Don't be moved to tears

When the motion demands of a new project aren't met by standard catalogue offerings, there's a temptation to design a system in-house. But this is not always the best approach, warns **Philip Wallington**, commercial director of the motion control specialist, Q-Sys

Precise motion and positioning control are essential elements in more and more machines, from large-format graphics printers, to digital hologram systems, and from laser wafer dicing to sliced-bread bagging. Because of this huge diversity of applications, each with its own, often very specific, requirements, selecting the right products – or even the right approach – for a given project can be a difficult task.

The first step for many designers is to search the Web sites and catalogues of motion component suppliers – a daunting task – with the aim of finding off-the-shelf products that will satisfy the project requirements. This is a time-consuming process and the end-result is often less than hoped for. Realistically, a standard product is unlikely to be the perfect solution for a specific machine requirement. Too often, the designer will either find no appropriate answer or may be drawn to an "almost good enough" standard product that will need design changes and probably performance compromises.

The only really successful machine designs using standard components are those produced with the motion components selected early in the process, with the rest of the motion system being designed around them. But sometimes this is simply not practical.

Without being able to use standard catalogue products, the designer now approaches what can be dangerous territory – designing and developing a system in-house. Most designers are skilled and experienced individuals – so why shouldn't they be able to design their own motion system? Well, put simply, it's a specialist field and there are many potential pitfalls. It's a little like me deciding to design and build my own house – it would be my design but, if I finish it and manage to build it, it will probably have taken too long, cost too much, may not be all I'd hoped for, and could certainly be improved upon with the involvement of experts.

There are many examples of motion system projects that have not yielded the expected or desired results. Often these systems have been designed or developed in-house by engineers at the top of their field and experts in their own processes. But the performance of a motion system is affected by many things, some far from obvious.

> The motor sizing trap

For example, motor sizing can be a trap for the unwary. It is not simply a question of finding a motor that delivers enough force or torque. Thermal performance is a major contributor to success or failure, and datasheet information is only part of the story. Small variations in motion profile and duty cycle can have huge impacts on the amount of heat generated – and that heat has to go somewhere. People often talk about system accuracies of a few microns, while overlooking the fact that 1m of aluminium grows by 23µm for every 1°C rise in temperature!

Uncertainty about thermal behaviour can equally tempt the less experienced designer to oversize the motors "just to be sure". A motor with a large safety margin will probably result in satisfactory technical performance, but will almost certainly mean that the machine costs too much.

In fact, over-specification is a common cause of price targets being overrun. Of course, this is not limited to the motion components – it is common for the mechanical assembly to be seriously over-engineered in an attempt to push the natural frequencies out of reach – but sadly this often pushes the costs to new levels as well! Or it may simply be that the initial machine specification has been aimed too high.

At the other end of the scale, systems run into just as many problems due to under-specification. The problem here is that large amounts of time and money are put into the machine, with the shortcomings only becoming evident when the first prototype – sometimes the only prototype – is built and tested. Then, more time and money are directed to trying to resolve the problems. Sometimes, the true cause takes a while to be exposed. In the worst cases, the problems may only be resolved by a complete redesign.

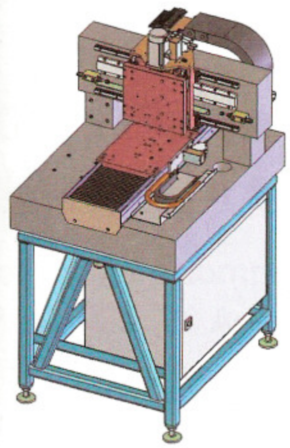
Any of these problems can result in what would have been a good product never making it out the door. Sometimes, the pain can be so great that it leaves the designer with a lasting mistrust of a particular technology that they will never overcome. In the extreme, it can cause some companies to head off in a completely different direction.

> Unique linear motors

For precise motion control, positioning and stability, linear motors often yield the best overall performance – but achieving this is not always straightforward. Because of the unique nature of the linear motor, it can expose the weaknesses of a machine structure like no other type of drive. Unexpected natural frequencies in the structure generate undesirable and often unacceptable resonances when performance is pushed – and linear motors give the scope to push performance to the limits. But their very strengths can be their downfall – many designers have tried, failed and walked away from the technology. That is very sad.

Often, motion control specialists are called in to examine a motion system that is not performing as expected – or is simply not performing! On one occasion, a linear motor stage had been mounted on an optical bench with the intention of improving the throughput of a system which repeatedly positioned a target over a fixed laser while details were written. All went well in initial tests, but as the speed was increased, exploiting the performance of the linear motor, the written features began to blur.

Examination showed that the linear motors were doing their job perfectly, but the resulting reaction forces were putting the entire optical bench into oscillation on its internal rubber isolation mounts. The motor performance had exposed a fundamental weakness in the system design that



An outline view of the inkjet print-head machine described in the box (right). A granite assembly supports three orthogonal axes, two linear motors, and a ballscrew with brake. The lower (X) axis is covered by a bellows to protect its motor and encoder from ink spills.

had gone unnoticed until then. In this case, it was not appropriate to redesign the bench mounting, so the problem was overcome by modifying the motion profile and the servo loop tuning to avoid exciting the natural resonance of the table. This resulted in a huge step up in system throughput.

On another occasion, a pick-and-place machine was designed, built and fitted with high-force motors, only to find on test that the entire machine frame was put into oscillation by the motion profile that was the cornerstone of the new system's specification. Dynamic analysis of the machine during motion revealed where the oscillations were emanating. The only answer was a significant and costly redesign of the steel frame.

> Datasheet limitations

Why do these things happen? Why do experienced engineers sometimes fail to develop a successful motion system, particularly when the published data seems so comprehensive? There are many reasons, but one is that no datasheet ever tells the whole story.

For example, iron-cored linear motors yield impressive levels of force density and efficiency – ideal for fast point-to-point motion with short settling times. But they also exhibit high attractive forces and some cogging. While the degree of cogging is relatively small, it can still cause unwanted effects in a precision system where smoothness of motion is required. To make things worse, it can also interact with those unwanted natural resonances.

The way to avoid this is to use an ironless motor with a balanced, or double-sided, magnet track. These exhibit almost no cogging and suffer no attractive forces. However, their design requirements are quite different and to change from one type to the other is no mean task. This is an example of the type of informed decision that needs to be made early, during the concept stage of the project.

Then we come to the thorny old question of accuracy – if indeed that is the specification that really matters in an application. Stage datasheets are full of impressive numbers, but always under controlled and ideal conditions – and generally measured right down on the stage. But almost all installations will see the action taking place some distance away from the carriage surface – often 200mm or more. Then, the other, less publicised, numbers start to have an effect – pitch, roll, yaw, straightness, flatness. These all contribute to moving the point of interest some distance from where you expected it to be. And that is before you start mounting one stage above another, typical of an X-Y stack. Then Abbé errors start to accumulate, where the errors of the upper stage are amplified by the lower. And the taller the stack gets, the worse the errors become.

Fortunately, for any designer throwing their hands up in despair and wondering why they ever agreed to take on that latest project, help is at hand. By calling on the services of an expert at the outset, you can benefit from all the experience and learning that has come from having "been there and done that" – and often for free!

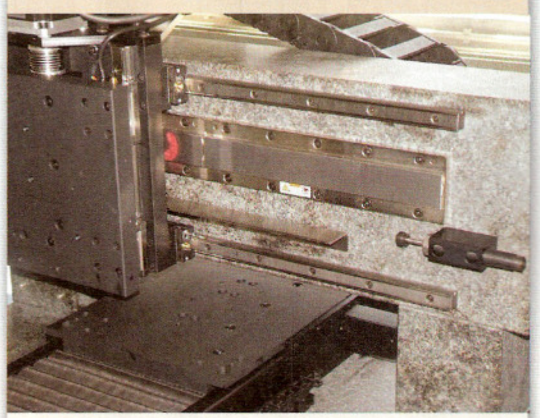
Experts who work daily with linear motors and motion control systems are able to develop right-first-time solutions. The crucial point, of course, is to involve an expert partner at the earliest possible stage in the project. Often, customised systems provide the best results and, when developed by an experienced design team, they can be exceptionally cost-effective. Even if standard catalogue stages are appropriate, making the right design choices from the outset can save an enormous amount of time and money.

Linear motors are efficient and cost-effective for a wide range of precision motion applications. Standard, off-the-shelf products may not, however, provide the required performance, and there are many pitfalls associated with producing custom designs in-house. Specialist advice and support at the earliest possible stage is, therefore, highly desirable – sometimes it's vital to know when to call in the experts to ensure a successful outcome! D&C

BESPOKE INJET MACHINE SLASHES CYCLE TIMES – AND COSTS

The benefit of engaging expert assistance early in the project is highlighted by a system recently delivered by Q-Sys to a manufacturer of inkjet print-head assemblies. The purpose of the system is to verify the correct operation of print-heads in manufacture by running test prints and evaluating the resulting patterns. Existing systems that do this are expensive and comparatively slow, taking several hours to evaluate each print-head.

The new system was designed in co-operation with the customer's engineers to provide a small-footprint machine on its own base frame that houses all of the system electronics. A split-axis configuration was used, with both X and Y axes being built directly onto prepared granite, to ensure system performance and stability. The X axis carries the print substrate while the Y axis holds the print-head. By scanning the substrate past the heads, an accurate test print is recorded which is then analysed by a camera on the machine.



The upper (Y) axis is mounted onto a granite bridge on widely spaced linear rails, with a linear motor, end-stops and an encoder mounting blade. A Z-axis ballscrew is mounted onto the carriage.

By designing the system with the specifics of the application in mind, it was possible to concentrate on the key motion platform performance parameters needed for a successful system. The final system delivers exactly what the application requires – no more and no less – and does it within the project budget. In this particular case, both axes are achieving repeatability figures of better than 0.2 microns. The finished system will cut the previous benchmark time from several hours to a few minutes, and at a quarter of the price.

Because of the expert involvement from the outset, the machine design meets or exceeds all of the user's requirements – and was delivered on time. This example illustrates that bespoke systems are not necessarily expensive – they are designed solely to meet the needs of the project, with both cost and performance targets firmly in view.