

INEXTENDABLE SOLUTIONS OF HYPERBOLIC MONGE-AMPÈRE EQUATIONS.

DMITRY V. TUNITSKY

1. HYPERBOLIC MONGE-AMPÈRE EQUATIONS.

Consider a Monge-Ampère equation

$$(1) \quad A + Bz_{xx} + 2Cz_{xy} + Dz_{yy} + E(z_{xx}z_{yy} - z_{xy}^2) = 0,$$

where coefficients A, B, C, D , and E are fixed smooth functions that depend on x, y, z, p , and q . Here x and y are independent variables,

$$z = z(x, y)$$

is an unknown function, and we use Monge's notations

$$p = z_x, \quad q = z_y.$$

Let $\mathbb{R}^5$ be the space of parameters x, y, p, q , and z . The linear differential form

$$\omega_0 = dz - p dx - q dy$$

defines the standard contact structure on $\mathbb{R}^5$. The effective differential 2-form

$$\omega = A dx \wedge dy + B dp \wedge dy + C(dx \wedge dp + dq \wedge dy) + D dx \wedge dq + E dp \wedge dq$$

on $\mathbb{R}^5$ is associated with the left part of the equation (1) in the obvious way (see [1]). The pfaffian

$$Pf(\omega) = -C^2 + BD - AE$$

of this form up to its sign coincides with the characteristic discriminant of the equation (1). Suppose the equation (1) is hyperbolic, i.e.,

$$Pf(\omega) < 0.$$

Put

$$\lambda_j = (-1)^{3-j} \sqrt{-Pf(\omega)},$$

1991 *Mathematics Subject Classification*. Subject: 53B05, 53C07, 53C30, 58G03, 58G16, 58G07.

Key words and phrases. Monge-Ampère equation, characteristic bundle, hyperbolic equation, multivalued solution, initial curve, Cauchy problem, inextendable solution.

where $j = 1, 2$.

Definition 1.1. *The characteristic bundle H_j of the equation (1) is the linear subbundle of the tangent bundle $T\mathbb{R}^5$ whose fiber $H_j(m)$ at a point $m \in \mathbb{R}^5$ is defined by the equality*

$$(2) \quad H_j(m) = \left\{ \xi \in T_m \mathbb{R}^5 : \xi \lrcorner \omega_0(m) = 0, \xi \lrcorner (\omega(m) - \lambda_j d\omega_0(m)) = 0 \right\},$$

$j = 1, 2$ (cf. [2]).

2. MULTIVALUED SOLUTIONS.

Definition 2.1. *An immersion*

$$(3) \quad \sigma : S \longrightarrow \mathbb{R}^5$$

of a two-dimensional manifold S is a multivalued solution of the equation (1) if the equations

$$\sigma^*(\omega_0) = 0, \quad \sigma^*(\omega) = 0$$

are through.

According to the Frobenius theorem for any point $r \in S$ of the solution (3) there exists the unique maximal one-dimensional integral submanifold

$$(4) \quad \gamma_{jr} : Z_{jr} \longrightarrow S$$

of the characteristic subbundle (2) that passes through the point r , i.e., $r \in \gamma_{jr}(Z_{jr})$, and

$$(\sigma \circ \gamma_{jr})_*(T_w Z_{jr}) \subset H_j(\sigma \circ \gamma_{jr}(w))$$

for all $w \in Z_{jr}$.

Definition 2.2. *The submanifold (4) is called the characteristic of the equation (1) that lies on the solution (3), passes through the point $r \in S$, and belongs to the j -th family, $j = 1, 2$.*

3. CAUCHY PROBLEM

Consider an initial value for the equation (1), i.e., an immersion

$$(5) \quad l : Z \longrightarrow \mathbb{R}^5,$$

$Z = (a, b)$, $-\infty \leq a \leq b \leq +\infty$, such that

$$l^*(\omega_0) = 0.$$

This immersion is called an *initial curve* to the equation (1) if it is *free*, i.e.,

$$\dot{l}(t) \notin H_j(l(t))$$

for $j = 1, 2$ and $a < t < b$.

Definition 3.1. *The multivalued solution (3) of the equation (1) is called a solution of the Cauchy problem (5) if there exists an imbedding*

$$L : Z \longrightarrow S$$

such that

$$l = \sigma \circ L.$$

This solution (σ, L) is called determined if for any point $r \in S$, characteristic γ_{jr} , and the initial curve (5) the intersection

$$L(Z) \cap \gamma_{jr}(Z_{jr})$$

consists of exactly one point for $j = 1, 2$.

Let (σ, L) and $(\tilde{\sigma}, \tilde{L})$ be two arbitrary determined multivalued solutions of the Cauchy problem (1), (5).

Definition 3.2. *A determined solution $(\tilde{\sigma}, \tilde{L})$ of the problem (1), (5) is called inextendable if for any determined solution (σ, L) of this problem there exists an imbedding*

$$\varphi : S \longrightarrow \tilde{S}$$

such that

$$\tilde{\sigma} \circ \varphi = \sigma, \quad \varphi \circ L = \tilde{L}.$$

Theorem 3.1. *Let the equation (1) be hyperbolic and its coefficients and the initial curve (5) be smooth. Then up to parametrization there exists a unique smooth inextendable solution $(\tilde{\sigma}, \tilde{L})$ of the Cauchy problem (1), (5).*

Proof. See [3]. ■

REFERENCES

1. Lychagin V.V. Nonlinear differential equations and contact geometry. Uspekhi Mat. Nauk. 1979. V. 34, no.1(205). P.137-165. (Russian. English translation in Russian Math. Surveys. 1979. V. 34.)
2. Morimoto T. La géométrie des équations Monge-Ampère. C. R. Acad. Sc. Paris. Série A. 1979. V.289. P.25-28.
3. Tunitsky D.V. On the global solvability of the Monge-Ampère hyperbolic equations. Izvestiya RAN. Seriya Matematicheskaya. 1997. V.61, no.5. P.177-224. (Russian. English translation in Izvestiya: Mathematics. 1997. V.61, no.5. P.1069-1111.)

INTERNATIONAL SOPHUS LIE CENTER, 3 - 9 - 19 PLUSCHEVA ST., MOSCOW 111524 RUSSIA.
E-mail address: tunitsky@yahoo.com