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Experimental studies of the cutting force and surface morphology of explosively clad Ti–steel plates

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ABSTRACT

The present work pertains to the study of clad material such as titanium plated steel in drilling process. The study was conducted for two types of indexable insert drills with different configuration of the tool coatings (TiAlN/AlTiN + TiN and TiAlN/TiN), the same geometry of insert and fixed machining conditions. Drilling process was assessed by the analysis of thrust force, torque and signal fluctuations of PSD function. In this context, surface morphology of the drilled holes and contact area was analysed. It has been observed that the use of the PSD function allows assessment of the drilling process in different layers of clad materials. Also was found that the parameters of the surface morphology are dependent upon the type of layers of the clad and the type of drill. Furthermore the reduction in torque results in obtaining smaller values of surface roughness parameter especially in the area of volume parameters of the bearing area curve.

1. Introduction

The design of new industrial applications requires investigating new construction materials, including multilayer materials such as bimetals. Explosive welding is one of the most widely employed methods for bimetals surface modification. This process offers the possibility of combining the properties of two or more metals or alloys. Explosive cladding is a well-known solid state welding process used for the manufacture of clad plates [1]. In this technique, energy produced by the explosive is used to accelerate a material (flyer plate) across a predetermined distance into contact with another material (base plate) [2]. There is a considerable demand for cladded sheets in both chemical and nuclear industries due to their good corrosion resistance and mechanical properties [3]. Titanium as a flyer plate is one of the most important non-ferrous metals and finds extensive application in bio-materials, because of its light weight, excellent corrosion resistance, high strength, and good biocompatibility [4]. Major industrial potential of explosive welding lies in the fact that it can be used to clad dissimilar materials, many of which are impossible to join by any other methods. Vast studies on explosive welding have been concentrated on the relationship of microstructure and properties of bonding zone [5–11] but those publications do not mention problems related to the flyer plate–base plate interface and surface inside the bimetals after machining process in industrial applications.

One of the widespread methods of machining of bimetals is drilling. The study of cutting tools results in a better understanding of their effect on the morphology of the sur-

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face of flyer plate–base plate interface and thus enable designing bimetal machine parts. Inappropriate geometry of tools and misconfiguration of coatings may result in cracking or delamination of materials during finishing. Therefore, cutting tools should be designed in such a way so as to prevent the formation of surface defects in cladded area. In this context, the selection of technological settings and tool coatings are particularly important as well as the tool geometry which allows reducing the thrust force, which may be responsible for the delamination of sheets.

Surface profilometry has been a well-known method of topography inspection [12–15] for many years. Wojciechowski et al. [12] presented the analysis of various factors affecting the machined surface texture. The investigation was focused on the ball end mill inclination against the workpiece surface. Krolczyk et al. [13] presented the analysis of surface roughness and surface texture of modelled parts machined by turning and produced by fused deposition. Koszela et al. [14] presents textured cylinder liners' surface topographies and computer software for visualization of oil pockets array on the machined surface. Using the surface parameters allows determining functions describing the surface behaviour. Krolczyk et al. [15] analysed surfaces of butt welded joints in steel tubes using an optical 3D measurement system to determine the morphology and topographic parameters. They established that pollution of the argon shield gas with oxygen did not influence the width of the heat-affected zone. The measurement of surface morphology parameters enabled the selection of a higher quality surface.

This paper focuses on research problems related to the cutting force and surface morphology after drilling process of explosively cladded Ti–boiler steel plates. The main purpose of this study was to determine the effect of the tool design as a key factor in controlling the cutting force. The aim of this study was also to determine the surface morphology inside the hole in the flyer plate–base plate interface in the drilling process.

2. Methodology of investigations

The investigations were performed for explosively clad materials. The cladder was composed of two layers. The base layer was 25 mm thick carbon steel P265GH. The flyer plate was made of 5 mm thick Grade 1 titanium. The specimens for drilling with dimensions presented in Fig. 1 were cut out from a single sheet.

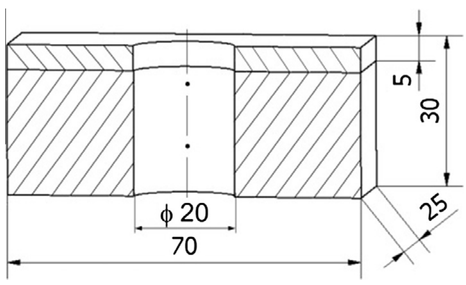

Fig. 1. Clad material specimen for drilling process with defined titanium Grade1 and carbon steel P265GH layers.

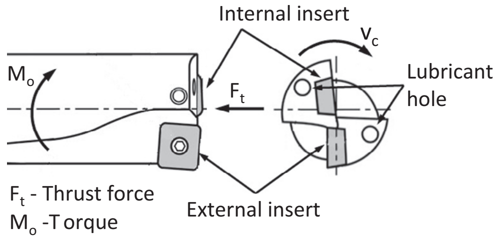

Fig. 2. Schematic illustrations of indexable drill insert with defined force and torque on the tip.

Titanium belongs to materials which are difficult to machine. Due to low thermal conductivity, its machining requires intensive cooling. It was determined that drilling would commence from the titanium layer which allows good cooling of the tool during the machining of this material. The investigation assumed that the entire cutting process will be carried out with constant technological parameters and their values were set according to the manufacturers' guidelines for machining titanium.

Drilling was performed with drills equipped with two cutting edges and cooling through the tool (Fig. 2). Based on the industry recommendations, a drilling tool was selected. Selected drilling tools have the same tool geometry. The differences related to cutting inserts geometry (especially the shape of the rake surface) and its coatings. The types of drills, applied inserts and coatings specification were presented in Table 1.

The tool No. 1 is an indexable square insert drill tool with coolant holes for the drilling depth of 3xD. For this tool the inserts with chipformer for medium to high feed rates and for tough materials were used. In this case the same inserts were used for internal and external slots.

The tool No. 2 was also an indexable square insert drill tool with special inserts for inside and outside slots. The inside slot was equipped with a SOEX 050204-01 insert coated with PVD-TiAlN/TiN multilayer (code BK8425). This layer grade increases wear resistance and is recommended for universal application. The outside slot was equipped with a SOEX 050204-21 insert coated with PVD-TiAlN layer (code BK2730). The special TiAlN layer is characterised by extremely fine grades and good edge stability. The manufacturer suggests using this insert when maximum wear resistance at medium and high speed ranges should be received.

In this study, the drilling process was carried out on a CNC milling machine equipped with Kistler9257B piezoelectric dynamometer with 5019B amplifier and NI 6062E, National Instruments, A/D multi-channel board. The visualization of the recorded force signals and their processing was performed using CutPro data acquisition system. Surface morphology analysis of the clad material was performed using Infinite Focus Measurement Machine (IFM). IFM is an optical 3D measurement device which allows the acquisition of datasets at a high depth of focus. The IFM 4.2 software version was used for the measurements. The cooling and lubricating fluid used was a coolant