

Methodology for dependence-based integrated constitutive modelling: An illustrative application to SiC_p/Al composites



Junfeng Xiang^a, Lijing Xie^{a,b,*}, Feinong Gao^a, Jie Yi^a, Siqin Pang^{a,b}, Xibin Wang^{a,b}

^a School of Mechanical Engineering, Beijing Institute of Technology, 100081 Beijing, China

^b Key Laboratory of Advanced Machining, Beijing Institute of Technology, 100081 Beijing, China

ARTICLE INFO

Keywords:

Constitutive modelling

Multi-objective

Parameter identification

SiC_p/Al composites

ABSTRACT

In industrial forming and machining process, the large plastic deformation of material takes place in wide loading ranges of strain-rate and forming temperature. A satisfactory modelling of quasi-static and dynamic material behaviors is of great importance for understanding physical process and processes optimization. A dependence-based integrated methodology, together with an improved weighted multi-objective parameter identification strategy is presented for the development of phenomenological constitutive model and the parameter identification using experimental data from quasi-static and dynamic tests with instantaneous strain rate variations and plastic strain-related temperature changes. The improved multi-objective parameter identification model is reformulated by introducing three weighting factors for valuing different measure errors and fit standard errors in individual objective function corresponding to each test, considering the sampling point number and active material parameter number under different loading conditions, and balancing optimization opportunity of quasi-static and dynamic sub-objective functions. The methodology is verified for feasibility through illustrative constitutive identification for SiC_p/Al composites. This may provide a methodology of constitutive modelling for predicting material behaviors in quasi-static and dynamic modes equally well.

1. Introduction

In manufacturing industry, almost all material forming and machining processes consist of deforming plastically workpiece under the forces applied by a die or tool [1]. Understanding of material flow behavior under different deformation modes is gaining critical importance in planning of material forming and manufacturing processes, selection of die/tool, design feasibility of final products [2–4]. A schematic of the dependence of analytical modelling and finite element modelling on constitutive model in material forming and machining processes is illustrated in Fig. 1. Therefore, it is necessary to develop/establish constitutive model reflecting the yield criteria, hardening laws and flow rule of the material under combined loading conditions of deformation rate and forming temperature.

The accuracy of numerical simulation available for industrial applications depends not only upon the applicability and flexibility of material constitutive model, but also the scheme applied to determine material parameters [5]. With the continuous emergence of new materials, classical constitutive models (e.g., Johnson-Cook [6], Arrhenius-type [7], Zerilli-Armstrong [8], etc.), much less so-called unified constitutive models that tend to describe a given crystalline structure or

crystalline system, cannot accurately predict the flow behaviors of those new materials in a wide loading range. These pose encountering challenges to the determination of material constitutive models.

For improving the applicability and flexibility of the above classical constitutive models, it is necessary to develop or modify advanced constitutive models based on the classical phenomenological constitutive models by introducing the coupled effects (e.g., between strain-rate and temperatures [9], between strain and temperature [10], between other physical or mechanical properties and strain [11,12], and among strain, strain-rate and temperature [13]), some special mechanical behaviors (e.g., strain-softening at high strain [14], scale effect [15], ratcheting effect [16], anisotropy [17], plastic strain gradient [18], etc.), and other experimentally observed physical or mechanical properties varying with deformation such as density in foam metals [19], microscopic damage in composites [20], phase transformation [21], and grain evolution [8,22], etc. This would also lead to the complexity of constitutive model involving more material parameters, and increase the experimental cost for developing constitutive model and identifying its material parameters, of which some can be attained through microscopic observation [20], and some can be also fit to numerous experimental data in quasi-static and dynamic modes [9–12].

* Corresponding author at: School of Mechanical Engineering, Beijing Institute of Technology, 100081 Beijing, China.
E-mail address: rita_xie2004@163.com (L. Xie).

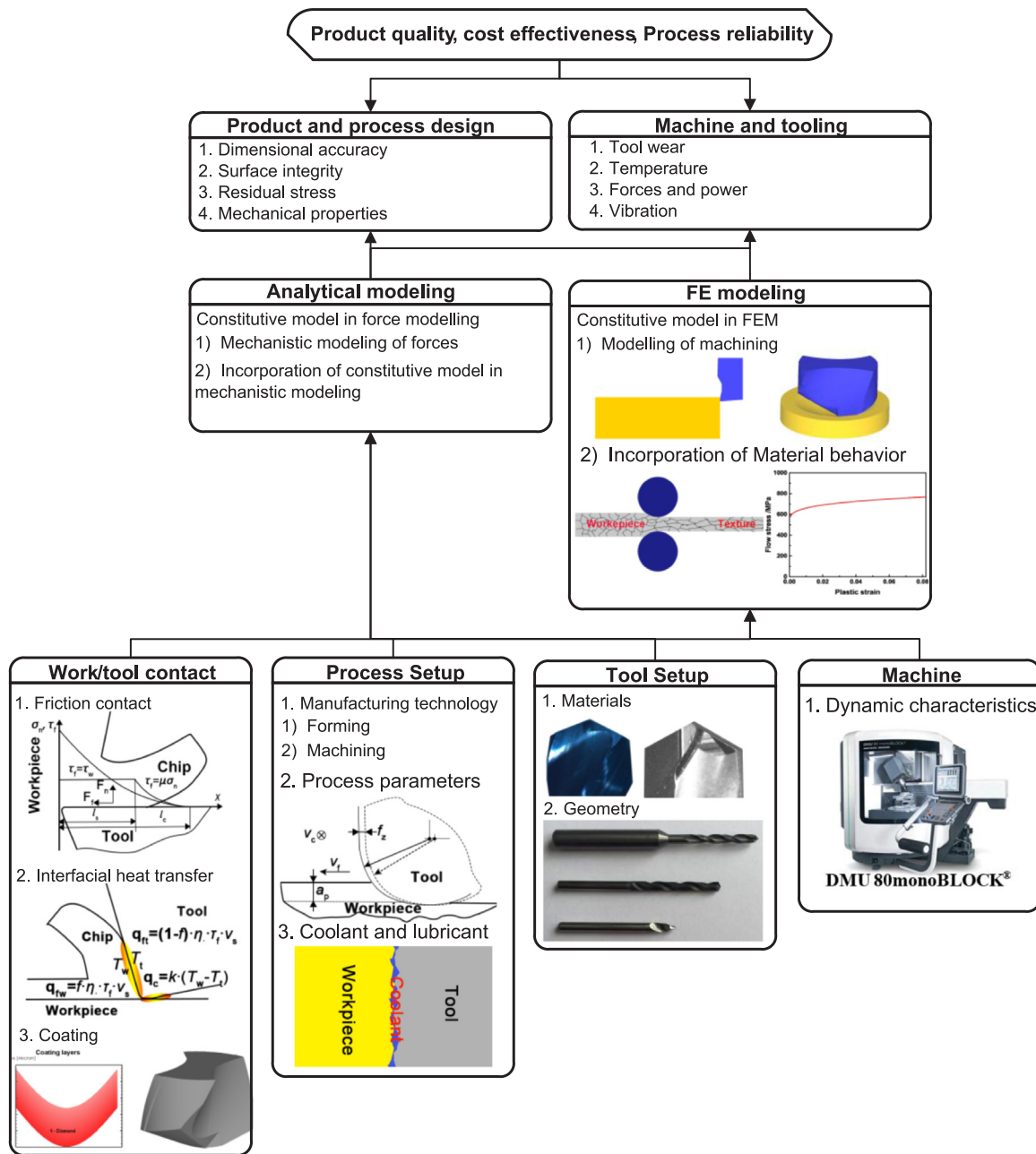


Fig. 1. Incorporation of constitutive model in analytical modelling and finite element modelling of material forming and machining processes.

Therefore, the major difficulties for widespread application of phenomenological constitutive model for industrial simulation consist in a larger number of mechanical tests over a wide range of loading conditions needed for using classical identification methodology of constitutive model, identification of coupled relations among explanatory variables, and the ensuing hard identification job of material parameters involved in constitutive characterization [23,24]. The aim of this paper is to present an improved methodology for dependence-based integrated constitutive modelling, together with multi-objective material parameters identification strategy. Using an illustrative, yet complex example for SiC particulate reinforced aluminum matrix composites using experimental data from quasi-static and dynamic tests, the methodology is verified for feasibility by comparing the overall fit quality of the identified constitutive model to experimental data.

2. Dependence-based integrated methodology for constitutive identification

A phenomenological constitutive model is actually an empirical relationship for mechanical characterization of complex material responses in different loading regimes [25]. The general formalism of a one-dimensional phenomenological model is to represent the dependence of flow stress on strain, strain-rate, temperature, and some physical/mechanical statistics during deformation, with the following formalism.

$$\sigma = \sigma(X) \quad (1)$$

where $X = (\epsilon_p, \dot{\epsilon}, T, \mathbf{M})$ is an array of measured properties including varying plastic strain ϵ_p , strain rate $\dot{\epsilon}$, forming temperature T , and $\mathbf{M}$

Download English Version:

<https://daneshyari.com/en/article/7887295>

Download Persian Version:

<https://daneshyari.com/article/7887295>

[Daneshyari.com](https://daneshyari.com)