

# Multiple-Objective Optimization Techniques in Laser Joining of Dissimilar Materials Classes: A Comparison between Grey and Ratio Analyses

K. F. Tamrin<sup>1</sup>, N. A. Sheikh<sup>2</sup>, M. S. M. Ridzuan<sup>3</sup> And A. N. Nadirah<sup>1</sup>

<sup>1</sup>Department of Mechanical and Manufacturing Engineering, Faculty of Engineering, Universiti Malaysia Sarawak (UNIMAS), 94300 Kota Samarahan, Sarawak, Malaysia.

<sup>2</sup>Department of Mechanical Engineering, Faculty of Engineering, HITEC University, Taxila, Pakistan.

<sup>3</sup>Department of Electrical Engineering, Politeknik Kuching Sarawak, 93050 Kuching, Sarawak, Malaysia.  
tkfikri@unimas.my

**Abstract**—Multiple-objective optimization using grey relational analysis (GRA) has found widespread applications especially in manufacturing and machining processes that involve complex processing parameters and output attributes. On the other hand, multiple-objective optimization on the basis of ratio analysis (MOORA) is often applied in the fields of construction and economy. One distinctive feature of MOORA is the assessment of relative importance of all responses (i.e. weighting ratio) which are taken into account mathematically while GRA emphasis the need of *a priori* information for accurate assignment of weighting ratio. This paper compares these two seemingly different methods by considering their applications in laser joining of dissimilar materials classes in a number of case studies: (a) laser joining of polymer and ceramic, (b) laser joining of polymer and stainless steel, and (c) laser joining of polymer and aluminium alloy. The outcomes of the two methods are compared and discussed. In majority of the cases, the predicted top-ranked alternatives were comparably matched. It is concluded that MOORA is more favourable compared to GRA since it eliminates prior assumption concerning the relative importance of the measured responses, which can lead to unnecessary bias.

**Index Terms**—Dissimilar Materials; Grey Relational Analysis; Laser Joining; MOORA.

## I. INTRODUCTION

Laser processing for machining process offers versatile functionalities which are otherwise not available in conventional machining methods. The non-contact and localized nature of the laser processing has led to product miniaturization especially in the field of smart medical [1], micro-electro-mechanical (MEMS) and bio-MEMS devices [2]. Often these devices are assembled using a variety of dissimilar materials such as ceramics, polymers, metals and glass. Selection of these types of materials depends on the application and working of devices. More often these dissimilar materials are joined together to derive advantage or complement benefits. However such joining process is complex and challenging due to dissimilar nature and properties of combining substrates. The combination process is influenced by the physical, chemical, thermal and optical properties of the substrate materials. In these scenarios, laser joining has enjoyed some success compared to other conventional techniques [3].

Amongst other material classes, combination of polymers with ceramics has numerous applications in microfluidics,

biosensors and lab-on-a-chip systems especially for analytical instrumentation. One example is replacement of brittle and relatively heavy glass substrate, often used as optical window, with transparent, biocompatible and lightweight polyimide polymer. While ceramic substrates can be used as an enclosure or housing due to their chemical resistant nature in adverse environments. However, a few studies can be found in the literature regarding joining these two materials. One of the key studies is of Kawahito et al. [4], which performed the joining process between Si<sub>3</sub>N<sub>4</sub> ceramic and polyethylene terephthalate (PET) polymer using a diode laser ( $\lambda = 940$  nm), and obtained an optimum bond strength of 3100 N at laser power of 170 W and scanning speed of 4 mm/s. Recently, Tamrin et al. [5] highlighted some important joint characteristics that may contribute to the overall strength of the joint. They studied the characteristics of lap joint between polymer and ceramic using CO<sub>2</sub> laser. Moreover, an optimal configuration of laser source parameters was also estimated using Grey relational analysis (GRA).

Joining of metals with polymers has also gained some interests due to its wide range of applications. For instance, titanium is an excellent biocompatible material having applications for implantable microsystems [6] and medical implants [7] when combined with polyimide. In a study related to laser joining, titanium was joined with KaptonFN composite for the application in electronics packaging [8]. Results on the joining process of PET and 316L stainless steel is reported by Wang et al. [9] using response surface methodology. While Yusof et al. [10] investigated the effects of anodization and laser process parameters on the resultant joint strength (nominal joint strength, shear strength and molten pool depth) between PET and A5052 aluminium alloy. Yusof et al. observed that the resultant joint strength increases with the increase of heat input and pulse duration, however the relationship is non-linear; the details are included in forthcoming sections.

Understanding the relationship between the process parameters and resultant joint characteristics of dissimilar materials is important. Usually controlled sets of experiments are used to deduce such relationships and design of experiment techniques prove quite useful. For instance, design of experiment using Taguchi method provides methodical approach where effect of a singular process parameter on a singular joint characteristic can be studied