World Academy of Science, Engineering and Technology
International Journal of Materials and Metallurgical Engineering
Vol:17, No:11, 2023

Mechanical and Material Characterization on the High Nitrogen Supersaturated Tool Steels for Die-Technology

Authors : Tatsuhiko Aizawa, Hiroshi Morita

Abstract : The tool steels such as SKD11 and SKH51 have been utilized as punch and die substrates for cold stamping, forging, and fine blanking processes. The heat-treated SKD11 punches with the hardness of 700 HV wrought well in the stamping of SPCC, normal steel plates, and non-ferrous alloy such as a brass sheet. However, they suffered from severe damage in the fine blanking process of smaller holes than 1.5 mm in diameter. Under the high aspect ratio of punch length to diameter, an elastoplastic bucking of slender punches occurred on the production line. The heat-treated punches had a risk of chipping at their edges. To be free from those damages, the blanking punch must have sufficient rigidity and strength at the same time. In the present paper, the small-hole blanking punch with a dual toughness structure was proposed to provide a solution to this engineering issue in production. The low-temperature plasma nitriding process was utilized to form the nitrogen supersaturated thick layer into the original SKD11 punch. Through the plasma nitriding at 673 K for 14.4 ks, the nitrogen supersaturated layer, with the thickness of 50 μm and without nitride precipitates, was formed as a high nitrogen steel (HNS) layer surrounding the original SKD11 punch. In this two-zone structured SKD11 punch, the surface hardness increased from 700 HV for the heat-treated SKD11 to 1400 HV. This outer high nitrogen SKD11 (HN-SKD11) layer had a homogeneous nitrogen solute depth profile with a nitrogen solute content plateau of 4 mass% till the border between the outer HN-SKD11 layer and the original SKD11 matrix. When stamping the brass sheet with the thickness of 1 mm by using this dually toughened SKD11 punch, the punch life was extended from 500 K shots to 10000 K shots to attain a much more stable production line to yield the brass American snaps. Furthermore, with the aid of the masking technique, the punch side surface layer with the thickness of 50 μm was modified by this high nitrogen super-saturation process to have a stripe structure where the un-nitrided SKD11 and the HN-SKD11 layers were alternatively aligned from the punch head to the punch bottom. This flexible structuring promoted the mechanical integrity of total rigidity and toughness as a punch with an extremely small diameter.

Keywords : high nitrogen supersaturation, semi-dry cold stamping, solid solution hardening, tool steel dies, low temperature nitriding, dual toughness structure, extremely small diameter punch
Conference Title : ICHNSSS 2023 : International Conference on High Nitrogen Steels and Stainless Steels
Conference Location : Istanbul, Türkiye
Conference Dates : November 13-14, 2023