Methods for efficient use of simulation in logistics engineering

Ass.Prof. DI Dr.techn. Christian Landschützer
Institut für Technische Logistik, TU Graz

Kurzfassung

Simulation von dynamischem Verhalten von Bauteilen und Baugruppen sowie ganzen Maschinen soll im Zuge der Leistungssteigerung auch in der Technischen Logistik Einzug finden. Am Institut für Technische Logistik der TU Graz wurden dazu in den letzten Jahren konsequent Simulationsmodelle mittels MKS und Systemsimulation entwickelt, um Komponenten, Baugruppen, Maschinen und ganze Systeme, wie Kettenzüge, Rollenförderer und Sortieranlagen, für die Möglichkeiten durch Modellbildung und Simulation zugänglich zu machen.
Aufgrund der geringeren Durchdringung des Fachbereiches mit modernen CAE-Werkzeugen als beispielsweise in der Fahrzeugbranche sind einerseits der Nutzen durch Simulation nicht ohne weiteres transportierbar und andererseits die Software-Werkzeuge nicht vorhanden, um für eine Verbreitung der Methode zu sorgen. Dazu werden nun Strategien eingesetzt und entwickelt, um die Erkenntnisse so breit wie möglich in der Branche verfügbar zu machen.
Der vorliegende Beitrag gibt Aufschluss über Methoden und Einsatzbeispiele zur Verbreitung von Simulation und Erkenntnissen daraus an Personen, die nicht a priori mit der Thematik vertraut sind.

Abstract

Simulation of dynamic behaviour of components and assemblies as well as complete machines is only partly established in the field of technical logistics. The Institute of Logistics Engineering at the TU Graz consistently developed simulation models and system simulation in recent years to make simulation accessible to components, subassemblies, machinery and entire systems, such as chain hoists, roller conveyors and sorting systems.
Due to the lower penetration of the field with modern CAE tools as for example in the automotive industry benefits by means of simulation on the one hand are not readily transportable and also the software tools do not exist to ensure dissemination of the method. Certain strategies are now used and developed to make the knowledge from and by simulation available as widely as possible in this industry.
This paper provides information on methods and application examples for the dissemination of simulation and resulting insights to the people not a priori familiar with simulation.

Challenges with simulation

It is without doubts that simulation empowered engineering massively through the last decades and nowadays, gaining for better, safer and more customized products through different worlds of product development.
Nearly all those products have to be distributed and shipped from business to customer (b2c) or business to business (b2b), which is the core topic of logistics. Especially b2c has large increasing volumes with an annual increase of nearly 10% per year over the last years in sending parcels from e-commerce to customers [15]. This increase results mainly from well-known megatrends, especially “individualization”, “demographic change” as well as from “globalization”, “new customer behaviour” and “urbanization”[16].
So it is obvious that logistics needs powerful operating machinery, to fulfil all customer demands and to cover with the large annual increase in throughput. The Institute of logistics engineering (ITL) has a clear vision, to establish well known simulatory approaches (i.e. from automotive and aerospace: MBD, system-simulation, FEA,… - beside those logistic material flow simulatory approaches, which are state-of-the-art here) in logistics product development, to develop safer, more effective and more powerful logistic machinery. Development can be structured into 4 layers: elements and components, assemblies, machines and systems. Each layer in different logistic operation needs adequate engineering approaches and basic modelling work should provide (small [12]) R&D groups of material handling equipment producers with valuable and reusable modelling know-how. As logistic machinery is mostly not newly developed for each project, once simulation libraries are built they can help to customize the machinery for each new project, as the goods that are transported are highly differing (clothes, drugs, food, electronics,…) machinery needs this customization!

Solutions to use simulation techniques within logistics engineering

Simulation in mechanical engineering is (in special branches) widely spread and well known, but there are no overall common view and standard monographs for structuring modelling and solving approaches through different methods and software-tools. Figure 1 therefore tries to differ between abstract signalflow systems and MBD systems in the field of logistics engineering. One main difference between those two worlds is the approach, how models are built. The signalflow system is abstract and reduces bodies to mass-points and needs explicit mathematic description of all describing interacting mechanisms. The MBD approach works with detailed body geometry (although in general the geometry is reduced to point masses) and builds describing equations implicit. Modern tools like SimulationX® try to combine both worlds, but starting modelling one has to proof carefully, which “world” is appropriate.

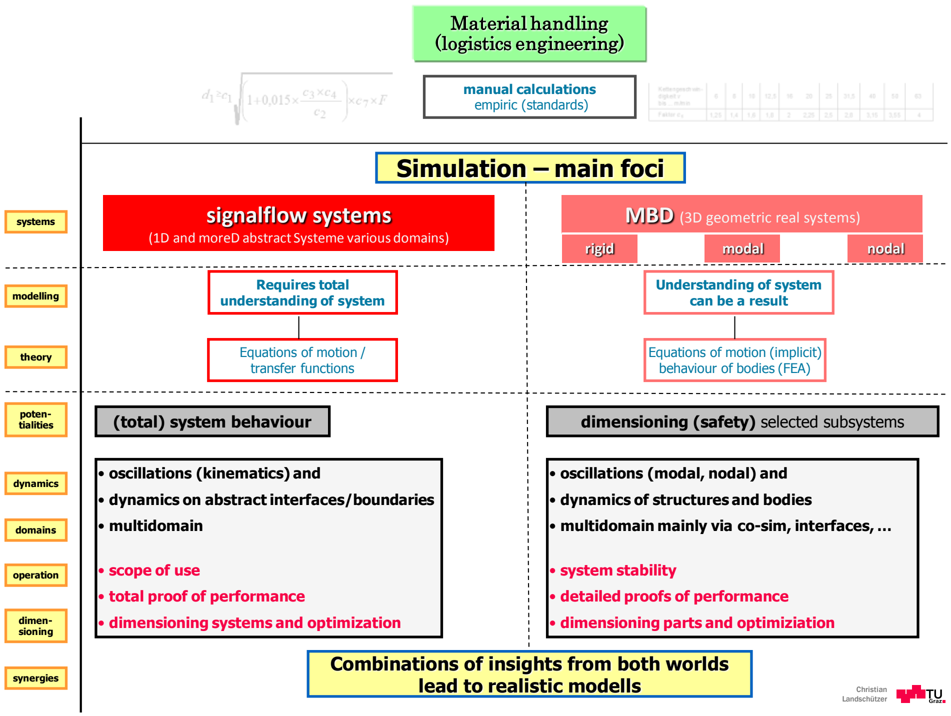

Figure 1: main foci of simulating mechanical structures with abstract signalflow systems and MBD in logistics engineering.

As engineering departments of material handling equipment producers aren't that large than those from automotive and aerospace [12] there are no special simulation engineers managing teams of specialists and libraries of sub-models.

Engineering design and dimensioning in logistics engineering and material handling is widely based on calculation schemes and standards, derived from empiric observations and well established over decades! What simulation con provide here is

1. a broader range of validity with higher accuracy for i.e. all parameters of dimensioning equations.
2. new dimensioning equations using regression analysis in different ways (not only linear regression [17])

If for case 1 governing equations are known in principle (i.e.: y = a x + b or y = c sin(x) + d sin(x) …) one can use several techniques, to search for parameters a and b. This has been done for the exact description of the polygonal effect [2] using the PTC.MathCAD® embedded algorithm "genfit" which bases on a Levenberg-Marquardt approach. This helped to define five different parameters (c, d, …) of a trigonometric function where the result $y(x)$ was available as a simulation result.

If for case 2 governing equations are not known (i.e.: $y = f(x_n)$) by observing single dependencies (like $y = f(x_1)$, $y = f(x_2)$) one can use general regression approaches like linear regression,… that are i.e. implemented in mathematic software like Microsoft EXCEL®. Once one gets an overview how y depends from different x_n (linear, quadratic, trigonometric,…) one can go ahead to formulate the complete function $y = f(x_n)$ as a

combination. What simulation can provide here is as many as necessary different runs for the single dependencies. This has been done for the analytical calculation for resonant chain lengths of chain hoists and maximum dynamic forces [11], [14].
The accordance between analytics and simulation results can be achieved by ordinary least-square methods (OLS) [17].
All those two use-cases lead to better and more accurate analytical standard calculations. If the problem isn't describable by analytics and simulation experts aren't at hand every day, guided-simulations are means to an end. Beside that SimulationX® provides a powerful environment with the "Analyzer Version" this approach can be too deep into simulation belongings anyway. So the ITL has chosen a way to propose and use code-exported SimulationX®-models which are steered by a superstructure very interactive graphical user interface (GUI) programmed in C. This has been presented and published in [1] and Figure 2 summarizes the approach as follows. Within the dynamic problem of breaking insulator strings that are coupled with up to 300 m of conducting wire ropes high dynamic transactions are taking place (the wire rope is a core element of material handling and logistics technology). The remaining, not broken, insulator has to take over all the load that has been carried by two of them before. Therein a SimulationX® invironment (MBD and signalflow for certain strain calculations) has been linked with different approaches to model the oscillating rope (string theory, FEA-models (abstract) – see Figure 2). All those models together have been code-exported from SimulationX® and the GUI configures these codes, starts calculation and presents the main results from simulation. Therefore the user hasn't to be a simulation expert, neither familiar with simulation as he can only modify special parameters like geometries or select between different geometric settings (one C-code each).

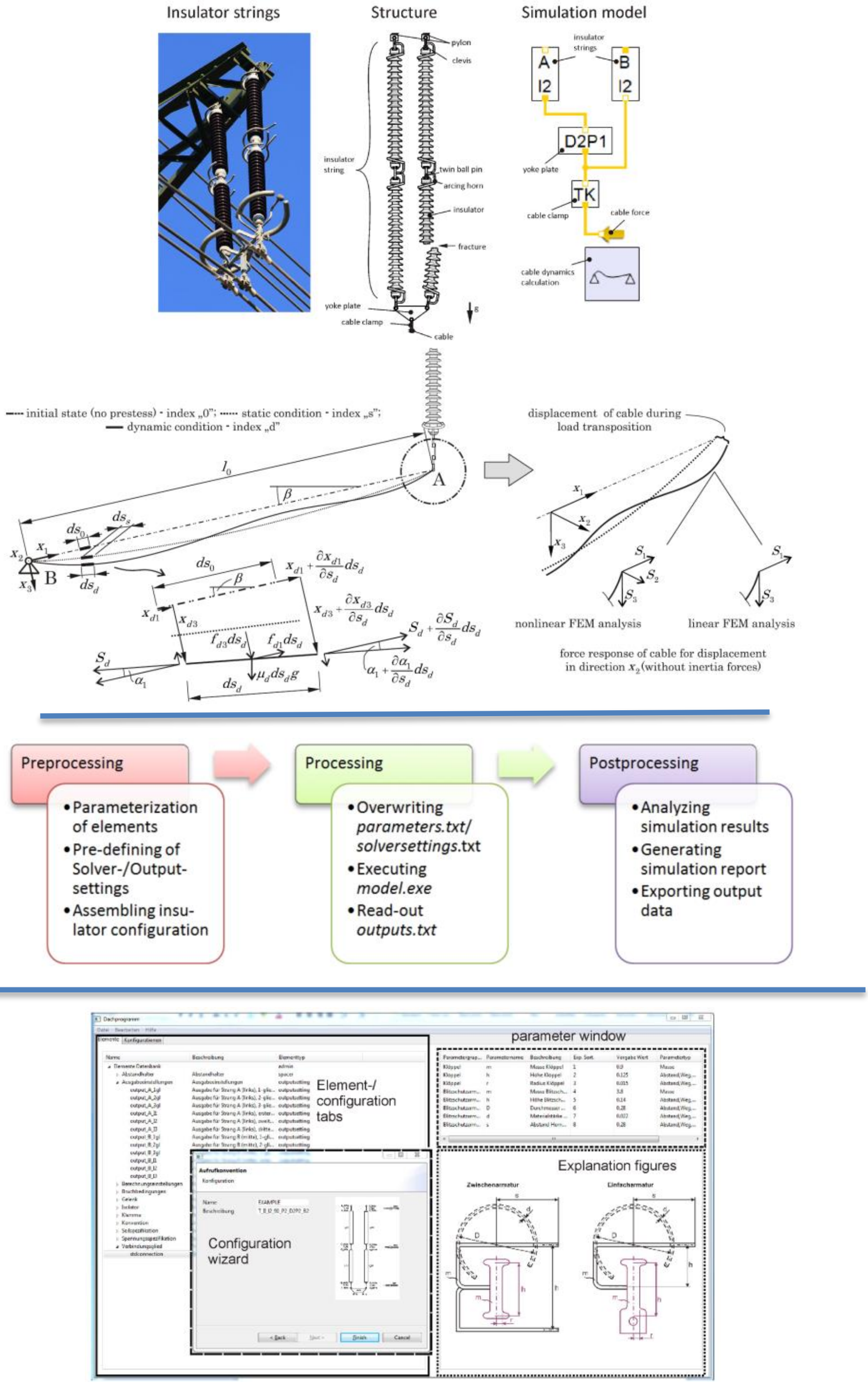

Figure 2: Theory, process and GUI for simulating load transposition effects at overhead conductor lines in form of guided-simulation [1], [3].

Best practice – examples from logistics engineering

As mentioned above much work on chain hoist engineering has been published by the institute. Figure 3 now opposes possibilities with signalflow systems to those with MBD in the field of the chain hoist. The main knowledge transfer takes place by finding the exact position of the links in the sprocket by MBD. It’s a result from acting forces, friction and geometries with 3D-contacts between links and wheel in MBD. This lets formulating a transfer function which can be used in the signalflow overall model which is dependent from the reacting total dynamic chain force.

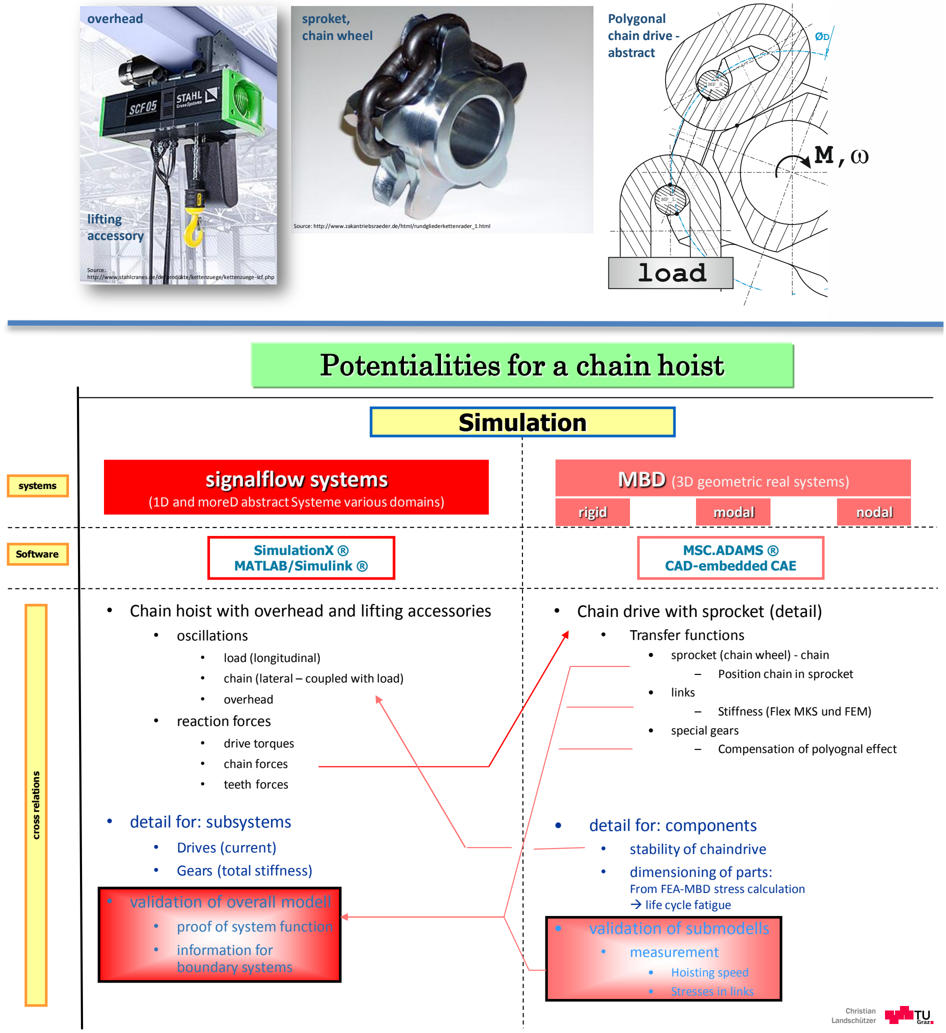

Figure 3: Potentialities with MBD and signalflow simulation for a chain hoist.

Further work in the very broad field of logistics engineering has been done yet. Table 1 gives an overview of all models for logistics engineering, that have been developed in the last years and used and spread successfully. Some models are modelled in signalflow as well as in MBD with interaction like mentioned above for the chain hoist.

Table 1: ITL – Simulation library for logistics engineering

level	model - function principle	simulation approach
basic function	interaction of loading devices with var. conveyors	MBD, flexMBD
	behavior of parcels	MBD, DEM(*) [7]
	Wire ropes	FEM, MBD and signalflow [3]
	(flat)belt drives and belt conveyors	MBD
	chain drives	signalflow and MBD
	tooth belt drives	Signalflow
sub-system	carousel system drive	signalflow [8]
	infeed of parcels on sorters	signalflow and MBD [6], [19]
	discharge of parcels from sorters	MBD [5], [6]
	discharge of loading devices from conveyors (var. principles)	MBD
	AS/RS dynamics	signalflow [4]
	piston compressors for tire repair	MBD, flexMBD [9]
	tilting arm gripper (charge/discharge in AS/RS)	Signalflow [10]
	personal rescue device	signalflow and MBD [18]
	sorter drives	MBD
	sorter dynamic behavior (wheel-rail)	MBD
	crawler drives	MBD, flexMBD
system	chain hoist (with cranes)	signalflow and MBD [13]
	overhead transmission – load transposition	signalflow and MBD

(*)…Discrete Element Method

Conclusion

Using simulation for optimized and safe products is nowadays method of choice. The introduced approaches to spread simulation know-how and its use in non simulation-friendly environment – like logistics engineering – should help to benefit from simulation in all possible fields of its application. The ITL of TU Graz will consistently develop further models for logistics engineering an try to spread them!

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