TWENTY FIRST EUROPEAN ROTORCRAFT FORUM

Paper No III.14

THE MORPHOLOGICAL (MULTIASPECT SYSTEM) RESEARCH A HIGH-SPEED HELICOPTER

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August 30 - September 1, 1995
SAINT - PETERSBURG, RUSSIA

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The Morphological (Multiaspect System) Research of a High-Speed Helicopter.

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The authors represent some preliminary results of using the morphological - nontraditional for the helicopter construction - point of view for solving the actuel problrms into this field of the technics. In particular, the most general problem in helicopter design and which is dificult enough for solution is to achieve higher helicopter speed and to overcome the modern speed barrier.

The choice of the morphologycal point of view (MPv) to solving this problem has been conditioned by the great possibilities of the heuristical methods which are grounded on the point of view. First of all, this is the possibility:

1) to ensure the correct problem statement

2) to ensure the efficiency (cleaness of purpose, reliability and operativeness of the seach, i,e. to receive the pre-stated solution as sooner as possible.

In other words, the morphological point of view ensures the purity and riches of the search field and high "productin yield, i.e. new technical solutions meeting the problem conditions.

F.Tswicky, the MPv founder has advanced only the idea of the morphological analysis (MA), has proposed some methods and modes of MA and illustrated its efficiency on the series of the examples [3]. He has shown what shoud be done to achieve the solution but unfortunalely, has not shown now to do it. He has not elaborated a MA procedure.

Proposed the complete sorting of solution variants by him described by the obtained morphological table (MT), is realize only for the case with the very small MT, contaning from 10^2 to 10^3 varriants. Usually, the MT contain 10^{10} and more variants, and the complete sorting is out of the questions. Any ways to go out the impass are not proposed by Tswicky.

V.M.Odrin has elaborated the classication of nontrivial problems on finding (PF)* solving.

The solving mecanism of nontrivial problem is chosen as the basis of the classification.

He has divided these methods in two classes: transformation

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* G.Polwa's term

and morphological [2].

The essence of MP consists in choising the unknown solution of PF from the set of all its known and contceivable solutions, which is called by the authors a morphological set [3-5]. At the first stage of nontrivial problem solution with the help of MP, i.e. at the stage of morphological analysis (MA), the morphological set is build. At the second stage (the morphological syntesis) the unknown solution of nontrivial problems is obtained, which satisfies the problem conditions, or by way of choosing it from the morphological set, or by means of constructing it, relying upon the MA results and upon the constructiv mathematic ideas and principles (the theory of deductive systems).

When elaborating MP V.M.Odrin and S.S.Kartavov have originated the MK (morphological classifiing) procedure. Which is now the only one in the world litersture. It is, by the way, only one technology classification world literature, while the whole number theories of classi fication are known.

The term "morphological syntesis" is proposed in [3] and its purpose is described. Then the nature of the morphologycal syntesis problem has been reseached by V.M.Odrin: it has been shown the PMS is the selection and optimisation problem at the same time (and the heuristical analog of the mathematic programming problem and the optimal control problem), and also it is the deductive system (the general-type calculation) [6]. A series of the efficience morphologycal syntesis methods has been elaborated by him [10,11]. After all the technology of the creative has been also elaborated by him.

It should be emphasised that our procedure of MA, which will limited to in our report, ensures the correctness, normatve completness and productiving (purposefull inclusion of not only the known but also the conceivable systems of the reseach class) of morphologycal, i.e. multiple (by number of bases) classifying.

Building the system of models of reseach-systems is stipulated by the procedure to ensure the MA correctness, normative completness and producivity. This part of our MK procedure (see Fig.1) (its I-V stages) is a procedure of system analysis of the reseach TS function and of the structure of these systems. The systems are

I Constructing and investigating the TSLC Model

II Investigated Systems Function Definition

III Defining the Investigated GFS

IV Constructing the Functional Models for TS of the Investigated Class

- 1 Collecting and making sense of the information about the known FS belonging to MSs and required (for making sense of) auxiliary information
- 2 Model construction itself
  - 2.1 "Investigated system action Tree" (AT) model construction
  - 2.2. "Investigated System Action Network" (AN) model construction
  - 2.3 "Generalized Functional System" (GFS) model construction
  - 2.3 "Generalized Functional System - Environment" (GFS - environment) model construction

V Constructing SFSR-I and SFSR-II

VI Finding the potential classification signs of the investigated systems

VII Selecting the classification signs essential for problem formulation

VIII Morpholo gical classification and construction of MT

Fig.1. Procedure of Morphological TS Analysis (Classification): TS - technical system; TSLC - TS life cycle; FS - functional system; GFS - Generalized FS; MS - morhpological set; GFSS - generalized functionally meaning full relation set for the GFS (GFS - environment) model or the set of internal (external) parameters of investigated systems; MT - morphological table.

reseached as the functional tional systems. This part of the procedure has also no analogs in the world literature. It is fit to realizing the system analysis of any systems because any systems (even so-called conception) have a purpose* and can be considerated as functional systems.

T.Ch.Bolieva and V.M.Odrin have adapted the MA procedure to solving the problem of how to make the helicopter speed higher.

In other words, the attempt to inscribe the MA into the problem of the general high-speed helicopter design is done, i.e. to pick out a heuristical problem (one or more) and to apply the method of its solving.

As the question of heuristical methods and heuristical problems is descussed, we consider the stage of the preliminary design and, more precisely, the elaboration of conception of the system, since the heuristical part of the design activities is realized mainly it this stage.

It is known that rizing helicopter speed is associated with solving some nontrivial problems concerned with a series of its subsystems: rotor, engine, transmission, control system; and also solving the problem to decrease the parazite drag of nonlifting helicopter parts.

In our reseach, the rotor is analysed in detail and other subsystems are analysed in a rough outline.

As for the rotor, we have considered the problems of decreasing the influence of the retreating-blade stall and the air compressing over the working of the rotor.

The initial problem of the general design was formulated by us in such a way:

To design the helicopter with Mgross = 4000 kg, which is able to achieve 500 km/p.h.

When the morphological reseach is done (more presily its first part - morphological analysis) we have obtained the high speed helicopter classifition and have determined the way of solving the main problems in their nontrivial statements. In other words, ***the new scientific results for two actual problems*** have been obtained:helicopter classifying and finding methods to increase helicopter speed.

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* For the artificial systems or the goals for nature ones

The classifying problem is not solved for the helicopter construction. The known attempts to classify helicopters and their subsystems have resulted in the so-called incoherent morphologycal tables [5], which are the ordered ennumeration of the realized constructions versions of the described system. Such classications are have the only cognitive-information importance and the very limited practically applications.

But the classification constructed by our morphologycal classifying procedure described the system at the principle, generalazing-functional level, that is, it practically describes all the known and potentially possible versions of its construction realization. Such classification allows to descover the new, with including principale new, technics solutions in the morphologycal syntesis. Such classifying is called by its authors the multiaspect productive classifying [5].

As for the second problem, i.e. rising helicopter speed, the basis of its solving is the classication obteined by us detalization level of which must be higher in accordance with each particular problem. Thus we have limited ourselves in our classification to considering the mentioned problems of the stall and air compressing influence by the analysis of the blade at a whole. The next stage is the analysis an aerodynamic flow the blade sectin, considering the transformation of the stream structure.

What is our constructed system of functional models?

The ***model "Life cycle*** of investigationed technical systems" (TSLC) does not need any special commentaries. It is intended for the subsequent formulating of the definition of the investigated technical systems function, which is used by us as its ***system- selection atribute***.

[5]. TSLC is compared with the conditions of the problem to make more exact which function of the whole collection is usually the operating function, but there may occur the problems that calls for considering transportability (for the especially heavy systems which should be assembled at the exploitation place) or utilizationbility of the systems and so on.

For finding potential classicating signs of investigating systems (Ki-x), the models "Action tree" (AT), "Action network" (AN), "Generalized functional system" (GFS), "Generalized functional system-Environment" (GFS-Environment)* are used.

The ***AT model*** (see Fig.2) reflects the functional structure of any of the investigated TS (a function is considered as TS suitability for the action for realization of which it is created). It is used for two purposes: constructing the model (GFS) and directly finding Ki-x of the system function itself, when its constructive realization, manufacture, technology and so on is not interesting for us.

The ***GFS model*** (see Fig.3) reflects the functional structure of any TS of the investigated class (any version (Wi MSt)). This is an archetype of investigated taxon [12;5,p.256], which is the MSt in our case.

The generalation functional models of subsystems (GFSS), their properties, the relations between them (names of realations) and these functionally significant relation properties (FSR) are merons of the archetype (GFS) [12;5, p.256].

To describe the environment, in which the investigated TS function, two models are constructed by us: GFS - environment, described earlier [3-5], and the new model "Action Network".

The ***GFS-environment model*** reflects the functional encirclement structure of any TS from all their investigated class; all that common things which are inherent in all the systems of TS (FS) MSt functional environment (so-called external functional invariants of the invrstigated TS).

The ***AN model*** (see Fig.3) reflects the temporal development of the action**is realized by any of the investigated TS (any Wi MSt) in the process of their functioning. The correspondence to each

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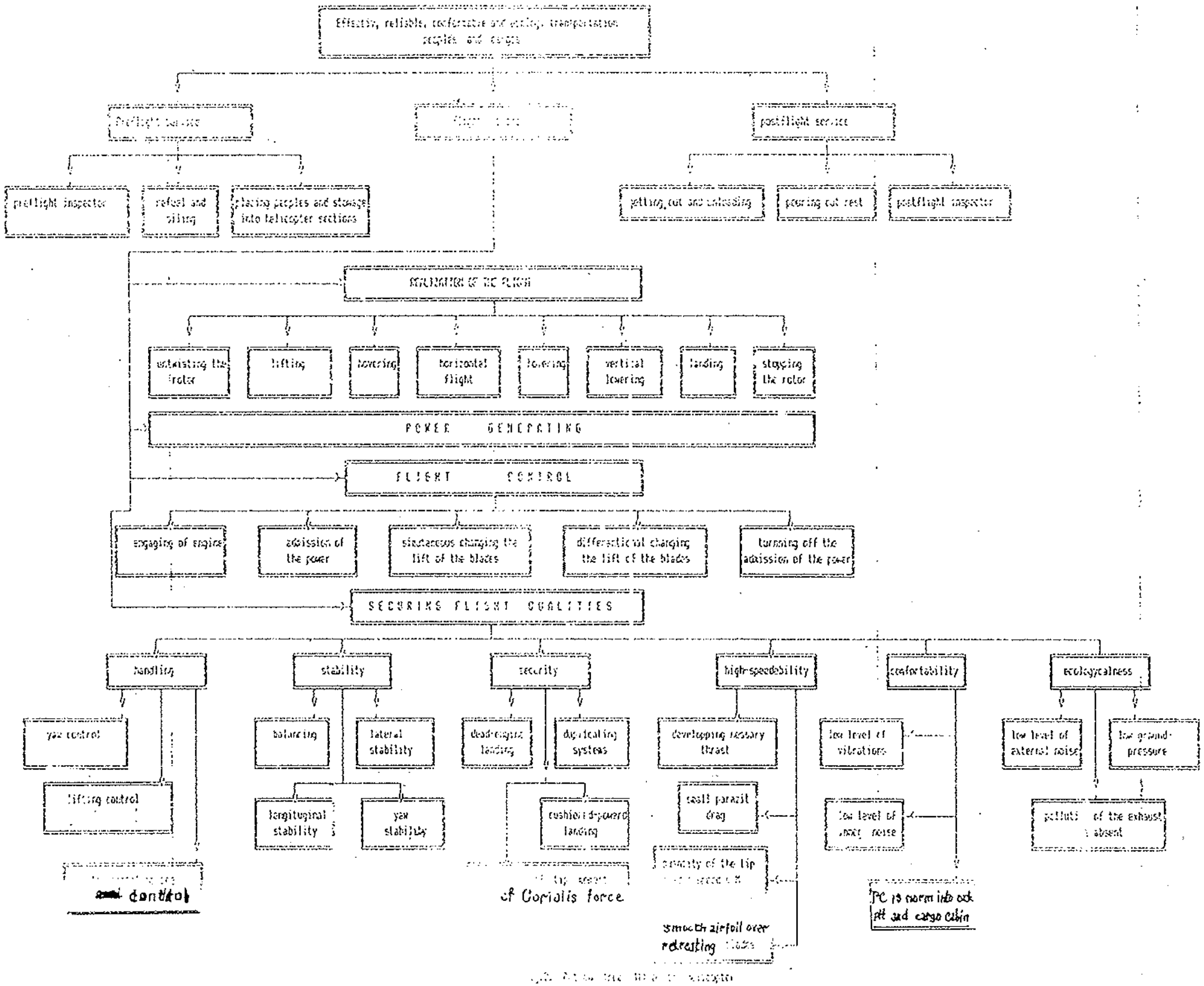
* Here the environment is in which the investited TSs function and usually the is the direct TS environment. Also, the "objects" may be considered which influence these TSs through such environment, i.e. this is the second level of their functional environment.

** Subactions of the main action for the implementation which the examined TSs are applied.


Effective, reliable, comfortable and ecology transportation peoples and cargos
postflight service
preflight inspector
refuel and oiling
placing peoples and stowage into helicopter sections
getting out and unloading
pouring out rest
postflight inspector
untwisting the rotor
lifting
hovering
horizontal flight
hovering
vertical lowering
landing
stopping the rotor
POWER GENERATING
FLIGHT CONTROL
engaging of engine
admission of the power
simultaneous changing the lift of the blades
differential changing the lift of the blades
turning off the admission of the power
SECURING FLIGHT QUALITIES
handling
stability
security
high-speedability
comfortability
ecologycalness
yaw control
lifting control
control
balancing
lateral stability
longitudinal stability
yaw stability
duplicating systems
cushioned-powered landing
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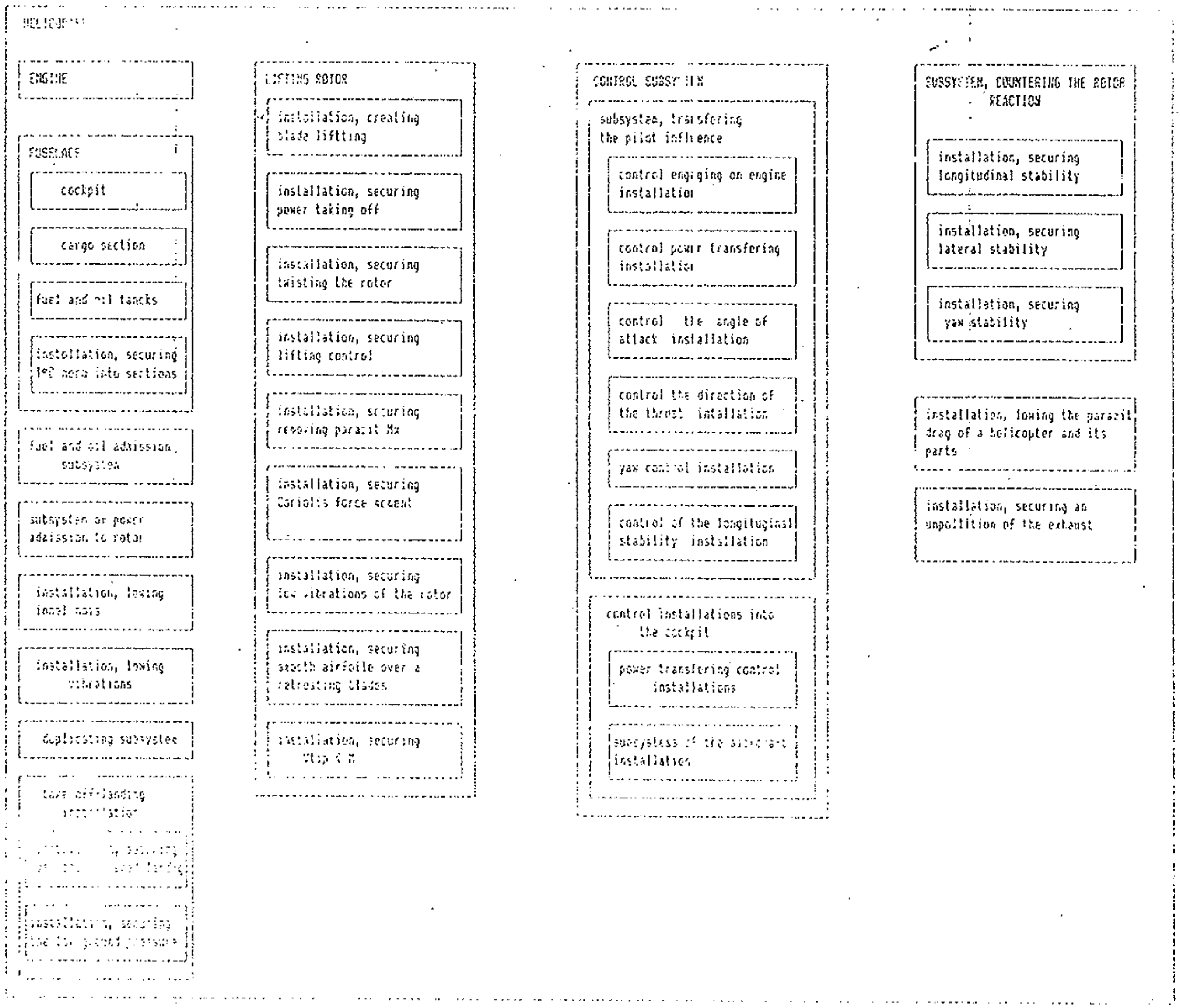
smooth airfoil over retreating
low level of vibrations
low level of noise
low level of external noise
low ground-pressure
of the exhaust absent


ENGINE
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cockpit
cargo section
fuel and oil tancks
installation, securing
fuel and oil admission subsystem
subsystem of power admission to rotor
installation, lowing
installation, lowing vibrations
duplicating subsystem
LIFTING ROTOR
installation, creating blade lifting
installation, securing power taking off
installation, securing twisting the rotor
installation, securing lifting control
installation, securing removing parazit Mk
installation, securing Coriolis force accent
installation, securing low vibrations of the rotor
installation, securing smooth airfoile over a retreating blades
installation, securing
CONTROL SUBSYSTEM
subsystem, transfering the pilot influence
control engiging on engine installation
control power transfering installation
control the angle of attack installation
control the direction of the thrust installation
yaw control installation
control of the longitudinal stability installation
control installations into the cockpit
power transfering control installations
SUBSYSTEM, COUNTERING THE ROTOR REACTION
installation, securing longitudinal stability
installation, securing lateral stability
installation, securing yaw stability
installation, lowing the parazit drag of a helicopter and its parts
installation, securing an unpollition of the exhaust

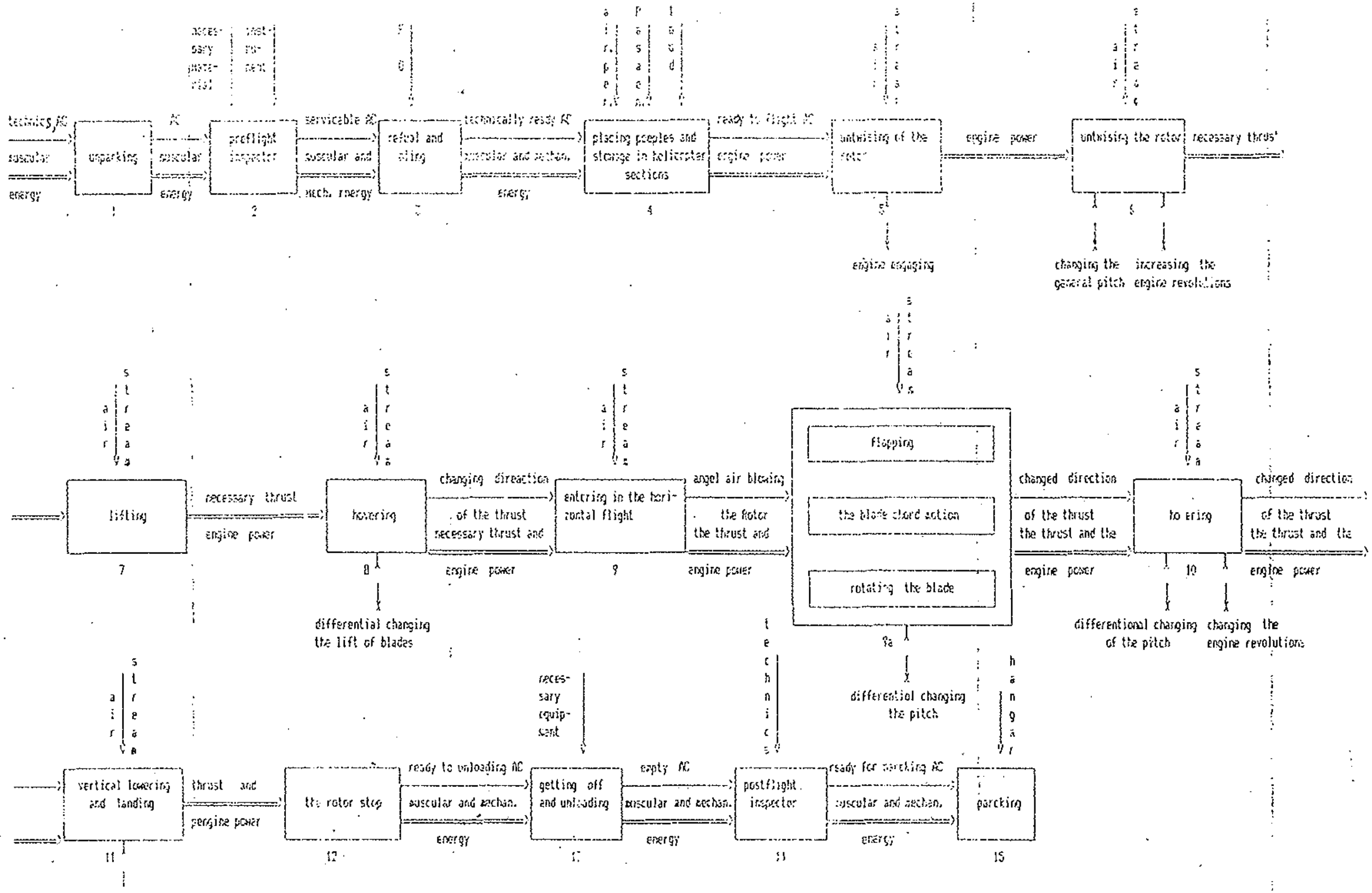

Fig.4. The Action Network of the Helicopter.

pondence to each subaction of GFSS are shown. The subactions are tied in the united chain by material, power and information streams, which transpierce all corresponding GFSS* in the course of the action the control influences (on evry subaction and the corresponding GFSS) and all the disturbances coming from an outer environment showing bearing points.

The classifying, i.e. finding the potential signs (Ki-x), selecting the most important signs and the ***construction of the morphologycal table*** (see Fig.5) can be accomplished using the AT or GFS, GFS-environment or AN models on the basis of special procedures (subprocedures of our procedure) and the corresponding set of the functionally-significent relations (SFSR). This is the systematized reference book (in our case, for the TS-class "Helicoters"), which is obtained when analysing the extnsive reference literature. The SFSR contains the hierarchy of all the conaeivable relations between FSS of the investigated FSs, including the unary realations, i.e. the properties of these FSs.

Conducting of the morphologycal analysis is not possible without the extensive manysided scientific and statistic information about the investigatsd system (TS). This information is actively used when stating the problem and practically at each stage of the morphologycal analysis. We have had the bank of the data composed on the basis of the historical scientific reseach of the development of the helicopter design and the aircraft itself, which is conducted by T.Ch.Bolieva [13].

The materials contain the detail morphologycal analysis of the high-speed helicopter are in print.

Since we consider first of all the classification problem, it must be noted that the obtained morphologycal classification of high-speed helicopters can be then used for solving a whole number of such problems as the morpohologycal prognostication of the possible high-speed helicopter development directions, finding the technical solutions for different subsystems of high-speed helicopter ets..

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* The [illegible]

name of GFSS- and RS-blocks* of NT		N of the classific. sign	name of classificating sign	name (value, limits of changing the value of the classicating meanning				
The rotor	blade	K_1	blade planeform	oval	rectangular	trapeziod	sector	
		K_2	blade tip form	....				
		...	....					
	....							
	subsystem, securing removing the moment of Coriolis force	....	....	....				
		K_{27}	Material	....				
Transmission		K_{28}						
subsystem of contaring rot. react.		K_{29}						
control subsystem		K_{30}						
Power plant	Engine	K_{31}	Type	reciproc.	turboprop	turbine	turbojet	ra
		K_{32}	Power, N h.p.	400 - 1000	1000 - 4000	4000 - 11500	> 115	
		K_{33}	Weit special	< 0,1	0,1 - 0,2	0,2 - 0,4	0,4 - 0,6	> 0,6
		K_{34}	Special fuel	< 0,08	0,08 - 0,12	> 0,12		
	subsystems	K_{35}						
Fuselage		K_{36}	Drag, $Cx_{parazit}$					
Take off-landing		K_{38}	Type	externable	fixed			
		K_{39}	Drag, $Cx_{parazit}$					

* RS - realations between systems

Fig.5. The morphological table of the high-speed helicopt… …

L I T E R A T U R E

1. Zwicky F. Entdecken, Erfinden, Ferchen im Morphologischen Weltbild.- Verlag Baeschlin, 8750 Slarus.- 1989 (Reprint)- 268 p..

2. Одрин В.М. Морфологический метод поиска технических решений: современное состояние, возможности и перспективы.- Киев:О-во "Знание" УССР, 1982 - 16 с..

3. Одрин В.М., Картавов С.С. Некоторые итоги и перспективы развития морфологического анализа систем. - Киев, 1973. - 84 с. - (Препринт/ АН УССР. Ин-т кибернетики: 73-82).

4. Одрин В.М., Картавов С.С. Ммopфoлoгичecкий анализ систем. Построение морфологических таблиц.- Киев:Наук.думка,1977.- 148 с..

5. Одрин В.М. Метод морфологического анализа технических систем. - М.: ВНИИПИ, 1989. - 312 стр..

6. Одрин В.М. Задача морфологического синтеза как многозначная задача и как модель творческого процесса// Теория и методы тезнического творчества. Тез.докл. - Ижевск: Изд.Удм.респ.упр.статистики, 1990 - с.64-65.

7. Одрин В.М. Морфологический синтез систем:постановка задачи классификации методов, морфологические методы "конструирования". - Киев, 1986 - 37 с.- (Препр./ АН УССР. Ин-т кибернетики им.В.М.Глушкова; 86-3)

8. Одрин В.М. Морфологический синтез систем: морфологические методы поиска. - Киев, 1986. - 40 с. - (Препринт/АН УССР. Ин-т кибернетики им.В.М.Глушкова; 86-5).

9. Одрин В.М. Морфологический синтез систем: автоматизация морфологического поиска. - Киев, 1992 - 25 с.-(Препр./АН Украины.Ин-т кибернетики им. В.М.Глушкова; 92-1).

10. Одрин В.М. Технология технического творчества как научная дисциплина и как учебный курс для изобретателей и исследователей. Всесоюз.науч.-практ.конф."Развитие научного и технического творчества трудящихся": Тез.докл.- М.:КМС ВСНТО, 1983. - С.77-80.

11. Одрин В.М. технология технического творчества: суть и назначение //Методологические проблемы творчества. I. Тез.докл..

12. Мейен С.В., Шредер Ю.А. Методологические аспекты теории классификации// Вопросы философии, 1976, N12 - С.67-79.

13. Болиева Т.Ч. Развитие методов проектирования вертолетов.//Канд.дисс. - М:АН СССР, 1987.