THE DYNAMIC SUBSTANCE - FIELD ANALYSIS IN ARIZ

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Introduction

In a sense this paper is a continuing and development of the work [1], in which dynamic technical contradiction model on 1.1- 1.6 steps of ARIZ-85B [2] is offered. Dynamic model helps to smooth logical jumps between steps since it has continuous time.

The First part of ARIZ has also 1.7 step, which come in ARIZ later, near 1989 [3]. Logical jump is too much between steps 1.6 and 1.7 as far as ARIZ begins to use other tools: Standard Solutions and Substance-Field Analysis. These tools can be used by itself and perhaps they are tantamount to ARIZ. This is difficult to insert one system in other system. This paper is written with the purpose of studying and simulation of transient process from the technical contradiction to the Substance-Field.

1.Relationship Between the Problem Model and Substance-Field (S-Field)

Substance-Field transformations and Standard Solutions are used for solving invention problem on 1.7 step of ARIZ. The First part enables to find Standard Solution in non-standard problem. Obviously, problem model on 1.6 step defines substances and fields required for the S-Field analysis.

Really, there is determination [3]: 'S-Field includes an article, tool and energy (field), required for influences of tool to the article'. On the other hand problem model has three objects too: tool, article and X-element, required for resolving of technical contradiction. Comparison of two triangular structures gives following result: X-element is identity mapping of energy (field).

For useful chains, two questions require answers:

What kind of energy is this field?

What place of S-Field structure occupies this field?

X-element is something unknown, certain changing a system, which decide our problem; i.e. will give a new result. When X-element becomes known, it brings a new knowledge in the consciousness of inventor. So X-element will be an information field with psychological energy.

Struggle of conflict properties give birth to new knowledge, which evolves inwardly technical (or physical) contradictions. Consequently, information field must arise and exist inwardly S-Field structure. G.Altshuller has indicated internal field in S-Field structure [4, problem 12]. Problem 12 has double-particle wedge; one part is made from the low-melting-point material. S-Field model of wedge extraction is brought in the fig. 1.

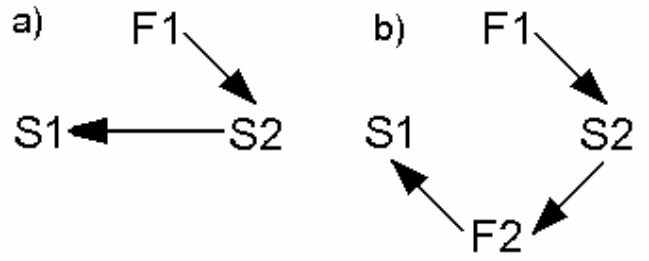

Figure 1. S-Field for problem of system construction

There are following indications in the fig. 1: F1 - heat (input) field, F2 - mechanical (internal) field, S2 - low-melting-point substance. Altshuller give two equivalent variants of S-Field (*a* and *b* in fig. 1). Hereinafter S-Field was usually used in the first variant (*a*), i.e. input and output fields were expressed. Exactly these fields possible was enter, change, find. Interaction between substances S1 and S2 was indicated without the internal field F2.

Thereby place of information field Finf is determined in the S-Field formula (fig. 2).

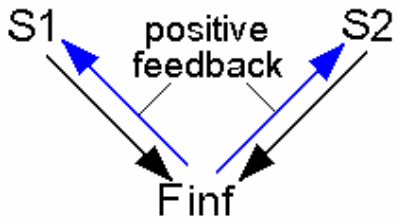

Figure 2. Self-evolution S-Field

In the fig.2 S-Field has no input fields and its evolution is two-way offensive battle, in which kicks are inflicted by information, energy and, may be, substances. Shall name such structured formula a self-evolution S-Field. Self-organization is characterized internal positive feedback, which intensifies a battle.

Push of battle is initial information field of prototype, i.e. non-S-Field (or incomplete S-Field: Finf +S). Substances S1 and S2 are opposite properties of technical contradiction, for instance, productivity and precision of processing, maneuverability and comfortability for transport, sensitivity and range of measurements for sensor (see Contradiction Table [3] on the whole).

Achievement of common purposes by mutual struggle is named homeostasis [5]. Natural organisms use homeostasis. For instance, one system increases a level of sugar in blood, but other system all along reduces a level of sugar. Dynamic balance is installed as a result. Structured redundancy gives ability to execute purpose of organization in conditions of self-contradictions and external influences.

Homeostat as structure is unfolded from Mono-system to Bi-system with inverse characteristics. Bi-system is formed substances S1 and S2 of self-evolution S-Field. Thereby, self-evolution S-Field is memory cell, which accumulates standard answer to standard situation. Problem model on the step 1.6 of ARIZ is a standard situation. Decay of self-evolution S-Field resolves contradiction and gives one of the possibles Standard Solutions.

Following structured sequence can be built by moving along steps 1.1 - 1.7 of ARIZ (fig.3).

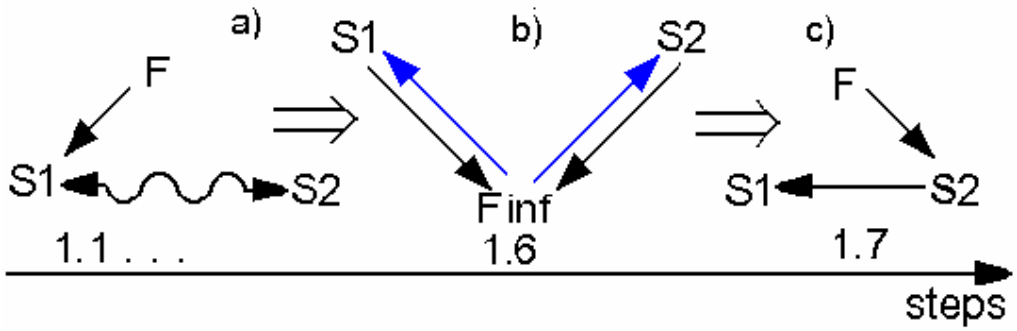

Figure 3. Development of S-Field structure in First part of ARIZ

Prototype has undesirable effect, so S-Field (fig.3a) has a harmful interaction between substances S. If prototype is runnable system, its S-Field is complete. The next stage is a self-evolution S-Field (fig.3b). Standard Solution is presented by final S-Field (fig.3c). It is possible an existence of intermediate stages, for instance, destruction of prototype S-Field between first and second stage.

Structured transformations reflect general transforming scheme of substances and fields by ARIZ (fig.4).

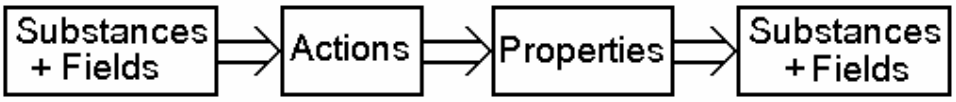

Figure 4. Transforming scheme of substances and fields

Input **substances** and **fields** of prototype are converted to **actions** a conflict pair (useful and harmful actions to an article from tool). **Actions** are converted to opposite **properties** of technical (and physical) contradictions. **Properties** are converted to output **substances** and **fields** of new solving. Output **substances** and **fields** of new solving are defined by **X- element**.

There is interesting to note a duality of X-element. There are following formulations of problem model (on Step 1.6):

'Given a conflict pair and technical contradiction. It is necessary *to enter* X-element ... ' and so on [3, p.110];

'Given a conflict pair and technical contradiction. It is necessary *to find* X-element ...' and so on [3, p.330] (underlined by me).

X-element is in the first formulation an external object for problem model. It can be incorporated for the conflict resolving. It is structurally known object since its place is determined in S-Field. Such formulation is characteristic for problem of system construction in S-Field analysis.

X-element is an internal object for problem model in the second formulation. It must be found since its internal essence is while unknown. Such formulation is characteristic for problem of field-substance detection in S-Field analysis. In this case the universal Altshuller's structure (see fig. 1b) of S-Field can be used also, only there is need to add certain relationship (fig. 5b).

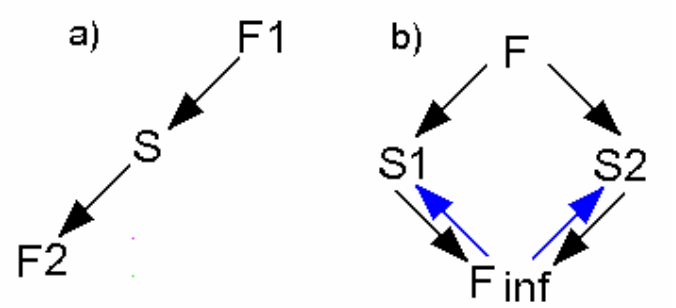

Figure 5. S-Field for problem of field-substance detection:
a) Standard model, b) homeostat model

There are following indications in the fig. 5: F1, S - detectable field or substance, F2 - output field (perceived by person), F - input information field of prototype, Finf - information field of X-element, S1 and S2 -opposite properties of

technical contradiction.

The output field Finf of homeostat model is detectable and perceived simultaneously, so there is a necessity to remember an information field of X-element. Substances S1 and S2 form homeostat of memory.

The destroying problem of S-Field penetrates the problem of finding too (fig. 6).

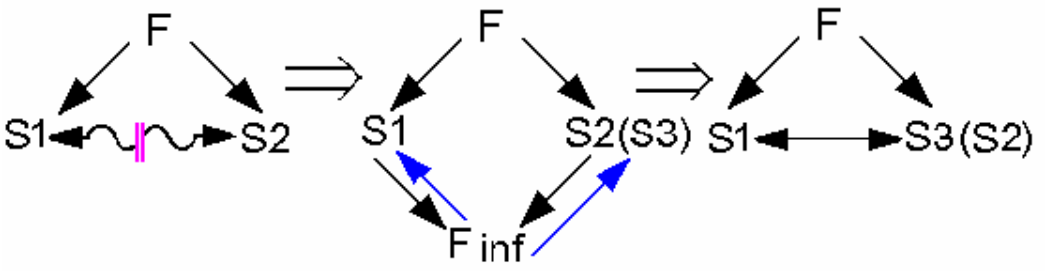

Figure 6. S-Field transformation in destroying problem

Information field of X-element must give knowledge of substance S3.

Simultaneous simulation of structures on first and second formulation gives a transformed self-evolution S-Field (fig. 7). Information field Finf of X- element is simultaneously introduced and detectable, input and output. Feedback becomes external and negative.

Information field of prototype comes up for an initial instant and it is nucleus of crystal for information field of X-element. Information field of X-element will be external under the maximum intensification of conflict.

Both fields are accumulated in the memory location.

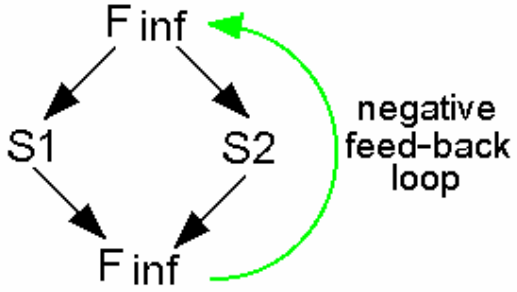

Figure 7. Transformed Self-evolution S-Field

Thereby, S-Field has two stages of evolution:

1. Embryonic growth (or "pregnancy" for substances S1 and S2).

Information field Finf grows in the subconscious of inventor. It is internal, unobserved and undetectable. Structure of such S-Field is provided in the fig. 2.

2. Birth and existence of X-element.

Information field comes up for the consciousness of inventor. It is born, i.e.

goes along the feedback and becomes an external field. Next it circulates between the consciousness and subconscious. Psychological energy of information field removes excitation between "parents" (substances S1 and S2) since feedback becomes negative. Contradiction perishes, new solution is received. Structure of such S-Field is provided in the fig. 7.

2. Dynamic Model of Self-evolution S-Field

Simulation of objects with memory requires storage devices. Such storage devices can be analog integrators. Differential equations required for mathematical integrator models. Differential equation gives a dynamic model. The catastrophe theory [6] will be used for dynamic S-Field model.

Shall suppose that S-Field model is characterized by the state coordinates y and p with potential function

$$U(y,p) = y^3 + p^3 - ayp + by + cp, \qquad (1)$$

Canonical catastrophe of kind of hyperbolic **umbilic** has such potential function. The three control parameters are called a**,** b and c**.**

The potential function gives a value of undesirable effect.

Shall expect S-Field is gradient system, tending to the potential function minimum. Then antigradient $-\partial U(y,p)/\partial y$ is proportional time velocity (or first derivative) of coordinate y, and $-\partial U(y,p)/\partial p$ is proportional time velocity (or first derivative) of coordinate p

$$K\, dy/dt = -\partial U(y,p)/\partial y = -3y^2 + ap - b, \qquad (2)$$

$$K\, dp/dt = -\partial U(y,p)/\partial p = -3p^2 + ay - c, \qquad (3)$$

where t denotes time, certain constant K equalizes dimensions. Meaning of constant K will be explained in the section 2.2.

Let be $y=p$, (4)

then equations (2) and (3) are completely equivalent for $b = c$.

Equation system (2), (3), (4) has mathematical redundancy. Really, substitution y = p or $p = y$ gives

$$K\, dy/dt = -3y^2 + ay - b, \qquad (5)$$

$$K\, dp/dt = -3p^2 + ap - c. \qquad (6)$$

Then one of the equations (5) or (6) is surplus under (4). However redundancy is an important characteristic of homeostasis.

Now we can introduce antisymmetric coordinate $x = -y = -p$ for forming an antagonism. Operation of gluing the antagonists [5] must be conducted for intensification of struggle. The gluing together opposite coordinates for

homeostasis can be made by substitutions y = - *x* in (2) and p = - *x*= *y* in (3)

$$K\,dy/dt = -3(-x)y + a(-x) - b, \qquad (7)$$

$$K\,d(-x)/dt = -3(-x)(y) + a(y) - c. \qquad (8)$$

Simplification of equations (7), (8) brings mathematical model of S-Field

$$K\,dx/dt = -3xy - ay + c, \qquad (9)$$

$$K\,dy/dt = 3xy - ax - b, \qquad (10)$$

$$x = -y. \qquad (11)$$

System of equations (9), (10), (11) will assign compensation homeostat with potential function

$$U(x,y) = -x^3 + y^3 + axy - cx + by. \qquad (12)$$

Simulation to two stages of Self-evolution S-Field uses this equation system.

2.1. Simulation to Stage of Embryonic Growth

Let value *y(t)* will assign evolutional property of substance S1 and an opposition coordinate *x(t)* will assign evolutional property of substance S2. Expect [7] values *y(t)* and *x(t)* are dissymetrical evolved in the consciousness of inventor, i.e. *y(t)* = - *x(t)* and *y(t)>0*, *x(t)<0*. Negativity of coordinate *x(t)* has conditional character. It only shows while one coordinate, for instance, precision increases, other coordinate, for instance, productivity decreases.

Now values of control parameters *a*, *b*, *c* must be determined. Self-evolution S-field realizes free self-motion in this stage, so input parameter *c* is zero in (9) and input parameter *b* is zero in (10). Then equations (9), (10), (11) give a homogeneous system (Lotka-Volterra system [8] with antisymmetric coordinates)

$$K\,dx/dt = -3xy - ay, \quad x(0) = -y(0) < 0, \qquad (13)$$

$$K\,dy/dt = 3xy - ax, \quad y(0) = -x(0) > 0, \qquad (14)$$

where $x(0)$, $y(0)$ - initial conditions.

This is easy work to find states of equilibrium and define their stability. Equation system (13),(14) has two states of equilibrium:

First state is $x_1 = 0$, $y_1 = 0$, $U(x_1,y_1) = 0$,

Second state is $x_2 = -a/3$, $y_2 = a/3$, $U(x_2,y_2) = -a^3/27$.

For $a>0$ first state of equilibrium is unstable, but second state is stable. For $a<0$ first state of equilibrium is stable, but second state is unstable.

Choose condition $a>0$ since value *x* must be negative. Then first state $[x_1, y_1]$ will be an unstable equilibrium of prototype, but second state $[x_2, y_2]$ will be a stable equilibrium of new solving.

Simulation results of system (13), (14) is provided in the fig.8.

Evolution of substances S1 and S2 forms positive and negative S-curves. Undesirable effect $U(x,y)$ decreases during the evolution. S-curves are approximated logistic curves (Ferhulst-Pearl curve [9]). For instance, substitution $x = -y$ gives in (14)

$$K\,dy/dt = -3y^2 + ay, \quad y(0) > 0 \qquad \text{or}$$
$$dy/dt = -(3/K)\,y^2 + (a/K)\,y, \quad y(0) > 0 \qquad (15)$$

where $3/K = m$ - birth rate factor of new ideas, $a/K = n$ - death-rate factor of old ideas.

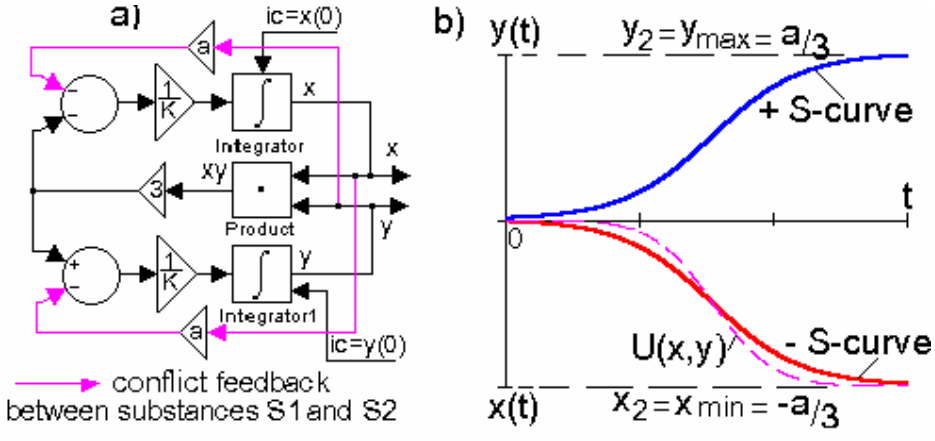

Figure 8. Simulation results to stage of embryonic growth
a) S-Field model scheme; b) evolution of substances S1 and S2

Quotient K/a has dimension of time and is identified time constant T. Time constant T defines thought process inertia and $T=1/n$. Factor a has dimensions of conflict coordinate y (or x) and $a = 3\lambda^{1/2}$, where value λ is named a conflict power [1] and $\lambda = (n/m)^2$. It defines ability of inventor to intensify conflict. Quotient $I = n/m$ can be named by **ideality** of thought. Substitution T and λ in (14) gives

$$T\,dy/dt = -\lambda^{-1/2}y^2 + y, \quad y(0) > 0 \qquad \text{or}$$
$$T\,dy/dt = -I^{-1}y^2 + y, \quad y(0) > 0. \qquad (16)$$

Thereby evolution of S-Field is defined by psychological characteristics of thought (I and T) and by prototype information (initial conditions $y(0)$, $x(0)$).

2.2. Energy Balance to Stage of Embryonic Growth

Equations (9), (10), (11) describe evolution of substances S1 and S2 in potential psychological field. For instance, possible write for coordinate y

$$K\,dy/dt = K \cdot V_y = F(x,y,a) = -\partial U(x,y)/\partial y, \quad (17)$$

where $F(x,y,a)$ - psychological resistance force, $V_y = dy/dt$ - velocity of changing a

coordinate y, K - psychological resistance factor, $U(x,y)$ - potential of psychological field or potential energy of thinking. Solving of equation (17) gives moving a material point in viscous medium. S-Field is material point (fig.9).

Psychological resistance factor influences on conflict power: $\lambda^{1/2} = K/3T$. Increasing a psychological resistance intensifies a conflict.

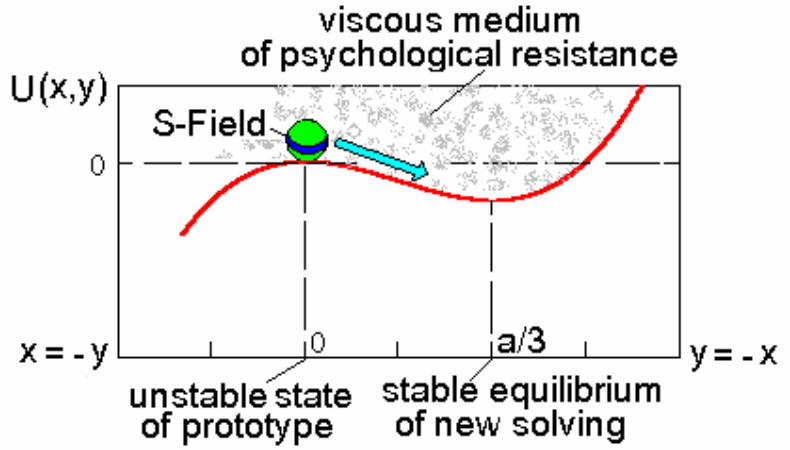

Figure 9. Evolution of S-Field in viscous medium of consciousness

The total psychological energy stays a constant value in accordance with the law of energy conservation during problem solving. We can write law of energy conservation as follows

$$P(x,y) = U(x,y) + H(x,y) = \text{Const}, \qquad (18)$$

where $P(x,y)$ - total psychological energy of problem, $U(x,y)$ - potential energy of thinking, $H(x,y)$ - kinetic energy of homeostasis for substances S1 and S2.

Consequently, energy of homeostasis is

$$H(x,y) = \text{Const} - U(x,y). \qquad (19)$$

Potential energy is defined from (12) accurate up to constant addend:

$$U(x,y) = -x^3 + y^3 + axy + D.$$

where D is constant addend.

Diagram of changing an energy of homeostasis can be qualitative built only because value of parameters a, D and Const are unknown. However there are such values of parameters, which give a curve of changing an information effect (see example on scaling a catastrophe in [1]). For instance, if we choose the following values: $D = 1$, Const $= 0.9$, $a = 3$, we get curves of changing an energy in the fig. 10. Curve $H(x,y)$ is an analogue of changing an economic effect for stages of technical system development [3]. Homeostatic energy is negative in first phase, because the substances S1 and S2 are struggled with viscous medium of psychological resistance. Struggle is external for the homeostat. Mutual struggle

of substances S1 and S2 begins in the second phase, when psychological resistance was overcame. Information effect of X-element becomes positive. End of third phase is peak of conflict. The X-element ready to be born.

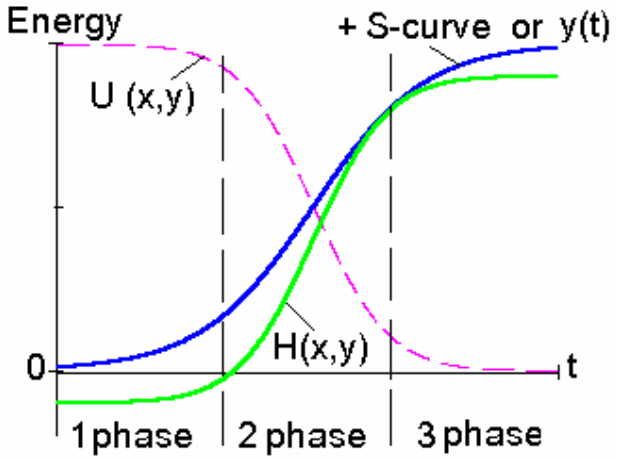

Figure 10. Changing an energy of S-Field to stage of embryonic growth:

U(x,y) - potential energy or undesirable effect, *H(x,y)* - homeostatic energy or information effect.

2.3. Simulation to Stage of Birth and Existence

When undesirable effect becomes minimum, then information field of X-element will be born. Hyperbolic umbilic tolerates mathematical catastrophe, consequently now we must define new values of control parameters in (9), (10), (11).

Choose critical value a=0 in (9), (10), (11) since appearance of X-element resolves conflict ($\lambda = 0$):

$$K\, dx/dt = -3xy + c, \qquad (20)$$

$$K\, dy/dt = 3xy - b, \qquad (21)$$

$$x = -y. \qquad (22)$$

Equations of fermentative kinetics [9] can be used for the determination *b* and *c*. Reversible chemical reaction of two reagents X and Y has formula

$$X + Y \rightleftarrows Z. \qquad (23)$$

Such reaction is identified bimolecular as far as two molecules X and Y will reversible converted in one molecule Z. Velocity of reaction is proportional concentrations of reagents in accordance with the law of acting masses. For instance,

$$d[Y] / dt = -k_1 [X] [Y] + k_{-1}[Z], \qquad (24)$$

$$d[X] / dt = -k_1 [X] [Y] + k_{-1}[Z], \qquad (25)$$

$$d[Z] / dt = k_1 [X] [Y] - k_{-1}[Z], \qquad (26)$$

where [X], [Y] , [Z] - concentrations of reagents X,Y,Z accordingly, k_1 and k_{-1} - the factors of direct and inverse reactions.

Let us use equations (25) and (26) hereinafter but substitution [X] = - [Y] and [Y] = - [X] in (25) brings equation for [Y]:

$$d[Y] / dt = k_1 [X] [Y] - k_{-1}[Z]. \qquad (27)$$

Substitution $[X] = x/v$, $[Y] = y/v$, $[Z] = z/v$ brings result

$$dx/dt = - (k_1/v)\, xy + k_{-1}z, \qquad (28)$$

$$dy/dt = (k_1/v)\, xy - k_{-1}z, \qquad (29)$$

$$dz/dt = (k_1/v)\, xy - k_{-1}z, \qquad (30)$$

where v - volume of viscous medium.

Analogous circuit of S-Field is presented in the fig.11. The scheme received by means of equations (28), (29), (30).

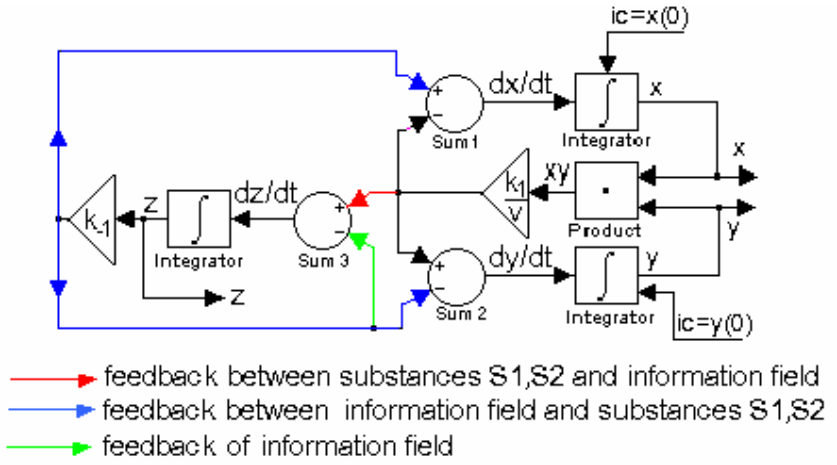

Figure 11. S-Field model scheme

Comparison of equation systems (20), (21), (22) and (28), (29), (30) allows to draw conclusions:

1. There is need to enter third coordinate z for property of X-element
2. Control parameters b and c must be equal

$$b = c = Kk_{-1}z, \qquad (31)$$

and $$k_1/v = 3/K. \qquad (32)$$

Equations (28), (29), (30) form a feedback system. Really, coordinate z reflects property of information field and it is input signal for substances S1 and S2. (blue arrows in the fig.11,12). Simultaneously product xy is an input signal for the information field (red arrow in the fig.11,12).

Equations (28), (29) can be received from (13), (14) by substitution $y = - z$ and $x = z$, i.e. mutual struggle stops between substances S1 and S2 (breakup of

the lilac color arrows in the fig. 12a) but genetic memory enters from ‘‘parents’’ to their ‘‘child’’. Product *xy* is a genetic memory of family. Consequently, not only mutual struggle, but also unity of oppositions passes through black arrows in the fig. 12a,b.

There is interestingly to notice a substance's struggle absence after birth of X-element. X-element is at war with substances through blue arrows in the fig. 12b, it resolves a contradiction and so substances S1 and S2 come to meet. However, substances resist against X-element through the red arrow in the fig. 12b.

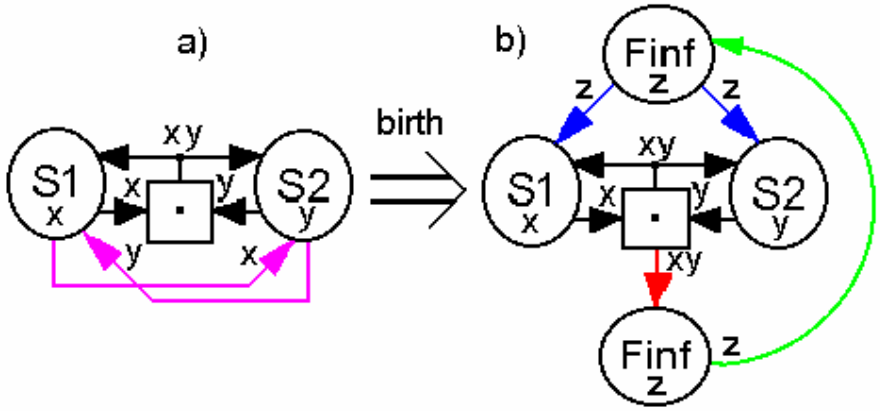

Figure 12. Structure of S-Field transformation
a) embryonic stage; b) stage of birth and existence

There is interesting to mention a following significant coincidence. For the first time Salamatov [10] used a sign of point in the S-field (fig.13).

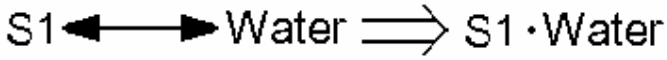

Figure 13. S-Field of maximum interaction

The point means a maximum interaction in the fig. 13. Chemical reaction between the substance S1 and Water gives a new substance. In the fig. 12 the point in the square is a marking of the most true mathematical multiplying. Properties of substances (or their scaled values [7]) can be multiplied. The birth of new substance or field by maximum interaction is a common result in the fig. 12b and 13. Multiplying gives both *product*ion and *product* justly.

Simulation results of S-Field model are brought in the fig. 14 (both stages).The fig. 14a and fig. 14b are distinguished by sign of X-element. The Main Manufacturing Process defines a sign of X-element on the ARIZ step 1.4. Sequence of signs in summands of equations (28),(29),(30) defines a development

of S-Field after the X-element birth.

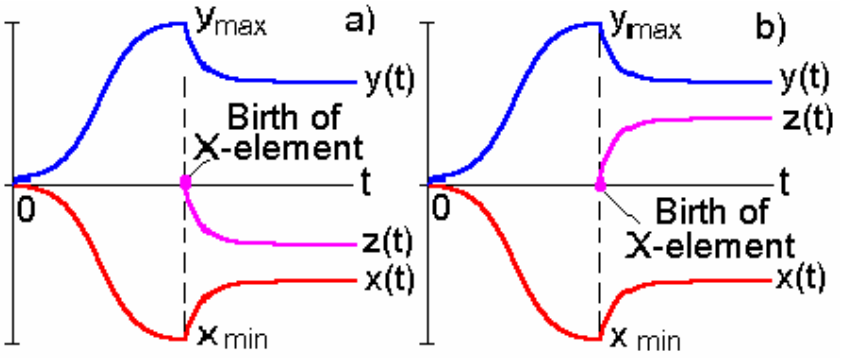

Figure 14. Partial solving of problem

For instance, sequence - ,+,+,-,+,- recorded now. Such sequence brings a result in the fig. 14a. Sequence -,-,+,+,-,- brings a result in the fig. 14b. Such sequences of signs give incomplete solving of problem. For instance, structure of S-Field is determined already, but kind of field not found else or technical contradiction is resolved already, but physical contradiction not resolved else.

Dynamic balance is installed between the X-element and substances S1,S2 because there is a reversible reaction in equations (28),(29),(30). Psychological resistance of medium, conflict power and other factors in equations (28), (29), (30) influence upon the balance level.

Other sequences of signs destroy a dynamic balance. For instance, sequence -,-,+,+,-,+ brings a peaking of contradictions after the X-element birth (fig.15a).

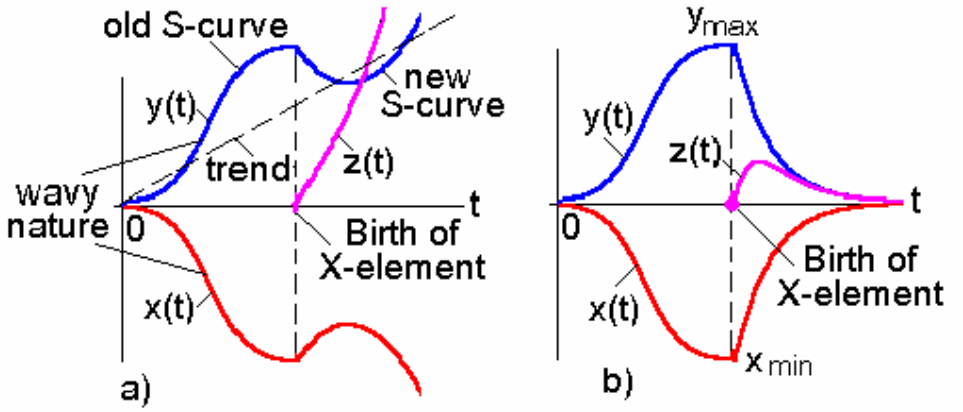

Figure 15. The peaking (a) and resolving (b) of contradiction

Figure 15a demonstrates wavy nature of the Altshuller's contradictions chain from administrative contradiction in the direction of technical contradiction and

physical contradiction. Old S-curve disintegrates and new S-curve begins comparatively with trend. Sequence -,+,+,-,-,- brings a resolving of contradiction, i.e. complete solving of problem (fig.15b). Reaction becomes inconvertible because feedback through the red arrow in the figure 13b changes its sign.

Negative feedback appears and contradiction is a damped motion. Shall find graphs of potential and kinetic energy in this case.

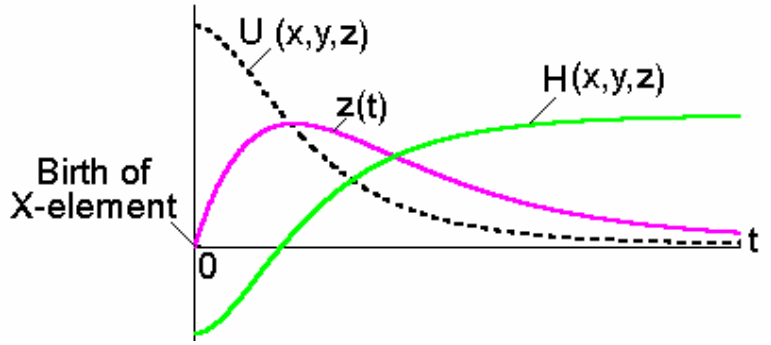

Figure 16. Changing an energy of S-Field to stage of birth and existence

There are following indications in the fig. 16: *U(x,y,z)* - potential energy or undesirable effect, *H(x,y,z)* - kinetic energy or useful effect. Potential energy is defined from (12) accurate up to constant addend:

$$U(x,y,z) = - x^3 + y^3 - Kk_{-1}zx + Kk_{-1}zy + D.$$

Consequently, kinetic energy is

$$H(x,y,z) = \text{Const} - U(x,y,z).$$

Wave of increasing contradictions and conflict resolving at the end can be received by approaching choice of control parameters and initial conditions in equation systems (13), (14) and (28),(29),(30).

Conclusion

1. Closed feedback S-Field demonstrates unity of three problems of Substance-Field Analysis, i.e. problem of construction, problem of destruction and problem of finding (measuring).

2. X-element is an information field; its energy depends on prototype information and psychological characteristics of thought, i.e. ideality and inertia.

3. Mathematical S-field model is compensating homeostat, which accumulates energy of information field. Maximum intensification of inconsistent characteristics brings homeostat in very non-equilibrium state. Very non-equilibrium state is a necessary sign of self-organization. Disintegration of homeostat gives new solving of problem.

4. Simulation has shown that kinetic energy curve of X-element complies with the known curve of economic effect. The potential energy curve of X-element is a curve of undesirable effect.

5. Mathematical models improve a theory of inventive problem solving and pave the way to problems of artificial intelligence.

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