Emerging Nano and Advanced materials

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Improvement in predictive accuracy of numerical simulation of sheet forming processes using advanced material characterization methods

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Abstract

In this work, numerical simulation of sheet metal forming process is carried out using advanced material characterization methods. Hydraulic bulge tests of AA5083-O aluminum alloy sheets are conducted for modelling the material behavior. The obtained material properties are incorporated in numerical simulations of hydraulic bulging using advanced yield functions and constitutive equations. Predicted results are compared with experimental measurements.

Introduction

- Virtual forming through finite element simulation prior to actual forming has become a necessary step.
- Uniaxial tensile tests are not adequate in defining the material behavior in the numerical simulations. Hence, an approximation has to be made while modeling the material behavior and the results predicted are not very accurate.
- The improvement in predictive accuracy of numerical simulation can be achieved by using advance yield functions and constitutive equations [1].
- However, advanced yield functions require material characterization in different stress states.

Experimental procedure

- Uniaxial tensile tests (UAT) are conducted on universal testing machine.
- Hydraulic bulge test (HBT) are conducted on hydraulic press integrated with 3D-optical strain measurement system.
- Material properties and flow curves are determined as per the ISO standards. The obtained material properties are used in numerical simulation of hydraulic bulging [2].

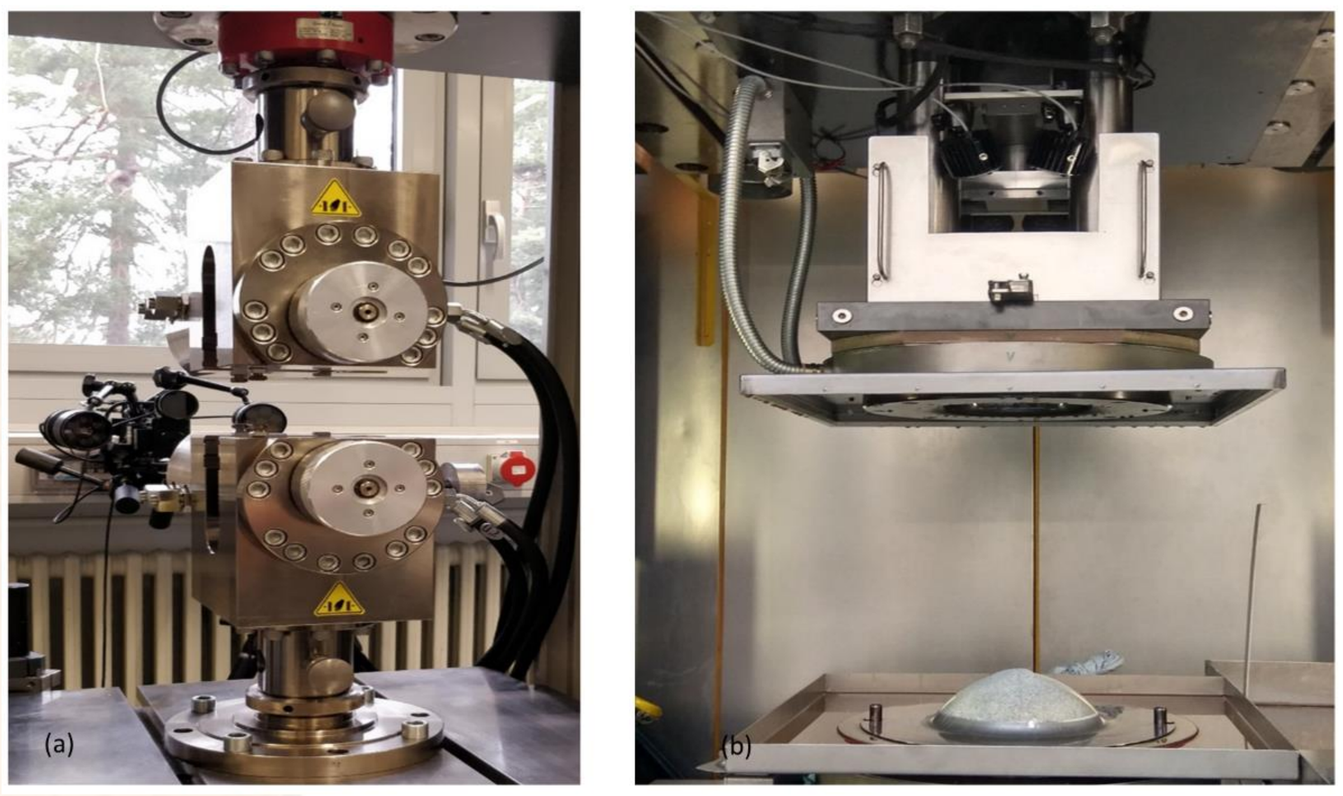


Fig.1(a) Uniaxial testing setup (b) HBT setup

- The schematic of working of HBT is shown in Fig. 2(a).
- Numerical simulations are carried out using software DYNAFORM with LS-DYNA solver. A quarter symmetric numerical model is shown in Fig. 2(b).
- Bulged sample from experiment (Fig. 2(c)) and simulation (Fig. 2(d)).

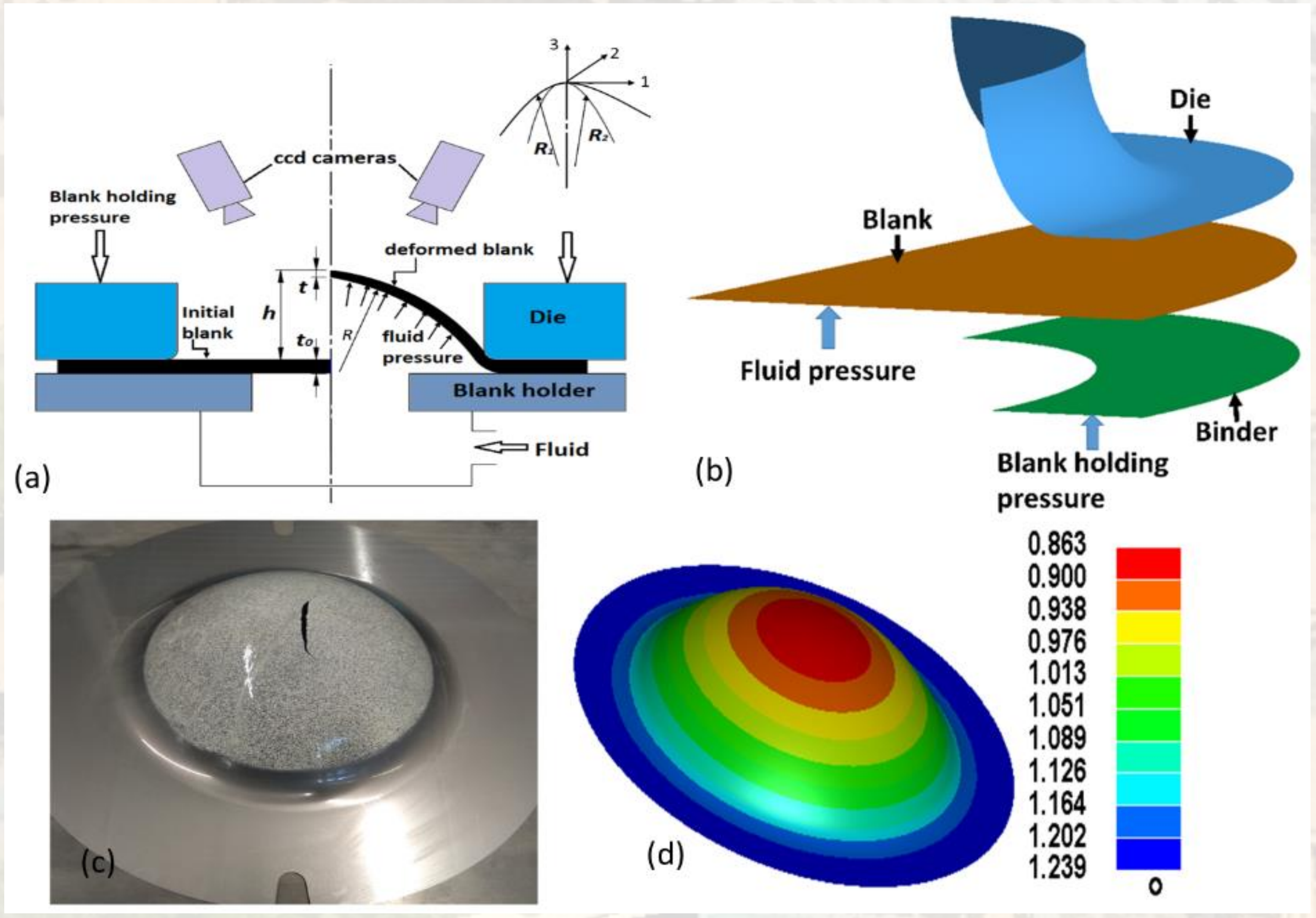


Fig. 2 (a) Schematic diagram of HBT (b) a quarter symmetric numerical model (c) bulged sample (d) bulged specimen with thinning contour

Results

- Stress-strain curves obtained from UAT and HBT are shown in Fig. 3(a).
- Yield locus predicted using different yield criteria are shown in Fig. 3(b).
- Hill48 and von Mises yield loci are based on uniaxial tensile properties only.
- Hill90 and Yld2000-2d yield loci are based on both uniaxial and biaxial tensile properties.
- Predicted dome height evolutions are compared with experimental measurements (Fig. 3 (c)).

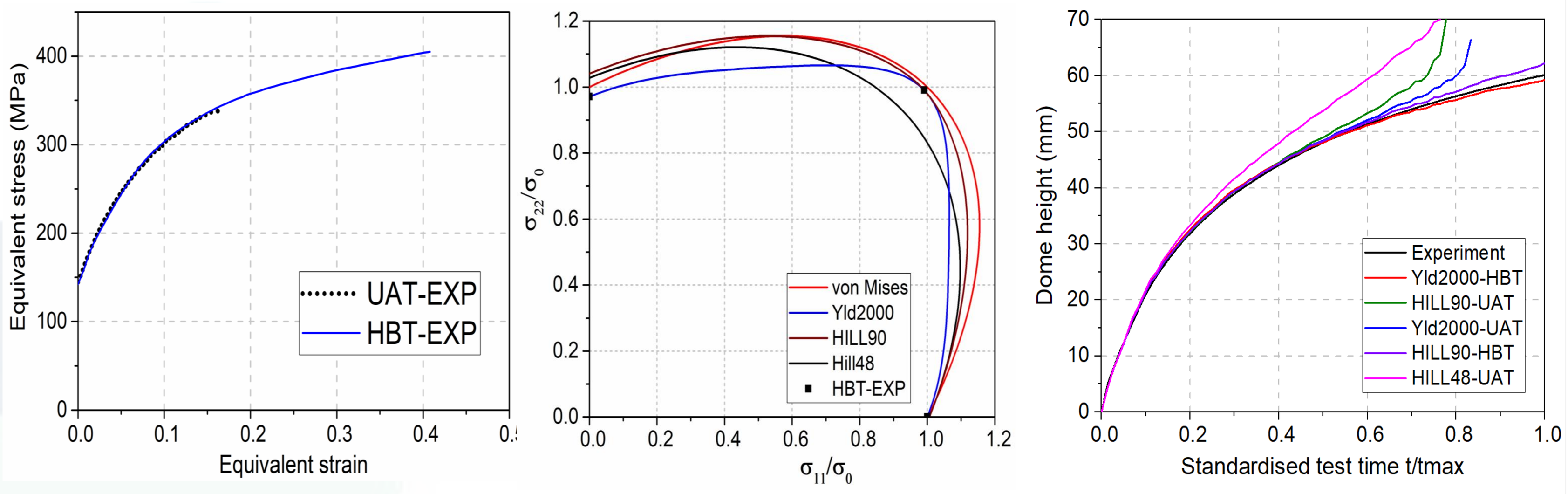
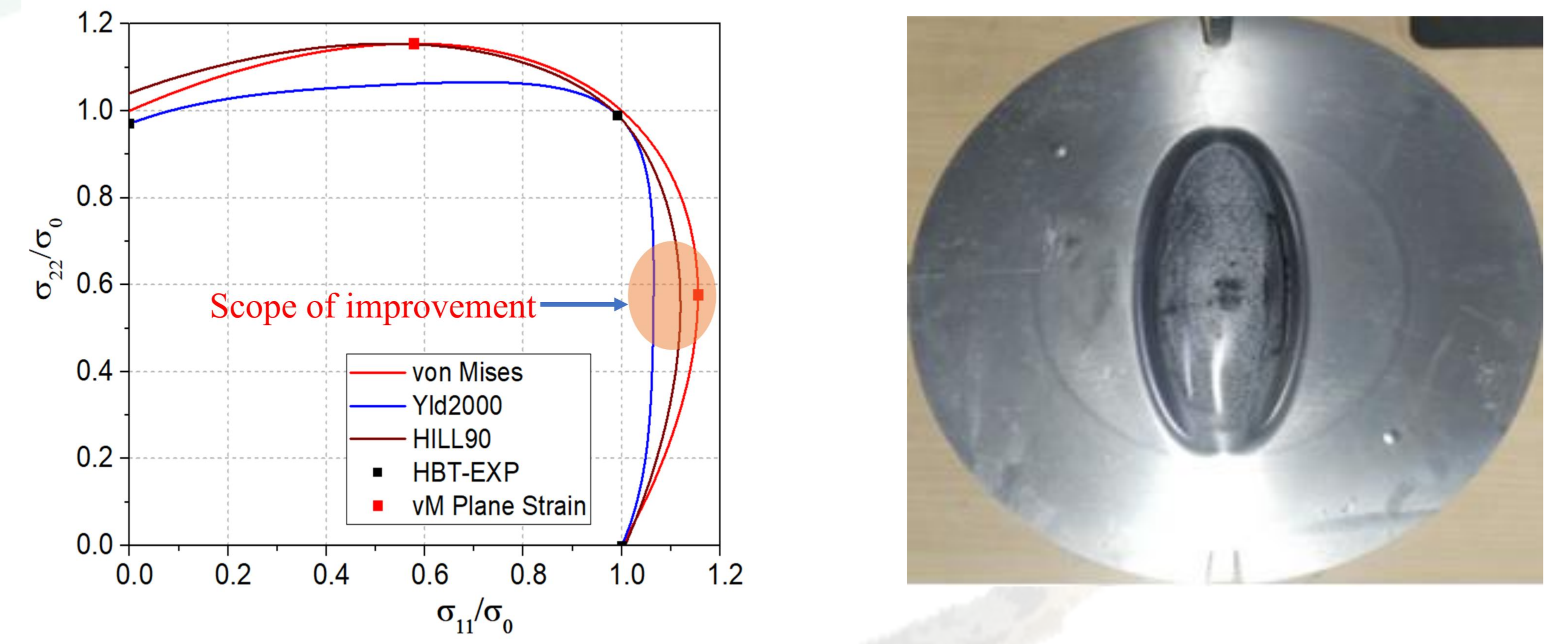


Fig. 3(a) stress-strain curve obtained from UAT and HBT (b) yield loci predicted using different yield criteria (c) predicted dome height evolution

Upcoming work: Elliptical bulge test

- Will be helpful in the numerical simulation of sheet metal parts in which failure mainly occurs in plane strain state.



Conclusions

In numerical simulations, yield function and hardening behavior, defined using uniaxial and biaxial tensile properties, is found to predict dome height evolution closer to the experiments than when defined using uniaxial tensile properties only. A further improvement would be possible to achieve using material properties in plane-strain condition.

Industrial Significance

Numerical simulation of sheet metal forming processes is important in successful manufacturing of sheet metal parts for automotive and aerospace industries to reduce defective parts and die trials. The methodology of material modeling presented in this work is expected to improve accuracy of prediction of thinning and forming load, especially in sheet metal forming simulation using lightweight Al alloys.

References

[1] Suttner S, Merklein M (2016) Experimental and numerical investigation of a strain rate controlled hydraulic bulge test of sheet metal. J Mater Process Technol 235:121–133.

[2] Ved Prakash, D. Ravi Kumar, M. Merklein, H, Hagenah 2019, “Numerical simulation of hydraulic bulging using uniaxial and biaxial flow curves and different yield criteria”, International Deep Drawing Research Group (IDDRG), International Conference on Metal Forming, University of Twente, Netherlands, 3rd-7th June, 2019.

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