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# Decision-Making and Support Tools for Design of Transmission Systems

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## INTRODUCTION

Transmission systems are crucial components of many machines and mechanisms. Ken Hurst (1998) highlights that whether you are designing power plants, cars, or washing machines, the power transmission system is an integral component responsible for product success or failure. The components that comprise a power transmission system include those that transfer power directly (coupling and shaft), speed and torque multiplication components (gears, belt drives, etc.), and the related mechanisms (clutches, brakes, etc.; see Freeman & Velinsky, 1995).

Transmission system design is a multistage iterative process of sequential generation and modification of design decisions. These decisions define in many respects the technical and economic characteristics of future products. Searching for suitable design decisions is a highly complex and time-consuming problem due to the necessity to consider and analyze many heterogeneous functional, technical, and economic factors. However, extensive computations, including solving very complex optimization tasks, are needed. As a rule, the design procedures are provided only by a very competent and experienced designer. With ever more complex and combinatorial decisions to be made, even the best designer will need competent design support, of which there is little. Therefore, the design of transmission systems is a wide open area for development and application of decision-making and decision support technologies.

The number of problems arising in the development of decision support systems (DSS) for the design of power transmissions is very large. In particular, the following apply:

- Development of computerized decision-making technology for each design stage with suitable partition of functions between designers and software tools
- Selection and analysis of main design tasks to be solved via software
- Formulation and study of a set of models for these problems providing different levels of model abstraction
- Development of methods and software for searching appropriate design decisions on the basis of these models, taking into account real requirements for accuracy and performances
- Creation of databases to support the decision-making process
- Embedding of optimization models into a user-friendly software environment

In this article, we present the main approaches and ideas of decision making for solving some above-mentioned problems of the initial stage of transmission design where the basic parameters of the transmission system are to be determined.

## BACKGROUND

Transmission design is a very complex problem. In literature, the main publications concern the design of specific elements such as springs, gears, and shafts;

see, for example, Litvin (1994), Shigley, Mischke, and Budynas (2003), and Su and Qin (2003). Methods were suggested for the synthesis of structure and choice of parameters for some kinds of transmissions (Hsieh & Tsai, 1996; Nelson & Cipra, 2005; Yan & Hsieh, 1994).

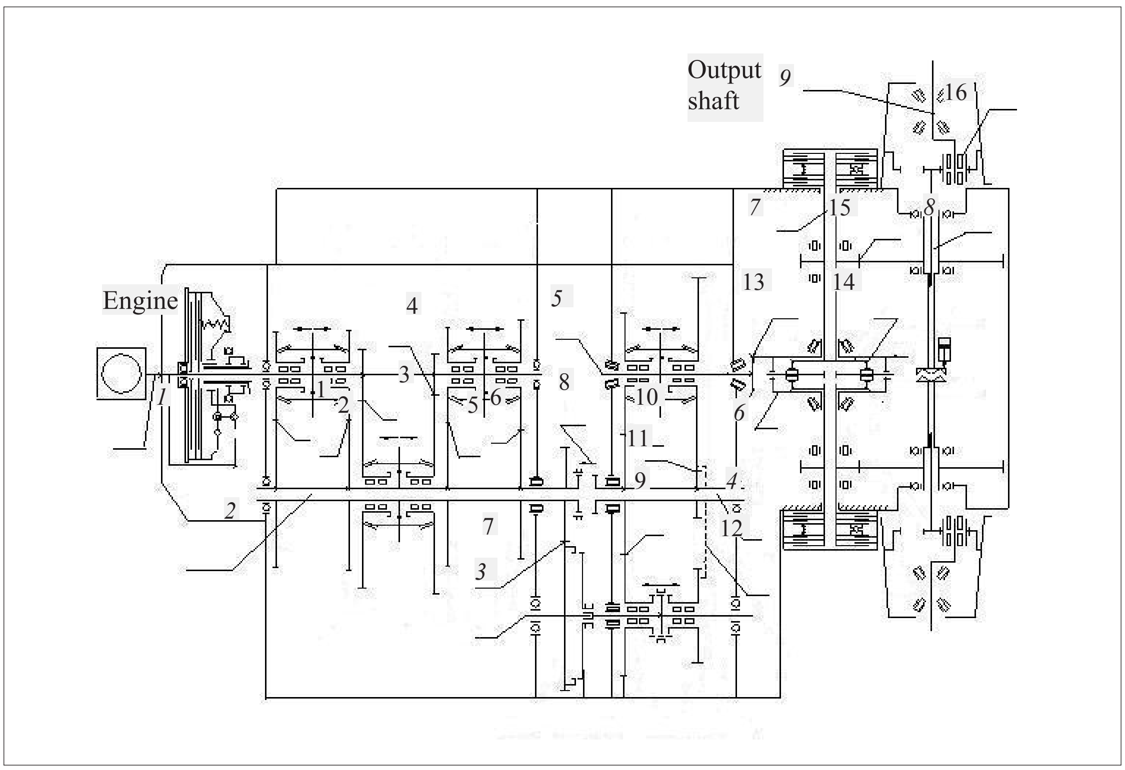
For the design of complex power transmission systems, the functional decomposition approach is often used (Guillot, 1987). Here, a complex transmission system is decomposed to a set of basic elements, and each basic element is then separately optimized. To take into account external conditions for components, complementary constraints are added (Dadié, 1996). Expert systems are widely used in order to consider engineering experience and to integrate partial optimization models into the design process (Dixon, 1995; Su, 1998; Su & Chen, 2003; Su & Qin, 2003). Another method deals with hierarchical decomposition (Dolgui, Guschinsky, & Levin, 1999, 2000, 2007; Krishnamachari & Papalambros, 1997; Michelena & Papalambros, 1995). The optimization model is decomposed and solved as a set of smaller, coordinated subproblems. Such a process is often followed intuitively during the development of the model by adding together selected objectives of each subsystem to obtain an overall system objective. For subproblems, often metaheuristics are used. For example, in Kalyanmoy and Sachin (2003), multiobjective evolutionary algorithms are developed for a gearbox design. Some graph theory models are considered in Guschinsky, Levin, and Dolgui (2006), Liu and Chen (2001), Michelena and Papalambros (1997), and Talpasanu, Yih, and Simionescu (2006).

These and other problems in the development of decision support systems for the design of multiple-unit power transmission systems are also considered in Guschinsky and Levin (2000) and Guschinsky, Levin, and Dolgui (2006).

## CONCEPTUAL PROBLEM STATEMENT

Modern industry uses a wide range of transmission systems. Each of them is defined by their functionality, their structure, as well as the characteristics and constructional features of each element and so forth. In this article, we consider mechanical power transmission

*Figure 1. Kinematic diagram of a transmission system*



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