transmission TECHNOLOGY INTERNATIONAL

AN **ENGINE + POWERTRAIN** TECHNOLOGY INTERNATIONAL PUBLICATION | 2021

LIGHT WORK

Exploring the ultra-lightweight titanium 8-speed collaboratively developed by Rodin Cars, Ricardo and 3D Systems that is leading the way in state-of-the-art additive manufacturing techniques

OEM INTERVIEW

Andreas Buchner, the man heading the EV push at BMW, discusses the evolving role of transmission engineers

TRIBOLOGY

Industry experts debate the fast-changing demands placed on oils and lubricants by drivetrain electrification

TESTING FOCUS

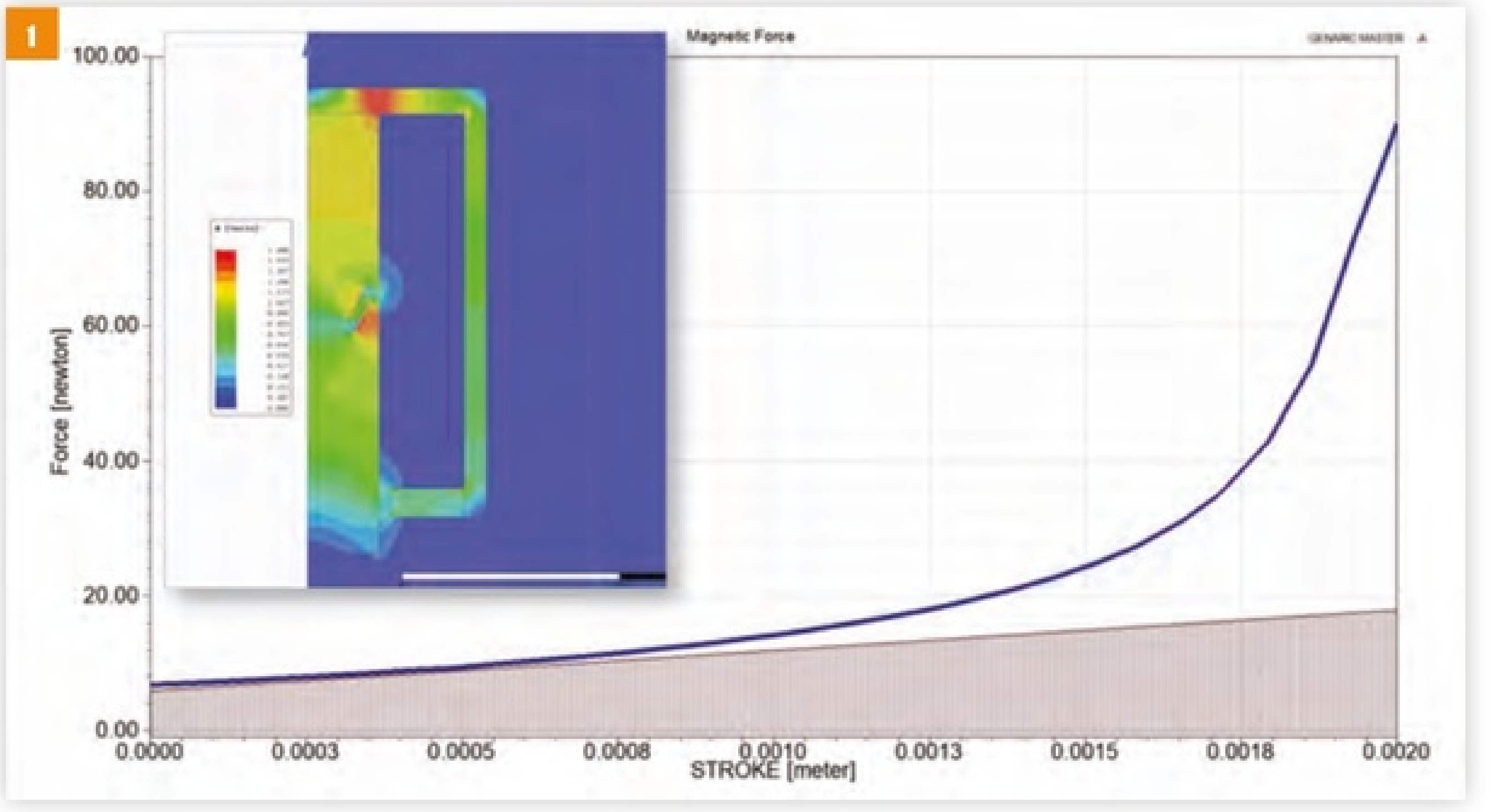
How breakthrough analysis and validation technology is changing system development

www.enginetechnologyinternational.com

engine + POWERTRAIN technology international

Energy efficiency

The peak-and-hold control strategy can be leveraged to mitigate the inherent inefficiencies of electromagnetic solenoids and thus optimize power consumption



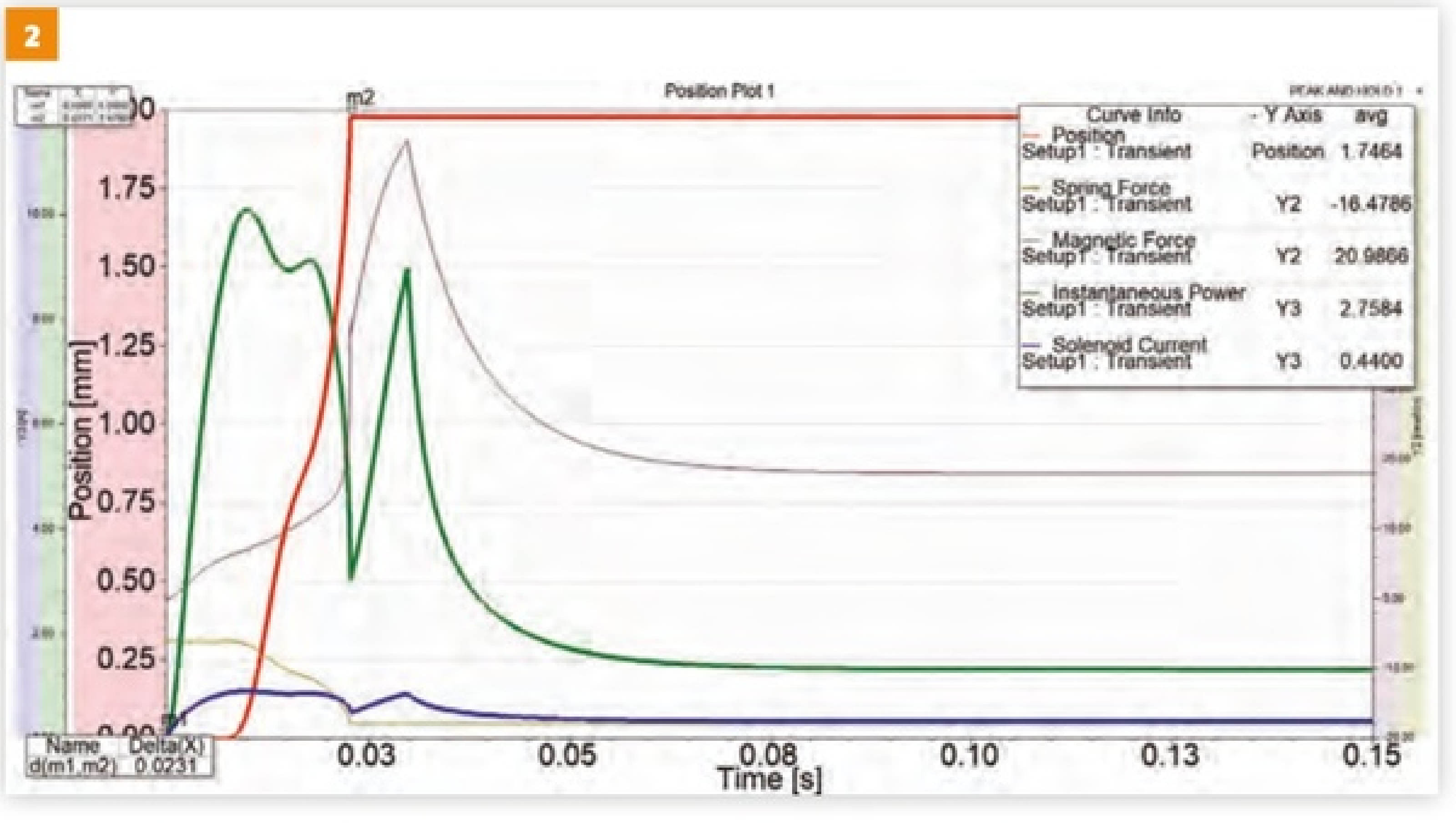
The continued push for electrification, as well as the adoption of alternative energy sources, is transforming system and component design in all types of vehicles. In the search for advanced battery technologies and more intelligent energy usage, the systems and components under development that will meet the challenges of current and future vehicle platforms will require efficient use of every joule of energy.

While solenoids and solenoid valves are proven, long-standing staples in converting electrical energy to work, one of the key characteristics that often gets lost in the specification details is the force versus position curve of the linear electromagnetic actuator. As the solenoid plunger moves closer and closer to the pole of the solenoid, force increases exponentially. For example, if a solenoid needs to compress a spring 2mm from a preload height and hold it there for 150ms, the preload is 6N and the spring's rate is 6N/mm. This would mean that 0.024Nm of works need to be performed (W=F×d). This is convenient since, in the context of units of work, the Newton meter is equal to the joule.

As can be seen from the force curve (Figure 1), there is just enough force to get the job done over the first millimeter of travel. Over the second millimeter of travel, the force becomes significantly higher than necessary, making it seem like this solenoid is inefficient in this application. In fact, the solenoid outputs 0.42J of work, almost double what is needed. The transient simulation of the actuation cycle reveals a compounding of this inefficiency because the position must be held (offer hold force without providing additional work) for an additional period. In all, 1.64J of energy are used during the 150ms cycle to do 0.024J of work.

1. As the plunger moves closer to the pole, the level of force required increases exponentially

2. Peak-and-hold control strategy simulation. This shows that significant gains in efficiency can be made by selecting the right control strategy



CONTROL STRATEGY

This inefficiency is simply the way electromagnetic force works. However, this waste can be mitigated by designing an appropriate control strategy for the solenoid valve. This is commonly known as peak-and-hold. Since 90N of force is achieved at the full stroke of the solenoid, the input voltage for the hold cycle can be reduced. Looking at the transient model of the solenoid (Figure 2), the spring is compressed and full stroke is reached within 22ms. This means that in the initial simulation, 1.22J are spent just holding the solenoid in place.

With a peak-and-hold control strategy, the hold voltage can be reduced to 4V or 33% of the voltage needed to accomplish the initial actuation and still accomplish the task of holding the spring compressed. For this example, 12V is provided for 30ms to accomplish the initial pull-in. The voltage is then dropped to 4V DC for the remainder of the 150ms cycle. Shown by the instantaneous power trace (green) in the transient model (Figure 2), the energy used is more closely matched to the energy needed to complete the task. The net result is a total energy consumption of just 0.41J – a 75% improvement.

The peak-and-hold control strategy is an ideal solution to mitigate the inherent inefficiencies of electromagnetic solenoids, allowing the same solenoid to do the same amount of work using far less energy. In addition, this is a great reminder for manufacturers to look beyond the specifications to leverage historic or current technologies in new ways to meet critical goals such as making gains in energy efficiency. ⦿