

6. Полученное значение напряжения подставить в уравнение пластичности  $\sigma_p - \sigma_0 = \pm \beta \cdot \sigma_s$ , откуда найти  $\sigma_p$ .

7. На основе уравнения (5) в зависимости от рассматриваемой технологической операции, условий ее проведения и граничных условий определить постоянную интегрирования  $C$ .

8. На основе полученного уравнения установить величину поперечной силы в пределах выделенного сектора.

9. Аналогично определить поперечные силы во всех выделенных секторах заготовки.

10. Найти результирующее значение поперечной силы путем векторного сложения сил, действующих в каждом выделенном сегменте, по всей поверхности заготовки.

## Выводы

1. Подтвержден факт возникновения поперечных сил при выполнении технологических операций обработки металлов давлением.

2. Предложен способ теоретического определения поперечных сил.

3. Подтвержден факт влияния поперечных сил на штамповую оснастку, следовательно, и прессовое оборудование. Вследствие этого поперечные силы должны учитываться при проектировании и эксплуатации оборудования и штамповой оснастки.

4. Предложенный новый способ определения исследуемых сил может быть использован на стадии проектирования оборудования и оснастки в качестве уточняющего к существующим.

*S. V. Kuznetsov*, PhD in Engineering, Associate Professor, Nizhny Novgorod State Technical University named after R. E. Alekseev

### Theoretical Definition of Cross-Section Forces Arising at Performance of Metal Pressure Processing

*The paper is devoted to working out of ways of theoretical definition of the cross-section (horizontal) forces arising at performance of technological operations of processing the metals by pressure depending on conditions of their carrying out.*

**Key words:** metal pressure processing, equation, calculation, force analysis, cross-section forces.

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## MECHATRONIC SYSTEM CONTROL PROPOSAL USING MATHEMATICAL EXPRESSION OF RELIABILITY VERIFICATION METHOD

*Submission is concerned to complete information system about quality, operation, automatic testing and new evaluating method of vehicle subsystem. Presentation of statistic significant group of tracing commercial cars is used. Data about operational parameters were taken from this group. Numeric analysis is realised on the base of automatic collection and systematic recording of commercial car operation. Proposed new information system about operation and trial process allows verification according to proposed method. Critical components verified in laboratory conditions are detected by numeric analysis of reliability. Trial method is described and also numerically compared in three levels. Quality level increasing not only for final product, but also related automatic test laboratory for cars is the result of these principles respecting.*

**Key words:** measuring information, trial automation, new methodology.

**T**endency to ensure car's high technical and operational parameters, and consequently successful realisation of any difficult technical system and mechanism comes out from perfect knowledge of operational conditions, knowledge of operation - technical characteristics and parameters of own system. This fact conditions to increase requests for technical level of measurement, actual time of measure results, precision of measurement results, possibility of measurement results processing, level of measurement automation i.e. measurement as method of objective quantification of physical values, or about relation between two or higher number of physical values. Analysis of achieved results from solving and car security area in whole scale of connectivity and relations confirms, that the role of laboratory verification is not replaceable in new quality man-

agement system. Complete access problematic to the test questions in new quality management system, continually to car production concept is getting necessary and logic part of car production process and, as analysis of development trends in car industry shows, effect of solution in testing automation has objective need [8].

It is necessary to concern about automation data gathering about component operation mode in real conditions. It is possible to define their reliability based on gathered data about operating and component failure accepting. It is possible to design device for test tracing of components and test method after defining critical elements.

This way to gather data about component operation, as a difficult system is in accordance with science and developing principles; by this we prevent un-controlled

production of non-verified elements in industrial production. Based on gathered data, it is possible to increase component reliability and to reach higher level in planned car production [1].

### GEARBOX QUALITY PROBLEM

Current dynamic development of car industry, continuous increasing level of their technical parameters and characteristics confirms continually whole process speeding competition in the world.

Using the gearbox as a car decisive component is limited also by complex access level to quality assurance. Gearbox general function model and its accuracy analysis is possible to realise based on present ways of functional unit and devices accuracy. General accuracy of function units is understood as quality of approach function and operational dependencies, acted in mechanisms to requested dependencies, for which these function units were constructed and are chosen [2].

From point view of gearbox utility, i.e. gearbox using and ability, general criteria is its quality and its basic intention, divided into:

– *manipulation ability*, if we evaluate it in aspect of control and manipulation with gearbox within speed striking,

– *technologic ability*, if gearbox is evaluated in aspect of use in car as mean of realisation of chosen drive kind.

### Problems with quality management

Today brings significant changes in product area, in all industry forwarded countries. Understanding of changes in quality is possible to characterise as a movement from clearly technical soundness to integral product quality. Product quality became significant criteria of science and research effect and big productivity reserve of common work.

This general definition of development in quality field and objective need to continually increase quality in application for cars, which reports to increasing requirements for high technical and operating parameters, requires:

– to direct systematically all related actions, i.e. arrange questions of quality management to whole creating process of gearbox

– to complex evaluate quality, which requires to use quantitative evaluation

– to identify quality, i.e. to evaluate reached quality level, which has basic importance to control whole creating process and innovation gearbox process

– to compare objective gearbox parameters with comparable world level types directly by measuring of chosen parameters, or indirectly by data from progressive technical information.

Quality management is concerned as complex, if it is expanded to all fields, which can have influence the final gearbox quality, including user's operation. This system, which dominate today in all industry forwarded countries, leads to create conditions in flow pre-production, production and after production activities by using objective methods for apply testing [6].

### Analyse of reliability influence to profitability and economic effect

Before analysis of gearbox reliability influence to economic effect, it is important to realise basic ideas of reliability theory and to check relation of coefficients quantitative reliability to economic coefficient and efficiency coefficient. Related basic ideas:

*Quality* of product is properties summary, expressing ability to fulfil functions, for which it is dedicated. We take into account also product economic coefficients, its outfit by accessories, spare parts etc., as well as premises, which producer creates to provide services connected to product use.

*Reliability* is general object attribute, reposing in ability to fulfil requested functions with keeping of values for specified operational coefficients in specified limits and in time according to technical conditions. Reliability is one of the most important groups of product quality marks [7].

### METROLOGICAL ASSURANCE OF AUTOMATION TESTING

From point view of measuring accuracy technics for test managing mechanism, it is necessary to look, that measuring technical assurance is realised mostly on principles of electrical measuring of non-electrical values with appropriate automation measuring process level and evaluating process. This concept of automatic measuring systems creation is not secured very well in the metrological way yet [3,4]. This field significantly documents the current status, advance of technical practice before readiness of metrological assurance. That is why it is possible to define requirements needed to metrological assurance at least of individual parts of automation measuring system i.e. individual measuring strings used in measuring and tests.

#### Measuring string structures

Measuring string – devices set intended to measuring, transport and data processing about measured value in general form represent sensor set, measures, measuring instrument, converters, measuring channels, analogue and numeric technical devices, computing devices, sensors and registered devices attached to one function unit in order to requested measuring, processing of data about measured parameters. Measuring string block schema is generally showed on fig. 1.

It is possible to characterise measuring string individual blocks in the way of functions by this description:

1. input block – is created by sensors set, which scan required measured parameters, ensure data entrance to measuring string.

2. block of converters – ensure data processing from entrance block to suitable form for following processing, mostly to the numeric form.

3. pre-processing block – is used to data pre-processing (check, filtration etc.)

4. processing block – ensure data processing by specified algorithm, it is composed with suitable computing devices including particular software.

5. Output block – ensure data output in required form. Printers, recorders, control panels etc belongs here.

Following memory device, where it is possible to store reached data for following processing.

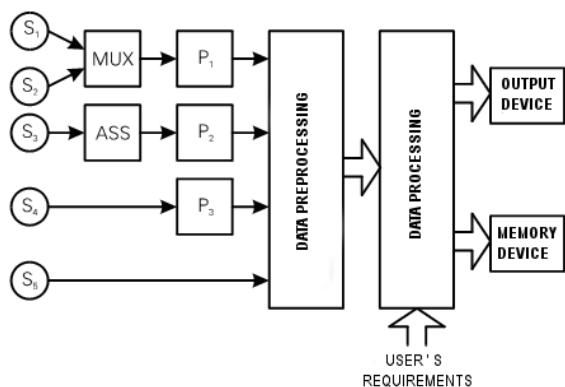


Fig. 1: Measuring string block schema:  $S_1...S_5$  - sensors;  $MUX$  – measuring switchers, multiplexer;  $P_1...P_3$  – analog-numeric converters;  $ASS$  – analog exekuting system

Measuring string does not have to contain all involved parts, it is possible to drop some of them, or to expire some parts and to complete according to requirements of concrete application [9].

**Follow component results in running**

Numbers of several speed degree exploitations are written in table 1. After mathematic counting of individual speed strikes, coefficient of exploitation has been stated for individual speed as well as for all gear system. To emphasize difference, measuring results of both modes are drawn to one graph 1. This result proves arguments of earlier car abrasion in city traffic. Values are concreted. After measuring results summary, it is possible to express also gear mechanism use in percents. Result is in graph 1.

Table. 1. Control mechanism and speed degrees of 5 speed degrees gerbox use

Geared speed degree	Number of gear n	use [%]	coefficient $f_j$ [%]
1	97555	20,4	8,49
2	114100	23,8	12,44
3	154050	32,1	26,06
4	91300	19,1	36,70
5	18805	3,9	15,80
R	3350	0,7	0,47
<b>TOTAL</b>	<b>479160</b>	<b>100,0</b>	<b>100,00</b>

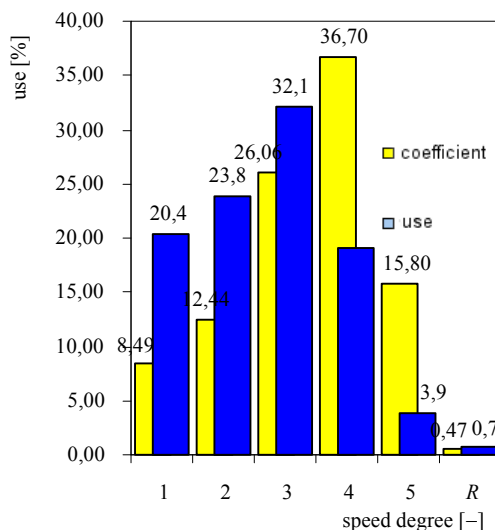
Graph 1 analysis provide following data perfect overview and is used as a base for development designers team.

**TECHNICAL MEANS OF AUTOMATION TEST SYSTEM**

The role of technical devices is getting important meaning in accordance with increasing technical level of developed devices and with motoring research trends, as well as with high requirements and method severity of their testing and evaluation [5].

Technical assurance of car components measuring, i.e. difficult devices must fulfil these limits and conditions:

- tests technical severity on moving car with big lack of place to install measuring and testing equipments to the car require to apply measure signal remote transmission on analogue or discrete signal level,
- it is necessary to measure mechanical values by transformation of physical parameter to electrical signal, i.e. with measuring method of no electrical values by electrical way. It is necessary to correct signal from sensor and store it so that it will be available for direct processing, or for analyse,
- test system must be able to automatic function, i.e. automatic scanning of measured values, their processing, storing and editing in suitable form for next using,
- in tests realisation, there must be connectivity between gear mechanism movement and measuring system control, that means test system must be automatic and connected to test cycle managing via control inputs of gear mechanism.



Graph 1: Control mechanism total use

Technical assurance and realisation of automatic test system has a lot of technical and methodical problems according to previous one. [11] We can mention these problems:

- accessories to follow and check of classic parameters is completely available from serial produced devices and measuring technical,
- accessories to follow mechanical (non-electrical) values, which are critical in term of utility attributes,
- Presented one is considered and, for technical assurance testing of control mechanism field, these directions and goals were specified:
  - to propose automatic test technics for mechanical values group,
  - to propose automatic test system to follow-up functionality and reliability of gear mechanism
  - to apply and propose computing technic hardware accessories for its connection to automatic test systems and propose idea of related software
  - to specify testing methodology

**Configuration of automatic test system devices and their connection**

As a result from present possibilities and the most necessary needs, configuration for ATS, which is drawn in fig. 2 was proposed.

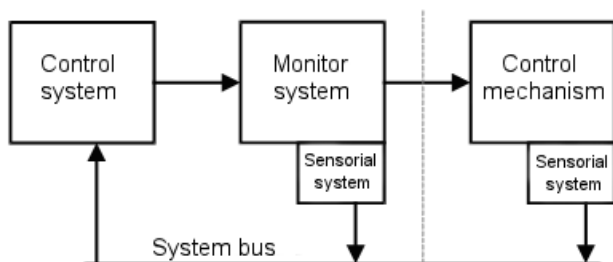


Fig. 2. Block schema devices ASS

Individual measuring equipments and control devices are connected to control system by system bus, which fulfil requirements for adaptability of devices configuration for individual measuring and testing tasks and for eventual configuration expansion [10].

**Automatic test system project**

It is possible to create concrete project solution of automated test system accepting results reached by now, according to fig. 3.

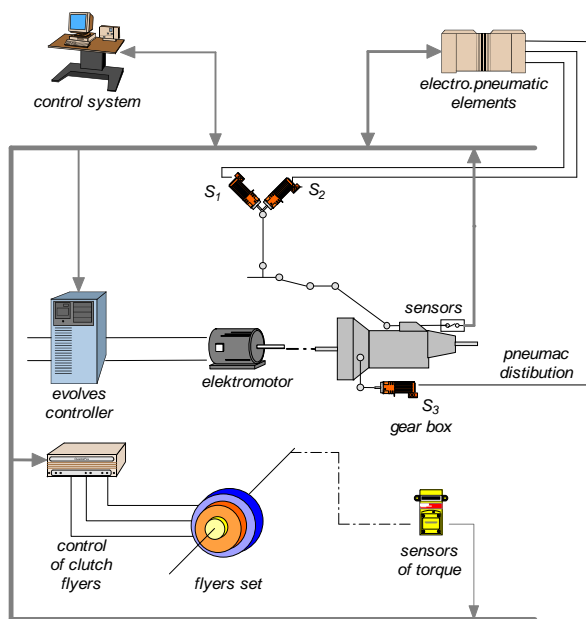


Fig. 3. Insertion ASS schema

As it comes out from gear mechanism test conditions, flyer system, evolve controller and starting clutch connection is not needed.

These parameters are necessary to take into account in speed degree gear (related to handle gear arm). This is test condition in laboratory conditions:

- 1) control power of default  $F_p = 50N$
- 2) control power of gear  $F_r = 70N$
- 3) path length by default  $l_p = 30mm$
- 4) path length by operation  $l_R = 55mm$

5) time of default  $s_P = 1sec$

6) operate of gear  $s_R = 1sec$

Pneumatic rollers  $S_1$  and  $S_2$  do speed gearing process. Double acting pneumatic roller  $S_1$  assure pre-selection of speed degrees directly at gear arm and double acting pneumatic roller  $S_2$  assure speed degrees gearing.

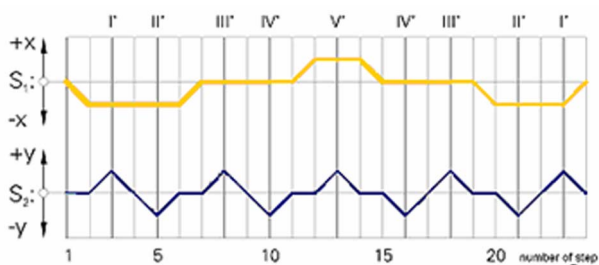
**Motive system acts description**

Algorithm of charging whole gear control mechanism is specified by pneumatic rollers synchronisation. One trial cycle is in table 2. It result speed degrees gear process-graph 2. This material is base for control system programming.

Gear mechanism trial process depends on its used level. The base of test is to repeat speed degree gear process. From 1 speed degree to 5 speed degree and inside out from 5 speed degree to 1 speed degree. Concrete algorithm of test pass includes methodology part.

Table. 2. Pneumatic rollers synchronisation

Number of step	Description	Roler $S_1$	Roler $S_2$
A C C E L E R A T I O N M O D E			
1	<b>Roler 1.</b> defaul 1. speed degree	✓	
2	<b>Roler 2.</b> gear 1. speed degree		✓
3	<b>Roler 2.</b> moves gearbox to neutral position		✓
4	<b>Roler 2.</b> gear 2 speed		✓
5	<b>Roler 2.</b> moves gearbox to neutral position		✓
6	<b>Roler 1.</b> moves gearbox to neutral position	✓	
7	<b>Roler 2.</b> gear 3 speed degree		✓
8	<b>Roler 2.</b> moves gearbox to neutral position		✓
9	<b>Roler 2.</b> gear 4 speed degree		✓
10	<b>Roler 2.</b> moves gearbox to neutral position		✓
11	<b>Roler 1.</b> defaults 5 speed	✓	
12	<b>Roler 2.</b> gear 5 speed degree		✓
D E C E L E R A T I O N M O D E			
13	<b>Roler 2.</b> moves gearbox to neutral position		✓
14	<b>Roler 1.</b> moves gearbox to neutral position	✓	
15	<b>Roler 2.</b> gear 4 speed degree		✓
16	<b>Roler 2.</b> moves gearbox to neutral position		✓
17	<b>Roler 2.</b> gear 3 speed degree		✓
18	<b>Roler 2.</b> moves gearbox to neutral position		✓
19	<b>Roler 1.</b> defaul 2 speed degree	✓	
20	<b>Roler 2.</b> gear 2 speed degree		✓
21	<b>Roler 2.</b> moves gearbox to neutral position		✓
22	<b>Roler 2.</b> gear 1 speed degree		✓
23	<b>Roler 2.</b> moves gearbox to neutral position		✓
24	<b>Roler 1.</b> moves gearbox to neutral position	✓	



Graph 2. Speed degrees gear proces

**RELIABILITY TRIALS METHODICS PROPOSE**

Automated reliability verifying and gear mechanism life cycle is the goal of test.

It is necessary to change dimensions, eventually construction nodes of least reliable elements before test. Test methodology is deduced from the way of speed degree gearing during car running. Speed degrees gearing flow is introduced in previous part. The flow repeats always the same way with aspect to chosen speed degree.

It is necessary to assure handle control power, path length of default and path length of speed degree gear. Gear mechanism lines effort by power intensity, which is prescript in tolerances during car running and followed construction nodes, ensure fulfil these conditions.

Whole system is specified to follow up gear mechanism in aspect of car reliability during car running. From table 1 is deduced that in aspect of number speed degrees gears the most used is 3 speed degree (32,1 %), and (26,06 %) in short path. 4 speed degree is geared in small number (19,1%), but it is geared on longer path (36,70 %). It is not possible to follow this reality in one aspect, because:

- a) if we want to follow results in aspect of number of gears, than it is in gear mechanism field
- b) if we want to look and follow the parameters change in aspect of gear length, than problem elements are gear-wheel, winches and their installing in gear box.

Test commerce car measuring results are base to propose the test method about control mechanism use in aspect of number of individual speed gear. Graph1 deducing from table 1 shows the ratio of gear mechanism use. This ratio must be keep during test and gear mechanism test in number, what is used and record in tables. Proposed ratio method seems to be the most suitable.

**Ratio method**

Ratio method comes from distribution of percentage ratio elements use of gear mechanism during speed degrees gearing. Values of use from table 1 are the base of distribution. Maximum level is reached when each component of gear mechanism will be running by distribution in table one during follow-up. Mathematic interpretation of number of gear  $z_u$  in one level and trial process is:

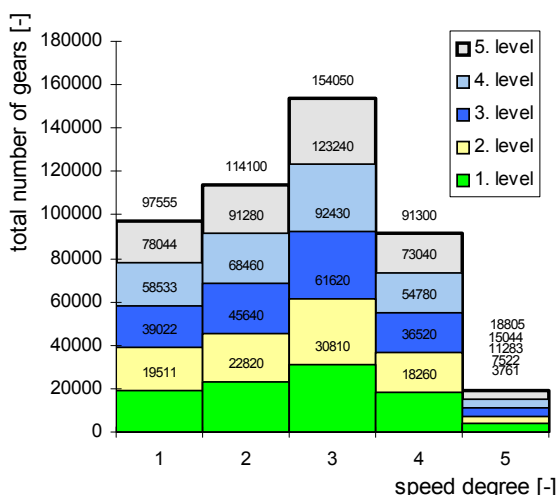
$$z_u = \frac{1}{u} \times \left[ \sum_{i=1}^n n_{1i} + \sum_{i=1}^n n_{2i} + \sum_{i=1}^n n_{3i} + \sum_{i=1}^n n_{4i} + \sum_{i=1}^n n_{5i} \right],$$

where:  $n_1-n_5$  – number of gear in  $u$ -level

$u$  – dividing level of max. number of gear  
 $z_{1r}-z_{5i}$  – number of gear of individual speed degrees  
 $n$  – maximum number of speed degrees gear of related speed

Example: if we want to follow-up gear mechanism element reliability in speed degree 5, then number of individual speed degrees gears will be:

- $n_1 = 97555 / 5 = 19511$  times
  - $n_2 = 114100 / 5 = 22820$  time
  - $n_3 = 154050 / 5 = 30810$  time
  - $n_4 = 91300 / 5 = 18260$  time
  - $n_5 = 18805 / 5 = 3761$  time
- Ratio method data are in graph 3.



Graph 3. Testing according to ratio method by 5 levels

Use coefficient estimate exactness or gear mechanism element reliability is higher, when dividing level is higher. It is important to know, same number of gears ratio in every level is kept in ratio method.

We can see on graph 3, that there is an area in the bottom, which is showing ratio number of gears of speed degrees of one level. Level 5 has 5 times smaller number of gears in same ratio as a basic level. It is possible to fill this area by trial in 2 ways:

- 1) vertical classification
- 2) horizontal classification

**Vertical classification**

The level of test according to vertical classification is divided in sequence according to speed percentage use. It means, that control program give command to gear speed degree 5 and then 4, 1, 2, and 3 as the last one. It is because all gear mechanism elements would be follow-up from the speed degree which use is the smallest.

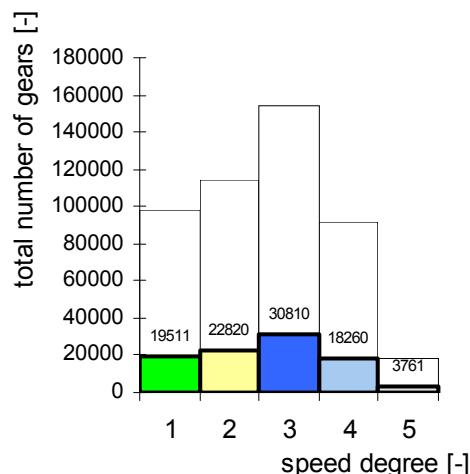
We have the biggest chance, that we verify biggest number of gear mechanism elements. We can see logical flow of gear mechanism test in graph.

Mathematic total number of gear  $z_{uV}$  in vertical classification, is expressed by relation:

$$z_{uV} = u \times \left[ \sum_{j=1}^{n_5} z_{5j} + \sum_{j=1}^{n_4} z_{4j} + \sum_{j=1}^{n_1} z_{1j} + \sum_{j=1}^{n_2} z_{2j} + \sum_{j=1}^{n_3} z_{3j} \right],$$

where:  $n_1-n_5$  – number of gear in  $u$ -level  
 $u$  – dividing level of max. number of gear  
 $z_{1i}-z_{5i}$  – number of gear of individual speed degrees  
 Vertical classification is risky, because rest parts of gear mechanism will stay untested for example by testing 4 speed degree by failure.

This negative solves trial according horizontal classification.



Graph 4. Level of test according to vertical classification

### Horizontal classification

The test of gear mechanism elements by horizontal classification is equable according to graph 5. All speed degrees gearing are in phase one. After that, control system gives command to test control mechanism from 4 speed degree. Test till 3 speed degree is done the same way. It is gear separately from neutral position. We can mathematically interpret the number of gears  $Z_{uH}$  by horizontal classification test like this:

$$Z_{uH} = u \times \left[ z_u - \sum_{j=1}^{n_5} z_{5j} - \sum_{j=1}^{n_4} z_{4j} - \sum_{j=1}^{n_1} z_{1j} - \sum_{j=1}^{n_2} z_{2j} - \sum_{j=1}^{n_3} z_{3j} \right],$$

where:  $n_1-n_5$  – number of gear in  $u$ -level  
 $u$  – dividing level of max. number of gear  
 $z_{1i}-z_{5i}$  – number of gear of individual speed degrees  
 Cycle is repeating after one level of test is finished according to proposed method.

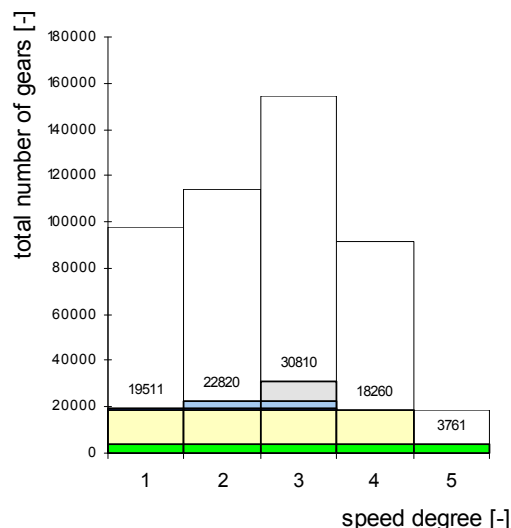
Slovak technical norms do not contain gear mechanism test method of car. That's why a space is given to this part, which will be needed to improve according to reached knowledge by test realisation.

### CONCLUSION

The base for evaluation, formulate and parameters assurance of technical level, running quality and car reliability or its components, is knowledge of their technical and running parameters and running conditions. It is important knowing in operating mode, dynamic stress, the way of operating and use during running.

Quality requirements are increasing also requirements to function models laboratory testing, their parts, prototypes and their new components. This comes out of facts.

Practise in foreign countries showed, and it should be advise for us, that it is profitable to apply car problem parts to development and research. This submission is specified to increase quality level not only of final product, but also to developing time by car automation test and its technical accessories.



Graph 5. Level of test according to horizontal classification

### ACKNOWLEDGMENTS

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### References

1. Bajcsy J. a kol. Meranie elektrických a neelektrických veličín. – Bratislava : ES STU Bratislava, 1994.
2. Bartová Z. a kol. Elektrické meranie – meranie na lukratívne merania.– Bratislava : ES STU, 1993.
3. Černecký J., Pivarčiová E., Dubovská R. Holografia a jej technické aplikácie. – Radom, Polsko, 2003.
4. Králik M. Automatizované projektovanie výrobných systémov // In.: Časopis Manufacturing Engineering. – ISSN 1335 – 7972. – TU Košice, 2004.
5. Králik M. Manufacturing Systems Layout // Annals of the Oradea University. Fascicle of Management and Technological Engineering. – Vol. III(XIII). – ISSN 1583 – 0691. – P. 158b. – CD-ROM Edition, 2004.
6. Labašová E., Labaš V. Modification of resonance method for determination of dynamic Young's modulus // In Vedecké práce MTF STU v Bratislave so sídlom v Trnave. – P. 75–80. – ISSN 1336-1589. – Trnava, 2004.
7. Zajac J., Vojtko I. Trendy v prevádzkovej diagnostike on-line. – Bratislava : Manufacturing Engineering, 2004.
8. Mudrončík D., Zolotová I. Priemyselné programovateľné regulatory. – Bratislava : ELFA, 2000.

9. Popelka V., Wenzlova M. Informacné technológie v poľnohospodárskych subjektoch // Zborník medzinárodnej vedeckej konferencie. – P. 88–90. – ISBN 80-7137-946-8. – Nitra, 2001.

10. Makyš P., Vidová H. Knowledge discovery from databases in marketing // In 12th international scientific conference CO-MAT-TECH 2004. – P. 826–833. – ISBN 80-227-2117-4. – STU Bratislava, 2004.

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### Усовершенствование управления мехатронными системами с применением математического аппарата теории проверки надежности

*В статье описана созданная информационная система, содержащая данные по качеству, функционированию, автоматизированным испытаниям и новому методу оценки транспортной подсистемы. Система протестирована на статистически важной группе коммерческих грузовиков. В данном случае была использована информация об эксплуатационных параметрах представителей этой группы. Численный анализ выполнен на основе автоматизированного сбора и систематической записи информации о работе коммерческих грузовиков. Предложенная новая информационная система данных по функционированию и испытаниям позволяет проверять надежность в соответствии с разработанной методикой. Детали машин, находящиеся в критическом состоянии, выявленные в лабораторных условиях, распознаются численным анализом надежности. Описана методика испытаний и ее численное моделирование на трех уровнях. Результатом работы является не только повышение качества готовой продукции, но и созданная автоматизированная испытательная лаборатория для автомобилей.*

**Ключевые слова:** данные измерений, автоматизация испытаний, новая методология.

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## УСОВЕРШЕНСТВОВАННАЯ МОДЕЛЬ СИНТЕЗА ВАРИАНТОВ ТЕХНОЛОГИЧЕСКОГО ОБЕСПЕЧЕНИЯ СТРУКТУР-СТРАТЕГИЙ ПРОИЗВОДСТВЕННЫХ СИСТЕМ МАШИНОСТРОЕНИЯ

*Рассматривается усовершенствованная модель синтеза вариантов технологического обеспечения структур-стратегий производственных систем машиностроения. Разработанная модель может быть использована при модернизации производственных систем, а также при смене номенклатурной модели предприятия.*

**Ключевые слова:** промышленная система, варианты структур-стратегий, модель синтеза.

**М**ашиностроительное предприятие, осуществляющее хозяйственную деятельность в условиях рыночной конкуренции, стремится минимизировать затраты на производство, а также максимизировать свою прибыль. Вместе с тем, по данным ассоциации «Станкоинструмент», парк механообрабатывающего оборудования, состоящий преимущественно из отечественных станков, за последние 15 лет практически не обновлялся, сократился на 1 млн единиц и составляет сегодня около полутора миллиона единиц. Более 70 % станочного парка эксплуатируется свыше 15-20 лет и находится на грани полного физического износа, а большая часть из более чем 300 предприятий России нуждается в модернизации и диверсификации [1, 2].

По мнению российских и зарубежных экспертов, любая модернизация машиностроительных предприятий должна сочетать в себе эффективную замену старого оборудования с внедрением современных

принципов и подходов в организации и управлении производством [1, 2]. Однако решение этой многокритериальной задачи невозможно без использования эффективных алгоритмов оценки и подбора новых элементов структур-стратегий производственных систем, а также подразумевает использование современных автоматизированных систем поддержки принятия решений.

Основой для усовершенствованной модели синтеза вариантов технологического обеспечения структур-стратегий производственных систем (ПС) машиностроения является базовая модель выбора технологического оборудования [3], не учитывающая ряд потребностей предприятий, таких как частичная модернизация производств.

Предлагаемая модель построена на основе комбинаторного алгоритма синтеза технологического обеспечения структур-стратегий производственных систем (ПС) машиностроения и является составной