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# DESIGN OF A UNIVERSAL DEVICE HOLDER SYSTEM

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**Abstract:** During the performance of the dust chamber tests, the device systems must meet not only mechanical but also flow aspects, for this reason a special system –which cannot be used on other test equipment– must be developed to perform the dust tests. During the development of the concept of the modular device system (MDDT: Modular Device for Dust Test) designed for carrying out dust chamber tests, the design methods based on function analysis, used in the design of production equipment, can be well applied.

***Keywords:*** *dust test, function structure, modular device system*

## 1. INTRODUCTION

In connection with several test devices, there was a need to develop a device system that could represent an economical solution for testing an extremely large number of products. A basic requirement for the device systems used in the test equipment is a high degree of universality, which can adapt as large a range of the vehicle components to be tested to the workspace of the test equipment as possible with the smallest possible number of components. Based on previous experience, such equipment problems can be effectively solved by creating a modular equipment system.

## 2. COMPONENTS OF MODULAR DEVICE SYSTEM

During the development of the concept of the modular device system (Modular Device for Dust Test, hereinafter MDDT) designed to carry out dust chamber tests, the first and most important operation is the exploration of the elementary functions of the planned system (Deutsches Institut für Normung, 1997). Among the basic functions, there are those without which the MDDT system does not work, these mandatory basic functions. There are elementary functions whose effects are equivalent to each other, but one of the alternative functions must be included in the MDDT function structures, these are the mandatory alternative elementary functions. The non-mandatory elementary functions can increase the function content of the component, but their application is not absolutely necessary for the operation of the component, they must be integrated into the MDDT system according to user needs. Figure 1 shows the symbols and meanings of elementary functions.

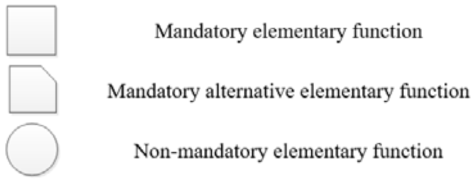



***Figure 1.*** *Symbols of elementary functions*

The modular device system designed to carry out dust chamber tests is made up of functional sub-units, the individual sub-units implement the elementary functions listed below.

$f(K)$

**f(K) – Device body**
The central function of the MDDT system is the device body (frame), which enables the inclusion of other functions. The device body must be designed in such a way that it does not create a significant obstacle in the way of the dust flowing from top to bottom in the test device and does not change the flow lines formed around the tested generator.

$f(R_K)$

**f(Rk) – Fixing the device body**
This function enables the device body to be fixed in several possible positions on the grid worktable of the dust-test equipment. When designing the function, it is necessary to ensure that, during installation and removal or relocation of the device body, it can also be fixed from the work area, and the grid worktable does not have to be removed from the test machine for this reason.

$f(S_X)$

**f(SX) – Displacement of the generator in the X-axis direction in the device**
The geometric dimensions of the generators to be tested are different. If the plane of the belt drive in the drive system cannot be changed, the generators must be made axially movable in the device. (The X-axis of the coordinate system is parallel to the axis of the drive.)

$f(S_Y)$

**f(SY) – Y-axis displacement of the generator in the device**
If the tension of the drive belt in the drive system cannot be adjusted independently of the device (e.g. with a tension roller), then the generators must be made movable in the Y direction in the device. (The Y-axis of the coordinate system is perpendicular to the axis of the drive.)

$f(S_Z)$

**f(SZ) – Shifting the generator in the Z-axis direction in the device**
The geometric dimensions of the generators to be tested are different. If the cross-sectional dimensions of the tested generator are larger, the generators must be made movable in the Z direction so that the tested generator can fit above the device body. (The Z-axis of the coordinate system is perpendicular to the worktable of the test equipment.)

$f(S_A)$

**f(SA) – Rotating the generator around the X-axis in the device**
The generators must be tested in the same spatial position as they are installed in the vehicle. This function will allow dust tests to be performed in any angle position. Tests in any angular position may also be necessary during the development of special generators.

$f(R_X)$

**f(RX) – Fixation of device elements moving in the direction of the X-axis in the device**
After adjusting the plane of the belt drive, the device components must be fixed.

$f(R_Y)$

**f(RY) – Fixation of device elements moving in the direction of the Y-axis in the device**
If the belt tension is adjusted by shifting the tested generator in the device, the device elements adjusted according to the belt tension must be fixed.

$f(R_Z)$

**f(RZ) – Fixation of device elements moving in the direction of the Z-axis in the device**
Device elements set according to the cross-sectional dimensions of the tested generator must be fixed.

$f(R_A)$

**f(RA) – Fixing the orientation in the device**
After setting the test orientation of the generator, the device components must be fixed.

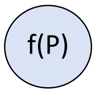
f(A)

**f(A) – Shape that does not affect flow conditions**
All elements of the MDDT device system must be designed in such a way that they do not create a significant obstacle in the path of dust flowing from top to bottom in the test equipment, do not change the flow lines formed around the tested generator, and ensure constant flow conditions during the tests.

f(I)

**f(I) – Common mechanical interface**
In order to the MDDT device system to be suitable for testing as many types of generators as possible using as few device elements as possible, it is advisable to concentrate the differences resulting from the geometric differences in the

perception of the generators on one element. This is the task of this function, so it matches the connector dimensions of the device and the tested generator.




**f(P) – Baffle plates to modify the flow**

This is an optional feature. After performing many dust tests, the experience may arise that the intensity of the dust flowing in the dust chamber around the tested generator must be condensed/thinned somewhere. The developed static flow capacity can be modified with deflector/shadow plates. These deflector/shield plates must always be designed according to the unique needs that induce the test. They can be fixed to the device frame or to the grid table of the dust chamber.

## 3. MDTT DEVICE SYSTEM

The elementary functions described in the previous point can be linked in many possible ways into a function structure that satisfies the requirements related to the design of the MDDT system. If we create device structures from predefined elementary functions, we essentially record the elements of the set whose elements we want to take into account in the formation of the versions (Tajnafői, 1993), (Takács G. , 1997), (Takács Á. , 2017). Figure 2 shows the relationship of elementary functions. It is also necessary to record how certain elements (atoms) of the set are connected to other elements (atoms) of the set. The above definitions can be considered as a graph in a mathematical sense, where the elementary functions are the corner points of the graph, the defined mutual relations are the edges of the graph, and the individual conceptual versions are subgraphs of the graph.

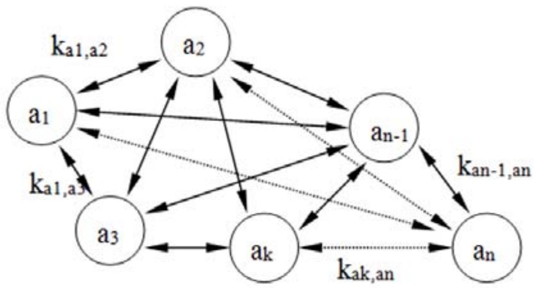



***Figure 2.*** *Characterization of the relationship of elementary functions with a graph*

The maximum number of edges (m) of a graph with n corner points can be calculated using the equation (1), which assumes that every atom is connected to every other atom and that there can be no parallel edges between two atoms.

$$m = \frac{n(n-3)}{2} + n \tag{1}$$

The edges of the graph define a connection between one atom each, so in the case of n atoms, a maximum of m connections must be defined. The connection between atoms can be described using relation (2), which is the adjacency matrix.

$$S = \begin{bmatrix} 0 & k_{a_1,a_2} & . & . & k_{a_1,a_n} \\ k_{a_2,a_1} & 0 & . & . & . \\ . & . & 0 & . & . \\ . & . & . & 0 & . \\ k_{a_n,a_1} & . & . & . & 0 \end{bmatrix} \tag{2}$$

The characteristic of the matrix is that the value set of the elements is 0 or 1, according to whether the relationship exists or not, its main diagonal is made up of zero elements, because the relationship of the elements with themselves cannot be logically interpreted. Another characteristic is that the matrix is symmetrical because the connection of the elements is mutual and bidirectional. It follows from the above that, in terms of the necessary information content, the triangular matrix above the main diagonal is sufficient for a clear description of the system of connections between elementary functions. The vertices can be arranged arbitrarily; therefore, a graph S can have many adjacency matrices, which means that the permutation of the rows and columns of S always results in a different matrix, but this does not change the content meaning of the graph, in this case the relationship of the members' connections. Figure 3 contains the adjacency matrix of the functions of MDDT system. To write down the device concepts, a graph can be used, the corner points of which are individual building elements that can be used to build the device system, and the individual connections between the elements are represented by the edges of the graph. The graph contains all possible device variants in the form of subgraphs. By determining the number of versions, it is possible to find out how many sub-graphs the complete graph contains, which as independent device versions can satisfy the device requirements for testing the generators. No general method can be prescribed for search and selection, the logic of the selection is provided by the specific planning task. In most cases, the method of equal probability can be applied well, but due to the homogeneous treatment of functions, it also creates many incorrect solutions during planning. This graph search method assigns the same random variable to each corner point of the graph.

| | f(K) | $f(R_K)$ | $f(S_X)$ | $f(S_Y)$ | $f(S_Z)$ | $f(S_A)$ | $f(R_X)$ | $f(R_Y)$ | $f(R_Z)$ | $f(R_A)$ | f(A) | f(I) | f(P) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| f(K) | 0 | $k(K,R_k)$ | $k(K,S_X)$ | $k(K,S_Y)$ | $k(K,S_Z)$ | $k(K,S_A)$ | $k(K,R_X)$ | $k(K,R_Y)$ | $k(K,R_Z)$ | $k(K,R_A)$ | k(K,A) | k(K,I) | k(K,P) |
| $f(R_K)$ | | 0 | $k(R_k,S_X)$ | $k(R_k,S_Y)$ | $k(R_k,S_Z)$ | $k(R_k,S_A)$ | $k(R_k,R_X)$ | $k(R_k,R_Y)$ | $k(R_k,R_Z)$ | $k(R_k,R_A)$ | $k(R_k,A)$ | $k(R_k,I)$ | $k(R_k,P)$ |
| $f(S_X)$ | | | 0 | $k(S_X,S_Y)$ | $k(S_X,S_Z)$ | $k(S_X,S_A)$ | $k(S_X,R_X)$ | $k(S_X,R_Y)$ | $k(S_X,R_Z)$ | $k(S_X,R_A)$ | $k(S_X,A)$ | $k(S_X,I)$ | $k(S_X,P)$ |
| $f(S_Y)$ | | | | 0 | $k(S_Y,S_Z)$ | $k(S_Y,S_A)$ | $k(S_Y,R_X)$ | $k(S_Y,R_Y)$ | $k(S_Y,R_Z)$ | $k(S_Y,R_A)$ | $k(S_Y,A)$ | $k(S_Y,I)$ | $k(S_Y,P)$ |
| $f(S_Z)$ | | | | | 0 | $k(S_Z,S_A)$ | $k(S_Z,R_X)$ | $k(S_Z,R_Y)$ | $k(S_Z,R_Z)$ | $k(S_Z,R_A)$ | $k(S_Z,A)$ | $k(S_Z,I)$ | $k(S_Z,P)$ |
| $f(S_A)$ | | | | | | 0 | $k(S_A,R_X)$ | $k(S_A,R_Y)$ | $k(S_A,R_X)$ | $k(S_A,R_A)$ | $k(S_A,A)$ | $k(S_A,I)$ | $k(S_A,P)$ |
| $f(R_X)$ | | | | | | | 0 | $k(R_x,R_Y)$ | $k(R_x,R_Z)$ | $k(R_x,R_A)$ | $k(R_x,A)$ | $k(R_x,I)$ | $k(R_x,P)$ |
| $f(R_Y)$ | | | | | | | | 0 | $k(R_Y,R_Z)$ | $k(R_Y,R_A)$ | $k(R_Y,A)$ | $k(R_Y,I)$ | $k(R_Y,P)$ |
| $f(R_Z)$ | | | | | | | | | 0 | $k(R_Z,R_A)$ | $k(R_Z,A)$ | $k(R_Z,I)$ | $k(R_Z,P)$ |
| $f(R_A)$ | | | | | | | | | | 0 | $k(R_A,A)$ | $k(R_A,I)$ | $k(R_A,P)$ |
| f(A) | | | | | | | | | | | 0 | k(A,I) | k(A,P) |
| f(I) | | | | | | | | | | | | 0 | k(I,P) |
| f(P) | | | | | | | | | | | | | 0 |

***Figure 3.*** *Adjacency matrix of MDDT system functions*

$$P_{a1} = P_{a2} = \cdots = P_{an} \tag{3}$$

Since the random variable Pai represents the selectability of each corner point of the graph in a subgraph, the value set of ai is 0 or 1. Figure 4 shows the selection of subgraphs.

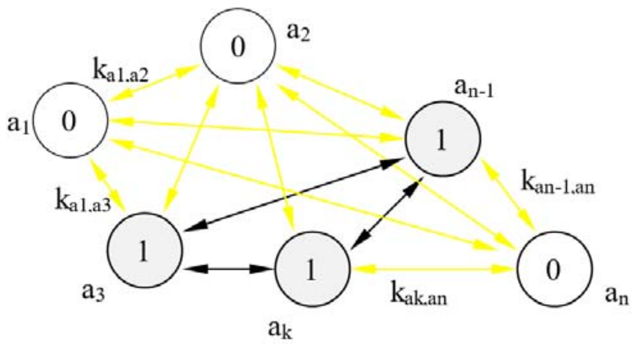



***Figure 4.*** *Selection of subgraphs*

The corner points of the entire graph take on different values for each calculation cycle, so a different subgraph can be formed in each cycle depending on the corner points with value ai=1 and the edges starting from them. After the individual corner points are randomly selected, several subgraphs can be formed at the same time, of which only the largest contiguous size (which contains more atoms) is taken into account. The defined functions can be connected to each other in several possible ways and with several possible contents. Figure 5 shows the adjacency matrix of the version that can be designed according to the requirements. Figure 6 shows the function structure corresponding to the adjacency matrix. The initial concept of the dust chamber device is presented in Figure 7.

| | f(K) | f($R_K$) | f($S_X$) | f($S_Y$) | f($S_Z$) | f($S_A$) | f($R_X$) | f($R_Y$) | f($R_Z$) | f($R_A$) | f(A) | f(I) | f(P) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| f(K) | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 1 |
| f($R_K$) | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| f($S_X$) | | | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 |
| f($S_Y$) | | | | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 |
| f($S_Z$) | | | | | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 |
| f($S_A$) | | | | | | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 |
| f($R_X$) | | | | | | | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| f($R_Y$) | | | | | | | | 0 | 0 | 0 | 1 | 0 | 0 |
| f($R_Z$) | | | | | | | | | 0 | 0 | 1 | 0 | 0 |
| f($R_A$) | | | | | | | | | | 0 | 1 | 0 | 0 |
| f(A) | | | | | | | | | | | 0 | 0 | 0 |
| f(I) | | | | | | | | | | | | 0 | |
| f(P) | | | | | | | | | | | | | 0 |

***Figure 5.*** *A possible adjacency matrix of MDDT system functions*

In addition to the specified dimensions of the generator, the component that implements the f(I) function depicted in red (see Figure 7) is capable of handling differences resulting from changes in installation dimensions. This is important because the other parts of the device may remain unchanged. In the final design, each generator group has one of these common parts. From the point of view of the tests, the most important function is f(A), which stipulates that all components must be designed in such a way that they affect the flow picture of the flowing dust as little as possible. The f(K) function (appliance frame) is designed in such a way that it can be moved to different places depending on the grid division and can be fixed there with hooks if necessary.

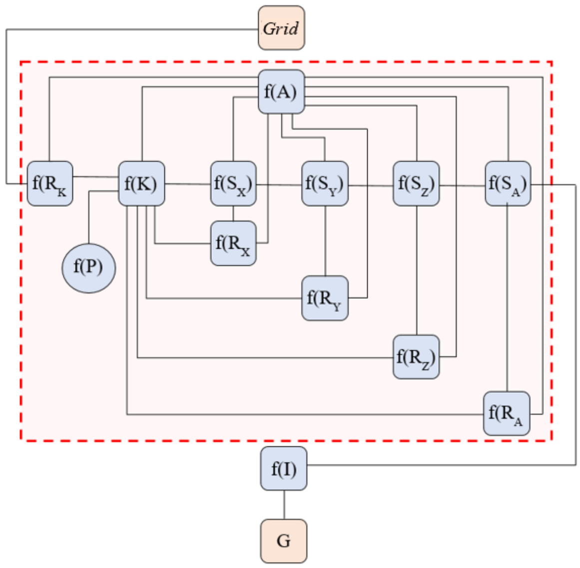



***Figure 6.*** *Function structure of a possible solution of MDDT system*

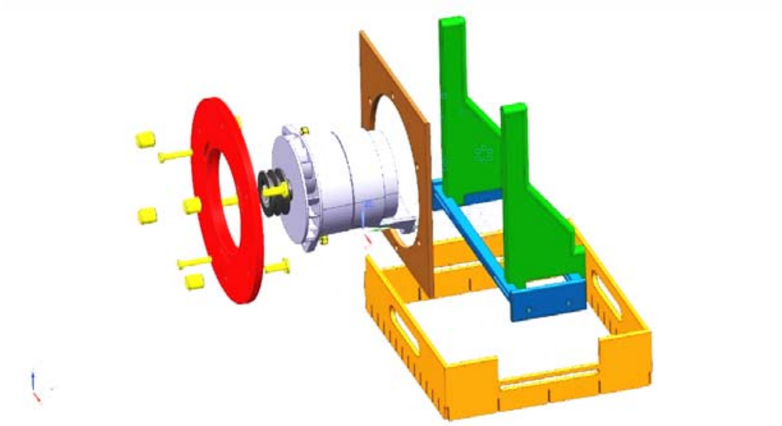


***Figure 7.*** *Exploded view of the dust chamber device*

## 4. Summary

Within the framework of this article, the development of the concept of a modular device system designed to perform dust chamber tests was presented. Based on the list of requirements established by the dust chamber, elementary functions were defined, from which a graph can be created. The optimal device concept can be selected from the device variations that can be derived from the graph. A study was prepared on the design process of the device concept, which is well suited for explaining the design methodology of methodical production device design.

## References

Deutsches Institut für Normung. (1997). DIN EN 60068-2-68. *Environmental testing - Part 2: Tests; test L: Dust and sand*.

Tajnafői, J. (1993). *Szerszámgéptervezés II. Struktúraképzések.* Budapest: Nemzeti Tankönyvkiadó.

Takács, Á. (2017). Computer Aided Concept Building. *Solid State Phenomena, 261*, 402-407. doi:https://doi.org/10.4028/www.scientific.net/ssp.261.402

Takács, G. (1997). Szerszámgép struktúrák tervezése grafikus adatbázisokkal. *PhD thesis*. Miskolc.