行政院國家科學委員會專題研究計畫成果報告

計畫名稱 ： 高溫超導線材之靜水壓擠製研究(二)

The study on hydrostatic extrusion of high-temperature superconductor wires (II)

計畫編號 ：NSC-88-2212-E-009-002

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一. 中文摘要

本研究計畫的目的在於建立一有限元素模型，來成功地模擬粉體/固屬複合包芯材的靜水壓擠製。在此有限元素模型中，我們導入了流體元素來施加包覆擠製胚料的高壓流體邊界條件。針對不同的擠製比和粉末的填粉密度，以此有限元素模型作模擬分析，所得到結果與實驗值做比較，則呈現了相當良好的一致性。

關鍵詞：有限元素分析，靜水壓擠製，流體元素

Abstract

The purpose of this study was to establish a useful finite element model to successfully simulate the hydrostatic extrusion process of powder/solid composite clad rod. The fluid elements were introduced into the finite element model, and were used to apply the boundary condition of high-pressure fluid surrounding the billet. The finite element model was used to simulate the cases with various extrusion ratio and initial filling density of powder. The results from this finite element model were compared to those from experiments and good agreements were achieved.

Keywords : finite element analysis, hydrostatic extrusion, fluid element

二. 緣由與目的

Rod materials with powder as the cores and metals as the sleeves are called powder/solid composite clad rods. This kind of composites can usually be applied to superconductor wires, dispersion strengthened or fiber reinforced metal matrix composites. For example, superconductor wires are exactly obtained from continuous extrusion processes by using powder/solid composite clad rod as the billet. Hydrostatic extrusion is particularly suitable for the extrusion process of superconductor wires because it can provide larger area reduction and good consolidation to superconducting powder. It is a process which uses the fluid as the working medium to provide isotropic compression to press the workpiece through an extrusion die. The typical arrangement of a hydrostatic extrusion for powder/solid composite clad rod is shown in Fig. 1.

In this study, we established the finite-element model of the hydrostatic extrusion process of powder/solid composite clad rod by using two kinds of boundary conditions to simulate the ambient hydrostatic fluid. Some experimental data were also conducted to verify the results of the finite element analyses.

三. 研究方法

The hydrostatic extrusion apparatus was designed by Hung (1997) and shown in Fig. 2. SKD61 was the chosen material for two-layer high-pressure extrusion container and die; it was heat-treated to reach HRC52 in hardness. Industrial high-pressure oil R68 was chosen as the hydrostatic fluid. Extrusion experiments with hydrostatic pressure as high as 10000 kg/cm^2 (about 10000 atmospheric pressure) can be accomplished.

The extrusion billet consists of powdered core and metallic tube sleeve. The tube was heat treated by full annealing to increase their ductility.

The enclosed superconducting powder was YBCO ($YBa_2Cu_3O_x$). The velocity of extrusion plunger was controlled at about 1.2 mm/min.

The simulation of hydrostatic extrusion of powder/solid composite clad rods concerns with three materials: fluid, powder and metal, whose material properties are completely different. The finite element code used in the study is ABAQUS/Standard.

The deformation of YBCO powder had been characterized by using the Drucker-Prager/Cap yield criterion with several material parameters. The cohesion and the friction angle of powder, which should be written into the input file of ABAQUS, vary with initial filling densities of powder. Both informations can be obtained from direct shear tests and constrained compression tests.

In the model of finite element simulation, surfaces of die and container are regarded as rigid during the working process. Two different kinds of approach had been tested to satisfy the boundary condition of ambient hydrostatic fluid.

(1) Hydrostatic fluid elements:

(2) Frictionless container:

四. 結果與討論

The typical deformed configurations with extrusion ratio 4.0 are shown in Fig. 4 for both approaches of boundary condition.

The extrusion pressure curves for extrusion ratio $r = 4.0$ and initial filling density $d_i = 3.0\,\mathrm{g/cm^3}$ with two approaches of boundary condition are shown in Fig. 5 along with corresponding experimental data. The extrusion pressure curve for the case with fluid elements is increasing with the stroke, and the result shows a good agreement in tendency with experimental data. The average maximum extrusion pressure of the direct extrusion with extrusion ratio 2.5682 is about 513 MPa, but that of hydrostatic extrusion with extrusion ratio 4.0 is only about 350 MPa.

The maximum extrusion pressures vs. various initial densities of powder with extrusion ratio 9.0 are shown in Fig. 6. For the cases with fluid elements, the simulation has to be forced to stop when the billet began to deform rapidly and coming out of the die. However, the maximum extrusion pressure still could be obtained because the extrusion pressure was getting lower and lower after the moment when billet coming out. From Fig. 6, we can conclude that the higher initial filling density can result in a higher extrusion pressure (load).

五. 計畫結果自評

In this study, a useful finite element model for simulating hydrostatic extrusion of powder/solid composite clad rod had been established. The fluid element approach has been proved to be more suitable for simulating the characteristics of ambient fluid. Effects of other possible forming parameters such as core radius and semi-die angle will be considered in the future study.

六. 參考文獻

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七. 圖表

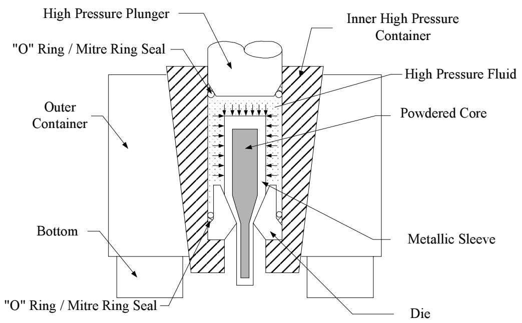


Fig. 1. Hydrostatic extrusion of powder/solid composite clad rod

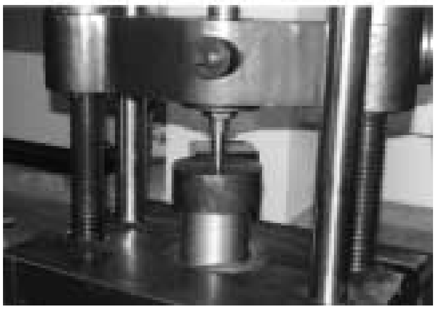


Fig. 2. The hydrostatic extrusion device

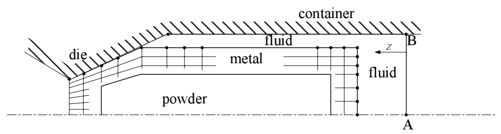
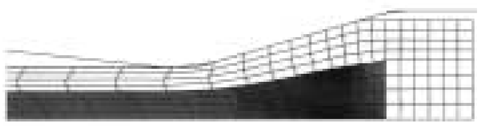
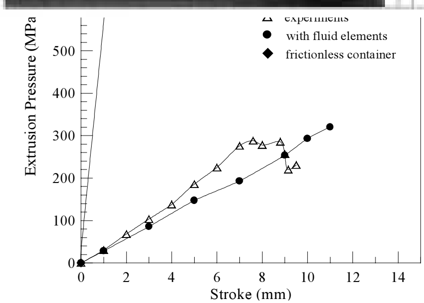
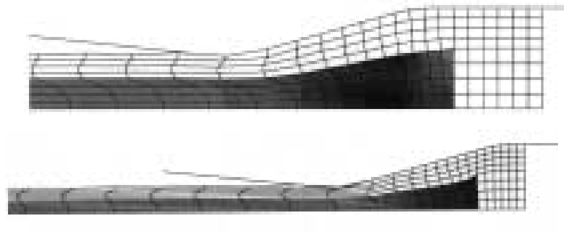


Fig. 3. Boundary condition for ambient fluid





(b) frictionless container, extrusion ratio 4.0



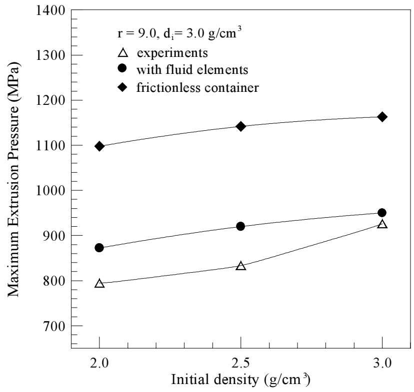
(c) frictionless container, extrusion ratio 9.0

Fig.4. Deformed configurations of various cases

(a) with fluid elements, extrusion ratio 4.0

Fig.4. Deformed configurations of various cases

Fig.5. Extrusion pressure curves for different approaches of boundary



conditions

Fig.6. Maximum extrusion pressure vs. initial densities