A case study of Multibody Dynamics Software development process by adopting lead users’ innovations

(With an example of escalator modeling application)

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Summary

One of companies which provide Multibody Dynamics software has continuously taken lead users’ innovative applications and adopted/implemented them into the software for lead users to use them as standard features as Toolkits for their own purposes. Multibody Dynamics software development process is taken in this study for understanding:

1) Lead users’ innovative usages using an existing product in the market,
2) Recognition and selection of lead users by a firm and
3) Adaptation of lead users’ innovations into a commercial product development and improvement.

This paper describes background of Multibody Dynamics which include definition of Multibody Dynamics, complexity of escalator system to the modeling and existing commercial software around the world, and its implementation to escalator system dynamics analysis as an example of lead user’s innovation. This paper also covers two types of developments in Multibody Dynamics modeling process, one from manufacturing sides (or commercial product makers), which is based on the general users or customers’ feedbacks and the other from lead users.

User communities are identified as three types of communities in Multibody Dynamics field, engineering technical conferences, Users’ Conferences and online engineering connection networks. Each type of community has its own characters to attract different types of users, and Users’ Conference is the most powerful community which provides a good playground for lead users not only to share their own studies, activities and tricks but also to complain issues or enhancements to the software developers.
**Background – Multibody dynamics modeling and the analysis of escalator system**

**Definition of Multibody dynamics**

The systematical treatment of the dynamic behavior of interconnected bodies has led to a large number of important multibody formalisms in the field of mechanics. The simplest bodies or elements of a multibody system were treated by Newton (free particle) and Euler (rigid body) (Nikravesh 1988). Basically, the motion of bodies is described by its kinematics behavior. The dynamic behavior results from the equilibrium of applied forces and the rate of change of momentum (Edward J. Haug 1989).

Nowadays, the term ‘multibody mechanisms’ is related to a large number of engineering fields of research, especially in robotics and vehicle dynamics (Ahmed A. Shabana 1998).

Escalator system is one of many applications in multibody dynamics, whose product development requires a lot of design information and dynamic outputs from the Multibody Dynamics simulation model in order to develop the design concept and optimization for reliability and ride quality (Yi-Sug Kwon 1998, 1999).

**Escalator modeling in Multibody dynamics**

One of the most difficult models in multibody dynamics is escalator system which is consist of more than one thousands of step chain links and rollers, several hundreds of steps, customized sprockets and thousands of the dynamic connections for the above rigid bodies (Yi-Sug Kwon 1998, 1999). Sometimes two continuous handrails are also modeled as many discrete rigid bodies connected with the equivalent bushing elements (Yi-Sug Kwon 2005).

The escalator system modeling which needs too many DOF (degree of freedoms) due to many components in it and non-linear contact problems in very high complexity has prevented general multibody dynamics users from building the models in Multibody Dynamics software.
There is a dozen of commercial multibody dynamics software available around the world (John McPhee);
1) ADAMS from MSC, the most widely used in the world,
2) Simpack from SIMPACK,
3) MotionSolve from Hyperworks,
4) Pro-E Mechanism from PTC,
5) Virtual Lab Motion from LMS and
6) RecurDyn from FunctionBay.

None of them could provide perfect capability to model the escalator due to the modeling size and complexity of escalator system. And they had not provided any escalator modeling toolkit which enables users to build the model in faster way until 2010. Therefore the simplified and lower rise escalator models had been built and used for the analyses, which prevented users from analyzing with models in high fidelity and high rise escalator system, and which even took more than 3 weeks of modeling time.
Innovations in Multibody dynamics modeling

Innovations from manufacturing side

For handling multibody dynamics models in many DOFs and high complexity, ADAMS from MSC, which is the most widely used in the world, has provided users an innovative way to build the models using ‘Script Function’ which is coded by C-language or Matlab (MSC) and enables for users to build their models in automatic way. However users have to be experts in C-language or Matlab in order to use the ‘Script Function’, and the debugging is not easy for users because the scripting is in implicit format.

Therefore only few expert users actually use this ‘Script Function’ for building multibody dynamics models in many DOFs and high complexity. The rests of software also provide users the similar innovative techniques to build the multibody dynamics models in many DOFs and high complexity, which have the same issue.

Innovations from lead users

FunctionBay, which is the latest entrant firm (founded in 2000) in this Multibody Dynamics simulation software market with RecurDyn software, has attracted users by offering Toolkits which are optimized for various applications across many industries such as media transport systems, systems with chains, belts and gears and tracked vehicles such as construction and agricultural equipment, as well as military vehicles (FunctionBay).

There has been a Chain Toolkit among Toolkits, which is optimized mainly for building automobile engine timing chain. Using the Chain Toolkit, users can build an automobile engine timing chain model in minutes by providing several standard parameters of link and sprocket or just link type in ISO standard (FunctionBay-1).

As a lead user I modified the Chain Toolkit in order to build escalator system dynamic models in RecurDyn. There were many issues to be resolved due to different dimensions in modeling scale and complexity between automobile engine timing chain model and escalator (10 mm vs. 150 mm in pitch, 10 g vs. 2 kg in link mass, 100 mm and 1000 mm in sprocket diameter, a single guide of 50 mm vs. 100 guides of 5 meter, chain links vs. chain links + rollers + steps, 2-dimension vs. 3-dimension, standard sprocket profile vs. customized profile). After spending several days, I modified the
Chain Toolkit to fit into escalator modeling. With the modified Chain Toolkit, the escalator models in high fidelity and high rise system can be built in hours, which were previously modeled in three weeks.

And other examples of this kind of Toolkit modification by lead users have been observed in different industries; media transport industry, elevator industry and military product industry (FunctionBay).
User communities

User communities are places where users can share their skills, knowledge, ideas and issues related to the Multibody dynamics field. FunctionBay has been looking for lead users in these communities in order to collect any opportunities in her product, RecurDyn.

There exist three types of users’ communities in Multibody Dynamics field;
1) Engineering Technical Conferences,
2) Users’ Conferences and,
3) Online Engineering Connection Networks.

Engineering Technical Conference is a very typical community to share academic level information between scientists and engineers and between engineers annually while Online Engineering Connection Network is to share a little trivial but very practical sticky information between lead users (general users usually do not involve in this network). Users’ Conference is the most powerful community which provides a good playground for lead users not only to share their own studies, activities and tricks but also to complain issues or enhancements to the software developers. At this community, FunctionBay has got huge information benefits from lead users’ own tasks.

Engineering Technical Conferences

There are more than 5 Engineering Technical Conferences related to Multibody Dynamics in North America annually. One of them is International Conference on Multibody Systems, Nonlinear Dynamics, and Control (MSNDC) under ASME, which is professional networking and research exchange across the multibody systems and nonlinear dynamics technical community (ASME). Professionals, professors, students and engineers in Multibody Dynamics area have shared their own problems, the methodologies and the application solutions throughout presenting them. Some beneficial theories, methodologies and solutions are adopted by lead users in different industries.
**Users’ Conferences**

Each software company hosts its own Multibody Dynamics Users’ Conference every year. The Users' Conferences are very good events for lead users not only to share their own studies, activities and tricks but also to complain issues or enhancements to the software developers. Some lead users are rigorously willing to share their own applications which require modification and customization of existing standard features or Toolkits. They tell exactly the software developers how modification and customization of existing standard features or Toolkits do they implement. Some applications are attracting the software developers’ attention, and the developers improve or update the features or Toolkits for lead users to build their own models without modifying and customizing them. One of them is Chain Toolkit case that I introduced at ‘Innovations from lead users’ part, which enables users to model escalator systems just by selecting escalator design parameters (Fig. 5).

**User Community Online Networks**

There exist many online engineering connection networks available on internet. Among them, some are specialized to Multibody Dynamics lead users, whose web sites are mostly provided by the software companies and by schools. At the web sites, users have shared sticky information such as bugs, the debugging techniques, alternative usages of tools and upgrade information of software that they have been using. Users can almost immediately get feedbacks from other users who had the same experiences.
User innovation implementation into Multibody dynamics modeling software

FunctionBay which is the latest entrant firm in this area is very aggressive to increase its market share and revenues (Fig. 1, 2). One of its strategies is to provide users customized Toolkits to save modeling time dramatically and completely to eliminate human errors in modeling (FunctionBay). Interestingly Toolkits of RecurDyn have the same five importance attributes of ‘Toolkits for User Innovation and Custom Design’: (1) It will enable users to carry out complete cycles of trial-and-error learning. (2) It will offer users a solution space that encompasses the designs they want to create. (3) It will be user friendly in the sense of being operable with little specialized training. (4) It will contain libraries of commonly used modules that users can incorporate into custom designs (Eric von Hippel 2005).

When it started its business in 2000, the software, RecurDyn had a few Toolkits available. Now RecurDyn has 23 Toolkits, and each Toolkit does provide users more options in customized formats so users can build their own systems by assigning several parameters (FunctionBay). Actually this strategy exactly satisfies lead users who want to save modeling time dramatically and to eliminate boring and repetitive modeling works but to spend more times on improving the models in higher fidelity. Some customers purchased the software not because of overall quality of the software but because of quality of its Toolkit which does enable users to build their own models in minutes. FunctionBay has developed and added Toolkits one by one by listening lead users’ voices, adopting lead users’ innovations into the software and improving them for users to use it for their own purposes.

FunctionBay has collected lead users’ voices and innovations in several ways; from its Users’ Conference, from internal program test team and from lead users who have used RecurDyn and other software such as ADAMS and Virtual Lab Motion which were dominant products in the market for 2005 or before. Lead users are usually experts in this Multibody Dynamics and willing to publish their outputs in academic and Users’ Conferences so they are easily exposed to FunctionBay’s product development team. The opportunities to FunctionBay are coming from lead users in different formats, which are complaints/requests on lack of functionalities and capabilities of Toolkit for a kind-of-
applications, unexpected usages of Toolkit into new applications (or innovation) and suggestions of new Toolkit developments. Once FunctionBay develops/improves a new Toolkit based on users’ innovation, the beta version Toolkit is provided to the lead users in order to verify the full automation process, efficiency, libraries and user-friendliness, and the final version is released as a new or improved Toolkit in the commercial product, RecurDyn. This interaction process to lead users is an important standard process in the product development road map in FunctionBay. And FunctionBay also has a reward/acknowledgement program in caring lead users, which provides a dozen of lead users the invitations to Users’ Conference and to visit FunctionBay headquarter with air ticket for round-trip and hotel for four days. This implementation process makes lead users rigorously try to new applications using RecurDyn Toolkits and to inform issues and opportunities to FunctionBay. Chain Toolkit for escalator modeling which is an example in this paper was developed and improved from the second opportunity which is unexpected usage of Toolkit into new application and adopted into RecurDyn throughout this interaction process. Belt Toolkit was also developed and improved in the same lead users’ innovative application for elevator system modeling.

This implementation process is a win-win strategy to FunctionBay and lead users. Now, RecurDyn is the only Multibody Dynamics software which provides Toolkits to develop elevator/escalator Multibody Dynamics models and has great market share in elevator/escalator industries. Several other examples in adaption of lead users’ innovations in RecurDyn are also available in Appendix.
Conclusions
This paper reviews a case study of Multibody Dynamics Software development process by adopting lead users’ innovations with an example of escalator modeling application. This paper shows how lead users use existing Toolkits in Multibody Dynamics software, RecurDyn for their own problems and applications, lead users and their innovative applications are recognized and selected by FunctionBay and how FunctionBay implements the lead users’ innovations into her own product, RecurDyn. This paper also shows that the adaptation of lead users’ innovations makes FunctionBay which is the latest entrant firm in this area succeed in this Multibody Dynamics software market with 20 % of market share (Fig. 1, 2) in 2011 and dominate elevator/escalator industries with great market share relatively in short period of time.
References


FunctionBay, http://eng.functionbay.co.kr/

FunctionBay-1, ‘RecurDyn Users’ manual’, 2011


Appendix

RecurDyn Toolkits

1) AutoDesign Toolkit: It was developed for lead users who need R&D Six Sigma with RecurDyn models in order to perform full design optimization in RecurDyn environment. Previously lead users performed this optimization by combining a simple standard DOE study function in RecurDyn environment and Response Surface Analysis/MonteCarlo in other statistics software.

2) Colink Toolkit: It was developed for lead users who have to simulate multi-disciplinary models which have feedback control logics. Previously lead users performed this multi-disciplinary simulation by using Simulink Co-simulation function which is very common feature of all existing Multibody Dynamics software.

3) Belt Toolkit: It has been improved/updated for lead users for elevator industry, who need elevator rope/sheave modeling by setting several parameters related to rope and sheave properties. This is the only Toolkit which can build elevator rope/sheave models in automation process around the world.

4) MTT (Media Transport) 2D/3D Toolkits: These were developed for lead users for elevator industry, who need to build sophisticated models of flexible media being transported by mechanical systems which are copy machines, fax machines and printers. This is the only Toolkit which can build and simulate Media Transport system models in automation process around the world.
Multibody Dynamics Software market and revenue data

Figure 1 FunctionBay Market Share (2000 – 2011) from FunctionBay America

Figure 2 FunctionBay Revenue vs. MBD Software total Revenue (2000 – 2011) from FunctionBay America
RecurDyn Software

Figure 3 RecurDyn main screen

Figure 4 RecurDyn Toolkits captured from FunctionBay America website, http://www.motionport.com/index.aspx?page=RecurDyn-Toolkits
Figure 5 Chain and sprocket GUIs in Chain Toolkit

Figure 6 Escalator chain-sprockets modeling in RecurDyn using Chain Toolkit