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# TECHNOLOGY TRANSFER ANALYSIS FOR ENGINEERING DESIGN

# MODERNO TEHNOLOĢIJU IZMANTOŠANAS PĒTĪJUMI INŽENIERPROJEKTU APRĒĶINOS

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## Introduction

In the process of product design all design operations are carried out with the help of CAD software, the incorporate CAE means ensuring the needed calculations. It refers practically to design processes of all kind of physical equipment – mechanical, electronic, pneumatic and other. However, the CAE means in CAD software cannot ensure all the necessary calculations and estimations for complex equipment [1] containing, at the same time, different physical components. To such issues we could refer:
- dynamic calculations of the equipment to be designed, in the course of which the response character of complex equipment can be determined, as well as the quality of transition processes, stability of the operation of the equipment, the geometric dimensions of dynamically-loaded parts,
- calculations of the necessary power of the working drives, taking into consideration power losses, technological, dynamic and other loads,
- the reliability of the operation and ergonomic characteristics of the equipment.

When it is needed to accomplish such tasks, there are used technologies linked with making and planning analytic experiments which in general are known under the name – simulation.

## The structure of calculations

In the case of carrying out engineering calculations they should be structured, i.e., contain definite subdivisions, the sequence of which should be observed. In a general case the subdivisions should be as follows:
- the task of the calculation, the necessity of solving it and its aim,
- the diagram of the calculation, the design plan and physical model of the object of calculation, the values of the used physical parameters, the parameter limitations and approximations,
- the mathematical model of the calculation, the analytic coherencies to be used and basis for their application,
- the calculation tools and used software,
- the final results of the calculation.

## Object and requirements to it

The application of the above mentioned technologies are considered on the basis of an example where in the automatic line for packaging medicines there is carried out control over filling packaging sockets with tablets. If any of sockets in packaging is empty, the packaging is rejected as defective and it should be singled out from the flow of suitable packages.

It can be done in different ways, mechanically pushing it, by an electromagnetic feeler, blowing away by a flow of compressed air or in some other way. Let us consider blowing away by compressed air, a sketch of its simplified variant is shown in Fig.1.

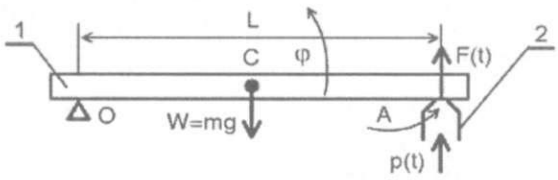


Fig. 1. A sketch of removing the position of defective packaging

In the automatic line medicine packaging 1 moves at the right angle to the plane of drawing. Having reached the position of removing defective packaging, it is supported in two points which are placed at distance $L$ – on the left side on support $O$, and on the right side on nozzle 2. When compressed air at pressure $p(t)$ is fed to the nozzle, $F(t) = p(t)A$ will act on the right side end of the packaging, where $A$ is the area (square) of the nozzle outlet section.
As the removal of the packaging must take place during its movement, the feeding of the compressed air at an industrially standardized pressure must be of short duration. Thus, the aim of the calculation will be to determine the area $A$ (constructive parameter), at which the value of force $F(t)$ is sufficient to raise the right end of the packaging at angle $\varphi$, which is larger then $\pi/2$. At such an angle value, the package with tablets will fall down into the defective product container under the influence of gravity force $W$.
The process is going continuously if a packaging with even one unfilled tablet socket finds itself in the sorting position.

## Analytic equations

One of the peculiarities of the calculation is a necessity to determine the law of changes of force $F(t)$ which depends both on time and the distance between the nozzle and the surface of the packaging. This distance depends on angle $\varphi$ of the packaging turn which allows us to write that $F(t) = F(t, \varphi)$ .
In correspondence with literature [2] the force of the air flow acting on the packaging surface can be detected by the expression (CAE formula):

$$F(t,\varphi) = p(t)Ae^{(-k\varphi)} \tag{1}$$

where $k$ – is the coefficient of proportion the value of which can depend on the nozzle shape, the value of pressure $p(t)$ and others s. The diagram of possible force $F(t, \varphi)$ change is shown in Fig. 2.
Throwing off the tablet packaging takes place during its movement, the feeding of compressed air to the nozzle is monitored in time and the action interval of force $F(t, \varphi)$ is shown in Fig.2. as $t_C$.
During throwing off the packaging an air resistance moment $M_G$ acts on the packaging when it turns. At small speeds $M_G$ is proportional to the linear velocity of the surface points. To determine it we shall consider the physical model of the equipment (Fig. 3.).
When the packaging turns, the end of its right side has the maximal velocity, but the average velocity of the surface is $V_V=(L/2)\omega$.
The moment $M_G$ of air resistance should be determined [2] as:

$$M_G = F_{GV}\frac{L}{2} = R\frac{L^2}{4}\omega \tag{2}$$

where $R$ – the coefficient of air friction resistance, $R = kS$, $k = 50\ N/m/s$, $S$ – the surface area of the package, $\omega$ - rotational velocity.

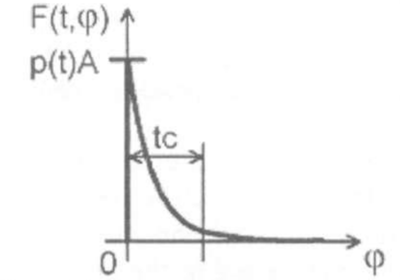

Fig. 2. The law of air flow force change

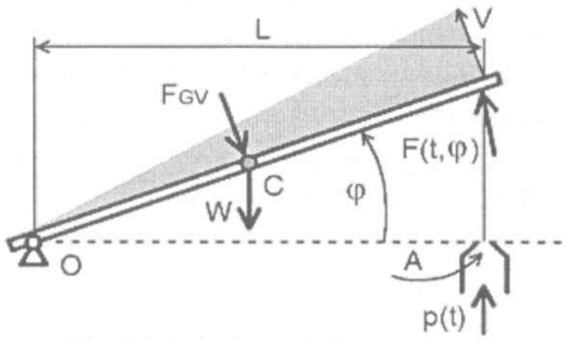

Fig. 3. Physical model of the equipment

As the last force which should be taken into consideration when analyzing the movement of the tablet packaging we shall mention the gravity force $W$, which is to be determined according to the generally known coherency $W = mg$, where $m$ – the mass of the packaging and $g$ – the acceleration of a freely falling body.
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$$J\frac{d^2\varphi}{dt^2} = \sum_{I=1}^{I=n} T_I \tag{3}$$

where $J$ is the moment of inertia in rotation against axis O, $T_I$– the torques formed by forces acting against axis O.
Expressing the torque values as the product of force and lever and taking into consideration the direction of torque action, let us write the equation of the packaging movement in the analyzed equipment:

$$J\frac{d^2\varphi}{dt^2} = f(t)p(t)Ae^{(-k\varphi)} - \frac{mgL}{2}\cos\varphi - RI\frac{d\varphi}{dt} \tag{4}$$

where $f(t)$ is the time function of the air flow control, $f(t) = 1$, if $t >= 0$, $f(t) = 0$, if $t>t_C$, $R1 = kSL^2/4$.
The calculation of the geometric dimension of the pneumatic nozzle can be taken down to the simulation task of the equipment work during which we must find the minimal area A at other fixed parameters. The working regime of the packaging movement at which its turning angle is $\varphi > \pi/2$ should be considered. For this purpose a differential equation (4) should be solved. At present modern computer software allows us to do it by numerical integration.

## Simulation software

We can mention software *MatLab* (abbreviation from *matrix laboratory*) with a subprogram *Simulink* as one of the most suitable programs for solving engineering problems [4]. It allows us to express a solution program of practically every equation in the form of graphic block diagram structure. Thus, it guarantees clearness, effective error hunting, parameter value adjustment, and evaluation of the modeling results.
To make a good use of *Simulink* possibilities it would be useful to rewrite the equation (4) in the following form:

$$\frac{d^2\varphi}{dt^2}=\frac{1}{J}[f(t)p(t)Ae^{(-k\varphi)}-\frac{mgL}{2}\cos\varphi-RI\frac{d\varphi}{dt}] \tag{5}$$

Using the methodology offered by *Simulink* the program of the equation (5) integration is shown in a graphic form in Fig. 5.
To finish the calculation we adjust the numerical values of the equipment parameters for all blocks, f(t) control time = 1s, coefficient $k$ = 1, and an arbitrary chosen initial value $A$.

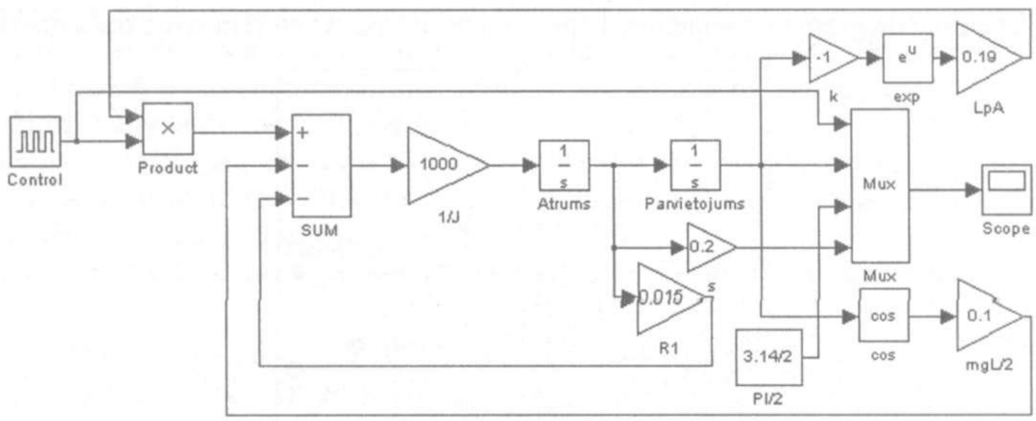


Fig. 4. The *Simulink* graphic program for numerical integration of equation (5).

By clicking the Simulation – Start button we integrate the equation. By twice clicking on the block Scope we evaluate the obtained time diagram. If the turning angle of the packaging is less than $\pi/2$ during the movement cycle, it is necessary to increase the value of $A$, if it is larger, the value of $A$ should be decreased. Thus, by planning and carrying out an analytic experiment we can get full information on the influence of the value of nozzle outlet area $A$ on the package removal process.

## Simulation and calculation results

In Fig. 4. we can see how the numerical value of $A$ can be changed by the common block parameter $LpA$, which expresses the maximal value of the torque if $\varphi = 0$.

The simulation results are shown in two cases: if the packaging removal is ensured and if it is not ensured.
It is necessary to note that the used equation (4) precisely reflects the movement of packaging if $\pi/2 > \varphi > 0$, in other ranges of $\varphi$ changes the results of time diagrams cannot be used.
The final calculation result can be obtained from the numerical values of *LpA* presented in Fig. 4. and Fig. 5.
We may write then

$$A = \frac{0{,}19}{Lp} \tag{6}$$

and at $L$= 200 mm, $p$= 60 N/m$^2$ we get that at a cylindrical shape of the nozzle with safety coefficient 2, its diameter D = 3 mm. Consequently the constructive dimension of the nozzle has been determined as a result of an analytic experiment.

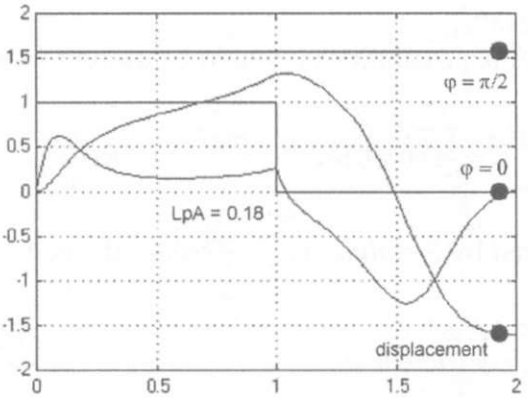


Fig. 5. The time diagram of packaging displacement in case when removing does not occur.

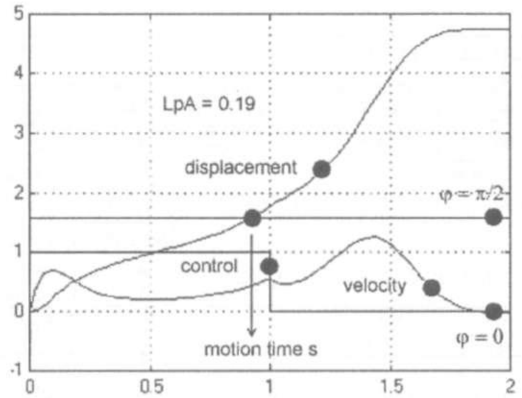


Fig. 6. The time diagram of packaging displacement in its normal removal process

## Ergonomic simulation base

In the modern world, when designing and developing different products, equipment and planning new work places, ergonomic demands are increasingly observed.
By the present time different somatographic templates have helped to observe human antropometric data in graphic 2-dimension project documentation, however, they are not suited for every human population , work position and drawing scale.
With the wide application of CAD/CAM/CAE technologies in design, the observation of the ergonomic aspects also changes. A specialized CAD software branch – *HumanCAD* has been

created.
Due to the high prices of the software ensuring the work of such technologies, they are not widely spread in the small and medium-sized enterprises in Latvia. The work considers the *ManneQuin* software.
*ManneQuin* includes an antropomorphic database for males, females and children based on collected data for creating 3D, ergonomically correct human figures, which can be given different postures.

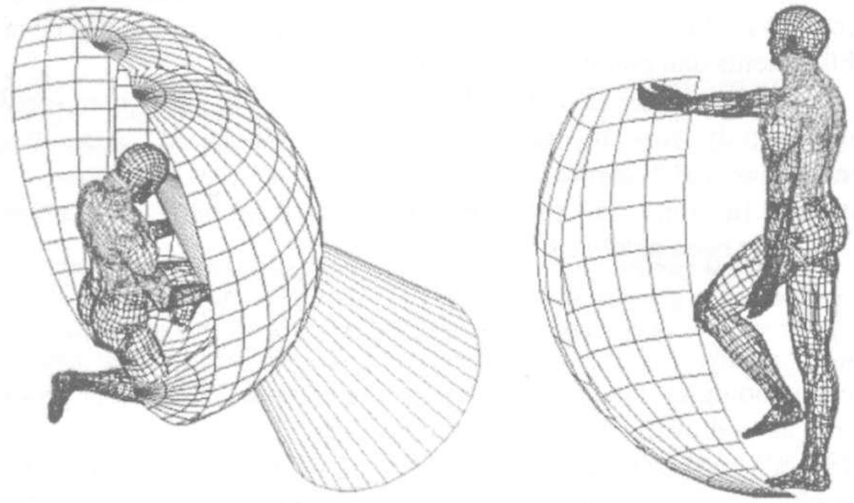

Fig. 7. Ergonomically correct human figures in different postures

It displays the environment as seen through a mannequin's ayes, tests the mannequin's ability to reach any point and displays the mannequin's field of vision, calculations can been performed by using revised *NIOSH* (National Institute for Occupational Safety and Health (USA)) Lifting Equation, allowing us to simulate lifting, pushing and pulling by adding forces and torques in any direction of any body part and perform other activities [5].
Quite similar technologies are used to evaluate the ergonomic (convenient and effective use) characteristics of an automatic line for packaging medicines and other goods, which are very important in market and competitive economy.
Fig. 8 shows only one of the aspects of the *ManneQuin* software application where it is used to

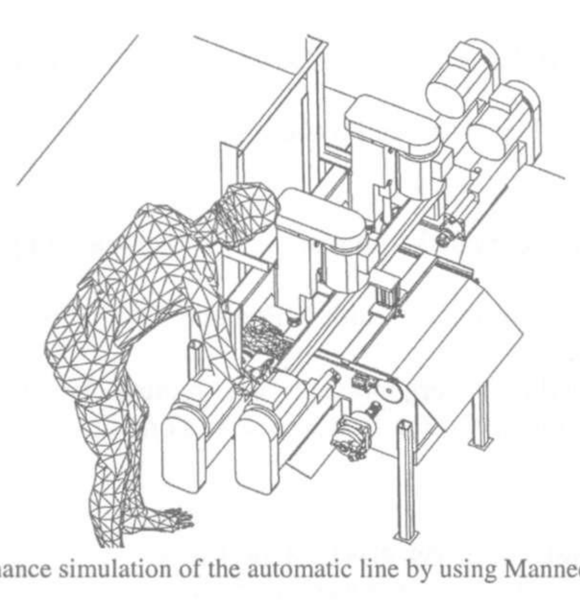

Fig. 8. Maintenance simulation of the automatic line by using Mannequin's software.

analyse how convenient it is for a human trying to carry out the maintenance and exploitation tasks of the newly formed automatic production line.
Although the use of *ManneQuin* is hampered by the fact that it ensures only visual control of the collisions of a person with other objects, and the analysis of the comfort of the assumed position, however, its comparatively low price, at least 10 times lower than that of the above mentioned *HumanCAD*, compensates for the shortcomings. The use of the *ManneQuin* programs in combination with universal CAD programs, for example *TurboCAD*, opens up additional possibilities, for example, lighting control in the zone of human visibility. Both from the point of view of the offered possibilities and prices *ManneQuin* program series could be acceptable to the educational establishments and enterprises of Latvia.
At Riga Technical University the BE and PRO versions of this computer software have been tested in the students' study work in combination with the low-priced CAD software *TurboCAD* (data exchange in DXF and 3DS formats).
Ergonomically correct furniture has been designed with their help, and convenience of self-designed automatons has been analyzed.

## Conclusions

Research on the technologies necessary for carrying out new work on product design and development allows us to draw the following conclusions:
- the tools and methods incorporated in CAD software do not allow us to solve all calculation and evaluation problems of complex dynamically controlled objects, - it is necessary to evaluate the product characteristics at the system level design stage by carrying out analytic experiments, simulating their process with the help of computer software,
- *MatLab* software can be mentioned as one of the best for analyzing and developing engineering projects,
- ergonomic software allows us to carry out research on convenient and effective application of a project, which is very important in market and competitive economy, moreover, application of *HumanCAD* in product design and development process can be considered a Synergy approach,
- *ManneQuin* software series could be acceptable to the educational establishments of Latvia both from the point of view of the offered possibilities and costs.

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***Šulcs A., Kaņeps J., Verners O. Moderno tehnoloģiju izmantošanas pētījumi inženierprojektu aprēķinos.***
*Rakstā apskatītas projektēšanas darbu izpildes tehnoloģijas, pie kurām inženiertehniskie aprēķini tiek veikti uz vadāmās iekārtas modelēšanas rezultātu pamata. Tiek analizēts pneimatiskas sprauslas izpildelements, modelēšanas uzdevumsr izpildīts izmantojot MatLab Simulink programmatūru. ManneQuin programmatūra tiek rekomendēta projektēšanas uzdevumu ergonomiskai analīzei.*

***Sulcs A., Kaneps J., Verners O. Technology Transfer Analysis for Engineering Design.***
*The paper considers the application of design technologies, where engineering calculations of the equipment are carried out on the basis of simulation of the dynamic behavior of the equipment to be controlled. A pneumatic nozzle example has been shown, simulation is carried out with the MatLab Simulink software. ManneQuin software is recommended for ergonomic analysis of the project.*

***Шулц А., Канепс Я., Вернерс О. Анализ использования современных технологий в инженерных расчетах.***
*В статье рассмотрена технология выполнения работ проектирования, при которой инженерно-технические расчеты оборудования проведены на основе моделирования динамического поведения управляемого оборудования. Анализируется исполнительное устройство в виде пневматического сопла, задача моделирования выполнена используя программу MatLab Simulink. Программа ManneQuin рекомендуется для эргономического анализа проекта.*