INDUSTRIAL ROBOT'S NC AXIS DRIVING SYSTEM OPTIMUM DESIGN USING ADVANCED DESIGN SOFTWARE PACKAGES

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Abstract: Continuing a suite of previously made papers, the present one synthesize main results obtained by the author in the field of optimum designing the full structure of industrial robot's NC axis, by using the Cymex 3.0 software packages. Details about specific software packages used for industrial robot's NC axis design as well included facilities, specific modeling techniques and results are resumed in this paper.

Key words: industrial robots, NC axis optimum design, Cymex 3.0 software package.

1. INTRODUCTION

IR's design is a complex process, which primarily involves synergetic joining knowledge of from many areas, as are: mechanical engineering, driving systems and electronics, manufacturing processes and systems, computer science and processes automation, etc.

However, IR's designing process cannot be considered as following anytime a "single straight-way", in many cases before having a "final product" being necessaries to look for alternative / different technical solutions than initial selected, as well as performing many times (repetitive) calculations in looking for optimizing, the same time, both, IR's partially assemblies design as well as IR's generally assembly design and IR's overall performances. Beside of these, accordingly the specificity of the application, in order to optimize IR's exploiting, different approaches need to be considered and specifically design methodologies developed for "general purpose IR's design" and respectively "specialized IR / modular IR's design".

From all above points of view, two aspects become very important to be permanently and jointly considered for IR's optimum design: "defining the ideal set of components included in each IR's NC axis", as well as, "optimum integration of each NC axis into IR's general assembly design", for both of them solution's evaluation being made by permanently keep looking on both factor's specific influence on "IR's overall design and performances".

From these points of view, in looking for a good strategy for approaching on IR's NC axis and general IR's assembly optimum design [1], first of all a correctly set procedure for evaluation of overall IR's 3D loading as well as reducing of this loads to NC's axis bearing / guiding system's level respectively driving system's level [2, 3] becomes very important.

In the same time, optimum selection of components included in each IR's NC axis become much important, the more than, based on the progress registered in their product's development, the producers are permanently extending their technical offers for new products especially dedicated for IR's design and manufacturing.

Considering both, designer's necessities for having efficient tools in deciding about alternative / different technical solutions as well as reducing the time-consumption in performing repetitive calculations, many manufacturers of mechanical components, driving systems, and control equipment, as well as full integrated assemblies / modules, in order to better promote their products are offering to the potential users different kinds of software packages special dedicated for rapidly selection of one / more specific products suitable to be included in IR's NC axis. However even in case of such advance tools and evaluation procedures availability, the final decision regarding the IR's NC axis optimized structure is still resting in charge of the design engineer.

Because, before starting benefiting from such valuable tools, first step for the design engineer is to understand offered facilities, basic operation procedure, and representative sets of achievable results, continuing a suite of previously papers, the present one is focusing on main advantages resulting from appealing to one of the most advanced software packages usable for (but not limited to) IR's NC axis driving system's optimum design. For this purpose synthetic details regarding main features of the "Cymex3.0" software package [4, 5, 6], have been selected for presenting in this paper.

Complementary details about "Cymex3.0" software's releases, educational / commercial licenses availability, full set of operation procedures, (including too specific training and / or practical demo too if requested), as well as specific features and performances of related range of products may be obtained by directly contacting the authors or consulting Alpha Getriebebau GmbH website.

2. THE CYMEX 3.3 SOFTWARE PACKAGE

In order to provide the best possible support in the use of motor-gearbox combinations, Alpha Getribebau GmbH developed seven years ago as a first gearbox manufacturer the calculation program Cymex (cyber motion explorer). It was the basic request to give a tool to the company's sales engineers and customers, which could support the calculation and optimization of drive systems including all data and procedures.

Originally planned as a product configurator especially for alphas gearboxes, Cymex has reached product status itself today (Fig. 1), being able to supplementary perform calculations like: safety factors regarding shaft strength, determine service lifetime of bearings, check overload situations, considering all inertias and friction effects as well as all geometric mounting scenarios between motor and gearbox. Regarding torque and lateral force, the profiles are used for the calculation of the service lifetime of the bearings and the strength of the flange of the gearbox. Briefly, here all product know-how is available to check the usability of motor and gearbox and their best fitting.

The challenge was to include all these features considering the complexity of gearbox design into a single software product that can be handled by most users without any special training. Seven years of development have made the program an engineering tool with quite a lot of features:

• 6 different linear standard applications including several data import and export possibilities (Fig. 2).

• Each selected application can be defined on two different ways, by switching over light bulb symbol: on the quickness (Fig.3 a,) or in detail (Fig.3 b).

The easy mode is characterized by simplistic input possibilities and diminished variation variety. The most important sign: It can be chosen only between three movement profiles 1/2 rule, 1/3 rule and steady journey.

Parameters like frictional coefficients and efficiencies are predefined in the background. (To find about their specific values it need to only double click on application
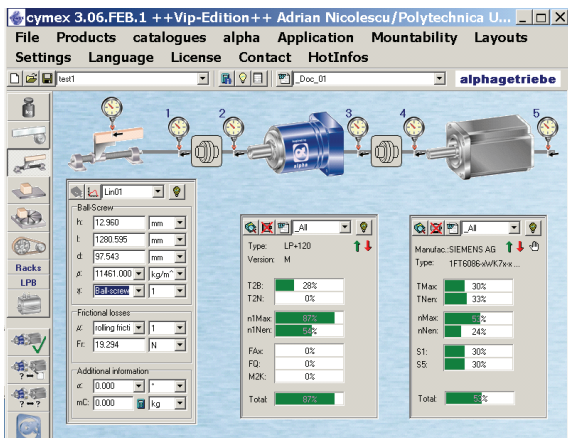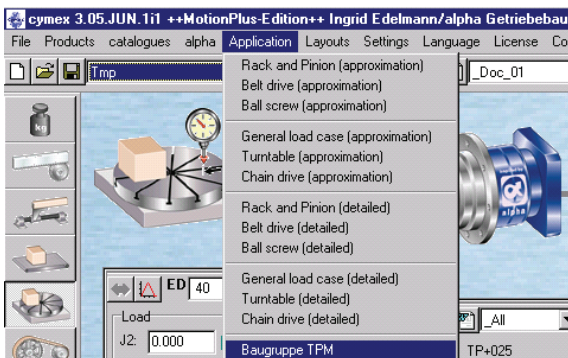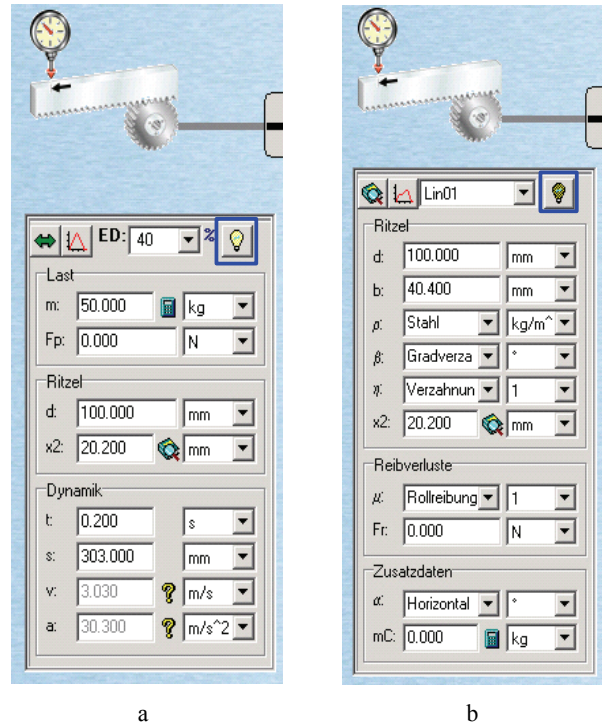

Fig. 3. Procedures for defining application's parameters.

sketch.) Masses as well as from the application being due geometrical parameters are questioned. Under dynamic load two up to four parameters must be defined in each case. Both others are calculated according to the elective movement profile. The question marks highlight the parameters to be calculated. The fields can be exchanged by clicking the question mark and allocation to another parameter for input parameter and arithmetic results. However, the detailed mode requires the input of all relevant parameters to the construction of the application in the above window. Moving loads defined in this mode, are taking into account the motion sequence in the motion profile dependent on time (see below).

• The static and dynamic characteristics of the system can be precisely described by using inertia calculator routine (Fig. 4).

Specific inertia calculator routine allow rapidly performing calculations for any combination of bodies including the mass moment of inertia, the position of the centre of mass, the static mass, specific routines being

Fig. 1. Cymex 3.0 release main window.

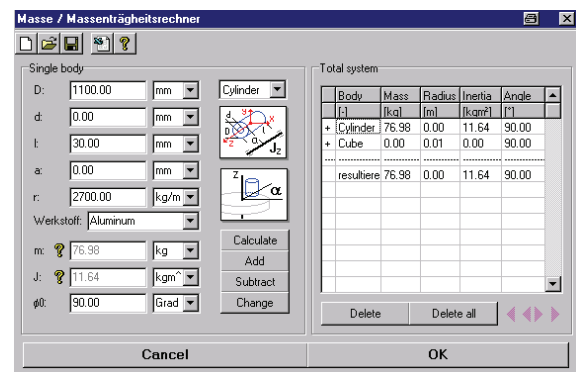Fig. 2. Application's selection window.

Fig. 4. Inertia calculator routine.

provided for determining total mass, resulting position of total mass centre, overall resulting mass moments of inertia, etc. Depending on from which physical data type (mass, mass moment of inertia, distance or angle) the calculator of inertia was started, the calculator will transfer the corresponding result to the input field. Since the calculator of inertia remembers the calculations between its being activated (and between the Cymex starts), all relevant results can be calculated when being activated the first time and been reactivated from somewhere else in the Cymex3.0 program when needed.

• Any type of motion / load profile defined by user can be calculated (Fig. 5) and as well, results of the simulation obtained by appealing to other software packages, (especially the torque, speed and force behavior), can bee loaded directly into Cymex.

For "Time / constant speed" motion profiles, there are two options for defining them in Cymex 3.0 Profiler. 1-st option (ramp) is utilised especially within a motion profile with several segments. This component transfers the exact value of the final speed of its preceding segment of the motion profile (e.g. an acceleration defined as time / speed)
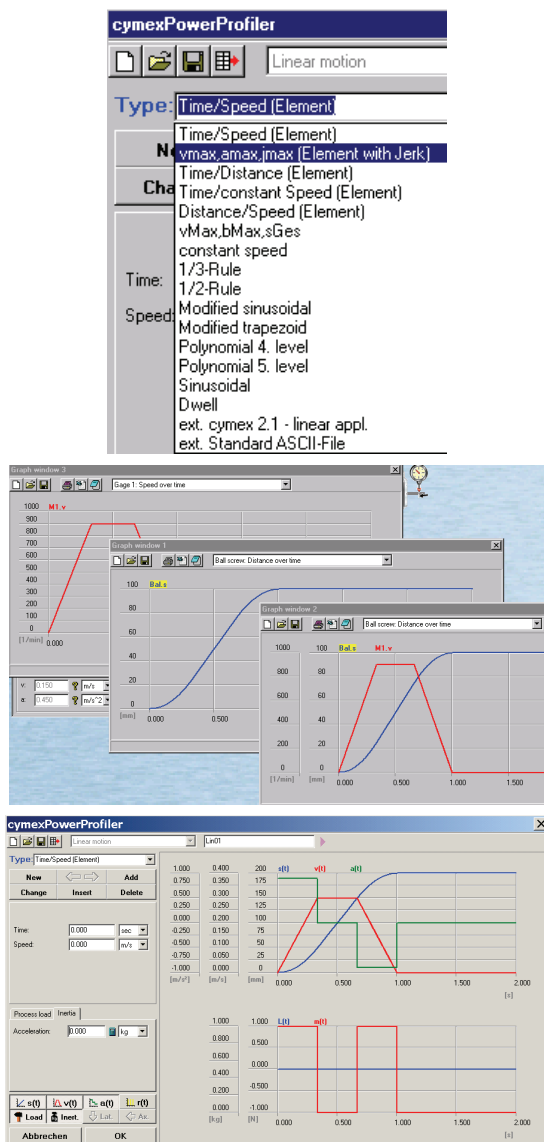
and keeps this value constant during the defined period of time. This is the reason why in Time/Speed (Ramp) option no speed has to be defined, since the speed has been taken dynamically from the previous definition. So there must always be a previous segment in the motion profile to append a period of constant speed to. Cymex 3.0 is able to alter this value dynamically if the speed in this previous segment has changed. This way parametric motion profiles can be generated. 2-nd option for motion profiles generation is used when a motion profile has to be defined by simply segments of different speed regardless the acceleration. In these cases there is no correlation between the different segments of the motion profile as such.

As a special new feature, in combination with the option "Time/constant speed (Element)" in order to form rounded motion profiles, jerk is taken into account in Cymex Profiler. For any "Time/constant speed (Element)" motion profile, the speed (as inserted) defines the final speed of the element, the acceleration defines the maximum acceleration and the jerk defines the constant initial and final jerk of the motion. If the path is too short to achieve the maximum acceleration, the maximum acceleration will be reduced accordingly. If the path is long enough, the profiler will insert a period of constant acceleration. This new feature allows the acceleration to any speed, during the acceleration respectively deceleration phase, path and time being resulting from speed, acceleration and jerk.

For any kind of motion profile (16 available profile types), up to 5 graphic windows at any gage may be parallel opened and combined with each other. By simply dragging the function name of the 1st diagram to the 2nd diagram, the program will generate a 3rd diagram as a combination of the 1st and 2nd diagram (Fig. 5).

• Complex loading behavior are considered by Cymex when calculating / selecting motor & gearbox driving system (Fig. 6), including: static forces resulting from the masses influenced by gravitation. static torques resulting from geometry and eccentric distribution of the mass, dynamic forces resulting from the translation / rotation of eccentric masses, dynamic tilting moments resulting from dynamic forces, dynamic moments of acceleration resulting form the rotary mass moment of inertia, external process torques and forces.
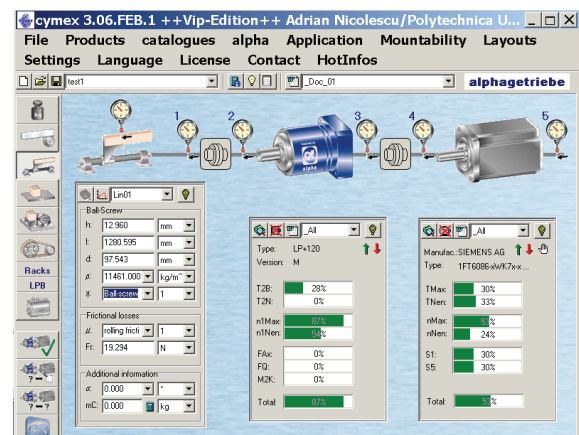

Fig. 5. Motion profile definition routine.

Fig. 6. Driving system's motor & gearbox selection.

The selection of the gearbox also has to consider the inertia of the motor. With regard to the motor shaft, high gearbox ratios cause low torque components coming from the application, but high torque components regarding the motor inertia. Small ratios on the other hand cause big torque component regarding the application but small torque components regarding the motor inertia. The designer has to balance out the optimized ratio in order to minimize the motor torque and the system's blind power:

- in conjunction with calculations, Cymex access intelligent databases for motors and gearboxes (Fig. 7), more than 6 000 data records of 50 manufacturers form the worldwide being considered from biggest available motor data base;
- multicriteria optimization of the designed driving system are available in Cymex, the designer being able to keep all motor-gearbox data in direct access (as Fig. 8 is showing) for automatically on-line adjusting overall NC axis driving system's performances;
- complex reports checking reciprocally compatibility of motor's & gearbox's geometry as well as personalized documentation may be obtained. A CAD generator allows the export of any type of 2D or 3D CAD files for final selected gearbox (Fig. 9).

Fig. 7. Interactive motors / gearboxes databases.
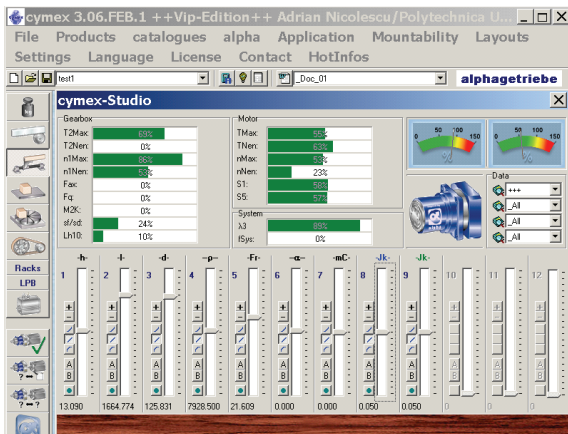

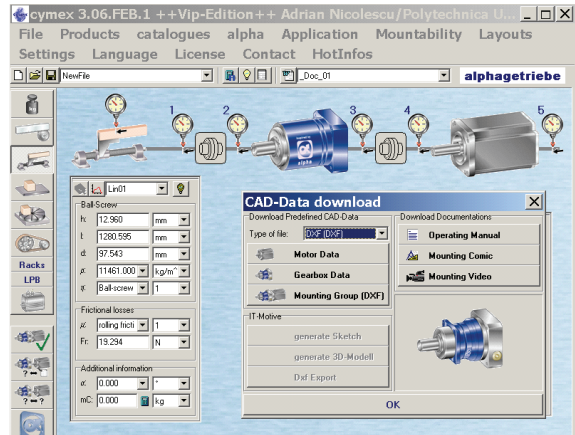**Fig. 8.** Driving system's multi criteria optimization.

Fig. 9. CAD generator for final selected gearbox.

10. CONCLUSION

The experience being made using Cymex as a data transfer and engineering tool, leads to further developments in this environment the more than corresponding know-how may be directly included into customer's simulation software, due to specific data export facilities. It is the basic goal to support customers more and more with special software in order to increase cooperation and partnership. Cymex is the first step into this direction.

REFERENCES

[1] Nicolescu, A.. (2005). *Industrial Robots* (in Romanian), Edit. Didactică şi Pedagogică, ISBN 973-30-1244-0, Bucharest.

[2] Nicolescu, A. (2006). *Optimum design of IR's NC axis – Part 1: General overview on IR's NC axis modern design. 3D load's distribution reducing on NC axis level*, 1st International Conference "Optimization of the Robots and Manipulators" OPTIROB 2006, Romania.

[3] Nicolescu, A. (2006). *Optimum design of IR's NC axis – Part 2: Load's distribution on guiding / bearing and driving systems level*, 1st International Conference "Optimization of the Robots and Manipulators" OPTIROB 2006, Romania.

[4] Gschwendner, P. (2004). *Cymex 3.0 Motion / Motion Plus Compendium Release 3.04.Nov. 1* (in German), Alpha Getriebebau GmbH, Germany.

[5] Gschwendner, P. (2004). *The Cymex Quick Reference (English) Manual Release 3.04.Nov. 1* (in German), Alpha Getriebebau GmbH, Germany.

[6] Gschwendner, P. (2006). *CymexHotInfo – Cymex release: 3.06.APR.1*, Alpha Getriebebau GmbH, Germany.

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