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Shot peening optimization with complex decision-making tool: Multi criteria decision-making

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ABSTRACT

Controlled shot peening process is performed on two independent ways: (1) Pre-shot peening of Almen strips to determine the desired intensity (2) Shot peening of the real sample with the Almen intensity obtained. Shot peening of Almen strips in the first step takes more time. This is because, the application of input parameters, also measuring arc height and controlling the Almen intensity stages have to be completed consecutively. The results influence the real sample characteristics directly. Still, the arc height measurements and the input parameters adjustment depend on technicians' expertness. So, numerical approaches by conducting finite element modelling (FEM), ANN (artificial neural network) and RSM (response surface methodology) takes more attention growingly. For this purpose, another numerical approach, multi-criteria decision making (MCDM) methods have been developed and verified among their counterparts and also by comparing the experimental results, surface roughness and surface hardness in this study. The results show that the MCDM methods are consistent within themselves and in the context of input parameters (air pressure, shot size, peening duration) and output parameters (surface hardness, surface roughness). The Topsis approach presents consistent results with compared to both the other approaches and the experimental conditions.

1. Introduction

Shot peening is one of the effective mechanical surface treatment in order to assist the metallic materials which are subjected to cyclic loadings, fatigue, fretting fatigue, corrosion and stress corrosion cracking [1–5]. The treatment is performed by impacting the specimen surface via high velocity media [6,7]. This treatment exposes high compressive stressed and plastically deformed certain layer near the surface [8–12].

The capability of shot peening on the surface layer by inducing compressive stress and generating deformed layer is determined and classified with Almen intensity [8,13–15]. The impact is calibrated by Almen intensity and affected by a wide variety of parameters such as shot size, shot velocity, air pressure, surface coverage and peening duration [16–18] (Fig. 1).

Almen intensity adjustment by calibrating the process parameters has been taken into consideration. Since, surface nanocrystallization, deeper compressive stressed layer, effective roughness topography, nanograined or super-plastic layer has been merely accomplished by modifying the peening treatment [5,19–22].

The simulation of shot peening treatments, the estimation and the optimization of the parameters by numerical approaches support the practical pre-determination of Almen intensity. Almen intensity optimization via finite element modelling (FEM) [23,24], response surface methodology (RSM) [25], artificial intelligence (AI) methods such as artificial neural network (ANN) [26] and etc. has been performed in order to optimize the desired outputs. Literature studies show surface coverage, surface roughness, residual stress and also plastic deformation levels obtained by numerical approaches are substantially consistent with the experimental results [27–32].

Pre-selection of input parameters to obtain optimized and improved shot peening conditions for effective mechanical and microstructural results is one of the important goals of the process. So, there will be an adequacy for making a decision which parameter is more crucial [33–35]. Logical, mathematical and statistical approaches provide elimination of inconvenient alternatives and select the most effective parameters. These approaches are called as multi-criteria decision making (MCDM) methods and includes TOPSIS (Technique for Order Performance by Similarity to Ideal Solution), VIKOR (VIse Kriterijumsko Optimizalarity KOmpromisno Rangiranje), COPRAS (COmplex PRoportional ASsessment), ELECTRE (ELimination and Choice Expressing the Reality), GRA (Grey Relational Analysis) and SAW (Simple

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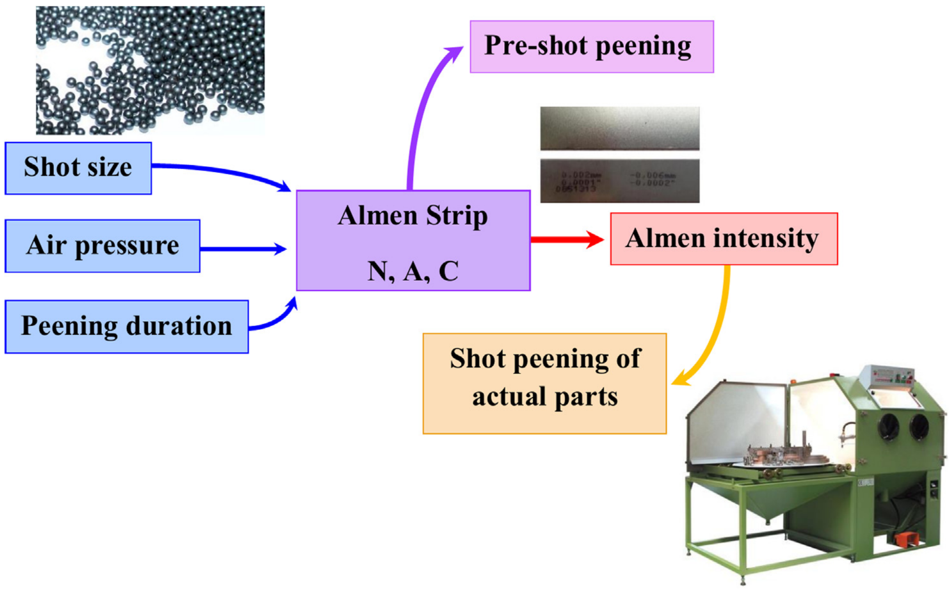

Fig. 1. The schematic representation of shot peening treatment.

Additive Weighting) [36,37]. Also, WASPAS, MOORA, MULTIMOORA, COPRAS, ARAS, ELECTRE, PROMETHEE, EDAS, CODAS and etc. are applied for MCDM methods [38-40]. In this paper, Almen strips are shot peened with a wide range conditions and optimum Almen intensity conditions are tried to calibrate by means of surface roughness and surface hardness via MCDM methods.

2. Experimental studies

Air blast shot peening has been performed to A type strip. These strips are manufactured from AISI 1070 spring steel. Fig. 2 shows the A strip dimensions and tolerances and arc height (deflection) after shot peening.

Shot peening has been applied by Peenmatic 2000S device with 200% constant coverage, 90 mm nozzle distance and 90^0 impact angle. Surface coverage has been selected constant for all the tests to minimize

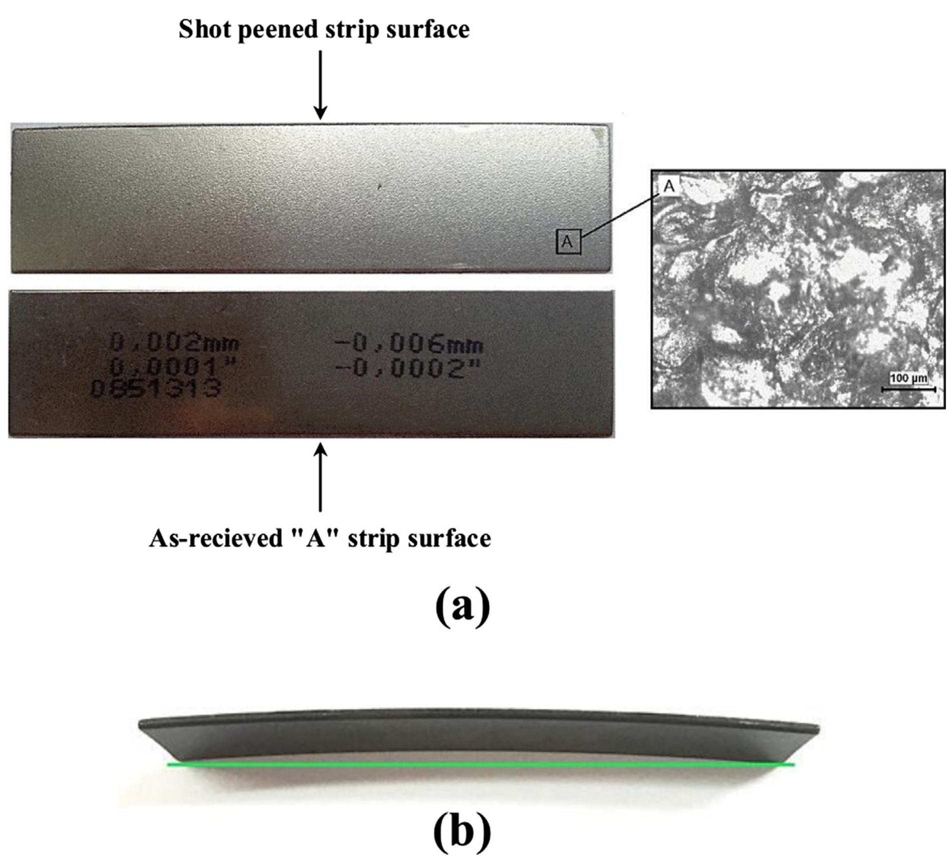

Fig. 2. “A” strip (a) dimensions and tolerances before and after shot peening and (b) created arc height (deflection) after shot peening.