Designs on expertise

Become an expert in automated virtual engine design

by Adam Green & Dermot Mackey

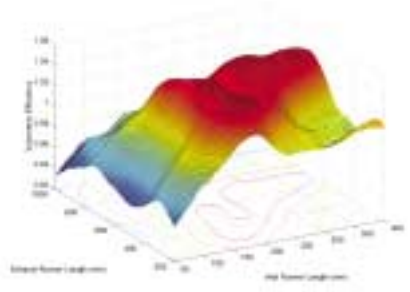


Figure 1: The image shows a clear response surface for a two variable optimization setup

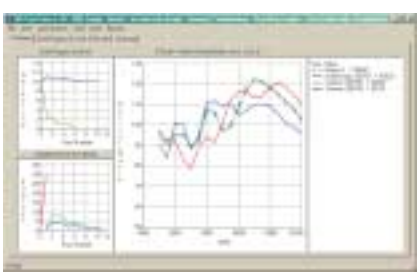


Figure 2: Status windows allow engineers to monitor the progress of automated engine designs

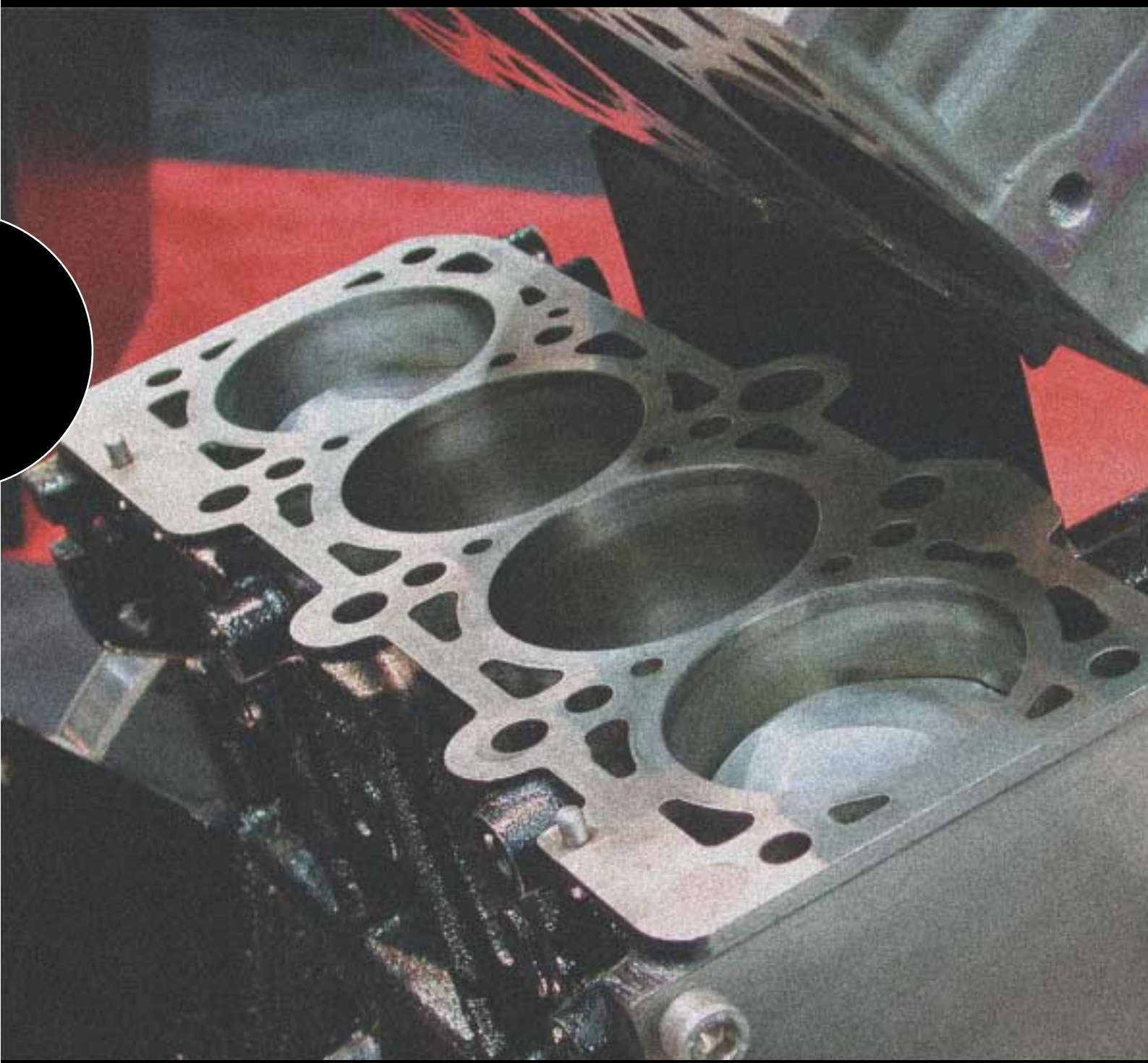
Imagine having a computer system that could be trained to solve your engine performance design problems 100 times faster than you currently can? What if you could choose between several different designs that meet all of your design objectives? Wouldn't it be great to capture all of your best design practices, parametrically, in every engine that you create? Imagine the quality improvements you could achieve if you could get the expertise of your best designers into every engine component that is created by junior members of your team. In reality, the above demands aren't simply wishful thinking: automated design with virtual engines can deliver all of these benefits and more.

Although engine cycle simulation software has become a standard analysis tool, assisting and improving engine design at every stage of the product lifecycle, a lot of time is still spent building and calibrating models, time that could otherwise be spent applying the tool to achieve better designs. Even after a good base model has been created, the number of possible engine parameters that can be assessed is overwhelming, giving the engine designer little or no chance of meeting all of the goals of their design project, using traditional trial-and-error methods.

Take the example of a four-stroke engine configuration. By adjusting intake and exhaust valve timing, valve lift, intake and exhaust manifold lengths and diameters, etc., the engine's performance characteristics can be altered radically. But which combination of these parameters can best satisfy all of the performance requirements of the new engine? The design space is enormous! Even if just five parameters are assessed, and each parameter has only 10 possible values, the total number of unique designs is 100,000...

Optimum Power Technology's automated design software employs a rigorous scientific design process that exploits the benefits of simulation-based virtual prototyping in order to rapidly create optimized designs in large design spaces. The system relies on the accuracy and powerful parametric capabilities of virtual engines to create and simulate the performance of each new design. In addition, it hides the complexity of robust and powerful design of experiments (DOE) techniques and provides a multi-user environment that supports network supercomputing and parallel-processing on ubiquitous PCs. However, automated design is much more than an engine cycle simulation tool with DOE capabilities. It is the world's first engine design expert system.

But what is an expert system? Basically, it is a computer application that uses an inference engine to simulate the judgement and behavior of a human or an organization that has expert knowledge and experience in a particular field. Typically, the system includes a knowledge base that contains



“Imagine being able to choose between several different setups and technologies that meet all of your design objectives”

accumulated experience and sets of rules for applying the knowledge base to each new situation that is described to the system. The knowledge base is the expert system's central repository for information, which is used to manage information collection, organization and retrieval. One may imagine a design expert system to be a diligent assistant, helping the designer by allowing him or her to access the prior knowledge of all human experts that previously used the system. But that is not all the system offers. Once the new design task has been defined, this tireless assistant automatically creates and evaluates thousands of designs, and creates new optimized designs if they are needed.

The major components of automated design with the virtual engine expert system are: release six of virtual engines cycle simulator; an SQL database and knowledge base that contains reusable design objectives and strategies; an inference engine that performs automated designs using the rules defined by the design's objective and strategy; and the Optimum Network Supercomputer.

All design objects are stored in a scalable Microsoft SQL 2000 database that can be located on a client desktop or on a server in a secure centralized location. This multi-user database can then be accessed simultaneously by hundreds of users. All items, such as engine designs, test specifications, or simulated or measured results, can be retrieved and reused by any user with the click of a mouse.

Automated design leads to DOE process automation by encapsulating its concepts in a structured, rules-based environment where the required goals of the engine design (objective) and how these goals can be achieved (strategy), are precisely defined in a reusable format. An automated engine design takes a base engine and applies a strategy to satisfy the final design objective in a rigorous and repeatable process.

All objectives and strategies are saved in the knowledge base together with pointers back to their predecessors. The system automatically tracks every change and can display the history or genealogy of any object. The strategies and objectives that provide substantial improvement can be organized within separate knowledge base subfolders called, for example, approved strategies and approved objectives. As such, the automated design knowledge base becomes a central repository of engineering expertise for other designers when they have problems in the future.

The objective describes the test specifications and goals of the design. Objectives can have multiple goals, and each is assessed with the same engine test specification (for example, engine speed, load and fueling). Each goal is normalized relative to the base engine to provide direct comparisons between alternative new designs. In addition to conventional maximization and minimization goals, a unique match goal can assess each engine design against a predefined characteristic, itself a function of engine speed. Individual weighting can be applied to each goal to precisely tailor the objective to specific requirements.

The strategy describes the method by which the objective will be achieved. This includes selecting the engine parameters and the limits and tolerance over which each parameter may be varied. Descriptive symbolic names are assigned to each engine parameter so other designers can easily recognize the intent of the strategy, and apply it to different engine configurations with little or no modification. Inference engine rules are included in the strategy and allow the designer to easily control the automated design process based on the size of the design space and computational power that is available to create the new design.

The previous impractical design strategies that generated thousands or tens of thousands of design alternatives, with even the most sophisticated DOE techniques, and took weeks to run, can now be solved in a matter of days or hours with the Optimum Network Supercomputer. The modern PC has immense computational power that is rarely used on a day-to-day basis in most organizations. The Optimum Network Supercomputer feature of automated design harnesses this latent computational power for engine design without any perceivable interference to the individual PC user. Believe it or not, the computational power of multi-million dollar mainframe supercomputers or multi-processor UNIX clusters can be created on existing networks by tapping the potential underutilized PCs.

At any time, a designer or manager can query the status and progress of any automated engine design with a few simple clicks of a mouse (Figure 2). At the start of a design, all goals and objectives are normalized to the value of one. As improvements are made, the objective value decreases when trying to reach the ideal value of zero (green line – Figure 2). The progress of the objective is displayed in a graph in the upper left hand portion of the status window. The right half of the status window shows the new performance characteristic of each improved design. The lower left hand graph displays the total number of designs that have been created and evaluated. As each automated engine design is completed, the system notifies the designer with a brief email message.

Automated design can reduce the analysis phase of any engine development project by several orders of magnitude while a better, cheaper design is reached. The expert system becomes more and more powerful as it captures the knowledge of every human expert that uses it in ways that can be repeated again and again on each new project. *ETi*

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