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Integration of Flow Analysis with Function Analysis

Flow analysis is an efficient tool for analyzing engineering systems in TRIZ. It supplements function analysis effectively because it enables to identify problems that cannot be revealed using other types of analyses.

Nevertheless:

- A generally accepted methodology for conducting flow analysis is still missing;
- Information obtained as a result of Function analysis (FA) is still not used in course of flow analysis;
- Results from flow analysis and FA are integrated only during cause-effect chains construction.

In this report the authors are making an attempt to consider flow analysis as a particular case of function analysis – flows in an engineering system are viewed as a particular case of system components possessing very important specific features.
The authors also analyze functional relationships of flows with other (“stationary”) system components – namely, source, channel, receiver and control system of flow, which, taken together, form functionally complete engineering subsystem.

The proposed approach offers the following opportunities:

- Opportunity to use well-proven techniques of function analysis when conducting flow analysis;
- Opportunity of partial integration of flow analysis with function analysis;
- Opportunity to identify components that interact with flows and that need to be improved.

PROBLEM STATEMENT

The practice of flow analysis application shows that it is a highly efficient tool. Correctly constructed flow model allows identifying problems that could be hardly identified by means of FA tools. The reason for that is clear – FA practically does not take into account information about spatial structure of ES under analysis, while flow model takes such information into account on intuitive level. Function model (FM) represents an “instant photograph” of ES made at a certain point in time. However, the dynamics of ES operation is completely (or almost completely) lost with such an “instant photograph”. When constructing a function model for an operating system, one has to try various tricks or simply neglect “canonical clarity” of description. A typical example - component1 moves component2. With strict adherence to the rules of flow model construction, this formulation is incorrect because it implies different position of components at different points in time.

Introduction of flow in the FM eliminates such difficulties, if **one views flow as a dynamic component of a system,** which components of a lower system level move in the space under the action of static components.

However, in contrast to FA, the flow analysis is currently formalized quite unsatisfactory. Indeed, uniform method for conducting flow analysis is missing at present. In addition, tools for exchanging information between FM and flow analysis model are also missing. These two types of analysis are conducted independently, and their results are integrated only in the course of cause-effect chains construction.

Several attempts were made to integrate these two tools. One of the most elaborate methods is described in TRIZ Master thesis by A.G.Kashkarov [1]. Unfortunately, the method proposed by A.G.Kashkarov is too cumbersome, which completely eliminates one of the most significant advantages of flow analysis – namely, intuitive clearness and transparency.

The authors of this paper discuss approaches allowing to integrate FA with flow analysis without loss of advantages inherent to both of them.

CHOOSING A PROTOTYPE METHOD

To continue discussing the proposed approach, we need to choose one of the existing options of flow analysis methods, which could be used as a base method for further improvement. Apparently, the relationship of flow analysis with other TRIZ tools is described best of all in TRIZ Master thesis by O.Gerasimov “Technology for Choosing Innovative Designing Tools on the Basis of TRIZ-VEA” [2]. However, this description is a short one, which significantly complicates its use in practical work. In addition, a number of notions introduced in the Trends of Engineering System Evolution (TESE) are used in this thesis (it has to be mentioned here that flow analysis initially appeared as a development of one of the

Trends – namely, Trend of increasing efficiency of using flows of substance, energy and information). It makes sense to remind here the origin and evolution of this Trend.

The trend of minimal energy conductivity of systems formulated by G.Altshuller [3] was a predecessor of the Trend of increasing efficiency of using flows of substance, energy and information. In the course of TESE evolution this trend remained practically unchanged for a long period of time (from 1975 till 2002 judging from publication dates). In particular, in the book written by G.Altshuller, A.Zusman, B.Zlotin et al. [4], this trend was just mentioned as a component of trend of increasing coordination in systems, and in the paper written by Yu.Salamatov [5], the trend is indicated almost word-for-word.

In the book written by V.Petrov [6], the trend is described as an increase of specific energy saturation of systems and viewed as a subtrend of the trend of system transition to the microlevel. However, in this book it is viewed not as a requirement of minimal needed level, but as a system evolution line.

In the article written by S.Litvin and A.Lyubomirskiy [7], the trend is completely revised and viewed as a “trend of increasing efficiency of use of substance, energy and information flows”.

One can readily see that in published works of Petrov and Litvin with Lyubomirskiy, this trend is actually an absolutely new trend – rather than amplifying its predecessor, it actually stays near its predecessor:

Firstly, this formulation of the trend indicates not to the possibility of system existence, but to the ways of actually operable system improvement.

Secondly, a set of flows under consideration in the article written by S.Litvin and A.Lyubomirskiy was extended quite significantly – from energy flow to all types of flows existing in systems.

However, rather than simply a trend (i.e., evolution line), description of this trend in [7] is a list of mechanisms (in essence, recommendations on improvement of flows in a system). The list of these mechanisms is quite long and includes 42 items. They are structured in terms of flow types and subdivided into two groups implying “variation of flow conductivity” and variation of flow efficiency”. The authors decided to choose this formulation of the trend and its recommendations regarding flow analysis as a prototype for their subsequent work.

WHAT ARE WE GOING TO IMPROVE?

First of all – definitions. Insufficient attention to terminology and definitions represents a serious demerit of the majority of theoretical publications on TRIZ. In particular, Litvin and Lyubomirskiy formulate four major sub-trends of this trend (parasitic flows as a particular case of harmful flows are described almost word-for-word compared to the description of harmful flows):

- Increasing the efficiency of using useful flows
- Decreasing the damaging ability of harmful flows
- Increasing the conductivity of useful flows
- Decreasing the conductivity of harmful flows.

The first two sub-trends are obvious to the triviality and trivial to complete non-instrumentality. And it is absolutely impossible to cast doubts upon them. It is also true that it is useful to formulate obvious things as axioms, which was actually done.

As for the last two sub-trends, there are serious problems with them.

- Increasing the conductivity of useful flows
- Decreasing the conductivity of harmful flows.

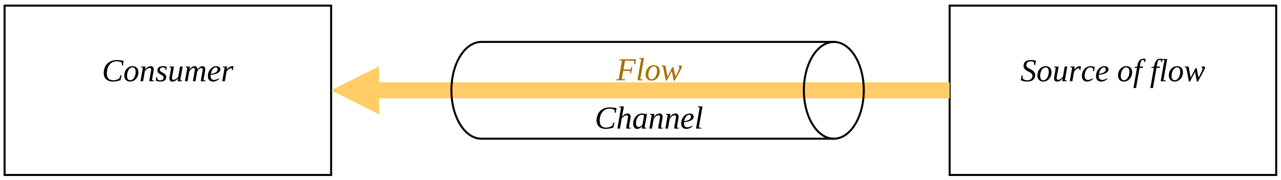
First of all, **"conductivity of flow"** sounds similarly to notions **"resistance of electricity" or "conductivity of water in a pipe".** One can talk about conductivity of **channels** (ducts) for flow ("resistance of **conductor** to electric current"). The issue is not simply in concord of cases in Russian text, but in separating different categories, which were previously confused in unified term.

That's why at first we will try to refine certain key terms.

Within the frames of the present paper

- **By flow - we will mean such movement of material objects, energy or information in a system, with which certain parts of flow move according to one and the same trend one after another (partially a flow may move in the supersystem, but the key issue is the existence of this flow and its movement within a system under consideration),**
- **By source of flow – we will mean a system component that forms a flow and that specifies initial parameters for this flow,**

- **By channel of a flow – we will mean a system component that determines path of flow motion (this channel could be distributed in space and it could have no clearly/well-defined boundaries),**
- **By consumer – we will mean a system component that is converted under the action of a given useful flow or a component that is directly damaged by harmful flow under consideration.**



Comments:

A. The above-indicated formulations are absolutely general for all conceivable cases, but they are sufficient for application-oriented purposes (analysis of ES and working out proposals on ES improvement).

B. Assigning one or another system element to one specific component is not absolute (it is determined by specific features of a problem to be solved).

C. For a considerable part of systems, a flow represents an object of conversion, rather than a subject of conversion. Hence, “Consumer” represents a subject and it would be more correct to name it flow “converter”. However, there is no significant difference for purposes of flow analysis practice; therefore, we decide to neglect this issue.

The use of such formulation allows subdividing into four types of system components that are essentially different (in terms of function) with respect to the flow under consideration:

- The flow proper as a subject of conversion
- Source of flow,
- Channel intended for retaining/restricting/directing the flow,
- Consumer – a component, upon which the flow acts directly thus changing at least one of component parameters.

In terms of “subject - function – object”, the channel converts the flow, and the flow converts a product. A significant issue – minimal FM consists of flow component and channel. It is possible that source of flow and consumer are not included in the FM.

Making the model more elaborate (i.e., introduction of new additional components) is a seeming task.

Explicit recording of a component, which previously was implied by default

- Makes the analysis of a model easier;
- Identifies directly the non-mediated relationship between flow model and function model, as well as between flow model and TESE. In particular,
    - A possibility appears in the flow model to operate with other components of a system (namely, source of flow, channel, consumer).
    - All flows under consideration appear if the function model in addition to components.
    - A possibility appears to coordinate (in the explicit form) four system components (source of flow, flow proper, channel, and consumer); those components are identified, due to which the controllability of flow could be enhanced (source of flow, channel), and so forth.

The above-indicated pairs of sub-trends are quite clearly subdivided in the proposed formulations:

- Enhancing the efficiency of utilization of useful flows by **consumer**
- Reducing the damaging ability of harmful flows in respect to **other components of ES**

BUT:

- Enhancing the conductivity of **channels** for useful flows
- Reducing the conductivity of **channels** for harmful flows

With such formulation the sub-trends become much more understandable. In addition:

- Non-completeness of the currently existing formulation of the trend becomes obvious,
- The second pair of sub-trends still draws serious objections.

Simple examples:

- Useful flow of heat in internal combustion engines. With the enhancement of conductivity of a channel for this flow, additional supply of fuel into combustion chambers would lead to incomplete combustion, which, in its turn, would result in a number of quite serious problems.
- Useful flow of hot water or steam in heat exchanger jacket. With the enhancement of conductivity of a channel, the heat will be removed from the system, though we need quite the opposite result.
- With the reduction of conductivity of a channel for the flow of electric current passing by electronic circuit, harmful flow of Joule heat will additionally heat the electronic circuit, though we need quite the opposite result in this case as well.

- With the enhancement of conductivity of electric conductor, useful flow of electric current in filament lamp would lead to a change in filament lamp rating, and above certain limit – simply to burnout of the lamp.
- With the enhancement of conductivity above certain limit, useful flow of semi-finished product to an actuating/executive mechanism (flow consumer) would lead to overstocking of consumer and/or necessity to introduce accumulating buffer storage.

Of course, one may make a reservation in many ways. A standard method for overcoming such occasions when conducting flow analysis or analysis on TESE looks as follows: "in this case another sub-trend exerts its action…". However, **reservations of this kind (and simply the necessity of making reservations) impair the instrumentality of the method quite significantly.**

Of course, enhancing the conductivity of a channel for a flow often turns out to be very useful. Techniques for such enhancement are described in detail in the existing option of the trend, and they remain true and undoubtedly useful. The same refers to cases involving reduction of conductivity for a channel.

Proposed refinements for notions (though, they may seem quite simple) enable to enhance the efficiency of flow analysis quite significantly.

ALGORITHM OF ANALYSIS

The authors propose the following logic for flow analysis

1. Construction of flow model according to existing methodology – chosen as prototype
2. Identification of disadvantages inherent to flows according to recommendations
3. Refining the identified disadvantages accompanied with determination of their types:
   - Inadequate parameters and functions of a flow
     - Inadequate and harmful functions of a flow,
     - Excessive payment factor for flow functioning
   - Inadequate parameters and functions of a channel
     - Inadequate and harmful functions of a channel
     - Excessive payment factor for the formation and functioning of a channel
4. ONLY FOR IDENTIFIED problem-causing sections of flows, we will construct refined flow models, in which we separate (in the explicit form) the flow proper from the channel.

5. On the basis of item 4, to construct function model for components associated with problem-causing flow and conduct standard FA. (Strictly speaking, this a standard and widely used technique used by practitioners – to construct a detailed FM of a deeper system level fro problem-causing part of a system identified by means of model of higher level).
6. To eliminate disadvantages (identified in the course of FM construction according to item 5), to apply recommendations of the Trend of increasing the efficiency of utilization of flows of substance, energy and information. In this process, it is convenient to use classification of flows and sub-trends characteristic for different types of flows. An attempt to offer such classification was made in [8].

CONCLUSIONS

The proposed approach:

- Does not represent a methodology aimed at direct integration of two methodologically quite different tools. Actually, the proposed approach allows applying well-proven and efficient techniques and methods of function ANALYSIS for convenient and clearly arranged flow MODEL.
- Is easy to use and could be quickly mastered by practitioners who are conducting function analysis separately from flow analysis. In addition, the approach could be employed by specialists who use different versions of both function models and flow models. It is not a secret that each practitioner constructs actual models in one’s own way to a certain extent. Therefore, strictly prescribed algorithm may turn out to be unsuitable for many practitioners.

Of course, it would be attractive to completely integrate both models – as was done, for example, by A.G.Kashkarov in [1]. But as a result in this case we would obtain a very cumbersome model overloaded both with information and graphical elements. The proposed approach, from our standpoint, allows obtaining quite weighty results with not so large labor input.

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