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The use of laser scanning technology to improve the design process

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Abstract. Benchmarking competitor products helps a company to identify opportunities to improve their product relative to their competitors. This allows a company to determine the basic requirements of a new product, and target potential areas for improvement, particularly within the automotive industry where there is considerable growth and competition. Automotive firms have been increasingly focusing on development processes. Reducing time to market and improving quality whilst minimising cost. Laser scanning technology enables companies to make design and engineering improvements through the ability to analyse a competitor's design. A case study of this generic process will be presented in this paper. The results have revealed that a company can create significant value-added activity, reduce the need for physical prototype costs and time, improve quality in new product development introduction.

Introduction

Benchmarking competitor products helps a company to identify opportunities to improve their product relative to their competitors [1]. A detailed analysis of competitor products can help a company to determine the basic requirements of a new product and target potential areas for improvement. More specifically, the benchmarking of competitor products can lead to a better understanding of a variety of product attributes, such as ease of assembly, manufacturing feasibility, cost and overall performance.

The automotive industry still depends on physical prototypes in combination with digital models. Physical models and prototypes require time and money to build [6]. However, it is increasingly critical to shift from physical to digital processes because of growing pressures to reduce development time and costs from a highly competitive, over-capacity automotive industry [16] [7]. Automotive firms have been increasingly focusing on development processes. Therefore, the development time of new vehicles must be shortened with a higher quality and at lower price [8] [9] Laser-scanning technology can be used to help firms develop products that meet tough quality requirements in automotive to shorten the process of new product development [2] [3] [4].

In engineering applications, a critical attribute of a component is often its geometry, particularly in mechanical systems such as power train and suspension applications. Quantifying the geometry of the components of a system enables its function to be simulated and its design optimised. The ability to simulate complex systems, reliably in a virtual environment is an important aspect of modern new product development processes as it allows numerous design iterations to be trialled quickly and at low cost.

Geometric properties of mechanical systems can often be captured through laser scanning, the outputs of which can be used to reverse engineer a digital model of the various components of the system. These component models can then be reconstructed into a virtual system which can then be dynamically simulated in software packages and its performance optimised. The use of laser scanning to capture the geometry has a number of advantages, including: the ability to scan a wide variety of materials such as plastics and composites and non-contact measurement also avoids contact with soft and fragile parts. An example of this generic process will be presented in the form of a case study, performed by WMG at the University of Warwick in collaboration with an industrial partner.

Captured scan data enables companies to identify, create and inspect product features for tasks such as inspection in 2D & 3D, rapid and digital prototyping at shorter time. 3D scan data allows virtual prototypes to be assessed in a similar way as a physical prototype. Therefore, products or sub-assemblies can be tested in terms of GD & T (Geometric Dimensioning and Tolerancing), ease of assembly, the standardizations of parts, etc.

The opportunity to make any changes during the development and production phase is limited and its consciences influence the outcome of product development program. However, if potential problems are identified during the design phase, they can be solved at minimum cost. Numbers of companies use the ratio 1:10:100:1000 to identify the cost of problem resolution. In other words, if a decision to make a particular change, it would have cost £1, £10, £100, £1000 in the design, development, production, in-service phase (respectively), as shown in Figure 1.

The scale factor applied to these change costs is 10:1, which is a value commonly quoted in industry as the result of issues not being identified until the subsequent development stage. In this case, component modifications have been made at the concept stage, with the design being solely in the "virtual" world. The subsequent stage of development involves physical modeling and prototyping, where the costs associated with modifying physical parts will clearly be significantly higher. It has been agreed by the industrial partner that a 10:1 ratio is appropriate to be applied in this instance.

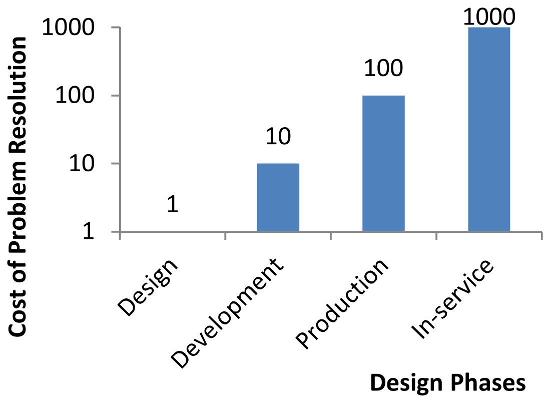


Figure 1: The cost of problem resolution

Case Study

WMG has a unique research and development facility that provides companies direct access to the latest product evaluation technologies and processes along with the expertise to identify solutions appropriate to real world engineering problems. One of its project partners has an interest in the introduction of a suspension system on future vehicles, and intends to produce a demonstrator vehicle with the system in order to assess its suitability. WMG has supported the project by assisting the Engineering team to develop a virtual model to conduct all virtual testing and development. Figure 2 demonstrates the process of project.

A Nikon Metrology K-Series optical CMM was used in this case study enabling complete detailed geometric scans of both small at large parts in a short time. This portable system can be taken to any location or site ant set up easily. Captured data can be seen in real time so provides immediate feedback such as scanning pace, progress and scanned area. The accuracy of the system performance is up to 37µm for single point accuracy and up to 60µm for volumetric accuracy with an uncertainty of +/- 2σ [17].

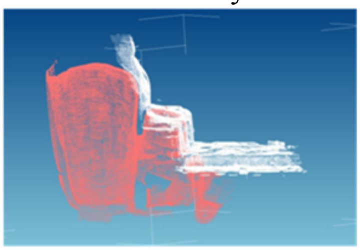
Methodology

Data Capture. Before capturing data, there are number of settings associated with scanning that needs to be addressed. For the laser head used in this case study, the most critical settings for optimum performance are as follows:

- **Data Quality and Saturation:** A typical scan path will consist of a 1000 measurement points per stripe. Every single collected measurement point has a quantitative value is associated with it. If the value is lower than the set threshold, the saturation filter would automatically segregate and remove non compliant measurement points from the dataset. Saturation filters are governed by the end user to ensure a certain level of quality is achieved and maintained to suit various scanning application. Having a higher intensity value for data saturation would ultimately improve the scanning resolution seen in the final scan data.
- **Scanning approach:** In order to maintain a consistent number of measurement points per scan path, it is critical that the scanning head used sustain the optimum distance between the scanning head and the scanning object. Maintaining a set distance reduces the level of data noise that may have a significant impact on the overall data. Many laser scanners have built-in laser guides to assist Metrology users to maintain such distances in order to reduce the likelihood of collecting quality data.
- **Laser intensity:** The laser has to be capable of scanning many different materials, which include characteristics such as color, material finish, surface quality and surface reflectivity. For the laser to work at its optimum, the laser intensity must be calibrated against the surface that it will scan. Generally light colors and glossy surfaces would require a low laser intensity to help reduce data noise. Higher laser intensity will be required for items that are dark or dull finish and appearance. Metrology experts understand that it is no possible to control what items would require scanning, therefore, the equipment has a calibration feature that can automatically set the laser intensity based on the color, material finish and surface quality.

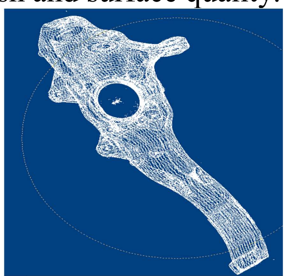
A. 1. Preparation Data

- Data Capture
- Registration
- Optimize scan
- Noise reduction



B. 2. Data Processing

- Data editing
- Data fitting
- Mesh creation
- Export mesh in STL format



C. 3. Outputs

- Visualize and communicate design intent
- Evaluate product for either inspection or reverse engineering
- Surface creation
- Rapid prototyping
- Export surfaces and datums in different file formats for downstream applications such as FEA & CFD analysis

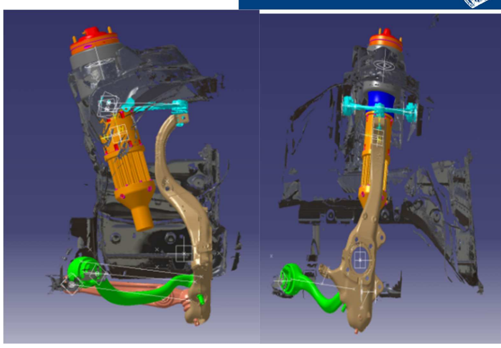


Figure 2: Figures A through C demonstrate the laser scanning and data manipulation process

For this case study, quality and saturation filter were switched on. The usual value of minimum signal strength is 50 when scanning shiny materials the peak might not reach 50 so a smaller value is recommended. Once the system is set up, the laser settings adjust according to the lighting conditions. The temperature was controlled at +/- 5°C relative to the temperature when calibrated.

Data Processing. Laser-scanning generates a large set of points. To create a CAD model, all these points are not necessary. Moreover, it can make the data difficult to manipulate and store; thus more time is required to generate a surface model. Therefore, it is critical to decrease the amount of data while keeping the required accuracy [10]. This requires pre-processing of a data before constructing a surface model because the accuracy of a laser scan is influenced by the operating environment, the shape, color and surface finish of the product, pre-settings, and the operator [11].

Most research indicates that the accuracy of a point cloud depend on the hardware and algorithms for data editing [13][14]. In this study, there were some predetermined parameter settings prior to capturing the point cloud. In order to optimize the usability of the data collected, in terms of file size, whilst still maintaining a high level accuracy. This inevitably affects the ultimate accuracy of the data and, hence, the CAD model produced [12].

Outputs. Recent developments in laser technology not only make available discreet editable CAD entities from the point cloud but also a full definition of the sequence and relationship of these different entities. During the different design stages, the design and development teams can identify design issues, and the effects of changing the design which would otherwise not have been revealed before the next physical product; thus, improving quality and communication as well as saving time and costs.

The industrial partner implanted following activities:

- Geometric benchmarking: suspension layout, number of parts materials used and fitment sequences were identified.
- Development of a new concept based on scanning data and targeting improvements on design deficiencies.
- Development of a prototype for physical testing, creating a design that is feasible for manufacturing and provide feedback to engineers, for example, problems and potential risks.

As a result of study, the design of the new suspension system was optimized by incorporating aspects of an existing best-in-class design and subsequently minimizing cost and development time. Specific benefit included:

- Value-added activity is £2.4m.*
- Reduction in “time to market”
- Introduction to new process
- Improvement in product quality
- Increasing technical knowledge

* The term can be defined as “value” is used to encompass factors including vehicle quality and craftsmanship and also address development process costs versus the capital costs of the models themselves [15].

Conclusion

The development of laser scanning technology over the last decade has enhanced the accuracy and efficiency of 3D scanners with higher performance at less cost. Computer technology can now handle large amounts data sets. The new laser scanning software can generate more information with less error. Today,, laser scanning is a viable technology for quantifying the geometry of existing components and systems and can give designers a significant head start when designing new products. This can subsequently save considerable time and cost in the development process, as demonstrated in the case study presented, helping companies to improve the efficiency of their New Product Development processes which has been identified as a critical factor success in the automotive industry.

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