Journal of Materials Processing Technology 172 (2006) 16–21

Journal of Materials Processing Technology

www.elsevier.com/locate/jmatprotec

A technical note on an experimental device to measure friction coefficient in sheet metal forming

L. Fratini *, S. Lo Casto, E. Lo Valvo

Dipartimento di Tecnologia Meccanica, Produzione e Ingegneria Gestionale, University of Palermo, Viale delle Scienze, 90128 Palermo, Italy

Received 15 October 2003; received in revised form 7 July 2005; accepted 26 August 2005

Abstract

In the paper the authors present the results of several experimental tests aimed to determine the Coulomb friction coefficient in sheet metal forming operations at the varying of the sheet metal material and for different operative conditions. In particular a few pressure and lubricating conditions have been investigated. In order to develop such experiments a dedicated fixture was designed and set-up starting from the one proposed by Wilson.

Keywords: Sheet metal forming; Friction test; FEM

1. Introduction

In the last decades, the optimization of forming processes and what is more the development of new metal forming operations has been developed utilizing numerical simulations based on the finite element technique. In this way virtual manufacturing try-outs utilizing concurrent engineering devices are developed with strong benefits which can be synthesized in a significant reduction of the time-to-market and of the products start-up costs.

In particular, as far as sheet metal stamping processes are regarded, the last requirements of the forming analysts take into account the full simulation of the stamping processes including deep drawings, elastic springback, trimming, again elastic springback and residual stress state evaluation. Furthermore, defects, both shape ones and ductile fractures, can be foreseen. Complex contact conditions are introduced, tailored blanks can be taken into account as well as anisotropy effects. All the required results should be obtained in a short computational time in order to make acceptable the modeling and computational time within the product development.

Anyway, it should be observed that the effectiveness of the results of sheet metal forming numerical simulations is strongly connected to the correct modeling of a few topic. Among these, probably the most important are the material characterization, i.e. the material flow rule, and the contact conditions definition, i.e. the frictional conditions modeling [1].

As far as the latter topic is regarded, it is well-known that Coulomb model is probably the most appropriate classic frictional model to be utilized in sheet metal forming simulations with respect, for instance, to the shear-factor one [2]. Nevertheless, the frictional coefficient μ has to be properly chosen in order to proper model the frictional conditions at the sheet metal–dies interfaces. Overall it should be observed that most of utilized tests give a global value of the frictional coefficient which hardly can be utilized to model the changing contact conditions which typically govern a forming process [3] and just in the last years a few models have been presented regarding variable friction coefficients [4].

As far as sheet metal forming is regarded several sheet drawing tests have been presented in the last decades. In particular Fogg [5,6] in the seventies started working on the frictional conditions occurring in sheet metal forming when external pressurized lubrication is provided. In the same period Kudo et al. [7] proposed a sheet drawing test in which the μ coefficient was determined by measuring directly the tangential and normal forces on a flat die surface; they utilized a fixture in which the approach angle of the sheet to the die surface was controllable. In a subsequent research Kudo [8] presented a further drawing machine able to reproduce the actual drawing speed occurring in sheet metal stamping.

Furthermore, in order to investigate the speed dependence of the coefficient of friction in sheet drawing Azushima et al. [9]

* Corresponding author.
E-mail address: abaqus@dtpm.unipa.it (L. Fratini).

0924-0136/$ – see front matter © 2005 Elsevier B.V. All rights reserved.
doi:10.1016/j.jmatprotec.2005.08.008

developed a sheet drawing apparatus characterized by a transparent quartz die and the increase of the friction coefficient at the increasing of the drawing speed was interpreted in terms of the measured volume of the surface pockets trapping lubricant. The research was then extended with the analysis of the influence of the die surface properties on the friction coefficient [10].

The so called strip-tension friction test was proposed by Weinmann et al. [11], in such fixture the flow of metal around the punch corner was reproduced stretching a metal strip around two fixed pins and monitoring and recording the strains in the wall portions and in the bottom portion of the specimens. Such data were utilized to calculate the corresponding tension values and from these the friction coefficients were determined utilizing the well-known belt friction relationship [11].

A relevant step forward in the evaluation of the coulomb frictional coefficient in sheet metal forming was done by Wilson and co-workers [12–18] who developed a proper sheet metal forming simulator (SMFS) reproducing the actual stamping conditions and the sheet metal flow around the die radii in order to evaluate the actual μ coefficient also considering such as the variation of the contact area during metal flow.

In the paper the results of a wide experimental campaign developed with an experimental device reproducing the Wilson friction simulator, are presented. In particular in the experimental tests a few different materials were taken into account; furthermore, the influence of the pin diameter, of its surface finish and of the utilized lubricant were considered. In the next paragraphs the developed device will be presented and the main features of the Wilson test will be recalled. Then the results of the carried out experimental tests will be reported and discussed.

2. The experimental equipment

In order to develop the experiments, a proper device was designed and set-up. As already observed the developed fixture was aimed to reproduce the process conditions occurring during a typical sheet metal stamping operation. In particular such device was made of several components as follows:

- mechanical components, in order to provide the movement of the specimens and their loadings;
- sensors (load cells), in order to measure the forces at the ends of the specimens;
- electronic device (amplifier), as interface between sensors and the acquiring system;
- acquiring system, able to record and to analyze the acquired data, made of an acquiring board and a PC.

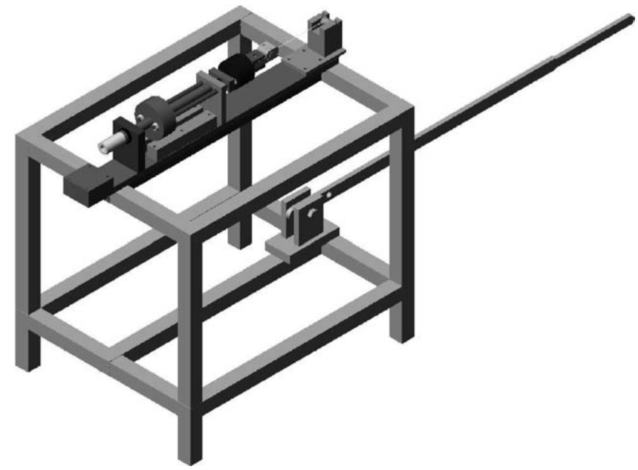

Fig. 1. Sketch of the utilized experimental device.

In Fig. 1 the CAD sketch of the utilized device is reported. In particular a proper reduction system was applied to the electrical engine governing the specimen movement. A screw traction system was set-up in order to guarantee the most uniform movement of the specimens (Fig. 2). The movement is transferred to the further moving elements through two tie-rods which undergo to tensile stresses during the loading phase and to compression during the unloading one. A further joint connects the two tie-rods with a load cell; on the latter is screwed the specimen clamping system. In particular, the clamping system (Fig. 3) was made of a block, aimed to avoid any slide of the specimen, and of a joint fixed to a tensile machine. During the assembly of the described fixture the correct planarity of the elements was addressed to in order to avoid any inflection of the structure and to obtain a pure tensile stress on the specimen.

The described traction system allows a sheet metal feed rate of 1 mm/s; the use of such value was aimed to determine the friction

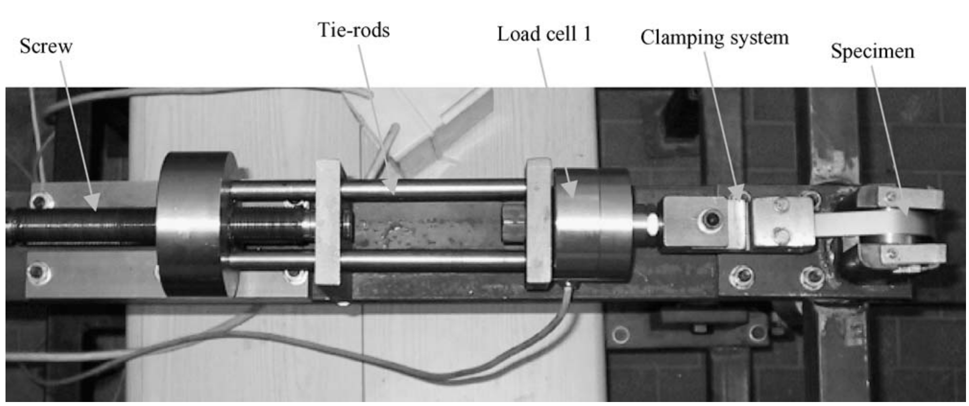

Fig. 2. Overview of the traction system.