Proceedings of Malaysian International Tribology Conference 2015, pp. 27-28, November 2015

Wear prediction of die coating in strip ironing by Finite Element simulation

Numchoak Sabangban[1], Sasawat Mahabunphachai[2], Sedthawatt Sucharitpwatskul[2], Numpon Mahayotsanun[1,*]

[1)] Department of Mechanical Engineering, Faculty of Engineering, Khon Kaen University,
123 Moo 16, Mittraphap Road, Muang, Khon Kaen 40002, Thailand.
[2)] National Metal and Materials Technology Center (MTEC)
114 Thailand Science Park (TSP), Phahonyothin Road, Khlong Nueng, Khlong Luang, Pathum Thani 12120, Thailand.

[*]Corresponding e-mail: numpon@kku.ac.th

Keywords: Finite Element simulation; strip ironing; wear

ABSTRACT – This paper presented a method to predict wear of the die coatings in strip ironing process by using finite element simulation. This method calculated the wear depth of the die coatings in each cycle of the strip ironing process. TiN and CrN coatings were investigated. The number of cycles until reaching die coating thickness was also determined. In this study, TiN provided lower wear depth and higher number of cycles.

1. INTRODUCTION

The recent trend in automotive industry is the increased use of Advanced High Strength Steel (AHSS) due to its high strength-to-density ratio. However, this material generates high stress during stamping, particularly in the thinning area of the sheet. This leads to tool wear and reduced tool life. Tool surface coatings are normally used to solve the problem. As a result, it is crucial to be able to predict wear of tool coating in order to obtain optimized coatings and forming conditions, particularly for strip ironing of AHSS.

Several research groups [1-5] carried out strip ironing experiments to investigate the friction and wear behaviors under different conditions. General guidelines for materials and forming conditions could be achieved through the experiments. In order to predict tool wear, many researchers [6-11] also developed different models and techniques to predict friction and wear in sheet metal forming, particularly by using finite element (FE) simulation. Generally, the results of stresses were analyzed to predict tool wear in the FE simulation of a forming cycle. However, in order to determine wear of die coatings, the wear amounts occurring in each forming cycle should be considered.

Thus, this paper provided a method to predict die coating wear in each strip ironing cycle by using the FE simulation. Two types of die coatings were examined (TiN and CrN). The number of strip ironing cycles that could be carried out until reaching die coating thickness was determined and compared between the two coatings.

2. METHODOLOGY

Figure 1 shows the FE simulation setup and steps of the one-sided strip ironing. The 2D non-linear plane strain structural approach was selected. The punch was moved downward with 0.1 mm/s sliding velocity for 100 mm. The punch was modelled as a rigid body and the die and sheet were modelled as deformable bodies. The material properties are presented in Table 1. Note that E is the Young's Modulus and Y is the yield strength. The arctangent friction model was selected for all the interfaces and the friction coefficient value was set to be 0.3.

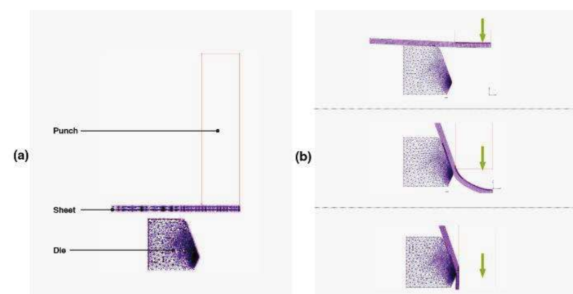

Figure 1 FE simulation the strip ironing: (a) model setup (b) strip ironing steps.

Table 1 Materials properties used in the FE simulation.

Materials	E (N/mm^2)	Y (N/mm^2)
Sheet	22,300	777
Die (TiN)	60,000	1,200
Die (CrN)	31,000	1,200

In order to obtain the wear depth for each forming cycle (W), Equation 1 was used.

$$W = k\sigma V t_c \qquad (1)$$

Where k is the specific wear rate, σ is the mean contact pressure, V is the relative velocity, and t_c is the mean total time per cycle. Table 2 presents the specific wear rate and coating thickness (h) of the tested coatings.

In this study, V was set to be 0.1 mm/s. In each strip ironing cycle, the FE simulation generated σ values, which could be used to obtain W. In order to obtain the number of cycles (N) until reaching coating thickness, Equation 2 was used.

Table 2 Specific wear rate and coating thickness.

Die Coatings	k (m^2/N)	h (μm)
TiN	1.96×10^{-16}	1.13
CrN	5.70×10^{-16}	4.00

$$N = \frac{h}{W} \quad (2)$$

3. RESULTS AND DISCUSSIONS

Table 3 provides a summary of wear depth per cycle and total number of cycles until reaching coating thickness.

Table 3 Wear depth per cycle and number of cycles until reaching coating thickness.

Die Coatings	W (nm)	N
TiN	0.75	1,516
CrN	33.6	119

It could be clearly seen that TiN provided lower wear depth per cycle and higher number of cycles until reaching coating thickness than CrN did. This could be due to the fact that TiN had a lower specific wear rate. The results demonstrated that the coating having low specific wear rate led to the increased number of strip ironing cycles. The obtained wear depth per cycle could be used to select appropriate coating types to reduce wear and increase tool life. The number of strip ironing cycles that could be performed until reaching the die coating thickness was also helpful to determine when to carry out surface treatments or tool replacements.

Nevertheless, other major factors that are influential to friction and wear in strip ironing should also be considered, for instances, sheet thickness reduction ratio, sliding velocity, contact pressure, lubrication, and temperature. Most importantly, the FE simulation results must be confirmed with the experiments in order to validate and improve the method used in this study.

4. CONCLUSIONS

This study calculated wear depth per cycle and number of cycles until reaching die coating thickness of TiN and CrN coatings in the strip ironing process by using FE simulation. The results showed that TiN provided lower wear depth per cycle and higher number of cycles until reaching die coating thickness due to its lower specific wear rate. The experimental investigation is currently being carried out to validate the presented wear depth calculation method.

5. ACKNOWLEDGEMENT

The authors would like to acknowledge the supports from Department of Mechanical Engineering, Faculty of Engineering, Khon Kaen University (KKU) and National Metal and Materials Technology Center (MTEC).

6. REFERENCES

[1] N. Kawai, T. Nakamura, and K. Dohda, “Development of Anti-Weldability test in metal forming by means of Strip-Ironing type friction testing machine,” *Journal of Engineering for Industry*, vol. 104, no. 4, pp. 375-382, Nov. 1982.

[2] Dohda, K., Kubota, H., and Tsuchiya, Y. “Application of DLC coating to ironing die,” *JSME International Journal*, vol.48, no. 4, pp. 286-291, 2005.

[3] Dohda, K., Makino, T., and Katoh, H, “Tribo-Characteristic of coated die against magnesium in ironing process,” in *ESAFORM 2009*, vol.2, pp. 243-246.

[4] J. L. Andreasen, N. Bay, M. Andersen, E. Christensen, and N. Bjerrum, “Screening the performance of lubricants for the ironing of stainless steel with a strip reduction test,” *Wear*, vol. 207, no. 1-2, pp. 1-5, Jun. 1997.

[5] I. M. Petrushina, E. Christensen, R. S. Bergqvist, P. B. Møller, N. J. Bjerrum, J. Høj, G. Kann, and I. Chorkendorff, “On the chemical nature of boundary lubrication of stainless steel by chlorine- and sulfur-containing EP-additives,” *Wear*, vol. 246, no. 1–2, pp. 98-105, Nov. 2000.

[6] D. Delarbre and P. Montmitonnet, “Experimental and numerical study of the ironing of stainless steel cups,” *Journal of Materials Processing Technology*, vol. 91, no. 1-3, pp. 95-104, Jun. 1999.

[7] Z. Wang, K. Dohda, and Y. Jeong, “FEM simulation of surface smoothing in the ironing process,” *Journal of Materials Processing Technology*, vol. 113, no. 1-3, pp. 705-709, Jun. 2001.

[8] S. Chandrasekharan, H. Palaniswamy, N. Jain, G. Ngaile, and T. Altan, “Evaluation of stamping lubricants at various temperature levels using the ironing test,” *International Journal of Machine Tools and Manufacture*, vol. 45, no. 4-5, pp. 379-388, Apr. 2005.

[9] H. Kim, T. Altan, and Q. Yan, “Evaluation of stamping lubricants in forming advanced high strength steels (AHSS) using deep drawing and ironing tests,” *Journal of Materials Processing Technology*, vol. 209, no. 8, pp. 4122-4133, Apr. 2009.

[10] D. Adamovic, V. Mandic, Z. Jurkovic, B. Grizel, M. Stefanovic, T. Marinkovic, and S. Aleksandrovic, “An experimental modelling and numerical fe analysis of steel-strip ironing process,” *Technical Gazette*, vol. 17, no. 4, pp. 435-444, 2010.

[11] S. K. Singh, V. Kumar, P. Prudvi Reddy, and A. K. Gupta, “Finite element simulation of ironing process under warm conditions,” *Journal of Materials Research and Technology*, vol. 3, no. 1, pp. 71-78, Jan. 2014.