Proceedings of the 72nd World Foundry Congress
21-25th May 2016, Nagoya, Japan

Streamlining the design, development and manufacture of grey iron brake discs through Computer-Aided Design, Manufacturing and Engineering

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It is now commonplace for foundries to be supplying more than just a raw casting. Machining, assembly, painting, etc. can all add profitable value when the core competence lies in the finished product. Casting buyers will often require the foundry to take responsibility for the design, development and prototyping of components, driving the process from initial concept to series production. Customers' SQA departments generally prefer pared-down supply chains where a single supplier can demonstrate competence at all stages leading to the delivery of finished parts.

In the procurement of OE brake disc rotors, design and development is often delegated to a nominated foundry as the first tier supplier.
The current method of producing a finished brake rotor from simple calculations to a fully tested and approved brake rotor takes the best part of a year and beyond. The sometimes laborious interactions between numerous independent companies or departments, demarcated by specialisation; design, engineering, foundry prototyping, testing, series foundry production, machine shop, paint shop, etc. increases the time-to-market. The "silo mentality" is a well-documented phenomenon. However, all of these stages can be completed effectively through a single, lean department when using well-trained, multi-skilled and motivated personnel. This presentation sets out to describe how the application of state-of-the-art software and technology (CAD, CAM, CAE and Rapid Prototyping) to the design, development and manufacture of brake rotors can be accomplished in a fraction of the time needed via more traditional routes.

Keywords: *Brake disc, simulation, agile, rapid prototyping, DISAmatic.*

1. Introduction

This paper summarises and highlights some of the steps involved in designing, developing and producing disc brake rotors for the OE marketplace, contrasting, where appropriate, those methods exercised at EURAC to reduce time-to-market based on a standardised *New Product Introduction* (NPI) process focusing on simulation, rapid prototyping and the skills profiles of the engineers involved.

2. Functional Test Correlation *(Benchmarking)*

Considerable effort has been expended at EURAC to enable the accurate prediction of braking performance using fully-coupled, thermo-mechanical and elastoplastic mathematical models. Such simulations have proven capable of predicting maximum bulk rotor temperatures to within 3 % when compared with actual results from several Grossglockner alpine descents. Given the repeatability of the thermal model, there is no need for complex, frictional models incorporating the contact regime between rotor and stator.

The brake rotor is a safety-critical automotive braking component which cannot be permitted to fail on the vehicle such that computer simulation does not negate the need for legislated, industry standard vehicle testing, but it does predict the test's successful outcome. This process reduces the time-to-market and prototyping costs, as only one design iteration is needed to produce the prototype component.

Figure 1. VW Touran wheels instrumented for road testing.

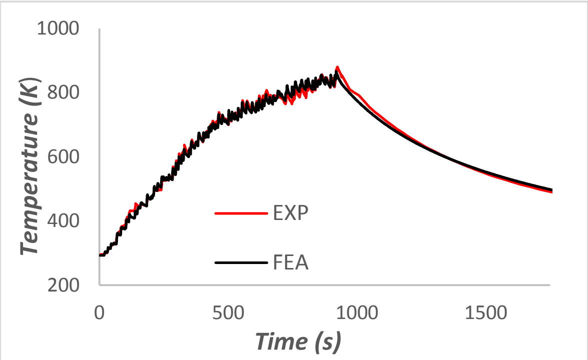

Figure 2. Correlation between experimental vehicle testing and FEA data VW Touran [1]

3. Rapid Prototyping of Castings

The *Rapid Prototyping* process can be used to directly print moulds and cores. These processes build the cores and moulds layer-by-layer by laser-fusing either polymer-bonded sand or using a wide-area inkjet to bond the sand [2].

Pre-production samples will be cast from these printed cores and moulds and will be designed around the intended patterns and runner system. These rapid-prototyped castings are produced on the same *DISAmatic* production line such that the resulting castings follow the existing foundry process and the desired in-specification material grade for production parts.

Once pre-production parts have proven successful, the foundry tooling is ordered and manufactured and will rarely require subsequent modification. The rapid prototyping of castings is the main factor in reducing lead times where there is no waiting for foundry tooling to be manufactured before samples can be cast, which would typically take in the order of 12 weeks.

Figure 3. Photograph of 3D printed core with as-cast holes in brake faces.

4. *Agile* multi-skilled Engineering Department

Many different engineering functions are involved in the various stages of the design and manufacture of an OE brake rotor. Mechanical Design Engineers, Foundry Method Engineers, Machine Shop Production Engineers and other skill bases are called upon to add value along the NPI process. This is in contrast to the engineering department at EURAC, where, although specialisms still exist, each individual is provided with the expertise and competence to lead projects effectively through each of the required engineering functions, across multiple disciplines.

This cross-disciplinary competence has been achieved by simplifying processes, designing standard work procedures, training people in these and ensuring these approved methods are being adhered to by robust audit procedures. Today, one highly-trained engineer can design a brake rotor to produce machining CNC code for the finished part and complete all the engineering tasks for each step in-between.

The benefits to the employee are vast such that they can take ownership of the whole NPI process with less fatigue and a more varied work content [3]. However, this style of working is also beneficial to the business because projects do not have to be planned to specific individuals and the customer benefits from much shorter lead times. In many ways, this agile, holistic approach brings lean manufacturing full circle.

5. Results, Conclusions and Recommendations

As a result of time saving initiatives, a 42 % improvement has been realised. A further direct benefit is project cost savings of up to 23 %. Future considerations should be given to product lifecycle management software, where all development work could be administered through a single software application.

Acknowledgements

Stephen Borthwick, www.eurac-group.com & www.matholdingsinc.com

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