Coupled Abrasive and Fatigue Wear Modeling of Blanking Punches for Prediction of Wear Using Linear and Nonlinear Wear Models

FFW 1553

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Introduction

- Conventional Archard wear models have been widely used to simulate punch wear.
- Nonlinear wear of punch increases due to fatigue damage during long-term cyclic loading.
- Coupled abrasive and fatigue wear model was proposed to predict fatigue-induced nonlinear wear behavior.
- Wear geometry update method was developed to simulate punch wear geometry in the finite element model.

Wear Models and Parameters

Abrasive wear model: Modified Archard wear model

$$W = k\frac{P^a V^b}{H^c}N$$

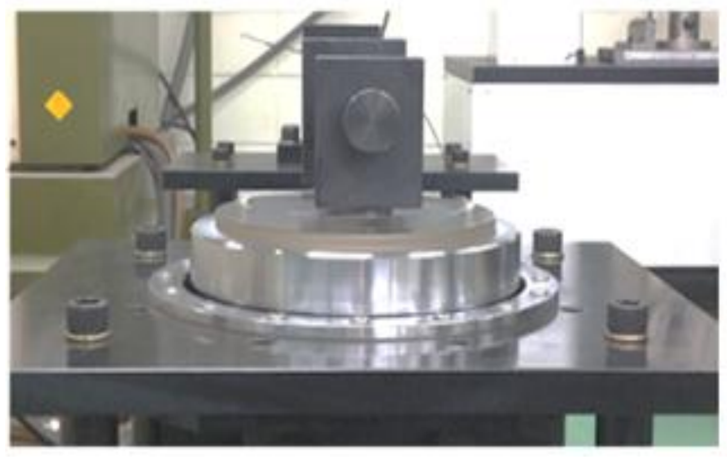
W: wear depth
N: accumulated cycles
a, b, c : wear constants

Fatigue wear model: Lemaitre damage model

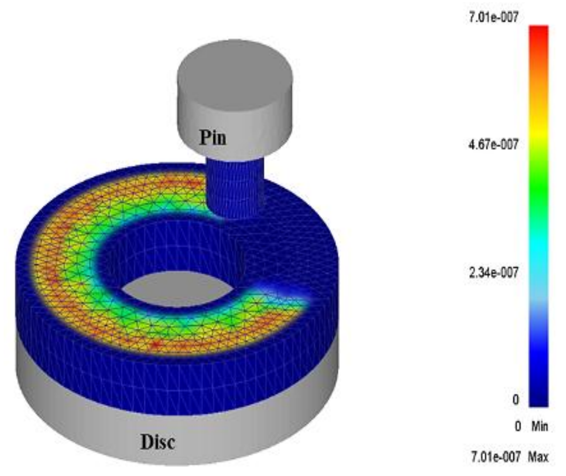
$$\dot{D} = \dot{\bar{\varepsilon}}_e\left(-\frac{Y_e}{S_0}\right)^{b_0}$$

S_0, b_0: damage parameters
D : damage variable
Y_e: elastic strain energy release rate

$$-Y_e = \frac{\bar{\sigma}_e^2}{2E(1-D)^2}\left[\frac{2}{3}(1+\nu) + 3(1-2\nu)\left(\frac{\sigma_{H,e}}{\bar{\sigma}_e}\right)^2\right]$$



Pin-on-disc test machine



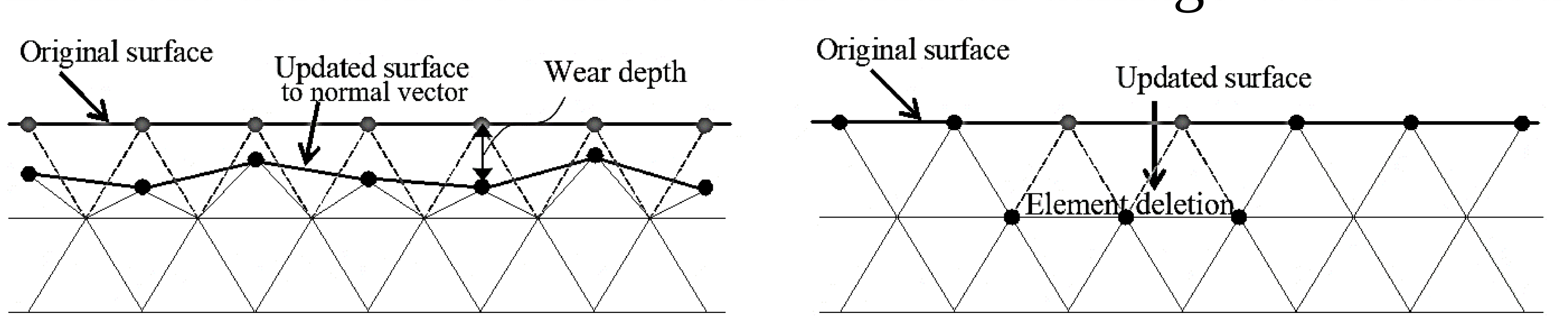
Finite element analysis

Table 1. Linear and Nonlinear wear model parameters

Wear model	Parameter	Values (AISI D2)
Linear wear	k	3.57×10^{-5}
	a	1.38
	b	1.48
	c	2.86
Nonlinear wear	S_0	5.06
	b_0	0.57
	D	0.68

Geometry Update Method

- Abrasive wear calculated using modified Archard model.
- Fatigue damage accumulated using Lemaitre damage model.
- To achieve faster wear prediction than blanking experiments, wear update was performed using accumulated cycles.
- Element deletion occurred when critical damage was reached.



(a) (b)

Fig. 1. Schematic representation of geometry update for (a) abrasive wear and (b) fatigue wear.

Results and Discussion

- Wear depth at the side surface was greater than that at the bottom surface of punch.
- Fatigue-induced nonlinear wear of punch occurred during long-term blanking cycles.
- The maximum relative error between the experimental and simulated wear depths was 7%.

Table 2. Linear and nonlinear wear model parameters

Division	Values
Punch Material	AISI D2
Heat-treated hardness	HRC 58
Sheet Material	AISI 430
Clearance and Thickness	8%, 1mm
Repeated Cycles	300,000

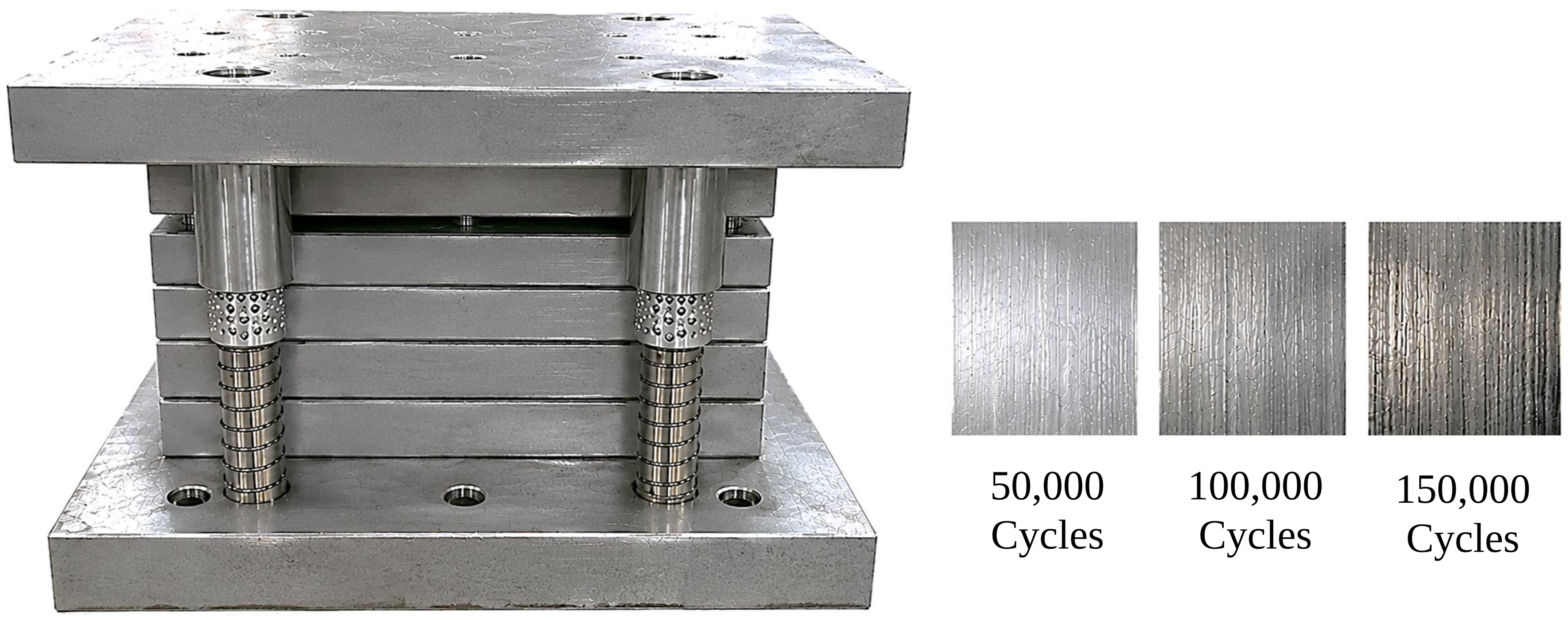
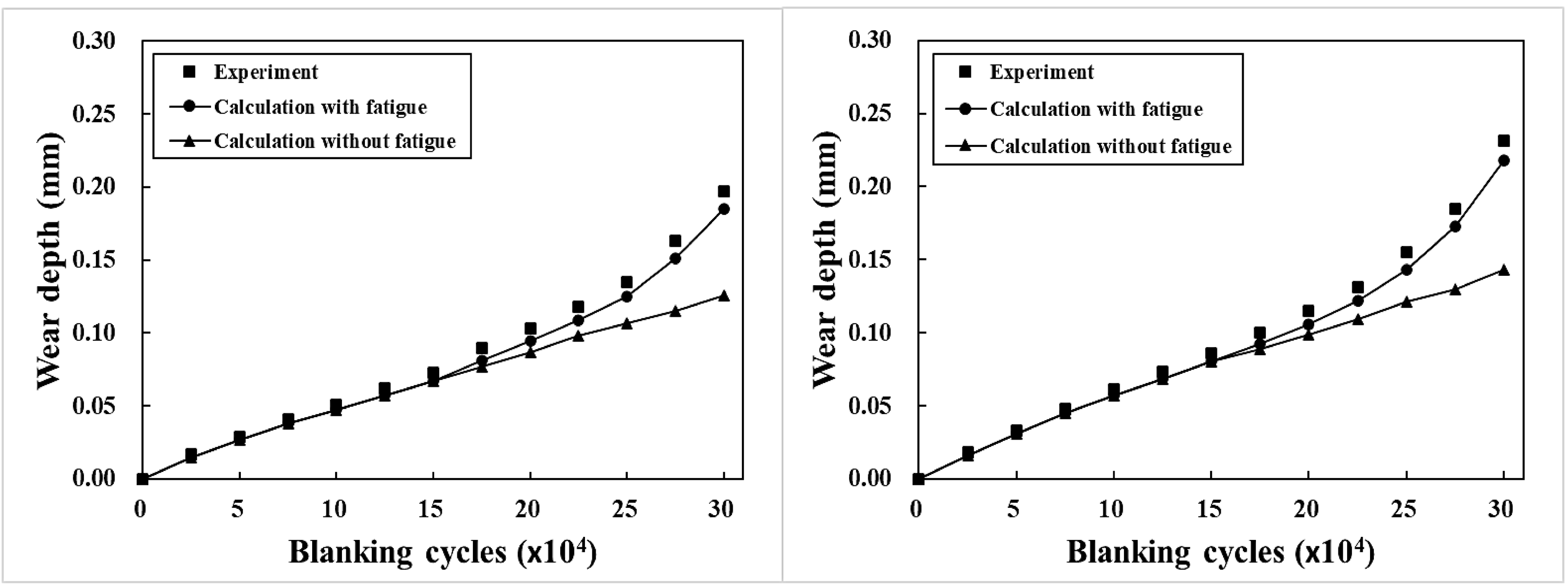


Fig. 2. Blanking die and punch micrograph after repeated blanking cycles



(a) (b)

Fig. 3. Wear depth evolution at punch (a) bottom and (b) side surface.

Conclusions

- Coupled abrasive–fatigue wear model developed for prediction of punch wear.
- Linear wear model effectively predict the wear evolution during linear wear region.
- Nonlinear wear model accurately captures fatigue-induced accelerated wear under long-term cyclic loading.
- Developed wear geometry update method using accumulated cycles was faster wear prediction than blanking experiments.
- Proposed model is applicable to prediction of industrial punch wear based on abrasive and fatigue wear.