STREAMLINING AN ELECTRO-MECHANICAL POWERTRAIN DEVELOPMENT PROCESS

How to keep ahead of the innovation curve, through a streamlined process comprising focused tools integrated into a flexible and empowering eco-system

Discussion paper

HEXAGON | Romax TECHNOLOGY

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Introduction: the growing demands of a growing industry

The need to adhere to market pressures whilst staying competitive in an evolving industry landscape means that companies need to radicalise their design processes in pursuit of nurturing growth and innovation.

As we look ahead, and wonder how things will change over the next ten years, one thing is certain. In order to adapt to whatever comes, engineers need to be fully equipped: with processes and procedures that are flexible and which can cope with constantly evolving demands. That, surely, will be the most effective way to survive our time of change in this challenging market.

This paper makes the case for a modern way of working. It has sprung out of the values that have stood behind Romax for 30 industry-leading years, and the philosophy which has driven our latest software development: Romax Nexus. It is a way of working which is currently giving our customers around the world, and in many industries, a competitive advantage. And we believe it is what will help them to meet the growing demands of our evolving industry.

A market in motion

In the search for innovation within a world of new challenges and high pressures, experience isn't going to cut it any more.

The demands on transmissions are changing. To amplify this challenge, the stakes are high. Ours is a market where one can easily get left behind. Pressures mount on all sides: from the imposition of new and strict government targets (with non-conformers punished by hefty fines) to the demands of customers, who constantly seek the best performance at the lowest cost, and as quickly as possible. If suppliers cannot meet these requirements, their place in the future of the industry is uncertain. If you're not keeping up, you're being left behind. The best place to be is at the helm, leading the industry's pursuit of innovation.

The electric vehicle market is moving very quickly, and even a two month delay, we are told, can be the difference between success or failure of a vehicle. But, whilst they are a very large factor, it is not just the dawn of electric vehicles that is changing the face of the industry. The increase in renewables is keeping the momentum in the wind market, whilst other sectors face tough new targets: aerospace in particular.

Within the automotive realm, other emerging trends also pose challenges, such as autonomous vehicles. Whilst these won't necessitate new layouts, designs or architectures, they will be accompanied by a huge focus on safety and on control, ensuring that vehicles are driven more efficiently than with a human behind the wheel. Thus we will see a move away from the world of mechanical, and even electrical, engineering into electronics. Subsequently, the need for integration and increased collaboration is only going to rise.

Over the next few years, improvements have to be made in areas of financial viability, so that electric vehicles can become the norm. While seeking to contribute towards a more sustainable world, the hard truth of the matter is that, however good the intentions are, they also have to be commercially viable. Environmental sustainability has to be matched with that of the commercial. In order to make the required steps and reach this new future, we have to let go of the old ways of working. Experience isn't all it takes any more; the only option is to innovate, and, to do that, to simulate.

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Successfully innovating in a time of change

Innovation: navigating a new landscape

With the increase in electric vehicles, engineers are having to imbibe a wide new set of skills, overhauling years of knowledge with new physics. The rapidly-moving electrification market is bringing novel systems (the general trend in EV passenger cars is for single speed), often using new gear architectures and running at much higher speeds than traditional transmissions and new vehicle powertrain layouts. Whereas an ICE might operate at 3000 rpm, these speeds might increase to 10-15,000 rpm for electric motors, with some experimental designs going up to 30,000 rpm.

Designers are pushed to get the most power out of the smallest motor size. The general requirement to pack as much power as possible into a smaller space means that EVs bring new packaging considerations. Fewer speeds and fewer gears, fewer components overall in fact, means the gearbox space can be made smaller, giving designers several options to explore: improve handling by redistributing the weight or placing heavier components lower down; increase available space for batteries; or increase passenger compartment room.

Other options are also being explored to allay concerns over vehicle range, such as lightweighting. Whilst there is still extensive use of aluminium and steel, there is an increasing general trend to use less metal. Advancements in this area are mostly led by aerospace, but automotive is following closely behind. As well as increasing range, reductions in weight have a positive impact on a vehicle's overall efficiency. Resin and fibre-based composites are being used for gears and non-structurally critical areas of the housings, as was done with ICEs, where cast iron was used for the outer housing and lighter composite materials used to fill in the blanks.

With efficiency a relatively easy box to tick in terms of EVs, concerns shift to managing the trade-offs these improvements bring, for instance the impact that high speeds have on noise and vibration. Any noise which does exist is no longer masked by a noisy engine, which, in the days of the ICE, veiled a multitude of sins. Of course, there are new and complex issues associated with motors themselves, however, they are generally quieter than the traditional engine. Engineers have to be wary that powertrain noise doesn't stand out as the most annoying sound in an EV. But, as with every aspect of transmission design, investment into NVH and efficiency performance has to be weighed up against cost and development time.

These new environments and layouts, combined with the new challenges they present, lead to a need to innovate and to protect any advancements made. The new, untrodden landscape means you can't always rely on previous expertise to give you the best answer.

What you need to survive: innovation and simulation

In this time of change, innovation is not just desirable, it's a necessity. Innovating among ICEs is a thing of the past. There are of course still areas of refinement to be done in their designs, but the main arena for innovation now is in the realm of EVs. As lots of companies move their investment into this area, everyone is trying out new things, having to work through the obstacle course of existing patents, and then subsequently wanting to protect their own intellectual property.

Successful innovation requires the management of innovation risk. There is no shortage of good ideas, just a shortage of time and money with which to assess their suitability. A CAE-led design approach with the appropriate tools allows you to identify if a proposed innovation is a go or no-go fast, so precious time and resource is not wasted on dead ends.

With the speed required to keep up with the market, you can't afford to build designs, try them out, fully test them, and only then find out whether or not they are good enough. The only way you can really successfully innovate is by pushing the boundaries, exploring the whole design space, and working out where the next design will come from. In short, innovation requires simulation-led design.

Traditional testing simulates designs after they have been made. But modern engineers need to be able to test designs before they're made, testing virtually, through simulation. Expediting the design process gives the option to either get to market quicker and save money, or to spend more time refining and doing trade-offs for better quality design. Though the need to do testing will never disappear, simulation provides the opportunity to create a new, digital testing environment. We need to be able to make crucial decisions without relying on cost- and time-consuming testing. Simulation has to be the primary testing tool for EV development.

Simulation holds many other advantages over testing. It is not the last phase in the process. Rather, it can be used to lead development, in the era of CAE-led design. Mistakes can be made upfront and in the virtual world, leading to less testing and subsequent gains in time and cost. It is easy to go back and make remedial changes to the design to solve any problems that have been caught early. For those still relying on physical testing, making such last minute changes may present engineers with a very difficult decision.

With the increased need to innovate in the EV market, simulation is key – it allows you to start with many experimental designs, to subsequently investigate problems and make sure you choose the best design to take forwards. This increased focus on virtual testing via upfront simulation allows more innovative designs to be explored – more than ever could be explored with reliance on physical testing.

Eventually, testing and simulation come together, to form the digital twin: the ideal concept still a little out of reach for most. The idea involves testing in a real life environment, an environment which you can then apply to a digital model, so you can predict exactly what will happen to the design before any mistakes are made, and understand how the performance changes over time.

Even though this is slightly beyond the reality for most at the moment, an increase in upfront simulation, and steps toward this digital twin, holds the key to innovation.

Demand more from your simulation

Demanding more from simulation

Increased application of simulation, born out of the need to innovate, means that we have to have high standards when it comes to choosing software products. If it is going to be a replacement for any amount of physical testing, then it must be validated and trustworthy. That is the first priority.

However, simulation itself cannot be the end goal. It is not endless graphs or highly advanced analysis which themselves bring about design improvements and innovation, but rather the engineering insight which they lead to, which allows design decisions to be made. It is this part which must happen quickly, in order to deliver innovation.

Since there are lots of people involved in the process of transmission development, and they all have different needs, they require access to software which empowers each of them to innovate. The more specialist the tool, the better, as long as it runs at a usable speed, and as long as it interfaces with the other specialist tools being used in the process. A one-size fits all product will not make the most out of your specialists.

Yes, simulation must, as it always has sought to do, ensure decent time to market, cost and performance, providing the right tools to enable a robust process which will bring quality products to market quickly and cost-effectively. But now, it also has to enable a greater degree of innovation and collaboration, to address the unique needs associated with systems engineering for electrification. The successful innovator needs access to the right tools and methods, backed up by validation and supported by experts.

'No man is an island'

In order to make sure the end product is the result of a thorough exploration of all possible options, and is innovative not for its own sake, but rather in order to achieve the perfect design for the job, many different people will be involved in the process. Together with the pace required to keep on top of this fast-moving market, this requires a great degree of collaboration. The ability to work together with partners, suppliers, and other colleagues working on a different aspect of the same powertrain is of immense importance. There is no benefit to hoarding knowledge or to taking pride in home-grown designs. Rather, expertise should be utilised from anywhere possible, taken advantage of and harnessed to improve your end product.

In new systems, there are many different physics that need investigating, many different specialisms that need exploiting, lots of new questions to ask to ensure a successful end product meets its targets. This is something which tools themselves can help with. But they are not the only story. It is also about the people. You must partner with the right people at the right time, to take advantage of experts, to leverage the best resources and support: finding a quality end product is, we might say, very much a team effort.

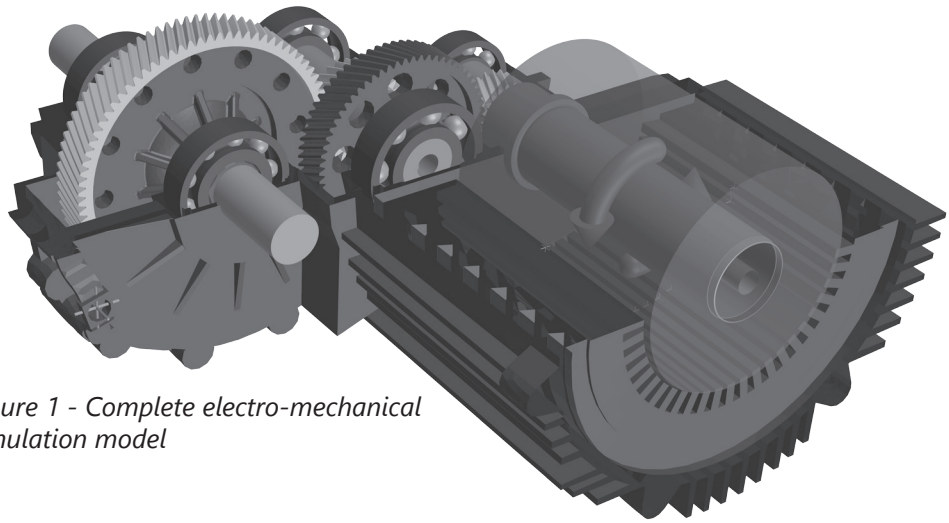


Figure 1 - Complete electro-mechanical simulation model

Proposal: a new approach

The ability to innovate and to manage the risk of innovation, through digital testing and advanced simulation, can be achieved with products which are focused, flexible and integrated - the cornerstones of a successful, adaptable, future-proofed process

Focused
Why should users specialising in concept level design, or bearing root cause analysis, or driveline optimisation for efficiency, be expected to use the same tool? Successful innovation relies on experts, and their tools should do them justice. Generalist tools won't do; they need specific, focused tools which enable them to transform their products.

Flexible
Whilst focus and specialism is key, these products need to slot together within a complete process. This means specific parts of the jigsaw can be adopted to enhance an existing process, or the whole tool suite can be taken on, to acquire a complete new process that could revolutionise development.

Integrated
Spending unnecessary time rebuilding models or re-entering data will stifle a team's ability to innovate. Tools need to integrate tightly, and allow expansion into an open eco-system which embraces sharing of expertise and innovation. Users in all areas of a development process need to share data not only with each other, but across other aspects of the supply chain, integrating with industry-leading programs from using CAD for design work, MBD for advanced dynamic simulation, and detailed component design and optimisation tools.

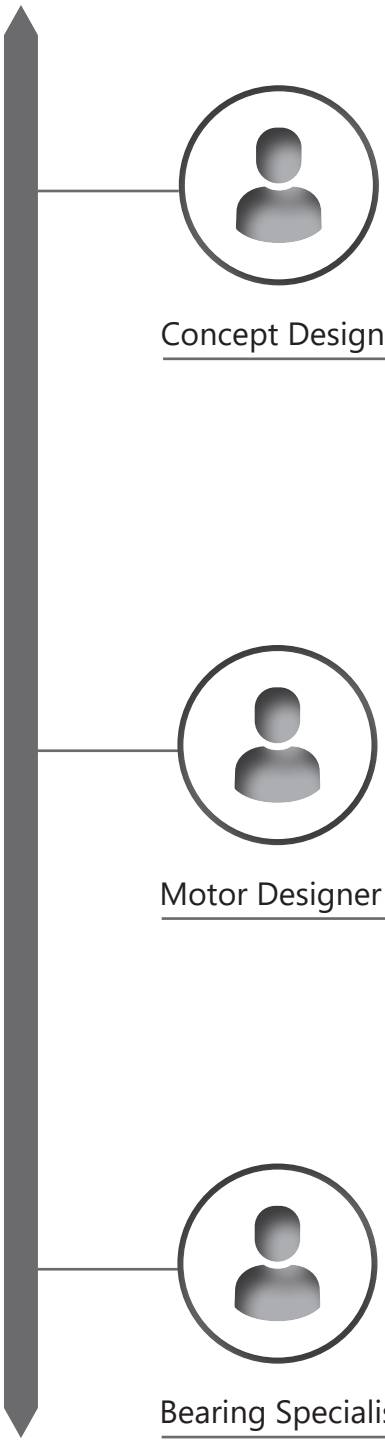
Supported by an expert partner

Behind these products, there needs to be the right support. Easy to find, online self-help materials are important, but also there needs to be further expertise and customer support available when you need it. In short, software partners need to be exactly that – partners, not just providers.

The solution is no "one size fits all"

Satisfying the needs of a complex development process

Within a toolchain comprising so many users, demands vary significantly



- I need to explore many possible layout options to find the right design based on a set of given criteria
- I need a tool which is fast and easy to use so that I can build models quickly, with an interface to CAD to avoid rebuilding existing models
- I need to quickly assess each design's performance in terms of durability, efficiency, NVH, packaging, weight and cost, so I can make confident engineering decisions
- I need to have a good idea of recommendations for gear design and bearing selection at an early stage
- I need to pass the best design forward to other colleagues, for more detailed refinement

- I need to quickly build and refine a complete model of an electric machine
- I need to analyse its structural performance, including identifying motor NVH problems
- I need to link to third party structural and electromagnetic tools
- I need to be able to pass my motor design to colleagues working at the system level

- I need to select optimal bearings for my system, from up to date bearing supplier catalogues
- I need to avoid premature bearing failures
- I need to perform advanced rolling element bearing simulation as part of a full electro-mechanical system
- I need to collaborate with bearing suppliers, but not be reliant on them
- I design custom bearings for clients - I need to analyse their behaviour in a full system, and want to share that with my customers, but I need to protect my IP
- I need a software tool which will provide insight - accurate results are not enough on their own, I need to be able to make improvements

- I need to confidently design lightweight and durable systems
- I need to minimise prototyping and testing to minimise overall product and manufacturing costs
- I need to quickly build a full system model, bringing in parts from CAD, where they exist already
- I need to use a CAE-led design process, with automatable analyses using realistic drive cycles
- I need to optimise my system for durability whilst balancing its performance in efficiency and NVH
- I need clear, easy to interpret results for certification
- I need a system level solution but with advanced capability at a component level, for gear and bearing design

Durability Engineer

- I need to understand a design's dynamic performance
- I need to confidently make design decisions based on simulation that I trust, and understand the effects of variability on NVH performance
- I have lots of new noise challenges associated with EVs - I need specialist tools and experts on hand to provide support
- I need to consider NVH performance right from the start, to prevent problems before they arise and reduce the need for prototyping
- I need to use tools that form part of an integrated workflow for simulation efficiency
- I need to understand powertrain sound quality from the end-user's perspective

NVH Analyst

- I need to meet tough industry challenges presented by industry bodies
- I need to select the right oil for my system
- I need to predict energy losses, CO_2 and fuel consumption using realistic drive cycle data
- I need to access efficiency maps
- I need to rapidly investigate efficiency of gears and bearings and update designs to improve performance, whilst balancing other criteria

Efficiency Expert

The Romax solution: integrated, flexible, focused

The Romax solution

Focused products which align with the development cycle

First in the development process is Romax Concept, which enables rapid and intuitive exploration of drivetrain ideas using easy drag-and-drop modelling, with fast analysis and optimisation methods. Aimed at early design stage engineers, it is also meant to be easy enough for occasional users to pick up and use when required.

After a model is selected to take through from the concept stage, it can be opened in one of the more advanced products (or models can be built from scratch in these environments if needed). There is Romax Enduro, which enables drivetrain designers and analysts to perform structural and durability analysis and optimisation; Romax Spectrum, aimed at allowing NVH analysts and engineers to perform full system NVH simulation from gear and electric machine design through to vehicle sound quality, and; Romax Energy, for global efficiency prediction of transmissions and drivetrains. Romax Spin builds on Romax's initial foundations, providing advanced simulation of rolling element bearings for bearing designers and analysts. And finally, a brand new product, Romax Evolve, provides electro-mechanical analysis for electrical machine designers.

Integrated within a flexible product platform: Romax Nexus

These user-focused tools are designed to slot into development processes to befit a modern, collaborative environment. All of the products work independently or together, so can be used by the same person or by separate users, enabling a level of flexibility that just hasn't been possible before. The products use a common file format to enable easy exchange of data. This flexibility promotes a highly collaborative environment and allows the technology to be deployed more widely across an organisation, to maximise investment in the software. A single user can use several products, or different users and departments can use different products specific to their needs, but easily share and exchange data, models and results. Romax Nexus products are thus broadly applicable and customisable.

Part of something much bigger

This flexible suite of focused products offers collaboration through integration with third party programs, ensuring our users get the most out of the partnerships which we foster through our academic, research and software eco-system. This includes a wide variety of interfaces to popular partner products, so that the Romax Nexus platform can sit at the heart of your development process.

Romax concept

Rapid and intuitive exploration of drivetrain ideas to enhance the early product development process

Romax enduro

Trusted structural simulation and optimisation for the design of durable and robust electro-mechanical drive systems

Romax spectrum

Full system NVH simulation from gear and electric machine design through to vehicle sound quality

Romax energy

A global efficiency prediction tool for drivetrains and transmissions

Romax spin

Advanced simulation of rolling element bearings for bearing designers and application engineers

Romax evolve

Electro-mechanical analysis tool for electrical machine designers

Conclusion

The new era of electric vehicles, autonomous driving and renewable energy is a substantial challenge to the drivetrain engineer. Innovation is no longer just desirable. It is crucial to stay ahead of the curve, remain commercially competitive, and avoid fines and charges. In order to innovate, transmission designers need to access focused, specialised tools, to enable them to pinpoint specific improvements and truly understand their impact on performance. These tools need to be integrated, in order to break down boundaries between departments, between companies, and to really harness all possible expertise.

It is these industry needs to collaborate and to innovate which have really been the driver for Romax Technology's reimagined software offering: Romax Nexus, an integrated environment of products designed to suit specific users and their workflows, aligning with the drivetrain and transmission development cycle, from rapid modelling and concept exploration to detailed simulation and virtual product sign-off. Our software suite offers a complete solution, for a complete system, across the complete development process, but within easily segmented products designed around specific workflows.

Innovation relies on the ability to explore new designs and take them to production level quickly and efficiently, in order to keep ahead of the curve. In other words, it requires the provision of engineering insight with speed and accuracy, qualities which we've proved time and time again through third party validation. Now our customers can do this in a highly focused, flexible and collaborative environment. It is a new way of working which will enable customers to meet the demands of our ever-growing industry.

The future of innovation is going to be reliant on breaking down siloes. Romax Nexus offers that, with a workflow and attribute-oriented suite of products blending together desktop and cloud technologies. Through its flexibility and its integration, Romax Nexus empowers its users to collaborate and innovate.

Romax have always found value, for us and our customers, in creating an ecosystem of partners throughout industry, academia and research. Our customers benefit immediately from the subsequent

interfaces and workflows with gold-standard third party products which our software enables. Beyond that, they benefit indirectly from the wealth of additional expertise and knowledge which our partnerships bring. By working together, and harnessing the best expertise to create a complete solution, we can work towards a better future. We approach our customer relationships in the same way: being merely a software vendor is of limited value to both parties. By building strong partnerships and working with our customers, we have a much better understanding of the industry and can provide more valuable, more relevant tools.

At Romax, we've been pushing the industry forward for decades, and Romax Nexus offers all of the pioneering component and system level driveline simulation technology which Romax are well known for. It enables our customers to engineer the next generation of drivelines, to meet pressures whilst maintaining sustainability, commercially and environmentally.
It facilitates the systems engineering required for robust development of the next generation of electro-mechanical drivelines. Intelligently integrated into the wider CAE world, Romax Nexus empowers your teams and enables Right First Time design.

About Romax Technology

Romax Nexus is founded on Romax's well-known expertise, our proven experience in automotive, wind, and aerospace, and the major role which we have played to help automotive customers, including major OEMs, to make the move to electrification.

With 250 employees serving 220 customers worldwide, Romax is based in Nottingham, UK and operates 12 offices in Europe, the USA, Korea, Japan, China and India. A world-class engineering technology and services company, we help our customers to solve the pressing business issues they face, particularly in reducing development time and costs, better supporting operations and delivering a more sustainable future.

We are constantly developing our technology and approaches by engaging in collaborative R&D that involves many of the world's equipment manufacturers and suppliers alongside academic and government organisations.

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For more information email enquiries@romaxtech.com
or call +44 (0) 115 951 8800

www.romaxtech.com

Romax Technology Limited, Romax Technology Centre, University of Nottingham Innovation Park,
Triumph Road, Nottingham NG7 2TU

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