Application of Knowledge-Based Design in Computer Aided Product Development

György Hegedűs

Abstract In the recent years, it can be observed that the products are launched by rapidity and short time. The lifecycles of user equipment has been shortened, the flow of information accelerated, the freely available information more widely accessible. One of the conditions of competitiveness for the arisen problems is the rapid and optimal solutions. Using a software or system, which supports the knowledge based design (KBD) the time and costs of the product development phase can be reduced. In this chapter the results of a product design and development process implemented in a PLM system will be presented on a ball screw drive mechanisms focusing on its returning guide.

Keywords Knowledge-Based design (KBD) · Product development · Computer aided design (CAD)

1 Introduction

In the last decades the computer aided design was the answer for quicker solutions. These systems and software supported the geometric modelling and manufacturing planning, especially (CAD/CAM). Due to the development the integrated systems were launched, which included the different simulation and analysing capabilities of the products. Nowadays the application of product lifecycle management (PLM) systems is an essential part of the product development. One of the advantages of these systems that knowledge-based design supporting modules are available, it is possible to create user-defined macros and algorithms, furthermore decision making and selection criteria arise during the design can be defined previously. Taking advantage of these properties the time of product design and development can be reduced significantly.

G. Hegedűs (✉)
University of Miskolc, Miskolc, Hungary
e-mail: hegedus.gyorgy@uni-miskolc.hu

K. Jármai and B. Bolló (eds.), *Vehicle and Automotive Engineering*,
Lecture Notes in Mechanical Engineering, DOI 10.1007/978-3-319-51189-4_11

2 Brief Overview of Knowledge-Based Design

Knowledge-based design focuses on the product design, development and its related procedures [1]. In a KBD environment the design process can be accelerated by reusing previously defined techniques, methods and procedures and these can be integrated into the desired tasks or workflows which are involved in the product development processes. The flexibility and complexity of knowledge-based design environment largely depend on the reused geometrical data, previously defined expressions and algorithms (see Fig. 1).

Formerly these environments included non-parametrised geometries (for example: neutral *.stp, *.iges, or converted CAD files). Complex CAD software support the parametrised surface, solid and assembly models, thus the knowledge based design and development can be achieved by the reused parametrised geometry. In product data and product lifecycle management software the mathematical expressions and logical relations or functions extend the capability of the knowledge-based environment. Most CAD, PDM and PLM software support user defined applications are developed in different programming languages such as C/C++, C#, Visual Basic, Java and specific built-in programming language [3]. Users can create their own applications that automatically perform repetitive tasks, accelerate design procedures, and automatically generate complex geometries. In such a case the user defined software obtains the parameters, equations, logical relations and functions from the CAD system and evaluates the numerical computations, algorithms end geometry creations. After that the evaluated parameters will be set into the CAD system. The flexibility, interactivity and time saving of repetitive tasks are the advantages of these KBD applications, however the disadvantages of these KBD environments are that all of the computations, numerical algorithms and communications between the CAD system and user defined software have to be programmed [4–7].

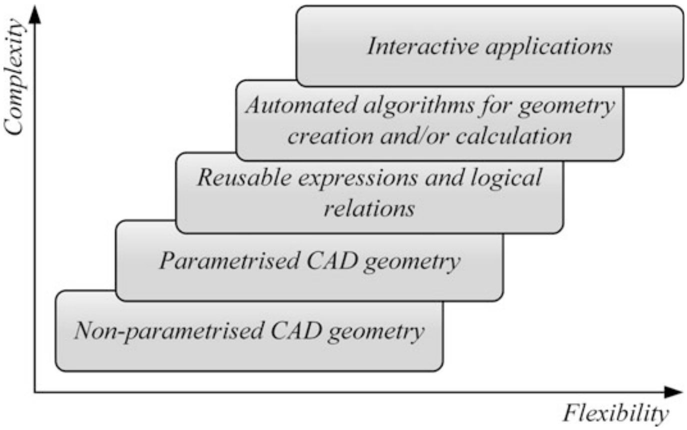

Fig. 1 Flexibility and complexity of a KBD application [2]

Knowledge-based design methods and tools can include rigid or variable geometry data, the integration of calculation and simulation procedures into the design process, or the application of problem-oriented software solutions that can be integrated into the design environment. Although one main advantage of knowledge-based design is that it makes existing, proven solutions available for specific tasks, this also involves some drawbacks that must be acknowledged [2, 8].

3 Application of Ball Screw Drives in Automotive Equipment

Gothic-arc profile ball screw motion transforming mechanisms are widely used to transform the rotational movement into linear movement and vice versa. Due to the automotive development these motion transformation mechanisms have been appeared in the electrically operated steering systems.

The electrically operated steering systems (Electric Power Steering, EPS) have introduced in passenger car steering systems during the last years. The use of these systems was originally limited to smaller vehicles, because the power density of the electronic parts and the energy available from the on-board wiring was not sufficient to serve bigger vehicles and higher steering powers.

New technologies enable the general use of EPS in the superclass now. The advantage of electric power-assisted steering compared to hydraulic power steering is that it is activated only when needed (energy is fed only when the car is steered). Due to this the energy waste and CO_2 emission are less.

The paraxial drive (EPSapa) is characterized by low system friction and high efficiency. The possible customer applications range from dynamic sports cars and upper mid-size cars to high load vehicles such as off-road vehicles and vans. Due to the combination of ball screw mechanism and toothed belt drive with paraxial drive is ideally suited for the customer's differing performance requirements. The wide range of positioning possibilities of the servo unit allows optimum use of the installation space on the vehicle. The linear movement of the steering rack is generated from the rotational movement of the electric motor combined with a toothed belt drive and a ball screw mechanism (see Fig. 2). The ball screw mechanism generates low noise and rigid connection between the steering gear and the vehicle body is possible [10].

Another solution of the application of ball screw drive mechanisms in EPS systems is the so-called rack-concentric steering system (EPSrc). The toothed belt drive is eliminated and the ball nut is connected with a hollow shaft and directly driven by an electric motor (see Fig. 3). The concentric arrangement of the hollow shaft requires a special servo motor, because the rack of the steering passes through the motor. The main advantage of the EPSrc system is its compactness, the disadvantage that due to the missing gear multiplication of the toothed belt drive the electric motor of an EPSrc has to produce a twice as high torque at the same output power level.

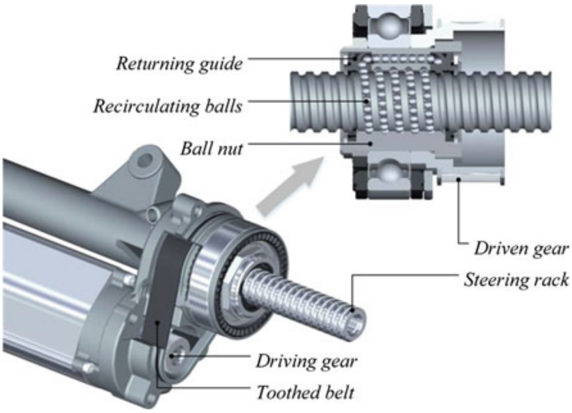

Fig. 2 Electric power steering with paraxial drive (EPSapa) [9]

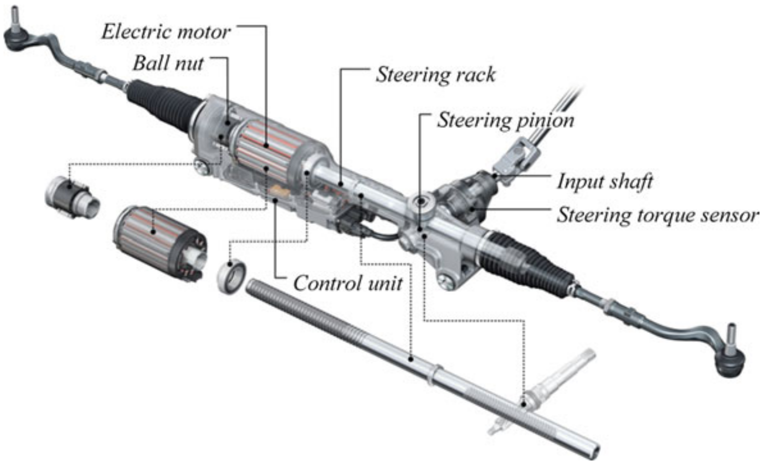

Fig. 3 Electric power steering with rack concentric drive (EPSrc) [11]

4 Application of Ball Screw Drives in Automotive Equipment

The customer's demand requires the development of ball screw drive mechanisms. Gothic-arc profile ball screw motion transforming mechanisms are commonly used in machine tools and the demand for high-lead ball screws is increasing due to high-speed manufacturing. The one of the problem of the high-lead ball screw drive is its manufacturing (determination of the profile of form grinding tool, collision avoidance of the quill and ball nut during manufacturing). The lead of ball screw mechanisms in an EPS system has a typical value of 5–10 mm. On low-lead ball

Table 1 The main design parameters of ball nut

Parameter	Description	Unit
P	Pitch of ball screw drives	mm
D_3	Internal diameter of ball nut body	mm
L_n	Length of thread	mm
D_{pw}	Pitch circle diameter	mm
R_{pr}	Radius of profile arc	mm
c	Centre shift of gothic arcs	mm
D_w	Ball diameter	mm

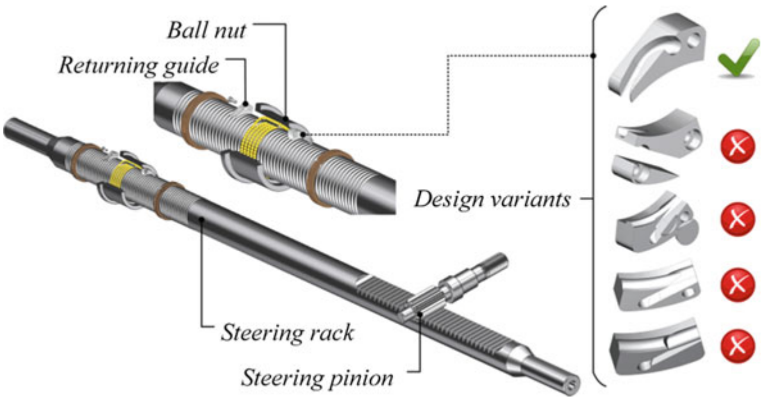

Fig. 4 Redesigned returning guides with KBD

screw drive mechanism the main problem is the arrangements of returning guides in the ball nut. Therefore new returning guides were designed to create a knowledge-based environment.

The KBD environment consists the reused design parameters of ball nut (see Table 1), the logical rules and functions.

The results of the new returning guide design variants are shown in Fig. 4, where the optimal solution was selected by value analysis.

5 Conclusions

This chapter has presented a product development process on the returning guide of a ball screw drive mechanism, which would be applied in automotive steering system. To reduce the time and cost of the development process a knowledge-based design environment was developed in a PLM software. Due to the favourable advantages of KBD system the time of the returning guide design variants generation is reduced and the selection of optimal solution can be carried out easier.

Acknowledgements This research was carried out as part of the TÁMOP-4.2.1.B-10/2/KONV-2010-0001 project with support by the European Union, co-financed by the European Social Fund. This research was supported by the European Union and the State of Hungary, co-financed by the European Social Fund in the framework of TÁMOP-4.2.4.A/2-11/1-2012-0001 'National Excellence Program'.

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