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A critical comparison of various data processing methods in simple uni-axial compression testing

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ABSTRACT

The paper compares the error associated with various data processing methods to obtain true stress–plastic strain data from the load–deformation curves generated from uni-axial compression tests. Towards this end, uni-axial compression tests have been conducted on three representative materials *viz.* modified 9Cr–1Mo ferritic steels, alloy D9 (a titanium modified austenitic stainless steel) and 316L(N) austenitic stainless steel in wide ranges of temperatures and strain rates. It has been observed that the absolute average error associated with maximum true plastic strain calculation in all the three materials is always more than 5% and sometimes as high as 42.1% if the elastic region is removed either from the load–stroke curve or engineering stress–strain curve to get the true stress–plastic strain curve. However, the absolute average error associated with plastic strain calculation is always less than 5% if the elastic region is removed from the true stress–strain curve.

1. Introduction

Uni-axial compression test is the most common method employed for data generation to study the flow behaviour and workability of the materials [1]. The data generated by uni-axial compression testing of cylindrical specimens are used to evaluate the constitutive flow behaviour of materials [2–10] as well as to identify the optimum process parameter for thermo-mechanical processing [11–19]. The data generated at various temperatures and strain rates are also correlated to the microstructural evolution in the specimen during the deformation [20,21]. The generated data or the constitutive equations developed using these data are given as input to the powerful computational software like Finite Element Method (FEM) to simulate the process to garner a better insight to the processing routes, to decide the final size of the components or to design the processing machineries [9]. To ensure the accurate simulation of the thermo-mechanical processes by the proper use of the simulation software, it is necessary to provide accurate input data [1]. In compression test, the information generated by the machine is the amount of load required to impart a particular amount of deformation in a material at certain condition of temperature and strain rate. The machine generates load–deformation curves which can be converted to the engineering stress–strain curve or true stress–strain curve as per the requirement of the users after removal of the machine compliance [22]. This is commonly known as data processing and is the first major step which connects the material testing and the analysis of the material's compressive strength as well as flow behaviour. Error in the data processing, if any, is carried forward to the next steps without the knowledge of the user. Hence, data processing deserves a careful attention in order to minimize the error associated with it.

At a particular temperature and strain rate, the entire stress–strain curve consists of two parts i.e. elastic and plastic part. In general, most of the materials obey Hook's law before the proportional limit [23]. The constitutive behaviour varies from materials to material in the plastic domain (i.e. after the yield point). The behaviour becomes more complicated with varying temperature and strain rate. For simulating the flow behaviour of the material under large deformation, it is required to develop the material model or constitutive law. The most widely used constitutive equations are based on continuum plasticity and these are used to predict the flow stress after yielding of the material. The power law, Ludwik equation [23], Johnson Cook material model [24], Zerilli Armstrong [25] and Modified Zerilli Armstrong model (MZA) [9] are some of the examples of the constitutive laws used for describing the plastic behaviour where true stress is the function of plastic strain and the these equations are valid only from the beginning of the plastic flow [23]. Therefore, it is necessary to obtain the true stress–plastic strain data from the load–deformation curve generated during the testing, before evaluating the material constants for these models. There are *three possible methods* to obtain the true stress–plastic strain data from the raw load–stroke data after removal of machine compliances. In the *first method*, initially elastic region is removed from the load–stroke data. Then the plastic load–stroke data is converted to engineering stress–plastic

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