LENS Ti-6Al-4V Alloy Material Properties Determination for LS-Dyna Package

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Abstract. A procedure for determining the material properties of LENS Ti-6Al-4V is presented. The elasto-plastic constitutive model with stress vs. effective plastic strain curve was selected in the study. In the first stage, experimental uniaxial tensile tests of the specimens manufactured from Ti-6Al-4V alloy powder by LENS were performed on a universal strength machine. Based on the experimental tests material properties of the samples were evaluated and correlated. The proper methodology of calculating the values of effective plastic strain and effective plastic failure strain used in the elasto-plastic constitutive model was emphasized and discussed. Correlated material properties were validated based on the static experimental compression test of a honeycomb cellular structure manufactured from Ti-6Al-4V alloy powder by LENS. The comparison of the results of numerical simulations and experiments showed excellent similarity.

INTRODUCTION

Uniaxial tensile test is one of the basic and fundamental experiments for evaluating the mechanical properties of engineering materials [(1)1-3]. From the measurements such properties can be determined as: Young's modulus, yield strength, ultimate tensile strength, maximum elongation and Poisson's ratio. Additionally, reduction in can be measured using a special equipment, i.e. extensometer. Based on the conducted tests, the coefficients and parameters are obtained for a selected constitutive model used for finite element analyses (FEA). Depending on the simulated problem a proper model should be implemented, especially when a material failure is initiated and plays a significant role.

There are several models in LS-Dyna which can be used for modelling material damage and failure. In some of them a simple failure mainly based on plastic strain can be defined, e.g. *Mat Plastic Kinematic*, *Mat Piecewise Linear Plasticity*, *Mat Simplified Johnson Cook*, etc. On the other hand, many of them are more sophisticated where damage formulations and failure criteria are implemented: *Mat Johnson – Cook*, *Mat Plasticity With Damage*, *Mat Damage 1*, among others. Moreover, an additional card *Mat Add Erosion* can be defined, where failure or damage can be also applied [4]. The presented paper is focused on the first group of constitutive models and the methodology for determining material properties of LENS Ti-6Al-4V alloy will be explained by the example of the elasto-plastic constitutive model with effective stress vs. effective plastic strain (EPS) curve (*Mat Piecewise Linear Plasticity*).

PROBLEM DESCRIPTION

Titanium is characterized by high melting point, high strength-to-weight ratio and excellent resistance to corrosion. Due to its properties, titanium is widely used in aircraft, biomedical and chemical industries. Laser Engineered Net Shaping (LENS) system can be also implemented for manufacturing various structures from titanium alloys [5]. The presented paper is related to a recent project aimed at optimizing the crashworthiness behavior of regular cellular structures manufactured from Ti-6Al-4V alloy powder by LENS. Within the project, FEA are crucial for subsequent optimization and a proper constitutive model must be applied in order to predict the real behavior of the cellular structure under different loading conditions. In the paper, the authors focused on a procedure for determining the material properties of Ti-6Al-4V alloy specimens manufactured using LENS technology. The adopted procedure follows a description in [6].

Material properties determination

Experimental tests with dog-bone specimens were prepared and the uniaxial tensile tests were performed on a universal strength machine at a room temperature of 23 °C. The specimens were stretched with a velocity of 1 mm/s and Digital Image Correlation (DIC) was used to measure contour, deformation and strain during tests. The selected constitutive model was correlated and tested under conditions corresponding to the experiment. Numerical simulations were performed using implicit LS-Dyna code with Newton-Raphson iteration scheme [4]. The adopted elasto-plastic constitutive model uses stress vs. effective plastic strain (EPS) curve and the erosion criterion based on the effective plastic failure strain (EPFS). Typically, the EPS is calculated based on the true stress - true strain curve obtained from experimental tests. However, in order to properly predict material behavior and its failure the values of EPS and EPFS must be iteratively calculated based on the experimental outcomes and FEA. Generally, they are not included in material databases, however in [6] a wide range of material properties data with the calculated EPFS and EPS can be found with a description how to determine their values. Unfortunately, the database does not include the LENS Ti-6Al-4V alloy, which is the subject of this work.

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