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<AT>Use of liquid lubricant for backward extrusion of cup with internal splines using pulsating motion
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<ABS-HEAD>Highlights► Backward extrusion of internal splines cup using pulsating motion was developed ► Seizure was prevented even for liquid lubricant without conversion coatings ► Inner of cup was re-lubricated by negative pressure with pulsating motion

<ABS-HEAD>Abstract
<ABS-P>To use liquid lubricants for cold forging and extrusion operations causing severe deformation without phosphate-conversion coatings, automatic re-lubricating using pulsating motion of a servo press was enhanced. In backward extrusion of a cup with internal splines, negative pressure for supplying the lubricant to the inner surface of the cup was generated under the punch bottom by the pulsating motion. Since the punch grooves are not fully filled with metal during extrusion, the gaps are formed in the grooves, and thus the liquid lubricant is supplied through these gaps up to the punch bottom without completely taking the punch from the cup. The effects of the holding time after each punch upstroke, the viscosity of the lubricant and the number of cycles on the seizure prevention and the surface quality of the formed cup were examined from experiments of extrusion with pulsating motion. To shorten the forming time, lubricant pockets on a punch bottom and billet top and increase in punch upstroke were employed.
<KWD>Keywords: backward extrusion; pulsation; liquid lubricant; seizure; servo press; internal splines; cup

<H2>3.1.1
<H2>3.1.2
<H3>3.1.3 1. Introduction
Although the phosphate conversion coating treatment is commonly used for lubrication in cold forging having severe deformation, this treatment has the disadvantages of sludge including heavy metals, a large amount of wasted water, substitutable lubricants, etc. The environmental load of the phosphate conversion coating treatment is problematic. Caminaga et al. (2006) evaluated liquid lubricants and lubrication treatments in cold extrusion of steel bars, and showed that the liquid lubricants without surface texturing were insufficient even for small enlargement of surface. Bay et al. (2010) summarised the environmentally benign lubrication for metal forming processes. Sagisaka et al. (2012) developed a double layer type lubricant composed of a high adhesive undercoat and a low frictional overcoat, and this lubricant was treated by dipping and drying. Arentoft et al. (2009) developed a lubrication structure having a porous layer for entrapping a lubricant by electrochemical deposition. On the other hand, Geiger et al. (2002) improved the tool life by generating lubricant pockets on the tool surface using micro texturing in cold forging. Wagner et al. (2008) locally optimised micro textures of the tool surface for the improvement of tool life. Merklein et al. (2010) locally applied the micro textures to improve the material filling of the gear tooth in plate forging, and Vierzigmann et al. (2011) investigated lubricant pockets on the sheet surface produced by coining. It is desirable in forming industry to develop approaches for applying liquid lubricants to cold forging without the phosphate-conversion coating treatment.