Key area of training and exploratory focus of mechanical engineering at Chemnitz University of Technology – Case studies for the development of new nonlinear drive concepts

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Introduction

The education of technical engineering in Chemnitz has a tradition that lasts for over 160 years. Founded as the 'Royal Trade School Chemnitz' in 1836, the Chemnitz UT has a very good reputation in Germany. Today there are more than 10500 students at 8 different faculties.

This article gives a short overview of the key course elements at the faculty of mechanical engineering, based on the data and facts of the Chemnitz University of Technology (Chemnitz UT). Main researches and research examples are shown, followed by the presentation of current research and development projects from drive technology, such as assembly and handling technology. Recent tools for integral system simulation of complex nonlinear drive systems will be placed in focus.

1 Chemnitz University of Technology and the education of technical engineering

In connection with the industrial development of the 19th century, the 'Royal Industrial School' (Königliche Gewerbschule) was founded on May 2nd, 1836 in Chemnitz. At this time the city had a population of approximately 11,000. In the beginning, the school had 14 students and 3 main subjects: Mechanical Technology, Chemical Technology and Agriculture. At the end of the 19th century, at the time of the industrial revolution, the number of students exceeded 1,000 for the first time. The school received the status of 'Royal Industrial Academy' (Königliche Gewerbeakademie) in 1900 [1].

Due to destruction caused during World War II, the academy had to be closed. After the war, it was reopened as 'Technical College' (Technische Lehranstalten Chemnitz) with about 500 students. In 1953, the name of the city was changed to Karl-Marx-Stadt and the school was called 'College of Mechanical Engineering Karl-Marx-Stadt' (Hochschule für Maschinenbau Karl-Marx-Stadt). In 1986 it received the status of a University of Technology with approximately 8,000 students.

After the reunification of Germany on October 3rd, 1990, the city was renamed Chemnitz again. Today, Chemnitz has a population of approximately 240,000 and more than 10,000 students are studying at the university in 8 departments: Natural Sciences, Mathematics, Mechanical Engineering, Electrical Engineering and Information Technology, Computer Science, Economics and Business Administration, Humanities Behavioral and Social Sciences. The departments are responsible for the correct completion of the respective courses of study. In some cases, they are subdivided into institutes that carry out teaching and research.

The research profile is based on interdisciplinarity. This structure corresponds to the dynamic interaction of science, economy, culture and society and is implemented more easily at a minor university rather than a large university. Scientists of all areas meet at the interfaces of humans, technology, management and communication. This characteristic not only puts the profile of Chemnitz University of Technology into shape, but it fits also extraordinarily well into the industrial tradition of Chemnitz.

The study system of Chemnitz University of Technology was entirely converted into the two stage scheme of Bachelor and Master until 2007. An increasing global competitiveness, international compatibility and even more practice orientation are only some of several reasons for establishing this model of studies within the European Higher Education Area.

2 Technology of mechanism at the TU Chemnitz

The current emphasis of technology of mechanism design in teaching and research at the Technical University of Chemnitz is constructed historically on the one hand and defined by the new requirements in mechanical engineering and drive technology on the other hand. By switching diploma degree to the Bachelor's and Master's degree, technology of mechanism teaching is mainly offered as electives in the master`s degree. This leads to a lack of knowledge of the young engineers, particularly in the field of the synthesis of mechanisms. Therefore, it would be necessary, that the procedures and methods for theory of mechanisms are available as additional features for commercial calculation software or CAD applications.

Nowadays, ideal solutions are not only realizable by perfect mechanical assemblies. Hence, the main areas of research are focused on the development of efficient and ideal mechatronic drive systems. Contrary to former times, when the way of working was highly determined by experimental laboratories, detailed virtual prototypes play a decisive role nowadays.

The technology of mechanism as a field of expertise has a long history in Germany. German scientists, mathematicians and engineers like F. Reuleaux, L. Euler, L. Burmester and M. Grübler contributed crucial input to the development of systematical theory of mechanisms and machinery. F. Reuleaux is often referred to as 'father of constrained motion' or 'father of modern kinematics'. Thanks to his tribute, the results of the theoretical kinematics are closely connected to the tasks of machine design since the mid-19th century.

The technology of mechanism in Chemnitz received a subsequent influence through Prof. Dr.-Ing. habil. Dr. e.h. J. Volmer. After initial lectures he became director of the department and head of the professorship technology of mechanism in 1962. Today’s professorship assembly and handling technology (MHT) arose from those historic roots and celebrated its 50-year existence in 2012.

3 The education in technology of mechanisms and references to software tools

The engineering education in technology of mechanisms of the professorship assembly and handling technology still relies on symbolic and graphic fundamentals and techniques, besides the mathematical-analytical as well as the computer-based methods, because the value of this discipline cannot be measured merely on its object-related contents. For an accurate model structure and an obvious evaluation of results, skills in the technology of mechanisms like characteristics of links and contactual-conditions, valuation of the degrees of freedom and redundant dimensionings as well as the evaluation of singularities and redundancies play a crucial part in the environment of software tools for multi-body simulation.

Nowadays the integrated observation of the system is central in the educational concept, although the electrical and cybernetical aspects come to the fore, besides the mechanical aspects.

On the one hand the focus lies on the application and extension of commercial software applications for construction and development (e.g. Creo/PTC), computation (e.g. Mathcad/PTC) or simulation (SimulationX/ITI) of complex system designs of drive systems. On the other hand, many graphics programs like 'Cinderella' (cinderella.de), 'Zirkel und Lineal' (zirkel.sourceforge.net) or 'GeoGebra' (geogebra.org) are available for a quick illustration of functional associations in the students’ education nowadays.

It is beneficial that many of those software solutions are available for free and in addition easy to learn and to handle. Geometrical methods for solutions in the section of analysis or synthesis of mechanisms can therefore be illustrated efficiently.

'GeoGebra' is for instance a free mathematics and geometry tool based on Java (Figure 1). It is available for current operating systems and is used as a supportive teaching material in scholastic mathematics and physics lessons in many countries. It also provides the possibility to include active worksheets on webpages.

Oftentimes it is very helpful for guided mechanisms of points or planes to analyze known structural mechanisms as references or starting solutions. Many point guided mechanism tasks can be realized with the help of crank-rocker mechanisms. To find starting solutions, printed or digital atlases of coupler cams can be used in the first step. For instance KOPAK is a digital atlas, which was developed by Schönherr and Berger in 1995 [2].

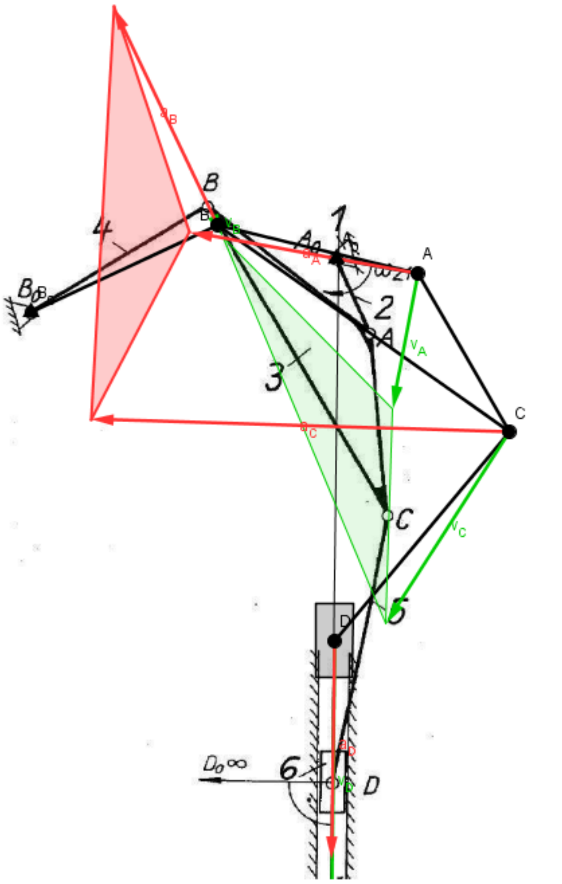

Figure 1: Use of 'GeoGebra' illustrating the method of analysis of mechanisms.

Thereby the user defines a trajectory as required. In general it is pointwise trajectory in a previous defined normalized frame system.

In case of KOPAK the user specifies the trajectory as polygonal line and declares further basic conditions like installation spaces of frame links or the valid minimum of the transmission angle. Consequently the user is shown the preferable mechanisms with their kinematic dimensions graphically and animated, Figure 2.

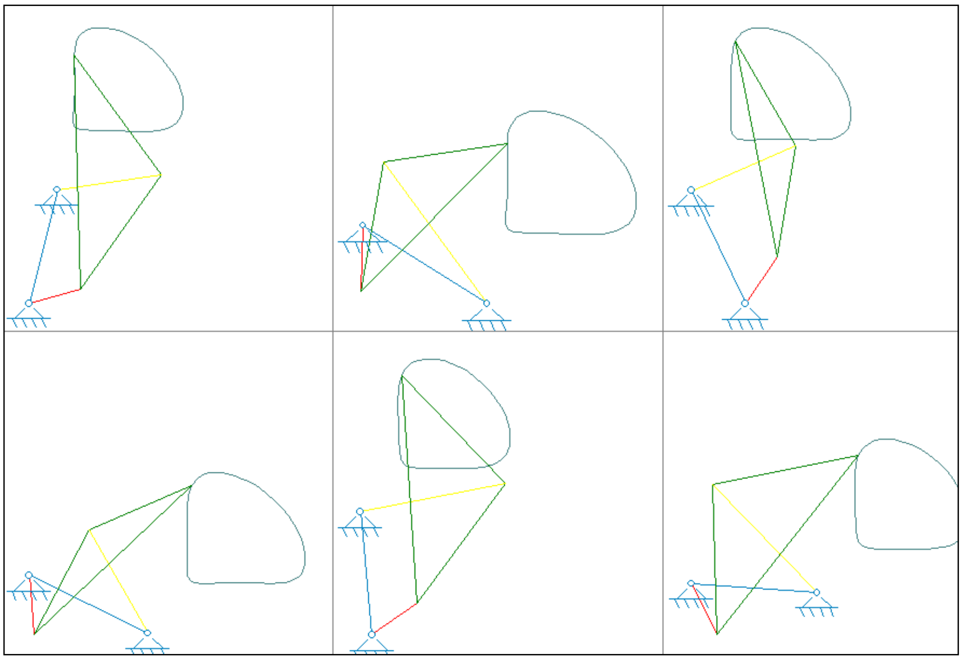

Figure 2: Software layout and mechanisms in KOPAK

4 MOCAD - A tool for graphical and interactive calculation and optimization of cam mechanisms and motion control systems

MOCAD is a modular application software for characterizing and free structuring of movement tasks as well as dimensioning of plane and spatial cam mechanisms and electronic cam profiles [3]. The graphic-interactive user interface offers a dynamic engagement in the development process with an automatic adjustment of all calculation steps in real time. Figure 3 shows an overview of the software concept.

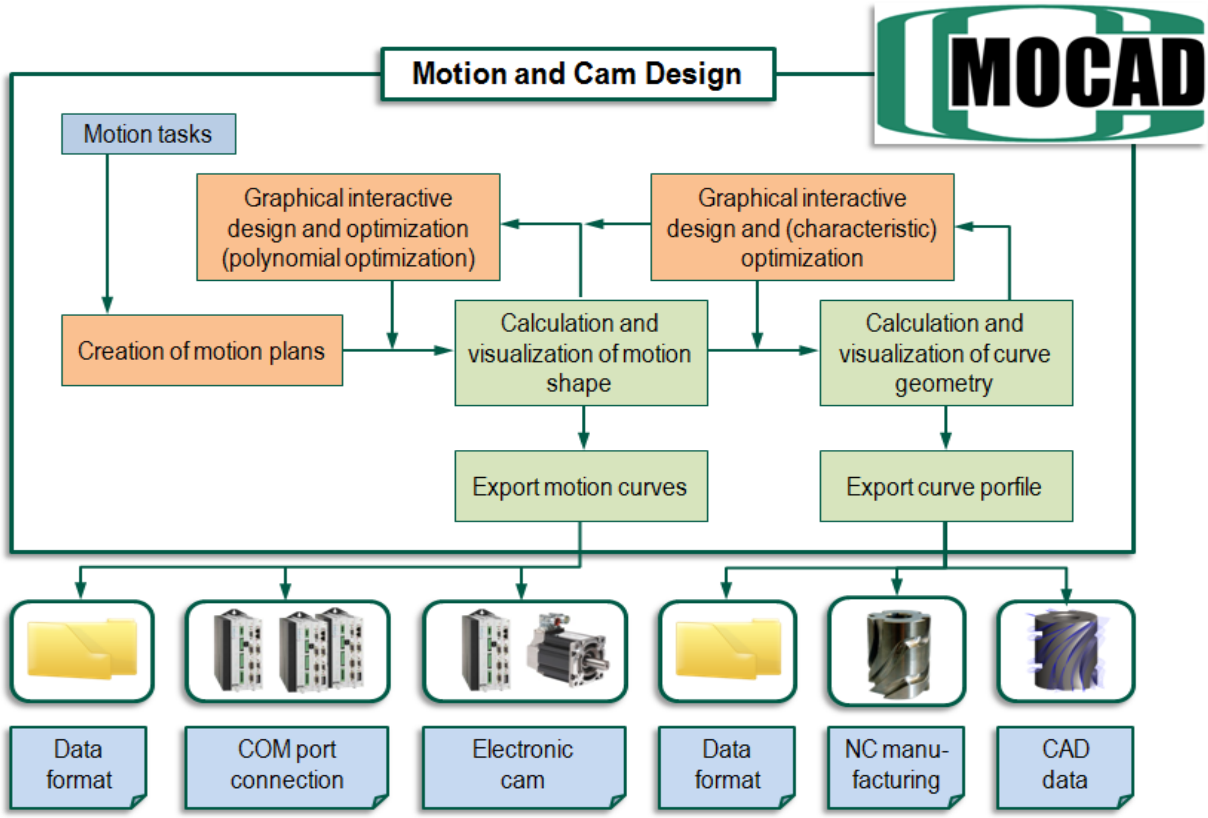

Figure 3: Systematical Overview of MOCAD

The plan of motion is an essential component during the construction phase and processing of a movement profile. It is possible to define and delete supporting points within the diagram intuitively, as well as the free manipulation of the transfer function and the marginal values up to the 6th order.

For the characterization of each section between the points of movement, a multiplicity of predefined laws of movement can be used. The implemented function library refers partly to the Guidelines, (particularly the German VDI Guideline 2143). In addition to the standardized laws of movement, the user is offered an automatic interpolation of higher polynomial, whose characteristics can easily be manipulated by directed setting of the marginal values. With increasing polynomial degree, higher derivations are considered.

If a comparison of movements is required, any number of motion plans can be edited simultaneously and diagramed. Aside from the coordination of motions, these motion plans enable the generation of a cam mechanism with different transfer functions and the comparison of kinematic and kinetostatic parameters of modified cam profiles. If identical or similar motion tasks need to be applied repeatedly, user-defined templates can be used (Figure 4).

Another focus of the software is the calculation of plane and spatial cam mechanisms, based on motion design settings. For different motion plans, the required curve shape and the kinetostatic analysis can be calculated simultaneously. User-defined diagrams enable an ideal comparison of the different dimensional parameter specifications and can be dynamically updated by the connection to the motion plan.

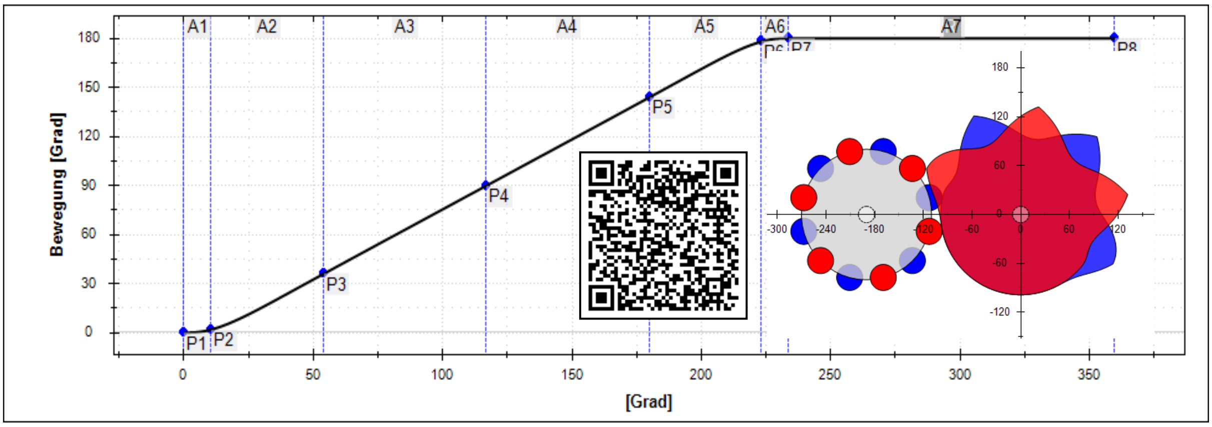

Figure 4: Motion plan and visualization of the cam mechanism in MOCAD (QR-Code).

5 Kinematic designs of new highly dynamic drive assemblies for knitting and braiding machines

Round braiders, which are available on the market nowadays, are at their technological limit regarding the operating speed. Two counterrotating carriers, on which coils for filling or chaining threads are attached, are rotating around the stationary cam ring [Figure 5]. The laying device (thread take-up lever), for realizing the required path of motions of the chaining thread, is mounted in the cam-guide (control curve) of the stationary cam ring on the one hand, and moveably at the chaining thread rotor on the other hand.

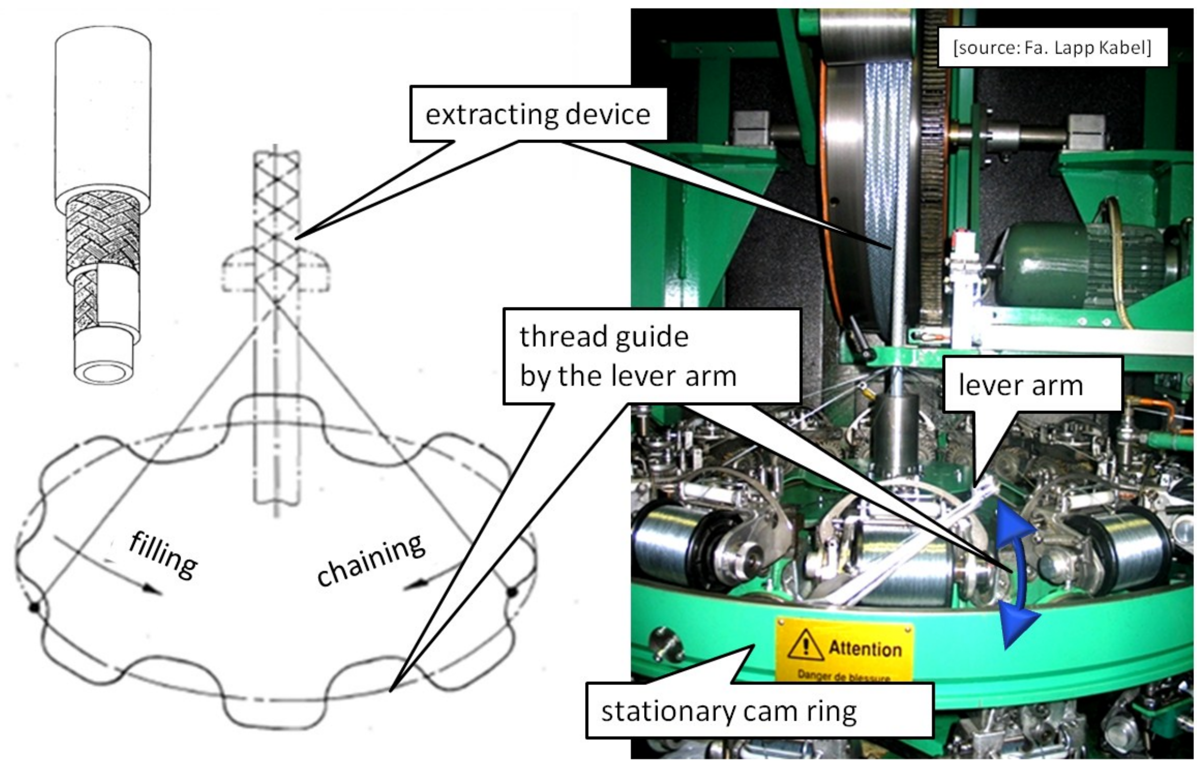

Figure 5: Round braiders which stationary cam ring

To implement a novel drive concept for the laying device, one has to desist from the principle of circular enclosure of the machine by the cam ring. For the processing of the new, nonlinear transmitting device for the laying of the chaining thread, kinematic initial values arise out of the analysis and interpretation of existing general mechanical principle.

To put the nonlinear drive function of the slider-crank after the gripping of the number of revolutions at the stationary bevel gear into effect, multiple options exist. A great nonlinear transmission is producible via the antiparallel-crank that is shown in Figure 6. Due to the required auxiliary gear, a constructive conversion in the highly dynamic range can be eliminated. Therefore the replacement transmission, an elliptic gear pair is chosen as primary gear unit. In the following, the drive concept to lay the chaining thread via a slider-crank and an upstream elliptic gear pairing with the required transmission to pass the “Shed” is dimensioned and designed [4].

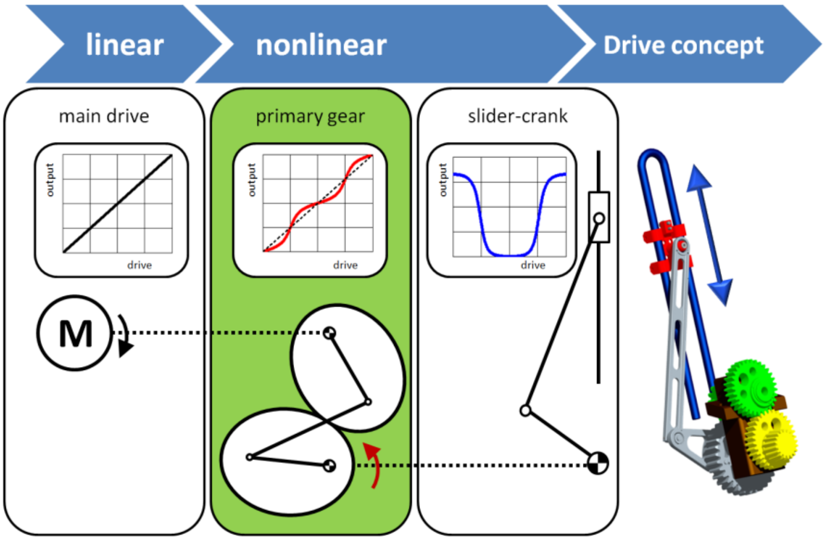

Figure 6: The new drive concept with slider-crank mechanism

6 Linkages and Band mechanism with nonlinear gear ratio – design and analysis in a total system network

The application of band mechanisms offers a wide range of possibilities in designing concepts of modern guide mechanisms. The applied belt pulleys are designed as continuous convex cam disks and allow the application of different transmission functions. Figure 7 shows an example of the application of band mechanisms with cams in sports equipment.

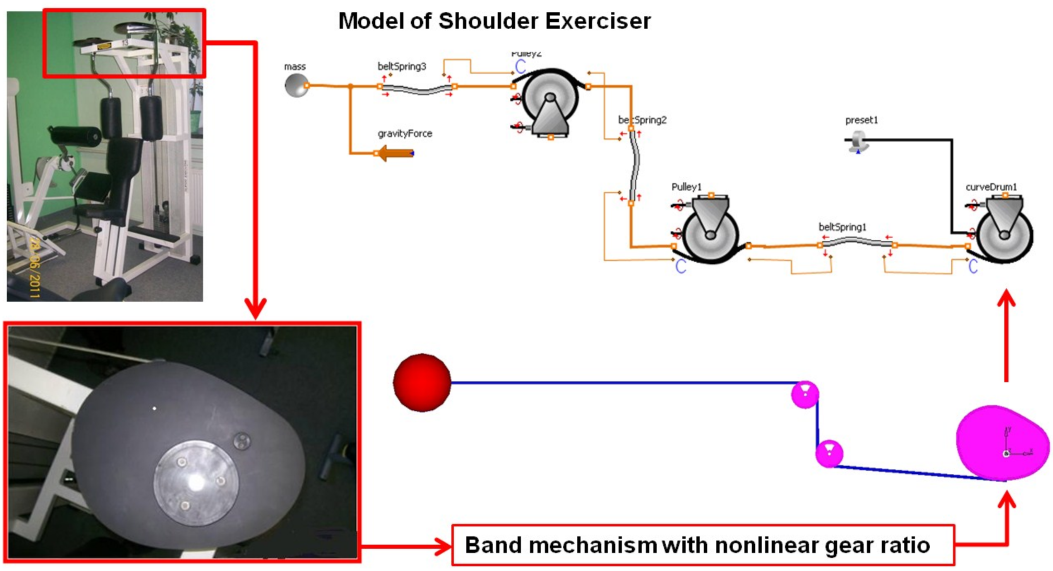

Figure 7: band mechanisms with cams – Shoulder Exerciser

A large number of transmission functions can be generated with convex curve shapes. It takes a great deal of effort to determine the correct pulley curve and is difficult for engineers without special knowledge to calculate. The syntheses process of a nonlinear band mechanism is based on the relationships between the evolute and evolvente. The evolute corresponds to the pulley curve and the evolvente corresponds, for example, to the curve of the fix point of a rocker arm. By applying this method in relation with the reverse kinematics and the maintenance of total band length, allowing to generate band mechanism with a required curve of transmission ratio.

Figure 8 shows the recalculation of a complete balance mechanism with nonlinear curve drum on the linkage crank arm in ITI SimulationX. Simple bidirectional working connections and interfaces allow to model and solve complex dynamic systems with many physical domains like 1D, 2D or 3D mechanics or pneumatics, hydraulics and controls.

The working principle of the new developed belt drive and linkage library is written in user manual of SimulationX [5].

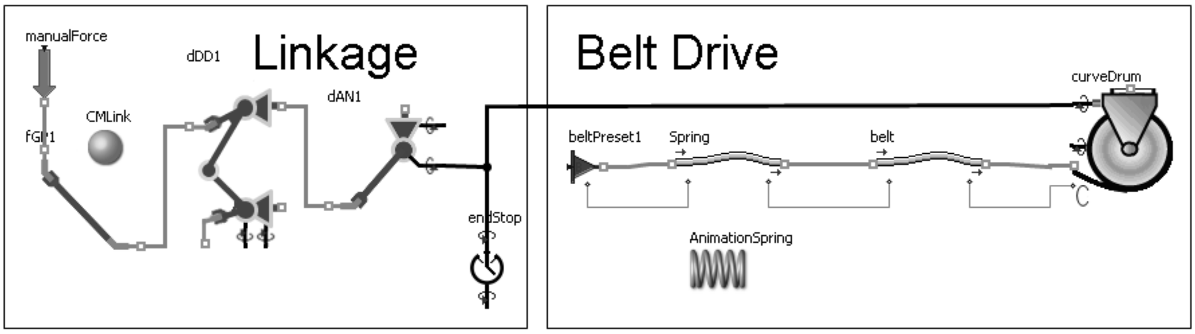

Figure 8: Model of complete recalculation of gravity balance mechanism with linkage gear in SimulationX.

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