is also carried out as the design of surfaces by methods of geometric transformations.

One of the important tasks in the practice of constructing geometric, technical forms is the restoration of the surface based on its discrete framework.

Thus, when designing the bodywork of a car, the hull of a ship, or the miscella of vegetable oil, distillation is also initially represented as a discrete set of lines and points, and then this framework is interpolated by a smooth surface [3-5], [6-8].

Let the framework of the modelled surface be given on planes parallel to the plane XOZ, consisting of plane curves of different orders.

Analysing the lines of the framework in each case at level y=o, i.e. the XOZ plane, we select the function z=f(x), where f(x) consists of a combination of special operations and functions that make up the lines of the framework. In this case, the curves are special cases of the curve.

$$z=(ax+b)(cx+d)(mx+n) \quad (1)$$

The operation of multiplication of base curves appears here as a special operation.

To draw the required surface incident to the given lines of the framework, the following algorithm is performed. By moving the moving coordinate system XOY parallel to itself in the direction of the OY axis, we achieve that the coefficients (1) in front of xк (к=0.1…..0.3) coincide with the corresponding coefficients li at these levels.

Let's set the problem. Determine the coefficients xk depending on the variable y.

Let the lines h1, h2, h3 at levels y1, y2, y3 have equations.

$$h_1 : z=(a_1x+b_1)(c_1x+d_1)(m_1x+n_1),$$
$$h_2 : z=(a_2x+b_2)(c_2x+d_2)(m_2x+n_2),$$
$$h_3 : z=(a_3x+b_3)(c_3x+d_3)(m_3x+n_3).$$

To determine the coefficients (1), for example, a, in this case, there are three points (y_1, a_1), (y_2, a_2) (y_3, a_3). Taking these points on the plane YOZ as interpolation nodes, we use the interpolation polynomial $a = P_1(y)$. The remaining coefficients of the curve (1) are determined in the same way, we denote them by $b=P_2(y)$, $c=P_3(y)$, $d=P_4(y)$, $m=P_5(y)$, $n=P_6(y)$.

Substituting these expressions into (1), we obtain the equation.

$$z= (P_1(y)x+P_2(y)) \ (P_3(y)x+P_4(y)) \ (P_5(y) \ x+P_6(y)$$

(2)

The desired surface.

Equation (2) at $y=y$, (y_1, y_2) defines the lines of the framework L_1 (L_2, L_3), i.e. the surface passes through these lines. By varying the polynomials Pi and the value y=C, it is possible to construct various surfaces and control the shape. Controlling the order of the framework lines at different levels is reduced to constructing polynomials that intersect OC OY at these levels, i.e. at these levels one coefficient, for example, C, takes a value equal to zero. Thus, the order of the framework line decreases by one.

The framework lines may include various algebraic and transcendental lines. With this method of interpolating surfaces at different levels, the base lines change their position so that the framework lines at these levels are the results of special operations on the base lines.

When the framework consists of lines of the same order, such an interpolation problem can be solved in another way. For example, to determine the coefficients of the base curves, one can compose a system of equations assuming them to be unknown and using the intersections of the base lines li with the plane XOУ, passing through the intersection points of the framework lines li with the same plane during the movement of the moving coordinate system XOZ parallel to itself.

Let us consider the problem of drawing a surface through a set of closed symmetrical plane curves of different orders in the form (Fig. 1).

Let the frame lines be given in the form:

- an elongated ellipse at $y = c1, l_1 : \left(\frac{x}{3}\right)^2 + \left(\frac{2}{5}\right)^2 = 1$

;

- circles at $y = c2, l_2 : x^2 + y^2 - 36 = 0;$

- flattened ellipse $y = c3, l_3 : \left(\frac{x}{4}\right)^2 + \left(\frac{z}{2}\right)^2 = 1.$

Airfoil curve

at $y = C_4\, l_4 : Z = (25 - x^2)^{0,5}(2(x-5)^2 + 1)(5 - \frac{x}{2}).$

For this case, we will choose three straight lines as baselines.

Z = ax,

Z=b(a+x),

Z=cx+d and a parabola

Z=m(xn)2+1, then performing the operations of multiplication, division and root extraction on them, we obtain a curve.

$$Z = \frac{b}{a}\left((a+x)(ax)\right)^{0.5}\left(m(xn)^2+1\right)(cx+d) \quad (1)$$

By varying the coefficients of curve (3) according to the above scheme, we can obtain the frame lines L_i l_i=1,4.

For example, to obtain a circle $x^2+z^2=6^2$ at the level $y=c_2$, it is required that the polynomials $a = P_a(y)$ and $b=P_b(y)$ pass at this level through the points $(a,y)=(6,c_2)$ and $(в,y)= (6,c_2)$, respectively. The curves of the polynomials $m=P_m(y)$ and $c=P_c(y)$ must intersect the OY axis at this level, and for the polynomials $l=P_l(y)_3$ $d=P_d(y)$, the condition $P_l(y)$, $P_d(y) =1$ is required. And for other lines of the framework, the same conditions can be formulated based on the analysis of the equations of the curve (3).

In essence, the equation of the interpolated surface at the levels of the framework lines takes on the values of special cases of equation (3).

The order of the interpolated surface depends on the number of frame lines, and at the level y=const, the type of level lines of this surface depends on the type of frame lines.

Interpolation of the surface framework obtained based on special operations on simpler functions and based on determining their coefficients simplifies the mathematical description of curvilinear objects and makes it possible to control the shape of the interpolated surface (2).

In general, it is easy to generalise this method of interpolation to describe multidimensional processes for which sets of levels are given.

Let us consider the control of the surface shape by varying the curve application.

To this end, we propose a method for solving the problem of controlling the shape of a surface using the multiplication of surfaces represented by equations in explicit form and which pass through given lines of the framework.

Let spatial curves $G_1(G_{11},G_{12})$ u $G_2(G_{21},G_{22})$ be given by two projections (Fig. 2).

$$\begin{aligned}
&G_{11}: x = f(y), \quad G_{21}: x = q(y),\\
&G_{12}: z = g(y), \quad G_{22}: z = t(y),\\
&G_1(G_{11}, G_{12}) = G_1(f(y), q(y)),\\
&G_2(G_{21}, G_{22}) = G_2(g(y), t(y)).
\end{aligned}$$

Let's draw a ruled surface through G_1 and G_2.

Moving the XOZ plane in the direction of the OY axis, parallel to itself, in each position, we draw lines through the intersection points of this plane with the spatial curves G1 and G2.

Let us proceed to an analytical description of this surface. Let G1 intersect the plane XOZ of level y=const, at the point A(x,z)=A(f(y),q(y)) and the curve

G2 at the point B(x,z)=B(g(y), t(y)). Then the equation of the line passing through points A and B has the form.

$$\frac{x-f(y)}{g(y)-f(y)}=\frac{z-q(y)}{t(y)-q(y)}$$ from here

$$Z=\left(g\left(y\right)-f\left(y\right)\right)^{-1}\left(x-f\left(y\right)\right)\ \left(t\left(y\right)-q\left(y\right)\right)+q\left(y\right) \tag{4}$$

Equation (4) for y=const defines a straight line in the plane of level XOZ, and in the general case, represents a ruled surface that passes through lines G1 and G2.

The proposed method of controlling the shape of the surface (4) is that the parameters of shape control are selected as applicates of points or the frontal projection of one of the curves G_1 and G_2, for example G1 modifying the frontal projection $G_{22}{:}Z=q(y)$ of the curve G_1, we obtained $G_{22}{:}Z=P(y)$ (Fig. 3). Now we draw a surface passing through the lines L_4 $(G_{11},\ P(y)/q(y))u$ $I_2(G_{21},1)$.

Then $(x-f(y))(g(y)-f(y))^{-1}=(Z-k(y))(t(y)-k(y))^{-1}$

from here

$$Z=(x-f(y))(t(y)-k(y))(g(y)-f(y))^{-1}+k(y) \tag{5}$$

Surface (5) contains lines L_1 and L_2, which are horizontal projections of curves G_1 and G_Z, respectively.

Let us define multiplications (4) and (5), and we obtain

$$\begin{gathered}Z=((((x-f(y)(t(y)-q(y))(q(y)-f(y))^{-1})(g(y)-f(y)))^{-1}+\\+q(y))\cdot(((x-f(y))(1-k(y)))(g(y)-f(y))^{-1}+ky))\end{gathered} \tag{6}$$

Surface (6) contains curve G_2 and transformed curve G_1.

If further modification of the curve G_1 is required, then in equation (6), instead of K(y), another function is substituted that ensures the passage of the surface through the required curve.

Example: Let curves G_1 and G_2 be given.

G1(2;3-12-1·(-y-6)2), G2(4-1y+1; -16-1y2+4)

It is required to draw a surface through given lines and control the shape of the surface by varying the applications of the G_1 curve.

$G_{11}: x=2$ $\qquad$ $G_{21}: x=4^{-1}y+1$

$G_{22}: z = 3-12^{-1}(y-6)^2$ $\qquad$ $G_{22}: z = -16^{-1}y^2+4$

Taking into account formulas (4), the surface passing through G_1 and G_2 has the equation (Fig. 4)

Ƶ$=(4^{-1}y-1)^{-1}(x-2)(-16^{-1}y^2+1+12^{-1}(y-6)^2)+3-12^{-1}(y-6)^2$

Let $\qquad G_{12}: z = q(y) = 3-12^{-1}(y-6)^2$ $\qquad$ is transformed into

$G_{12} = P(y) = 6 - (y-6)^2$

Then $\qquad k(y)=P(y)(q(y))^{-1} = (6-(y-6)^2)(3-12^{-1}(y-6)^2)^{-1}$

And according to formula (6), the transformation surface has the form

Ƶ$=((4^{-1}y-1)^{-1}(x-2)(1-16^{-1}y^2+12^{-1}(y-6)^2)+3-12^{-1}(y-6)^2)\cdot$

$\cdot((4^{-1}y-1)^{-1}(x-2)(1+(36-(y-6)^2)^{-1}(12(6-(y-6)^2))+(36-(y-6)^2)^{-1}(72-12(y-6)^2)$

With this method of controlling the shape of the surface, the frontal projection of any curve can be selected as shape control parameters, they can alternate, or horizontal projections can be selected.

The problem of controlling the shape of a surface can be solved by using other special operations on functions, for example, the method of adding up applicable surfaces [1].

In this case, the lines of the surface framework (6) are second-order curves.

It is possible to increase the number of Gi lines; then the order of the frame line increases depending on the Gi lines; the choice of another surface, which is multiplied by the original surface and changes its shape, depends on the type of special operation.

The lines of the outline of the covered plan can be included in the number of G1 lines, thereby taking into account another boundary condition of the constructed surface.

1. A multi-level, hierarchical structure based on system analysis has been developed as a second-order hypersurface for organising the process of final distillation of vegetable oil miscella, taking into account the input and output parameters of each component.

2. Developed on the system approach of geometric modeling of construction of hypersurface of miscella by the method of geometric transformations of the process and starting from the lower level of hierarchy, also generalization of the received analytical and tabular information compiled analytical model in the form of a system of equations the main matrix of the problem of linear leveling to automatic approximation of hypersurface of the second applicable to CAD name computer modeling of the process of final distillation of miscella of vegetable oil.

The proposed method allows for to construction of a surface passing through several given spatial curves, having similar curves of the required type or order in parallel sections, and to control the shape of the surface by varying the application of one of these curves. Which makes it possible to study the geometrical place of points, i.e., a set of particles of a miscella as an object of study, making it possible to apply methods of mathematical modelling.

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