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ON THE FATIGUE PROPERTIES OF 3D STEEL STRUCTURES WELDED ONTO CERAMICS

Seyed M. Allameh
Northern Kentucky University
Highland Heights, KY
allamehs1@nku.edu

Douglas Alexander
Northern Kentucky University
Highland Heights, KY
alexanderd1@nku.edu

Roger Miller
Northern Kentucky University
Highland Heights, KY
millerr@nku.edu

Avery Lenihan
Gatton Academy of
Mathematics and Science
Bowling Green, KY
Avery.lenhan@yahoo.com

Hadi Allameh
Sullair
Michigan City, IN
hallameheng@gmail.com

ABSTRACT

Fabrication of prototypes and custom-made parts, made of various metals, has become possible by additive manufacturing. Like any new technology, reliability of the products is of utmost importance, especially, when it comes to life-sustaining structures or for applications where human life is at stake. A less common method of making 3D metallic object is by 3D welding. This method is more appropriate for structures where dimensional and esthetic characteristics of the structures are of secondary importance. An example is steel rebar in concrete where it requires rough corrugated surfaces of the rebars. This walled metallic structures, used especially for loadbearing applications, where load is not fixed will require investigation of fatigue properties. Conventional testing methods may not be appropriate for small cross sections. To address this problem, microtensile testing allows characterization of mechanical properties of small structures as thin as a few millimeters. Past work on the monotonic and cyclic properties of microsamples extracted from weldments made on metallic substrates has shown superior tensile strength and enhanced fatigue resistance compared to the base metal. It is interesting to see how the results would be different if ceramic substrates were used. This study utilizes a gantry type 3D printer, equipped with the gun of a MIG welding machine to fabricate steel weldments on ceramics using 3D welding technique. The process involves starting of the arc from a grounded piece of metal, then continue the motion of the gun and guide the motion of the molten metal pool in desired direction, maintaining the continuity through the solidifying bead. Weldment samples fabricated by this technique are then machined by a CNC mill to extract microscale dog-bone-shaped samples with a width of 200 micron and a gage length of 1000 micron. The top and bottom surfaces of the samples are polished to a mirror finish and subsequently the microsamples are mounted in the grippers of an Electropulse 1000 Instron load frame. Monotonic and cyclic loading mechanical tests in tensile mode are conducted and data are collected and plotted in terms of stress-strain as well as stress-life curves. These results are then compared with those of samples made by 3D welding of steel-on-steel substrate. Since the cooling rate of molten metal on steel substrates differs from that of ceramic substrate, fatigue properties may be different too. The implications of the reliability of reinforcement steel bars printed by 3D welding will be discussed.

INTRODUCTION

Additive manufacturing of metals including steel, titanium and aluminum has been established through laser beam melting, electron beam melting and laser metal deposition. The relationship between microstructure and mechanical properties has been investigated, and found to greatly depend on the processing method, composition of the metal powder among other experimental parameters [1].

Because of the nature of the process, type of bonding of the layers, residual porosity, impurities, surface roughness, type of heating and cooling, the microstructure varies, making the prediction of mechanical properties challenging. Additive Manufacturing has shown to change the typical yield, and