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ANALYSIS OF THE PERTURBATIONS BROUGHT ABOUT BY THE TOOL FLOW IN THE MANUFACTURING SYSTEMS

Magdalena BARBU[1], Gavrilă CALEFARIU[2], Gheorghe BONCOI[3]

Abstract: *Production diversity imposes a real technology variable in time, which in its turn requires a variable structure of the manufacturing system and therefore a diversified tool flow. The notion „tool flow" is defined, emphasizing the differences from the material flow of the semi-products. When a parameter of the process is liable to asynchronisms, it is a source of inevitable but also necessary perturbations during the processing. Asynchronism itself is the measure of perturbation. In the majority of the practical cases, the output perturbations are decisive upon the stability of the process, the input and consequently the endogenous ones depending on the former. Therefore, in planning a production system, first and foremost the output values with their perturbations are settled, then the commands with their perturbations are determined and finally the production system is planned.*

Key words: *tool flow, perturbation evaluation, analysis of inputs / outputs.*

1. INTRODUCTION

The specialized literature does not offer a systemic analysis upon the input / output of the tools in the structure of the production system, upon the hierarchical arrangement of the tools in the structure of the production system, upon the main perturbations induced by the tools to the production system, upon the interactions of the tools with the main components of the production system

In the paper, the authors analyze the place and the role of the tools in the production system [1, 2]. The flow of tools is defined as an atypical flow. The perturbations caused by the flow of tools in the manufacturing systems, as well as their apparition causes are defined and classified.

2. FLOW OF TOOLS

The entirety of tools needed to carry out a process, the less so the entirety of tools existing in the factory at a given moment, does not meet the conditions, either theoretical, or practical, for making up a system. Therefore, the tools will be considered hereafter as a flow running from the central factory warehouse (total central set of tools – SScC = the tool requirement or the general level of tools – NSc), to the zonal section warehouse (zonal set of tools – SScZ), to the local machine storages (local set of tools – SScL), to the machines (set of tools for operation – $SScOT_i$), following the route of monitoring and corrections of perturbations (control, selection, resharpening, removal of broken tools, setting, pre-adjustment).

[1,] PhD, Assistant Prof., *E-mail: magda.n@unitbv.ro*

[2,] PhD, Professor, *E-mail: gcalefariu@unitbv.ro*

[3] PhD, Professor

University Transilvania" of Braşov, I.E.S.P. Department, Brasov, Str, Mihai Viteazu, nr. 5w Tel:/Fax. 0268477113

The flow of tools can be interpreted as including, as necessary, a logistic system of the tools called the tools handling system.

Besides the fact that F_lSc is a special, atypical subsystem, it has only a distinct and relevant input, its output in EMe only existing as waste, since the tools are entirely used up during the processing; on the output in EMe, the used-up tools are emergently incorporated in P_f, thus contributing to the process synergism.

All the entities components of F_lSc shall have their own inputs and outputs for tools, materials and information, which are distinct, clearly related one to the other by interactions. Part of them (SbMan, SbSt, m_i) will function in the tool demand-delivery relation. Others, such as: PCt, PSel, PAsc, PSet, PPrereg, PDeş, will function only in the receipt-by-decision - delivery relation. All the points of the monitoring flow will operate informational only at request, by superior decision, the communication consisting in informatic reports.

3. PERTURBATIONS IN THE FLOW OF TOOLS

Perturbations are endo and exogenous phenomena whose effect consists in the undesired output modification when the input command (decision) is not modified [3]. The perturbation causes are endo and exogenous and consequently the perturbations will be endo and exogenous. The endogenous causes of the perturbations are: subjectivism in monitoring and management, utilization of natural technologies in processing, blockages, adaptation process and the exogenous causes are: relations with the input and output exo-environments. Consequently, the perturbations are unpredictable, unstable and impossible to avoid, which raises the SP vulnerability.

For F_lSc the main endogenous perturbations are: wear and tear, break-up, setting, tool pre-adjustment, non-observance of the process technological parameters, F_lSc organization, tool penury along the flow, absence of the standard piling up tool stock, and the exogenous ones are: unstable relations with the tool suppliers, the manner of organizing the tool provisioning, which are, in general, managerial causes [4, 5, and 6].

The internal tool consumption is a perturbation as it influences the outlets for stationary inputs; the consumption is brought about by the causes: break-ups, wear and tear, derangements denominated as follows tool flaw. If the wear and tear are predictable and therefore may be foreseen in anticipation, with correction effect, through preventive programs, the breaking up and the deregulations are pre-eminently unpredictable, with decisive influence upon the variation of the quantitative level of the tool flux. The wear and tear only influences the local hierarchical level of the tools, in great number and with relatively great frequency. Through preventive programs, the influence of the wear and tear upon the level of the tool flux may be reduced up to zero value. The breaking up; and the derangements influence all hierarchical levels: central, zonal and local, bringing along the tool circulation along the entire flux. Although the number of the breaking-ups, of the derangements as well as their frequency is small, comparatively to the wear and tear, their influence upon the variation of the quantitative level of the tool flux is of significance. The tear and wear bring along the tool circulation, exclusively in the endoenvironment, between the local piling up stock – tool dresser for re-grinding/sharpening and zonal piling up stock – local piling up stock for replacement, without affecting the quantitative level of the tool flux. The derangements bring along the tool circulation, exclusively within the endoenvironment, between the local piling up stock – post of pre-adjustment for the adjustment and the zonal piling up stock – local piling up stock for replacement, without affecting the variation of the quantitative level of the tool flux. The breaking ups induce the tool circulation in the endo-exo-environment and its reverse. The endo-exo-environment motion results in eliminating the broken tool, as waste, between the local piling up stock and the post for collecting the waste from the exo-environment and the circulation exo-endo-environment consists in provisioning from the exoenvironment, the central deposit, followed by its motion, set-up and pre-adjusted, through the zonal piling up stock, in the local piling up stock. Consequently, the tool breaking up affects the variation of the quantitative level of the tool flux. The complete utilization of each tool, after a predictable number of re-sharpening operations, influences the quantitative level of the tool flux. Consequently, the provisioned tool quantity, on the inlet, modifies the quantitative level of the tool flux in the endoenvironment. Quantity supplied on entry into the central warehouse is the result you want to cancel the disturbance of endoenvironment - breaking and complete exhaustion of tools in manufacturing. The quantity of provisioned tools depending on the breaking up, and likewise tear and wear of the tools, unpredictable and consequently unforeseeable, must be managed (monitored) in real time being unpredictable. In SFa functioning, the perturbations manifest themselves in every interaction

$$S_i \lhd S_j, 1 \le i \le m,\ \ 1 \le j \ne i \le n,$$

not as much on the input, as on the output.

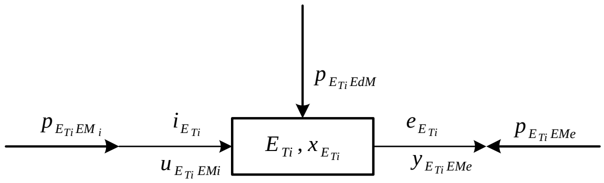

Fig. 1. Scheme of perturbations upon a E_{Ti}.

A component entity in SFa is isolated, as in Fig. 1, undergoing perturbations: its own $p_{E_{Ti}EdM}$ called perturbation proper to the endo-environment; on the input $p_{E_{Ti}EMi}$, with effect on the command $u_{E_{Ti}}$ called pseudo-command and on the output $p_{E_{Ti}EMe}$, with effect on the output $y_{E_{Ti}}$ called pseudo-output; all three types of perturbations are dealt with as interactions this way:

- in their own endo-environment $E_{Ti} \rhd EM_{E_{T_i}} \to p_{E_{T_i}EdM} = df$ perturbation in their own endo-environment;
- in the input exo-environment $E_{T_i} \rhd E_{T_{(i-1)}} \to p_{E_{T_i}EM_i} = u_{E_{T_i}EM_i}$ =df pseudo-command;
- in the output exo-environment $E_{T_i} \rhd E_{T_{(i+1)}} \to p_{E_{T_i}EMe} = y_{E_{T_i}EMe} = df$ pseudo-output.

There ensues that the three types of perturbations in the interaction $\mathrm{S_i} \rhd \mathrm{S_j}, 1 \le \mathrm{i} \le \mathrm{m},\ 1 \le \mathrm{j} \ne \mathrm{i} \le \mathrm{n}$ are expressed through the relation of dynamic interaction of the perturbations:

$$v_{pi}(k+1) = v_{piu}(k+1) + v_{piy}(k+1) + v_{piP}(k+1)$$
$$= \sum_{j \ne i, j=1}^{n-1} g_{iju}(x_j(k)) + \sum_{j \ne i, j=1}^{n-1} g_{ijy}(x_j(k)) + \sum_{j \ne i, j=1}^{n-1} g_{ijP}(x_j(k)), \qquad (1)$$

in which g_{iju} represents the interaction function expressing the influence of the perturbations on the command, g_{ijy} represents the interaction function expressing the influence of the perturbations on the output, g_{ijP} represents the interaction function expressing the influence of the perturbations in their own structure and v_{pi} the global interaction of the perturbations of E_{Ti} with $\forall E_{Tj}$.

As the interaction relation above depends on the SFa structure, being an additive relation for a given composition of n sub-systems, there ensues that the number, the nature of the perturbations and their influence on the partial and global outputs depends on the structure of the system and therefore, for determining them, the real structure of the system must be known.

In the particular case of $\mathrm{F_lSc}$, there is specified that:

- for NL:
  - $\mathrm{p_{EdM}}$ are: diversity of the tools in $\mathrm{STL_\alpha}$; states – GOOD, WORN AND TORN, DEREGULATED, BROKEN; the $\mathrm{STSc_s}$ non-existence in $\mathrm{STL_\alpha}$ necessary in any moment of the processing; functional and organizational (managerial) blockages in EdM;

- p_{EMi} are: $STSc_s$ non-existence in STZ necessary for processing the following mark; functional and organizational blockages in EMi;
- p_{EMe} are: functional blockages and the non-existence of the interactions between PCt and PSel;
- tool consumption is an important perturbation in the endo-environment. In material processing, tools are consumed. The tool consumption may be *structural*, brought about by the processing diversity which consequently requires a great tool diversity with high change frequency, and *of level* (quantitative, in number units tools/τ_f) brought about by the dimension and frequency of the same manufacturing lot within the time interval τ_f. The structural consumption rises once with the manufacturing diversity increase and the one of level once with the increase of the production volume of the same mark R_k (with the product $n_{PLk}\, n_{Lk}$)

- for NZ:
  - p_{EdM} are: $STSc_s$ non-existence in STZ for processing $\{Pr(R_k, k\text{=var})\}$, diversity of the tool change activities, diversity of the tool manipulation trajectories;
  - p_{EMi} are: functional blockages and non-existence of the interactions among PSel, STC and STZ;
  - p_{EMe} are: functional blockages and non-existence of the interactions between STZ and STL_α, $\alpha < I < q_{SM}$

- for NC:
  - p_{EdM} are: non-existence of $STSc_s$ and of PS as standard central piling stock in STC, diversity of the tool change activities, diversity of the tool manipulation trajectories;
  - p_{EMi} are: managerial dysfunctions in ApSc, functional blockages and non-existence of the interactions $STC \triangleright EM_i$, $STC \triangleright PSet$, $PSet \triangleright PPrereg$, $AtAsc \triangleright PPrereg$, $PPrereg \triangleright STZ$, $PSel \triangleright (PDeş, AtAsc, PPrereg)$;
  - p_{EMe} are: managerial dysfunctions in organizing the tool manipulation, functional and organizational blockages and non-existence of the interactions $STC \triangleright STZ$, $STC \triangleright PSet$, $PSet \triangleright PPrereg$, $AtAsc \triangleright PPrereg$, $PPrereg \triangleright STZ$, $PDeş \triangleright EMe$.

Every perturbation provokes a blockage in the SFa functioning which, for its elimination, requires an auxiliary time, whose size negatively influences the value of the performance functional. To the purpose of optimizing the performance functional, there must be known the perturbations and the blockage causes, as well as their quantitative and qualitative evaluation, which should allow the minimization of their influence upon the performance functional.

As the perturbations are of different natures, have different causes, are expressed in different units of measure and have different influences, their correct treatment cannot be done through determinist models, only through fuzzy models.

4. EVALUATION OF PERTURBATIONS

Following the previously presented facts, the perturbations are of quantitative and qualitative nature. The perturbations of a quantitative nature may be quantitatively evaluated and they directly influence the performance functional; and those of a qualitative nature may be evaluated and indirectly influence the performance functional [3].

The global manipulation process of a tool in a complete F_lSc unfolds on the three levels and consists in the following activities, consuming the time marked in parenthesis:

- on local level (NL) – t_{ManNL}
  - manipulation of Sc_1 from AP of m_α in PCt_α (t_{ManSc1})
  - manipulation of Sc_2 from STL_α in AP of m_α (t_{ManSc2})
  - control of Sc_1 in PCt_α, framing Sc_1 in one of the states – B, U, D, R and its marking (t_{CtSc1}).
- on zonal level (NZ) – t_{ManNZ}
  - transfer of Sc_1 from PCt_α in PSel (t_{TfSel})
  - reading the Sc_1 marking and selecting the transfer in PSel (t_{CitSel})
  - transfer of Sc_1 B in STZ (t_{TfSTZ1})
- on central level (NC) – t_{ManNC}
  - transfer of Sc_1U from PSel in AtAsc (t_{TfAsc})
  - transfer of Sc_1D from PSel in PPrereg ($t_{TfPrereg1}$)
  - transfer of Sc_1R from PSel in PDeş ($t_{TfDeş}$)
  - transfer of Sc_1Reasc from AtAsc in PPrereg ($t_{TfPrereg2}$)
  - transfer of Sc_3 from STC in PSet (t_{TfSet})
  - set-up of Sc_3 with PS in PSet (t_{Set})
  - transfer of set up Sc_3 from PSet in PPrereg ($t_{TfPrereg3}$)
  - pre-adjustment of Sc_1Reasc and Sc_3 Set in PPrereg (t_{Prereg})
  - transfer of pre-adjusted Sc_1 and Sc_3 in STZ (t_{TfSTZ2})
  - transfer of Sc_1R from PDeş in EM (t_{TfEM})

There ensues that:

$$\begin{gathered} t_{ManNL} = t_{ManSc1} + t_{ManSc2} + t_{CtSc1} \\ t_{ManNZ} = t_{TfSel} + t_{CitSel} + t_{TfSTZ1} \\ t_{ManNC} = t_{TfAsc} + t_{TfPrereg1} + t_{TfDeş} + t_{TfPrereg2} + t_{TfSet} + \\ t_{Set} + t_{TfPrereg3} + t_{Prereg} + t_{TfSTZ2} + t_{TfEM} \end{gathered} \tag{2}$$

and the total manipulation time in a complete cycle will be:

$$t_{Mant} = t_{ManNL} + t_{ManNZ} + t_{ManNC}. \tag{3}$$

In the relation above, the highest importance is held by the pre-adjustment/set-up times and the transfer times. Hence the perturbations caused by these times will be the most important. To the purpose of reducing them, the automation / mechanization of these activities is recommended.

The perturbations produce auxiliary times which negatively influence the performance functional. From this standpoint they are undesired. However some of them as: settings, pre-adjustments pertaining to the adaptation process; control which is a necessary process for the quality of production; sharpening, necessary for the complete utilization of the tools, are needful for optimizing the material processing.

When a parameter of the process is liable to asynchronisms, it is a source of unavoidable but also necessary perturbations during the processing; asynchronism itself is the measure of perturbation.

Production diversity imposes a real technology variable in time, which in its turn requires a variable structure of SFa and consequently a diversified F_lSc. SP identification and controllability imposes the orderly development of all processes, with the observance of the technological precedence conditions and of the restrictions in the relations of equipotency, coordination / subordination, which entails priorities among the different production activities. This way, the modification of the orderly range of the technological operations in the process implies the modification, the change of the transport trajectories of the semi-product in the processing, the tool change, the modification of the stocks on the flow, of the utilization degree of the manipulation and storage facilities for S_f/ P_f and tools, of the tool programming, of the production capacities and of the manipulation and storage facilities. The greatest effect of these modifications pre-eminently manifests itself in the transitory regime, whose duration must be minimized.

In the majority of the practical cases, the output perturbations are decisive upon the process stability, the input and consequently the endogenous ones depending on the former. Therefore, in planning SP, first and foremost the output values with their perturbations are set, then the commands with their perturbations are determined, and finally SP is planned. Depending on the origin of the cause in the external environment, the exogenous perturbations are: on the input p_i and on the output p_e. A multitude of exogenous factors bring about perturbations. Among them, the most important are: the rhythm and the level, unpredictable, of the clients' orders and of the market requirements, the diversity of the market requirements, limited resources of the factory on determined time intervals (production capacities, facilities, SDV-s etc.), time lags in provisioning from the suppliers of raw materials, tools, etc. All perturbing factors mentioned above create a great degree of vulnerability of the factory, whose effects may be minimized only through realistic prevision, dynamic monitoring in real time and optimal decisions, which may be dynamically correlated, of a competent management. The technical entity – the tool flow in a factory presents no sensitive vulnerability with high risks at strong perturbations, of any nature, being relatively stable.

In the time interval of the complex process consisting in the succession decision – command – action – perturbations – monitoring – corrections, in real industrial environments, delays appear inherently and naturally

The delay is defined as the time interval elapsed between the decision taking moment and the perturbation correction moment.

This means that the total delay measured in time includes all partial delays which arise in the succession key points, which are: decision, command placement, command execution action, measurement of the execution real result, perturbation assessment, a new decision of perturbation correction, re-evaluation of the new execution until annulling the perturbation.

The resulted perturbation is evaluated in time, will be called temporary perturbation and is expressed:

$$p_t = \sum_{c=1}^{\min 8} t_{pc}, c \in N \qquad (4)$$

in which the causes c are: initial decision, initial command, execution, error measurement, perturbation evaluation, correction decision, correction command, action re-evaluation, perturbation annulment.

The value of p_t determines the duration of the transitory process whose minimization min p_t is desired to be as short as possible.

5. CONCLUSIONS

During material processing tools are worn and broken; these ones constitute main perturbations in administering tools; for their correction, tools undergo off-line or on-line control, and the used and broken tools are sent to a selection post for worn tool reconditioning / broken tool elimination.

Another important perturbation detected through the off-line, on-line control of the semi-products/finite pieces is the deregulation of the tools in the process.

During a long time interval, tools are flawed (cracked, shattered, broken into pieces) or broken, and they can be no longer used and consequently are eliminated as waste. Hence, tool penury may come up with the undesired effect of the manufacturing organizational blockage. Tool penury may appear at the machine, on the flow, in the zonal section warehouse or in the central factory warehouse. This is a major perturbation which must be eliminated through managerial measures. To this purpose, the tool global administration, including the automated evidence and monitoring is an issue of the tactic management (planning, programming, monitoring department).

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