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KNOWLEDGE BASED ENGINEERING AND MODERN CAE FOR SORTING SYSTEMS

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Abstract: *Focusing on modern engineering technologies – as known from automotive sector – the authors will present two promising approaches to straighten (CAD)-development tasks for sorting systems.*
As sorting systems are highly customized products, there are lots of repeating tasks, which steal creativity potential from the design engineer for so called "donkey work". Here the KBE approach is presented as a powerful instrument in the use of system design, without automating every single detail, but interconnecting available parametric models with layout planning. Different views on engineering task automation are made to make accurate biddings in an early design stage. The authors introduce their KBx approach and will bring insights in ongoing research, to handle KBE and KBx tasks with software, using the xKBE-methodology, that brings together data, information and knowledge from various sources in the desired quality at the right stage in the developing process.
To boost sorting capacity the exact knowledge of the physical behaviour of sorting goods is essential. Sorting system development is highly empiric and therefore time consuming and expensive. CAE techniques offer a wide range of parameter variations within a validated model, to search for optimization potentialities such as minimizing the distance between the good, ensuring correct handling anyway. The authors will present a Multibody Simulation of a tilt-tray sorter which is used for improved unloading point design. An overview over CAE techniques complements the paper.

Key words: *Knowledge-based engineering, CAE, Multi Body Simulation, sortation system, tilt tray sorter.*

1. INTRODUCTION

This paper focuses on the Knowledge-based engineering (KBE) method of material handling products. As in other engineering fields this is a widespread technology, the authors try to introduce the benefits of KBE in general and applied to a tilt tray sortation system.

Enlarging the KBE approach to systems where completely automated design is not appropriate leads to two further layers, KBSD (system design) and KBL (layouting). Together, they form a powerful tool to the engineer to deal with nowadays demands on engineering development, driven by cost reductions and time shortcuttings. The authors will illustrate different applications and ideas of KBSD and KBL to a tilt tray sortation system.

Sortation systems play an important role in a wide range of application fields; the reader may consider airport logistics, distribution centers or mail handling systems. Applying CAE to the development of products is a central issue of KBSD as well as analysis of functionality and dependencies among system's parts.

2. CAE IN MODERN ENGINEERING

Introducing a new product on the market today forces industry to combine two controversial aspects: On one hand time to market should be as short as possible on the other hand quality, functionality and personalized variants are keywords in regard to customer's view. This divergence leads to the usage of modern software products for simulation. In modern engineering the definition CAE (Computer Aided Engineering) stands for processes of replacing expensive experiments with results derived from MBS- (Multi-Body-System-), FEM- (Finite Element Method-) or CFD- (Computational Fluid Dynamics-) Simulations. Sometimes CAE is enlarged to CAO (Computer Aided Optimization) by appropriating evolutionary algorithms, neural network techniques etc. to combine analyzing tools with optimization [15].

However, one task is still left in engineer's hand: Building a simulation model which is able to display the right results and interpreting those after simulation process cannot be taken over even by high end software products. These two stages are often called as pre- and post-processing – they are at least as important as the processing (solution of the mathematical model by the solver) itself. At this point, KBE is of particular importance: As described in chapter 3 KBE supports the engineer to apply appropriate knowledge in the process of developing products – including simulation software and knowledge about.

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Table 1

MBS and FEM

Category	MBS	FEM
scope	displacement velocity acceleration, force moment	strain tension
number of bodies	large	small
approach	bodies connected by joints and constraints	finite elements connected by nodes
degree of freedom (DOF)	small to medium	large

MBS, FEM and CFD determine the world of CAE where every domain has its own focus. According to this paper the authors only want to consider the MBS and the FEM part because CFD is of less importance in regard to sortation systems. In table 1 some characteristics of MBS and FEM within the scope of mechanics are shown [15].

MBS is a useful tool simulating many different bodies connected by constraints and joints. Results of a MBS simulation are mainly kinematics, forces and moments where FEM focuses on strain and tension of usually only one body. Some MBS-software-packages can handle flexible bodies as well; however the number of bodies is limited.

Today different simulation-software is offered, the engineer can choose between products primarily specialized in one domain and products providing more applications by simplifying the functionality of one single domain. To avoid problems with interfaces between products (usually companies do not use exclusively MBS, FEM or CFD) some providers of CAD products have integrated MBS, FEM or CFD tools.

3. xKBE AND KBx

The classical KBE approach, automating repetitive tasks with from design experts captured knowledge [7], which forms the powering and steering rules, has been described in different ways. There are papers of application [3, 2] as well as theoretical and general [6] methodologies which nearly focus all the same principal steps [4] and a review in [2, 5]. The main intents to reduce lead engineering and developing time by KBE are always in foreground.

3.1. KBx

Besides general remarks and demands on modern KBE in application and methodological development [5] the authors will introduce their way of view how to classify KBE tasks depending on their degree of automation and overall size of the steered product (a horizontal dimension in table 2 – the KBx approach). Therefore the actual stage and shortcomings have been identified [5]. General literature resources as mentioned and experiences of the authors in generating the solution complement the ideas that have been discussed with many engineering experts from various branches.

To make KBE successful it's necessary, as a key result of literature review, to differ between the various degrees of automation in design work. Design work in material handling is completely different if one has to design a wire-rope drum or if one has to layout a complete storage system. There are tasks more or less predestinated for KBE so that with a determination that reflects this degree of automation the authors will talk about KBx. The manifestations of automated design in KBx will than have a clear database, interconnections and goals for varying applications [2, 3, 10]. Focusing on three successfully realized applications of design automation, and assessing efforts of building automated designs, the authors introduce a way to differ between Knowledge-based:

- Engineering (KBE);
- System Design (KBSD);
- Layouting (KBL);

which have very different scopes of use, functions, powering knowledge and application (table 2).

The sortation system in chapter 4 is a good example, how the domains KBSD and KBL of the KBx approach come together, and where KBE isn't appropriate. With dimensioning the material flow system partly automatically in KBL, all relevant parameters for defining key-components and assemblies are transferred to KBSD. KBL allows to make offerings in a bidding process as accurate and fast as possible, by automated generation of real BOMs. With KBSD one can derive variants of the sorting systems, using different subassemblies with their technical specifications, chosen from a functional way of view, assessing parts and assemblies towards their mechanical functions.

3.2. xKBE; methodological ideas and possible ways of implementation

As well as classifying KBx tasks, the authors introduce a classification or more than that a new way of thinking, how captured and in various sources stored knowledge can merge together, providing the design engineer with somewhat than the right information at the right stage in appropriate quality during the design process. This will lead to enlarging a conventional way of thinking (formalizing captured knowledge in steering rules) towards a richer use of knowledge – the extended-KBE-methodology (vertical dimension in Table 2) (abrev. xKBE).

As Material Handling Equipment Design and Engineering isn't as well equipped with manpower as engineering in automotive and aerospace industry, it isn't astonishing that KBE and all its fields of developing and application are rooted in those branches. KBE-solutions in the material handling world are used, but can only be seen as augmented CAD-KBE (definitions in [2]) with automation of time consuming “donkey-work”.

The by interviews captured knowledge (necessary to develop KBx solutions) [7] in form of best practice, CAD-methodologies and general engineering know-how meets with those from standards, knowledge-databases (like company wikis), supplier data and PLM-databases for CAD. These are the powering sources of data, information and knowledge which are the informal base for development of a KBx-solution. With every material handling design solution driven by the two main parameters throughput and capacity, the various sources of knowledge for KBx can be seen in table 2 as an information basis.

Table 2

KBx defintions and xKBE methodology

size of systems vs. Degree of automation →

KBx

Knowledge-based engineering approaches at differnt detail design levels

depth of knowledge and used tools and techniques ↓

		KBE Knowledge Based Engineering	**KBSD** Knowledge Based System Design	**KBL** Knowledge Based Layouting
traditional KBE	**scope of automated engineering**	components, parts, machines	machines and systems	systems
	functions	full automated (detail) design of parts and subassemblies	full automated master and layout design of assemblies and systems, specification of machinery	full automated layouting of systems, specification of systems
	use for	- customizing machinery - tailored products - product families	- dimensionig motors - defining interfaces - CAD top-down design - CAE models (structural, dyn.)	- space requirements - early cost estimation (bidding) - drafting bill of material
	CAD domain	detail geometry models	reduced geometry for CAE	shrink wrap geometry for layout
	data, information and knowledge sources (beside employee know how and workflows)	- standards, best practice - production facilities - manufacturer data **engineering theory**	- standards, best practice - supplier and engine data **eng. and mechanics theory**	- standards, best practice - manufacturer database - customer rel. management **logistics theory**
		material flow calculation (throughput, capacity)		
	practical applic.	wire rope drum [3]	AS/RS [2]	HRL-tool [11]
xKBE	**2.0 knowledge sources**	web services, online databases, knowledge managment systems		
	2.0 technologies	wikis, semantics		
	practical applic.	tagged standards and technical docs, relation matrices (chapter 4)		

Bringing all those information together makes common known KBE more powerful and better structured for development and maintenance. Retaining on the wide spread expression "KBE" the authors will name the new methodology, bringing together different classes of information, xKBE. This extended KBE is different from Pokojski's [11] one, who sees extension towards early system development and drafting, not as an enriching of empowering underlying knowledge technologies. xKBE can be seen as a way how to and where from recovering information, how to merge it with information from other instances (classes). It's neither a fixed process nor a complete methodology but a way of thinking and bringing information together, to support the design engineer with accurate information at the right stage in the design process. Thus it can be seen as a technical book 2.0 or a Knowledge Management System with connection to engineering. xKBE is now the data, information and knowledge basis and the way how to use it that can power automated design solutions for KBx. Chapter 4 will introduce some demands for a software, how to work with xKBE out of an engineer's way of use and view.

A very first scope of application and powering technologies can be seen in [10]. Various attempts how to realize a xKBE-application are undertaken at the institute, testing CAD-systems to merge with self-developed knowledge databases with graphical user interfaces. This is an ongoing process with first promising results. But the main role of the institute isn't located in developing a new software tool. More it is defining scopes of use and application and categorizing and making accessible the xKBE-methodology empowering knowledge from standards, books and articles, transforming classical books to information and knowledge sources towards a book 2.0.

4. THE SORTATION SYSTEM - CONVEYOR

Sortation systems can be found in various applications: Baggage handling in airports, distribution of parcels, mail order business, etc. The heart of a sortation system is the sorter (Fig. 2), which distributes the goods to their specified accumulation area. Different types are used due to the orders they have to handle: Line sorters, loop sorters or ring sorters.

In general a sortation system is sub-divided in five different parts (Fig. 1):

1: Induction: goods/parcels enter sorting system

2: Preparation: goods/parcels get separated and oriented

3: Identification: scanner identify goods/parcels and read out their destination

4: Sorter: goods are distributed to their allocated output

5: Accumulation area (Discharging): goods leave the sorting system

In this paper the authors focus on the sorter itself, for details of other parts the reader may refer to literature [1].

Distribution centers use a wide range of sorting techniques, this paper outlines the tilt tray sorter (Fig. 2) which allocates goods like parcels by tilting trays towards the specified accumulation area.

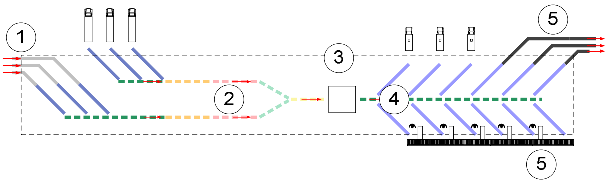


Fig. 1. Sortation system [1].

Fig. 2. Tilt tray sorter [16].

Developing a tilt tray sortation system a few input-parameters are determinant: The required throughput, good specifications (measures, weight, properties, …) and potentially layout constraints. According to the required throughput the sorter's layout has to be designed (number of outputs, number of induction lines, etc.).

The maximum throughput of a sorter is

$$\lambda_{max} = \frac{v_s}{s_{min}}. \tag{1}$$

Smaller distances s_{min} between goods (which mean smaller trays) increase the throughput but decrease the possible parcel size and weight. The reader may notice the important fact that smaller distances between goods force a highly accurate actuating of the tilting mechanism at the output and the behavior of moving goods must be well known (ref. chapter 4.1). Higher sorter speed v_s raises the throughput as well - its limit is determined by centrifugal forces respectively the curve radius [1].

Based on the layout concept the carrier itself has to be designed, where the calculation of required power P plays an important role. The calculation has to consider all resistances and the degree of efficiency; it follows

$$P = \frac{(F_R + F_{Acc}) \cdot v_s}{\eta} \tag{2}$$

with

$$F_R = F_M + F_A + F_E. \tag{3}$$

F_{Acc} accumulates resistances against acceleration (inertia) and F_R against constant movement, sub-divided in different categories:

- Main resistances F_M: Consider inclines and friction (rollers, bearings)
- Additional resistances F_A: Consider turning of sorter modules, resistances caused by induction and unloading of goods
- Extra resistances F_E: Consider resistances of sliding conductors, etc.

The required power can be covered by one or more drives, the correct positioning of more than one leads to significant reduction of conveyor forces (e.g. inner forces in a chain).

4.1. Potentialities with CAE – a MBD-modell for sorting systems

As described in chapter 2, CAE techniques with various commercial and free software-tools offer valuable insights in technical problems, not to be achieved by conventional engineering methods (analytics, empirics, test stands). One of the major advantages of onetime proven CAE-models is that they can be seen as virtual test stands. Therein it's much easier and less expensive to change "parameters" instead of rebuilding complete test stands. Therefore the range of variants for investigation is much broader than in empiric test stand variant building.

Sorting systems, as described in chapter 4, are undertaken this approach here, to optimize size of outputs to optimize system performance up to maximum sorting throughputs around 40.000 sorting operations per hour. With completely different sorting goods and their parameters (load distribution and friction) a safe, secure and appropriate operation of the system must cover all variations of parameters. Therefore building a test stand is the classical way, but doesn't cover as many parameter combinations as the virtual test stand here.

MBD theory – necessary fundamentals. Before building up a MBD-model, independent from the underlying software product, the engineer has to be aware of the principle modelling approaches and functions, how i.e. contact and friction is modelled. As the commercial tool ADAMS is used here [12], basic theory for friction and contact follows.

Friction modelling in 3D solid-solid-contact modelling is different from the common known Coulomb-approach in classical mechanics. ADAMS uses a velocity-dependent friction model to avoid undefined stages at stiction (friction without relative velocity). Therefrom the system of differential and algebraic equations (DAEs) becomes solvable [9] also in stiff stages with standard integrators (friction models see [8]). One appropriate function to model discontinuities in numerical simulation is the so called STEP function as described in (4). Its second derivation is also continuous and therefore appropriate for MBDs.

$$a = h_1 - h_0 \quad und \quad \Delta = \frac{x - x_0}{x_1 - x_0}$$
$$STEP = \left| \begin{array}{ll} h_0 & x \le x_0 \\ h_0 + a\Delta^2 (3 - 2\Delta) & x_0 < x < x_1 \\ h_1 & x \ge x_1 \end{array} \right. \tag{4}$$

The friction function itself is now described as velocity dependent (v_s), keeping in mind that at zero relative velocity there isn't friction.

This is what the analyzing engineer has to keep in mind during postprocessing, to hold stiction and friction transition velocity (v_s and v_d) appropriate to keep sliding friction distance so small, that this slow-sliding equals quasi-stiction.

$$\mu\left(v_{Slip}\right)=\left|\begin{array}{ll} -sign\left(v_{Slip}\right)\cdot\mu_d & \left|v_{Slip}\right|>v_d \\ -STEP\left(\left|v_{Slip}\right|,v_d,\mu_d,v_s,\mu_s\right)\cdot sign\left(v_{Slip}\right) & v_s<\left|v_{Slip}\right|<v_d \\ STEP\left(\left|v_{Slip}\right|,-v_s,\mu_s,v_s,-\mu_s\right) & -v_s<v_{Slip}<v_s \end{array}\right.$$

$$=\left|\begin{array}{ll} -sign\left(v_{Slip}\right)\cdot\mu_d & \left|v_{Slip}\right|>v_d \\ -\left[\mu_d+\left(\mu_s-\mu_d\right)\cdot\left(\frac{\left|v_{Slip}\right|-v_d}{v_s-v_d}\right)^2\cdot\left(3-2\frac{\left|v_{Slip}\right|-v_d}{v_s-v_d}\right)\right]\cdot sign\left(v_{Slip}\right) & v_s<\left|v_{Slip}\right|<v_d \\ \mu_s-2\mu_s\cdot\left(\frac{v_{Slip}+v_s}{2v_s}\right)^2\cdot\left(3-2\frac{v_{Slip}+v_s}{2v_s}\right) & -v_s<v_{Slip}<v_s \end{array}\right. \tag{5}$$

Figure 3 depicts the friction function in ADAMS.

C*ontact modelling with 3D solid-solid-contact* also needs some basic theory outlining in advance. The CONTACT (IMPACT)-function bases on:

- Two approaching bodies can't merge into each other but only penetrate each other, with measuring there relative distance by the gap-funtion g with $g > 0$ in case of penetration.
- Contact normal force F_n is always positive for a force depenetrating both bodies; $F_n > 0$.
- F_n is non-zero only during contact of the bodies $F_n \cdot g = 0$.
- F_n is non-zero only with relative velocity between the bodies equal zero $F_n \cdot dg/dt = 0$.

ADAMS/Solver with its IMPACT-Funktion works according to (6) with remarks in Fig. 4:

$$F_n=k\cdot g^e+STEP\left(g,0,0,d_{\max},c_{\max}\right)\cdot\frac{dg}{dt}$$

$$IMPACT=\left|\begin{array}{ll} Max\left(0,k\left(x_1-x\right)^e-STEP\left(x,x_1-d,c_{\max},x_1,0\right)\cdot\dot{x}\right) & x<x_1 \\ 0 & x\geq x_1 \end{array}\right. \tag{6}$$

Within the IMPACT-function and penetration of body J with I (Fig. 4) the damping achieves its maximum at $p > d$. Stiffness is an exponential function according to penetration with $e > 2.1$ for numerical stability during solving.

The MBD model of a tilt-tray-sorter is depicted in Fig. 5 with a roughly reduced CAD-geometry. It consists of bodies, planar and rotational joints, driving forces and torques and 3D solid-solid-contacts between tray/parcel/output.

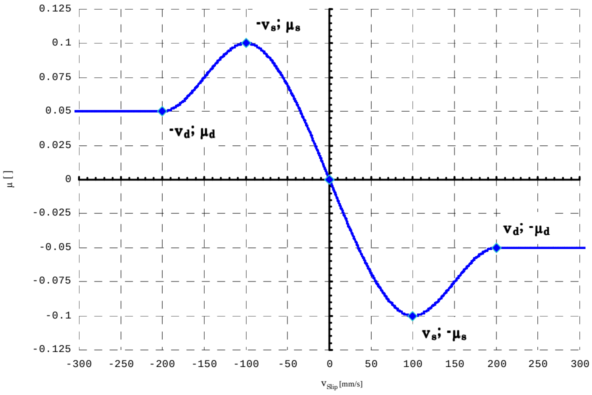


Fig. 3. Friction-velocity dependency of ADAMS FRICTION-function.

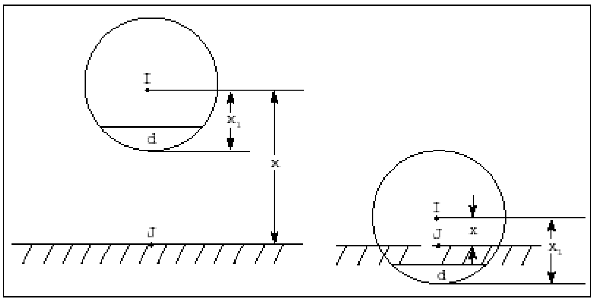


Fig. 4. IMPACT-Funktion (msc.software, 2005).

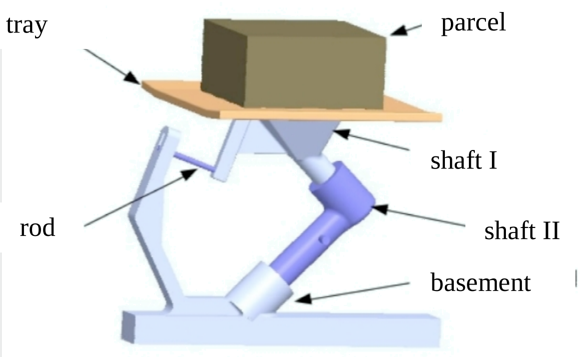


Fig. 5. Reduced CAD-geometry for MBD-model.

The contact between the plane bottom surface of the parcel and sorter tray is difficult to use because the contact-function between two planes and planar surfaces has no unique solution (indifferent placement of contact points). Therefore the parcel got some small contact-edges, modeled in CAD as spherical calottes to declare defined contact points. This is subject to further investigation and improvement, validating modeled and computed contact pints with those measured and observed, but the various variants tried out here (enlarging and replacing those calottes) show very realistic behavior.

Figure 6 shows those four calottes and the four reaction normal forces with friction force components effecting against direction of motion with the parcel sliding towards the accumulation area.

Simulation runs now can be undertaken by variation of relevant parameters. Overall more than 70 different simulation runs were computed with variations of the parameters according to Table 3.

Friction parameters have been investigated by simple sliding of different parcels over an inclined plane. Table 3 shows further that those 70 simulation runs are only a small amount of overall interesting variations, where during this work especially masses (geometry and weight) remained unchanged, because of the underlying theory of non-dependency of friction to geometry and no complete different sliding behavior of lighter and heavier parcels. Details therefore are topics of ongoing research at the institute.

The principal results of the simulation runs are whether the parcel targets the output or not and how large the sliding velocity is, which can be observed by analyzing contact forces and videos as well as the overall amount sliding velocity vector. Figure 7 shows the sliding process with three interesting incidents in form of the parcel contacting the output with reaction forces depicted.

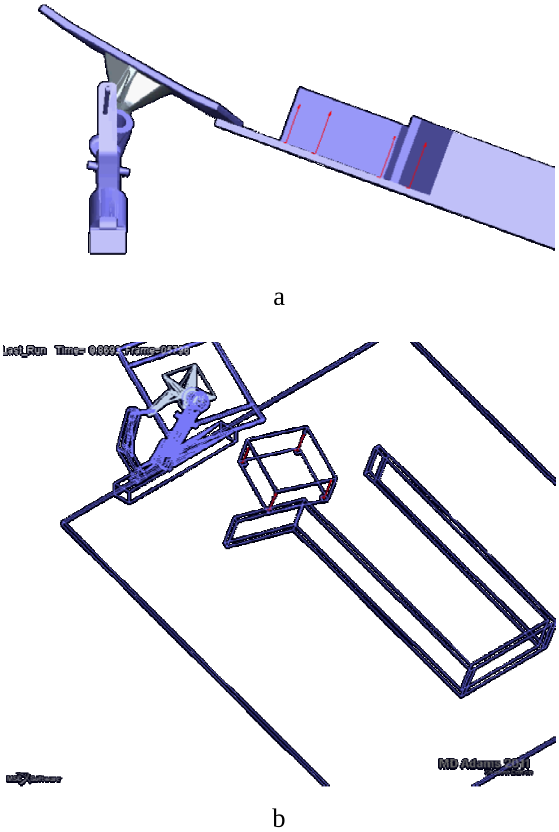


Fig. 6. Virtual test stand (MBD-modell) of a tilt-tray-sorter in MSC ADAMS.

Table 3

Parameters/key findings (grey) of the virtual test stand

	parameter	low	high
dynamics	static friction μ_s	0.1	0.55
	static friction velocity v_s	--	--
	dynamic friction μ_d	0.1	0.35
	dynamic friction velocity v_d	--	--
	tilting speed	37.5 °/s (parabolic acceleration)	
	sorter speed	1.9 m/s	
parcel	mass parcel	2 kg	
	size parcel	500 × 500 × 250 mm	
	position parcel	upper left	lower left
		upper right	lower right
load	mass load	8 kg	
	position load in parcel	upper left	lower left
		upper right	lower right
		middle	
output area	Inclination	20°	
	size opening (width/angle)	1150 mm / 130°	1380 mm / 105°
	speed in output area	0.8 m/s	4.5 m/s

Detailed analysis of contact forces with respect to parcel's strength allows also estimating whether the parcel becomes damaged or not.

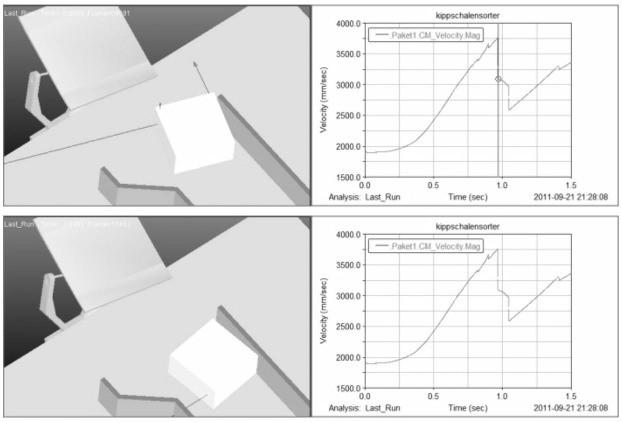


Fig. 7. Parcel sliding process into the output area.

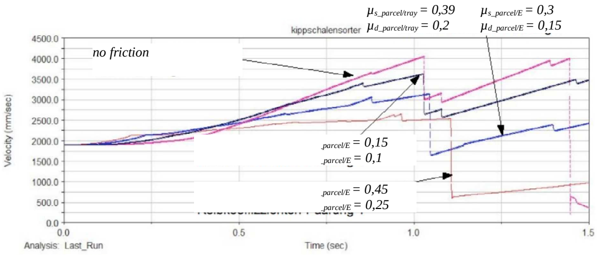


Fig. 8. Velocities at various friction stages.

Figure 8 now shows how the overall amount of sliding speed changes with respect to friction variation and also depicts that with varying friction coefficients, there can be more or less contact incidents than in Fig. 7, effecting parcel's strength. A rule of thumb for contact force size can be seen in the amount of overall sliding velocity decrease in Figs. 7 and 8, with the larger the decrease the larger the contact-force.

MBS of tilt tray sorters offers a wide range for optimization of parcel's and sorter's dynamical behavior. Further investigations at the institute will focus on validation of simulation by building up a test stand with measuring and video capturing devices.

4.2. KBx for sortation systems

Applying the concept of KBx to a tilt tray sortation system the KBE, KBSD and KBL approach are used in different stages of product-development. In regard to a faster and more accurate process of bidding this paper focuses on KBSD and KBL, KBE might be subject of further research.

Analyzing the tilt tray sorter from the view of KBSD, in a first step the functionality of its parts and assemblies have to be outlined and interfaces have to be defined. Different characteristics of one category are classified in Table 4 (non-exhaustive enumeration, arrows show one possible configuration).

Table 4

Morphologic box of a tilt tray sorter

Category	Drive mechanism	Tilt mechanism	Tray	Conveyor
Variants	linear induction	mechanic switch	single	rubber drive belt
	friction wheel	electric drive	double	cardan chain
	chain	free motion		3D-carrier chain

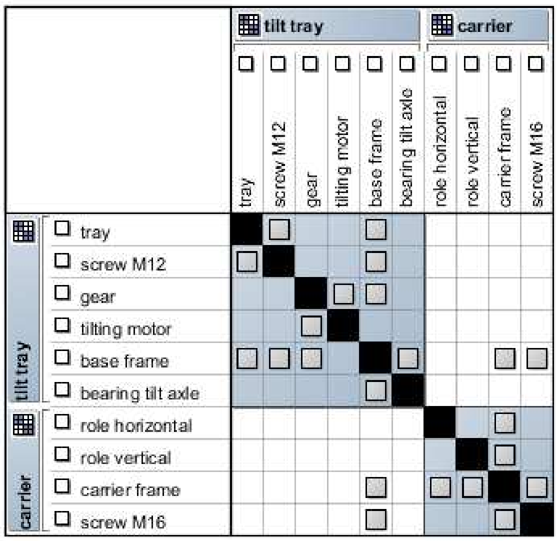
Obviously different combinations are possible which may lead to a completely new system – used in the creativity technique “morphologic box” [13].

In regard to KBSD two additional aspects are considered: Benchmarking between the alternatives within one category and dependencies between all elements of the tilt tray sorter.

Comparing elements within one category by pairs from a special point of view (costs, power efficiency, …) and creating a 2D-Matrix out of these results leads to a clearly laid out benchmarking and can be used in further ratings. Weighting every single benchmarking and accumulating the weighted results is a basis for engineer’s decisions. This approach is derived from a method called value benefit analysis or scoring-model.

Determining the dependencies among elements of the tilt tray sorter gives information about connected or independent parts. To simplify this process, in a first stage the dependencies within one assembly are investigated, afterwards the relations of the whole system have to be determined. Those extracted dependencies are illustrated in matrix form, the so called DSM (Design Structure Matrix). A DSM is a square matrix with the same row and column headings, in this case parts of the assemblies. Its primary purpose is to show relations between elements regarding a certain aspect (in the example below the physical connection between parts of the assembly). Reading a DSM across a row shows the unidirectional relations to all other elements (row-element A influences column-element B, D, etc.). If one part directly influences another part, the related element of the DSM is marked with a square. Assuming a bidirectional relation (A influences B, B influences A) there exist two symmetric entries in the matrix. A useful tool for illustration is offered by University of Cambridge: The Cambridge Advanced Modeller [14]. Figure 9 shows the assemblies tilt tray and carrier in the focus of physical connection between parts.

KBL, the third pillar of KBx, focuses on layout aspects like ascertainment of boundary conditions, appliance of (partly) automated layouting and simulation or calculation of material flow.



		tilt tray						carrier			
		☐ tray	☐ screw M12	☐ gear	☐ tilting motor	☐ base frame	☐ bearing tilt axle	☐ role horizontal	☐ role vertical	☐ carrier frame	☐ screw M16
tilt tray	☐ tray	■	□			□					
	☐ screw M12	□	■			□					
	☐ gear			■	□	□					
	☐ tilting motor			□	■						
	☐ base frame	□	□	□		■	□			□	□
	☐ bearing tilt axle					□	■				
carrier	☐ role horizontal							■		□	
	☐ role vertical								■	□	
	☐ carrier frame					□		□	□	■	□
	☐ screw M16					□				□	■

Fig. 9. Design Structure Matrix (DSM).

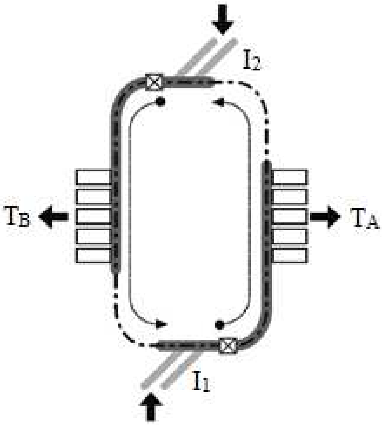


Fig. 10. Loop Sorter.

As introduced in chapter 4, a specified throughput combined with size of orders determines the number of discharging points and induction lines:

- Higher throughput and smaller size of one order (batch) leads to more accumulation areas
- If one induction line cannot cover the demanded throughput a second might be applied (Fig. 10). The reader may notice that two induction lines do not mean a doubled throughput: Due to its specified accumulation area a parcel inducted at I_2 has to be removed at T_A or T_B. Thus at least one place after I_1 (dotted area) must be free if the parcel is tilted out at T_A which decreases the induction potential of I_1. Expecting 50% parcels of I_1 leaving at T_A, λ increases only by 33% [1].
- Different approaches improve the covered throughput: presorting, bypasses, etc.

Sharing this knowledge at the right time in the process of layouting to the engineer is a central issue of KBL. Further the routing of the sorter can be split in modules of lines, curves and inclines/declines, which are connected by defined interfaces. Using the potential of modern CAD software, constraints, control algorithms and automatized modeling support the engineer during the whole process. Proceeding like this, a bill of material for the routing is generated automatically after having finished the layout concept which leads to a fast process of bidding with accurate results.

Since KBL and KBSD are interconnected modules, iterative processing is essential in developing a sortation system: Designing a layout (KBL) influences the mechanical parts and assemblies of the sorter (KBSD) and vice versa (e.g. assuming a specified length of the loop, an appropriate number of drives has to cover the resulting resistances against moving – controversially the conveyor technique may take influence on the layout like maximum values for inclines etc.).

Figure 11 illustrates the process from input data to a sortation system from the view of KBx, where every part has his own focus. Applying this approach to a tilt tray sorter, the authors have shown different methods and techniques to support engineer’s tasks during project work.

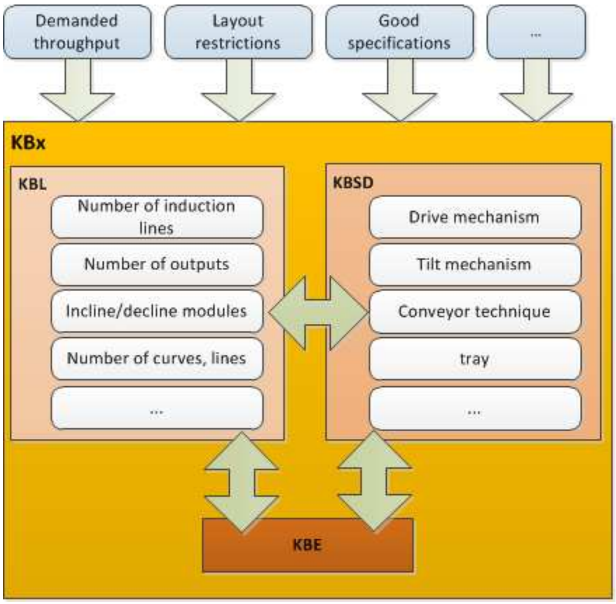


Fig. 11. KBx of a tilt tray sorter.

5. CONCLUSIONS

According to modern requirements in product development the approach of KBx was applied to a tilt tray sorter. Domains like layout and system design of a sorter can be assigned to KBL and KBSD, layers of KBx. The authors want to outline the benefit of simulation software (CAE) combined with knowledge based techniques in early stages of development process. Further research will focus on realizing (partly) automatic layouts, identifying interrelated modules and applying CAD/CAE to more parts of the tilt tray sorter.

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