An Inverse Analysis Method Applied to Optimization of Specimen's Shape for Performing Hot Rapid Crushing Tests from Homogeneous Initial Temperature Field

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Abstract. Specific experimental tests with loadings conditions close to those of industrial fast forming processes as rapid forging, rapid stamping or high speed machining, characterized by large plastic strains, localized deformations and important gradients of strain rates, strain and temperature, requires to analyses material flow behavior at different initial temperatures. One of the more important conditions to obtain intrinsic rheological constitutive equations is to have a quasi-homogenous initial temperature distribution and especially to keep constant the material microstructure during the specimens heating. The rapid induction heating seems to be one of the most reliable processes. This scientific study proposes an inverse analysis technique based on numerical finite element modelling to define on the thermal point of view, optimal specimen shapes for performing hot rapid crushing tests from homogenous initial temperature field.

Keywords: Hot SHPB pressing, Thermal Cooling, FEM, Inverse Analysis.

1 Experimental and Computational Principles

Metals with high thermal diffusivity as aluminum or cooper alloys require short times between the stop of the heating process and the start of mechanical loadings.

Outside the possibility to have a real time loop to launch a mechanical experimental test, generally a short thermal cooling period occurs between the two different stages: thermal heating and mechanical loading. Identification of thermomechanical behavior properties requires to control the homogeneity of specimen initial temperature field and to keep the initial material microstructure. According to these needs this scientific paper proposes to analyses shape optimization of material specimen for a hot rapid crushing test. An Inverse Analysis Method [1-3] will be applied to a Non-Linear Finite Element Model describing here the short thermal cooling during a specified time period, in order to obtain specimen's shape sizes corresponding to the need to have initial material temperatures close to an imposed value, minimizing the temperature gradient on all the useful sample area. All thermal phenomena as conduction, convection and tool's heat transfers will be taken into account. To avoid mechanical buckling and contact friction during the specimen deformation, corresponding constraints will be added along a specific formulation of the cost function. A strong numerical coupling between the direct FE model and an improved gradient Gauss-Newton optimization algorithm, based on a multi-objective cost function formulation, is performed. Starting from standard uniform specimens generally used by mechanical tests, optimal dumbbell samples and cap specimen shape are identified to be the most reliable in order to can achieved SHPB hot rapid crushing tests from a quasi-homogeneous distribution of material initial temperatures.

2 Results and Conclusions

After a short presentation of the problem formulation, details will be making for the corresponding thermal finite element model, the numerical optimization strategy and especially concerning the used inverse analysis technique. Based on specific numerical simulations and optimizations applications for the optimal design of AA5083 specimens shape will be given concerning a hot rapid SHPB crushing test [1].

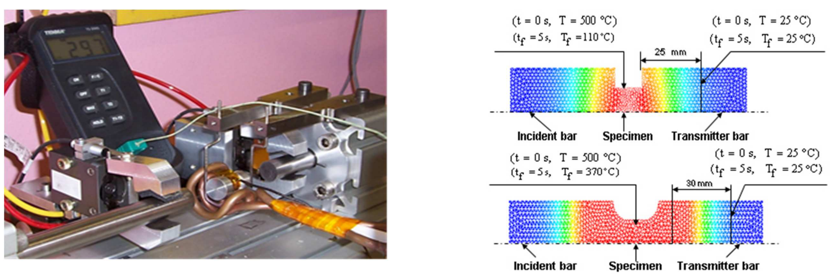

Fig. 1. a) Hot SHPB rapid compression test device, b) Comparisons of Finite Element temperature fields obtained after a time of 5s corresponding to a material cooling from a setting temperature of 500°C reached by a rapid induction heating in the case of an uniform cylindrical specimen and of a dumbbell shape sample [1].

It is shown that the dumbbell specimen with identified specific geometric dimensions permits to have a quasi-homogeneous initial temperature field with average material temperature close to the rapid induction heating's setting value.

References

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