Metal Matrix Composites for Automotive Components in Depth Case Study: Development of Automotive Brake Disc

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Introduction

The increasing demand for fuel efficiency and light weight components in automobile sectors lead to the development of advance material parts with improved performance (Natarajan *et al.*, 2006). A specific class of MMCs which has gained a lot of attention due for its potential is aluminium metal matrix composites (Al-MMCs). Al-MMCs have a big potential for several applications in automobile parts. This specific class possesses high wear resistance and high specific mechanical property, 67% lower density than cast iron and three times the thermal conductivity, thus Al-MMCs are ideal materials for the manufacture of lightweight automotive components (Prasad and Asthana, 2004). Initialisation of Al-MMCs application in automotive industry was in car engine, which utilised reinforced Al-MMCs for pistons in the Toyota diesel engine (Chawla and Chawla, 2006a; Evans *et al.*, 2003). Experimental studies have been carried out to evaluate the effect of sliding velocity and applied load on the wear characteristics of Al-MMCs (Rao and Das, 2010) which indicated some potential for application in vehicle braking system.

Automotive braking system is subjected to mechanical and thermal stresses, hence depends on a combination of properties. Thus it is hard to select a material based only on one of these properties. The material applied in brake disc must bear thermal fatigue, moreover it should absorb and dissipate quickly heat generated during braking (Cueva *et al.*, 2003). Although MMCs have been applied for brake disc, the product has not yet been highly produced and used widely for replacement of the existing iron brake disc due to high manufacturing cost for mass production (Miracle, 2005). Therefore, this indicates a potential avenue of further research in the field of MMCs and to identify its potential as a replacement for the existing conventional brake disc.

The consequences of globalisation have essentially changed the nature of world market competition (Priest and Sanchez, 2001). Subsequently, first class companies need to employ the right strategy of product development to stay ahead of the competition. They are required to implement product development (PD) strategy which can deliver product with high performance in terms of time to market, product cost and quality (Durmusoglu and Barczak, 2011). Product development plays an important role in the success of manufacturing enterprise and many researchers have enhanced their understanding to manage it strategically (Ayag and Ozdemir, 2009). Product development is concerned with parallel iterations running in a smooth operation and at the moment most influential paradigm that transpired has been the change from the "over-the-wall" strategy or sequential engineering to philosophy of concurrent engineering (McGrath, 2000). Simultaneous approach is part of concurrent engineering (CE) where it promotes parallel consideration of all design parameters where they were considered sequentially in the past. The previous method of sequential engineering has been considered inefficient, since it causes longer development time, higher cost, lower design quality and generates lower profit (Koufteros *et al.*, 2001).

According to Yang *et al.* (2006) CE stimulates simultaneous approach of design activity and other product development life cycle aspects in one working environment. Thus this would lead to product quality improvement, reduced cost, shortened design cycle, reduced time to market and fulfilled customer expectations (Xu *et al.*, 2007). Meanwhile Winner *et al.* (1988) defined CE as a simultaneous and systematic approach to the integrated design of products and their related processes, including product supports. Thus CE forms the foundation for engineers to develop product by taking into account all components of the product life cycle from conception to disposal, including quality, cost, production detail and user requirement (Hsiao, 2002).

Concurrent engineering is a philosophical strategy signifies simultaneous approach to be implemented in the product development process where a product and its manufacturing plan are developed concurrently, cross-functional activities are performed to achieve integration, and prioritize the customer's requirement in the product development process (Fatchurrohman *et al.*, 2015a,b). CE is a direct philosophy, but it has proven to be a powerful PD strategy (Kayis *et al.*, 2006). Some companies reported to have gained up to 60% reduction in time to market, up to 50% reduction in life cycle costs and a maximum 95% of reduction in engineering change demands as the results of implementing CE (Fine *et al.*, 2005).

In the area of product development the need for integration between design parameters selections has been identified by Lu and Deng (2004), where the majorities of materials selection has not been directly linked with engineering aspect coordination including manufacturing process selection, especially at the early design stage. While, Edwards (2002a,b) outlined that the research of materials in some areas is not always relevant to industrial requirements, i.e., it is not oriented to specific applications. Moreover, Ljungberg and Edwards (2003) highlighted the significance of integrated design of product and materials selection and market-oriented design. Product development is related to the selection of design parameters in the early stages as highlighted by Gironimo *et al.* (2006). Early identification of the optimal parameters is a serious job of the design process in order to satisfy