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CoDe-09 – a System for Environmental Assessment of Mechanical Engineering Products in their Conceptual Phase

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ABSTRACT
Design and development (D/D) procedures of mechanical engineering products (MEP-s) are explored as a holistic ones, and are modeling by means of the sets system. The individual sets represent technical, economical, environmental, aesthetic and market requirements. The specific eco-design philosophy is derived from the environmental aspects and requirements. The final result of this process are the environmentally compatible MEP-s. This philosophy is applied for the conceptual phase optimisation of MEP-s. The described procedure is applied as a fundamental core for the software product CoDe-09 and its structure. An application in the automotive industry is described in the paper.

KEY WORDS
environmental assessment, mechanical engineering products, conceptual phase, non-reducible system, automotive industry.

INTRODUCTION
Improving product design by applying ecodesign principles is a big step towards the presentation of environmental problems at source and, hence, towards a more sustainable society.Ecodesign, or the integration of environmental aspects into the familiar product development process, is important from both the environmental and business perspective. Ecodesign projects carried out all over the world have shown that as well as helping improve the environment, ecodesign also often offers business financial benefits.

Environmental assessment of the developing engineering products, one of the possibilities, how to achieve the environmental and economic objectives. There are a lot of different analytical tools, by means of it can be carried out. One of those tools, having the software character, focused on the conceptual phase is described in the following parts of this paper.

D/D PROCEDURE OF MEP-S AND ITS FORMAL EXPRESSION
At the present time, an up-to-date MEP must fulfil the technical, economic, environmental, aesthetic and market requirements. Formal expression of these requirements is carried out by means of a set system. Its graphical representation is in Fig. 1.

Put simply, with conventional D/D constrains solution had to be found in the MR area, where the four basic sphere overlapped. The addition of the EN sphere has modified the scope of possible solutions which must be chosen from within area where the all spheres overlap. By this way the environment has been integrating into MEP-s D/D.

(It is well-known, that eco-design means to integrate environmental aspects into product design and development).

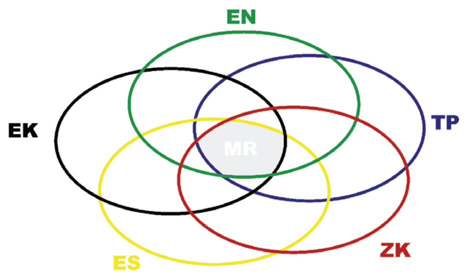

Fig. 1: *Graphical representation of the different requirements on the up-to-date MEP-s by means of the set system. Abbreviations: TP – technical, EK – economic, EN – environmental, ES – aesthetic, ZK – market requirements. MR – area of the possible solutions.*

CONCEPTUAL PHASE OF ECO-DESIGN – THE MOST IMPORTANT ONE IN MEP-s LIFE CYCLE

Almost all properties of the D/D MEP-s are determined in their conceptual phase. The D/D of an environmentally friendly MEP requires the assessment of its potential environmental impact during the D/D process. Particularly in the early MEP D/D stages the potential for the environmental optimisation is high – see Fig. 2.

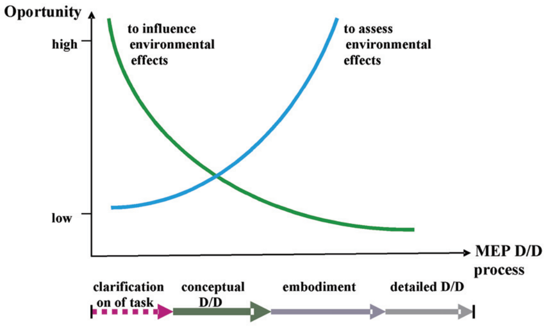

Fig. 2: *Opportunities to influence and assess environmental effects during the MEP-s D/D process.*

Once requirement have been defined in the requirements list, the MEP designer and developer has to convert them into concepts. A MEP concept is an approximate description of systematically generated and assessed **principle solutions**. In course of the concept D/D process, the solutions are generated by a stepwise concretisation of the MEP-s functions, physical effects and **working principles** and assessed with regard to the requirements defined in requirements list. In the following the concepts are serving as basis for the embodiment and detailed D/D – see the Fig. 3.

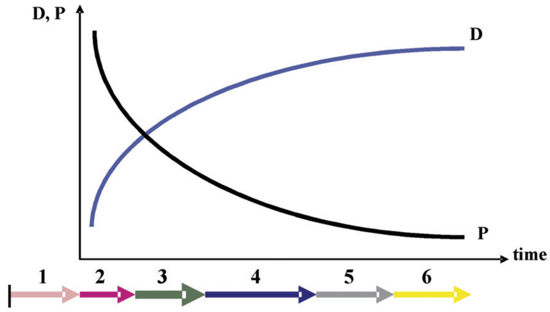

Fig. 3: *Relations of the conceptual D/D phase of MEP-s to the other life-cycle phases. Abreviations: D – Definition of Costs, Quality, Eco-Effectiveness, . . . P – Possibility to influence the D/D, 1 – Potential & Risk Identification, 2 – MEP Definition, 3 – Conceptual D/D, 4 – Embodiment & Detailed Design, 5 – Testing & Validation, 6 – Start of Production and Market Launch.*

This approach, described in [1], has been applied as one of the basic principles in the CoDe-09 system.

THE CoDe-09 ”PHILOSOPHY” AND APPLIED METHODS

The aim in development of the CoDe-09 software has been that a developer, who is user of this system, is able to obtain in the short time the required results in connection to the assessed conceptual variants of MEP-s.

Some conceptual variants of a MEP are represented by their functional or working principles. The question has been: Which of them is the best one from the environmental point of view? It is well-known, that in the conceptual phase of D/D there are no suitable technical, economic or other data to compare the disposable variants. If the approximate results are sufficient (for the first orientation), the **Guideline VDI 2225** and its analogy can be applied (see [1]). The different concepts can be assessed on the basis of environmental criteria with values expressed by points ranging from 0 (unsatisfactory) to 4 (ideal). Presuppposition of this method application is the functional decomposition of a construction unit, representing its own functional or working principles, at the simplest functionally conjoined parts (FCP-s). The FCP-s is necessary to understand as a non-reducible complex system; taking away only one part – the system is beeing defunct (see system theory).

If the more exact results are required, it is necessary to apply some other approach and methods. The **EI-99 method** (see [4]) has been applied in this case, in the software CoDe-09. Of course, for its application a lot of specific data must be at ones disposal (amount and type of materials, energy consumption, consumption of consumables, manufacturing procedures, etc.). In this case, the simplest functional part is – a component.

STRUCTURE OF THE CoDe-09 SYSTEM

The architecture of the CoDe-09 system is of building-block form and has hierarchical relations between the programme modules Fig. 4. At present there are an informative part (system charakterization, and instructions for its usage), determination of the basic input data (data concerning the different concept variants, and of course, generation of the promotional spot (modules LOGO, etc.).

After it, the processing is divided into two flows - approximate environmental assessment of concept variants, and exact ones. In the first case, there are 4 master programmes and 2 sub-routines (EIJ and SUM). In the second one, there are 5 master programmes (MAT, PROC, APLY, RECY, ASSE) and 9 sub-routines (MASS, JOINT, BZVO, BZVH, SZVO, SZVH, SSUL, SSUSN, UZP).

Output data are: CVH - overall weighted value, SMP(j) - overall sum of mP (milipoints), $j = 1,2,\ldots,m$, j – variant index, m – number of variants, $i = 1,2,\ldots,n$, i – parameters index, n – number of parameters. Other informations are evident from the flow-chart in Fig. 4.

AN APPLICATION IN THE AUTOMOTIVE INDUSTRY

The presented application is in connection to the three concepts of a passenger car door frames, and their environmental assessment.

- The basic input data:
  - **1st variant** The car door frame conzists of 5 components (Fig. 5), applied material is steel, spot welding is applied during assembly.
  - **2nd variant** Like in the 1st variant, of course, the applied material is aluminium.
  - **3rd variant** The car door frame is a composite construction, and conzists of one component only. Applied material is PA + mineral fibres - reinforced (armed).
- Approximate assessment:
  - **j** – variant index, number of variants $m = 3$;
  - **i** – item index, number of items $n = 6$.
  - **Input data:**

$$T_v = 0.3,\ T_p = 0.6,\ T_d = 0.1$$
$$(T = T_v + T_p + T_d = 1!);$$

$$v_1 = 0.13,\ v_2 = 0.13,\ v_3 = 0.32,$$
$$v_4 = 0.32,\ v_5 = 0.1,\ v_6 = 0$$
$$(v_1 + v_2 + v_3 + v_4 + v_5 + v_6 = 1!);$$

$$\mathbf{j} = \mathbf{1} \quad e_{11} = 3,\ e_{21} = 3,\ e_{31} = 2,$$
$$e_{41} = 2,\ e_{51} = 4,\ e_{61} = 0;$$
$$\mathbf{j} = \mathbf{2} \quad e_{12} = 3,\ e_{22} = 4,\ e_{32} = 3,$$
$$e_{42} = 3,\ e_{52} = 3,\ e_{62} = 0;$$
$$\mathbf{j} = \mathbf{3} \quad e_{13} = 4,\ e_{23} = 3,\ e_{33} = 1,$$
$$e_{43} = 4,\ e_{53} = 0,\ e_{63} = 0.$$

  - **Output data:**
    $CVH_1 = 2.46$; $CVH_2 = 3.13$; $CVH_3 = 2.51$.

The overall weighted value CVH_2 represents the best concept (the second variant, car door frame is made from aluminium).

- Exact assessment:
  The basic input data are given above. The other data, during the interactive procedures between CoDe-09 system, and the operator, for their multiple number and specific character are not given here.
  The obtained results are:

$$SMP(1) = 11\,712.48 \text{ mP},$$
$$SMP(2) = 7\,665.34 \text{ mP},$$
$$SMP(3) = 17\,978.40 \text{ mP}.$$

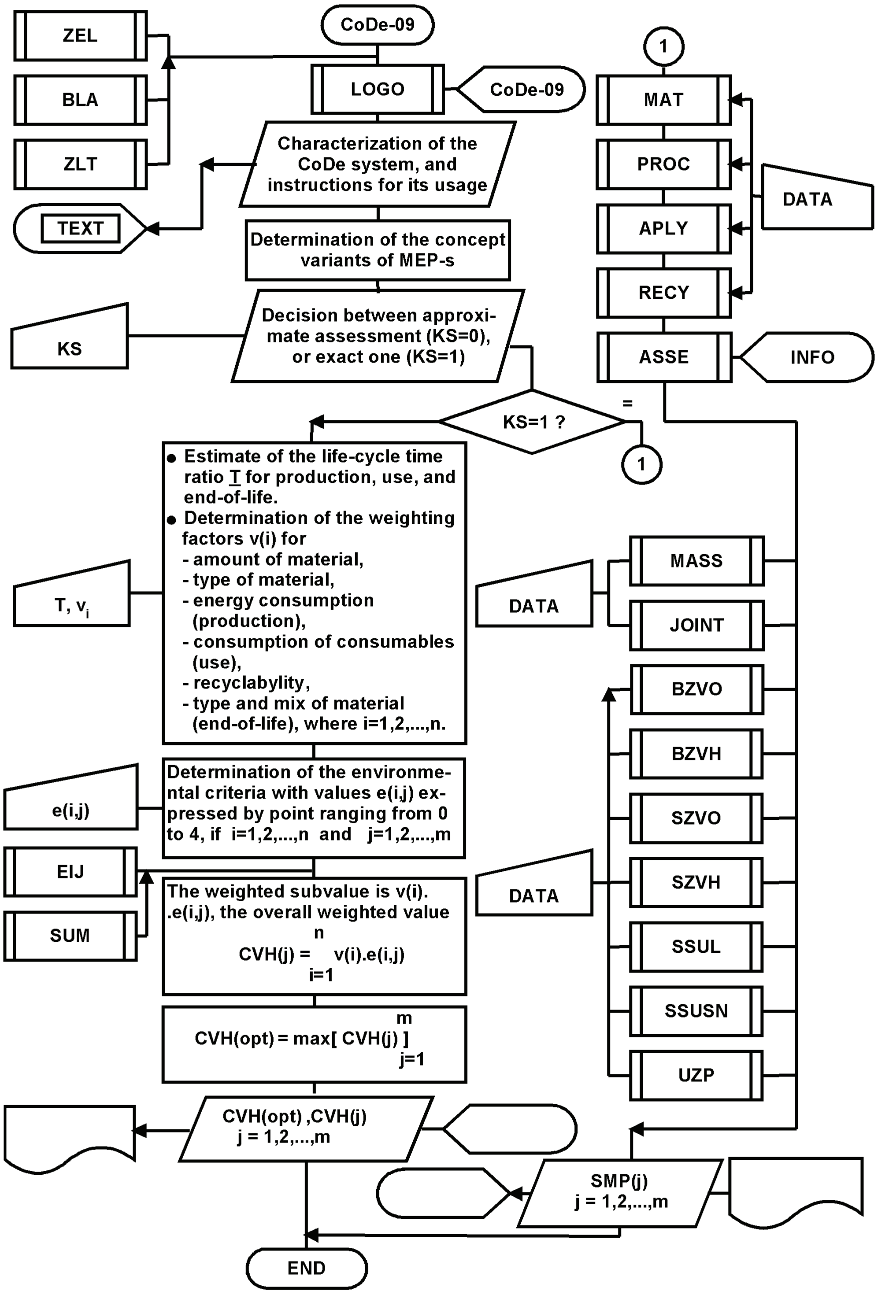

Fig. 4: *Software configuration of the CoDe-09 system.*

The best concept, according to the approximate and exact assessment is the same, but the car door frame made from steel, according to the exact assessmet, represents environmentally more suitable concept variant than the third one.

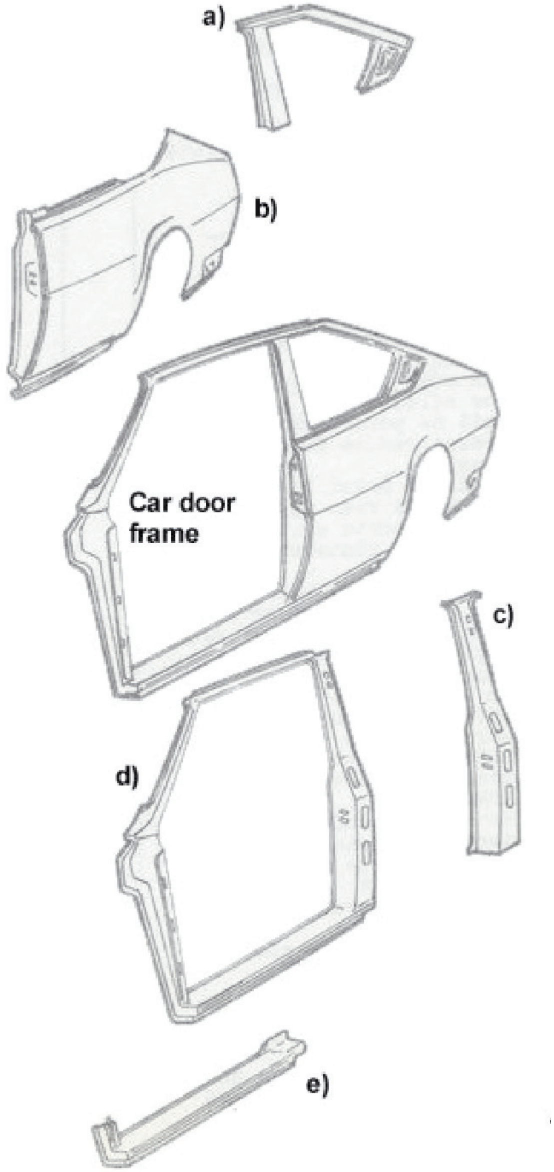

Fig. 5: *a) Door frame rear upper, left hand; b) Door frame rear bottom, left hand; c) Door frame, front complete, left hand; d) Centre pillar bracing complete, left hand; e) Door sill, front, left hand.*

CONCLUSION

CoDe-09 and Eco-Design technology, often thought of as tool that is useful in the first stages of product design and manufacture, is now being used to project a products life analysis, to ensure an environmntally / economically sound product in the first place.

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