[Nam* *et al.*, 5(9): September, 2016]
IC™ Value: 3.00

ISSN: 2277-9655
Impact Factor: 4.116

IJESRT

INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

DAMAGE ANALYSIS OF DEGRADED SLITTING KNIFE

Ki-Woo Nam*, Cheol-Su Kim and Seok-Hwan Ahn
*Department of Materials Science and Engineering, Pukyong National University, Busan, Korea
UR Interdisciplinary Program of Mechanical Engineering, Graduation School, Pukyong National University, Busan, Korea
Department of Mechatronics, Jungwon University, Chungbuk, Korea

DOI: 10.5281/zenodo.61480

ABSTRACT

This study analyzed the damage to a slitting knife after cutting steel sheets. Damages to the structure were observed and wear tests were conducted. In addition, the degradation on the damaged and undamaged parts was compared with a Vickers hardness test. Weibull statistical analysis was carried out in order to evaluate the reliability of the Vickers hardness measured data. Spalling of the edge portion occurred by degradation during use over a long period. Rough parts in the specimens were caused by damage because the slitting knife was used for 1 year. The friction coefficient and wear loss at the damaged parts of the knife edge were slightly larger from shock due to repetitive cutting operation. The Vickers hardness followed a two-parameter Weibull probability distribution.

KEYWORDS: Slitting Knife, Damage Analysis, Wear Test, Vickers Hardness, Weibull Analysis

INTRODUCTION

Progression studies were conducted on parts of the machine and the automotive to determine wear resistance and frictional properties in order to prevent degradation damage during use.[1] Generally, the slitting process involves cutting the width of a standard fit of parts for use in automobiles.[2] The slitting process is performed by grinding using the edge of a slitting knife.[3] Therefore, the slitting knife is strictly limited with regard to the outer diameter and thickness to maintain precision. The operating principle of a slitting knife is to cut in the longitudinal direction while passing through the top and bottom of the mold. This is, to cut the raw steel sheet to the size of the product. Therefore, if the dimensional accuracy of the slitting knife is high, the cutter can cut a larger number of steel sheets. The life of a slitting knife is reduced by abrasion damage caused by repeated operations. In addition, wear damage affects the precision of parts created during the cutting operation. Therefore, SKD61 is usually used as the material for the mold of slitting knives.[4] SKD61 has excellent wear resistance and heat resistance. Tempering of the slitting knife is conducted in two steps to improve the knife's ability to withstand wear and impact. The slitting process has been studied by finite element analysis,[5] but abrasion damage-related research with actual usage does not exist.[6,7]

This study analyzed the damaged parts of a slitting knife used for cutting steel sheets.[6] Damages to the structure were observed and wear tests were conducted. [8-10] In addition, the degradation in the damaged and undamaged parts was compared with a Vickers hardness test. Weibull statistical analysis was carried out in order to evaluate the reliability of the Vickers hardness measured data.[11-13]

MATERIALS AND METHODS

Fig. 1 shows the appearance of the slitting knife. This was used during one year on site of automobile parts manufacture. This has peeling the surface by the degradation.

Fig. 2 shows the slitting process. The slitting knife is mounted on the upper mold and the steel plate is cut while rotating the lower mold. The material used for the mold in this study is SKD61 steel.

Fig. 3 shows the heat treatment conditions for SKD61 steel. Heat treatment was performed with oil-cooling after quenching for 25 minutes at 1010 ºC. Tempering was carried out twice with air-cooling over 120 minutes at 560 ºC. Damaged parts were examined with SEM at 300x and 70x magnification. In addition, mirror-polished specimens were etched with a solution of 95% $FeCl_2$ + 5% distilled water, and structures were observed with a metallurgical microscope.

The type of test machine was a "block on ring". This equipment consists of a circular plate ring-shaped counterpart material that rotates during the test and a rectangular-shaped specimen under constant load in order to maintain contact with the counterpart material. The counterpart material was HAP72 with Φ35 and a thickness of 7 mm. The test conditions were as follows; (1) the rotation speed of the ring, which had a dimension of 35 mm, was 50 rpm; (2) the load was 14.25 N; (3) the total wear distance was 500 m; and (4) the tests were performed at room temperature in a dry condition. To obtain high reliability, 55,000 data points, which were obtained at 10 data points per second, were used.

Hardness was measured using a Vickers hardness tester (HV-114, Mitutoyo). The specimens were measured for 10 seconds from the indentation loads of 4.9 N. Weibull statistical analysis was performed with hardness data measured 10 times for each specimen.

Fig. 1 Appearance of slitting knife

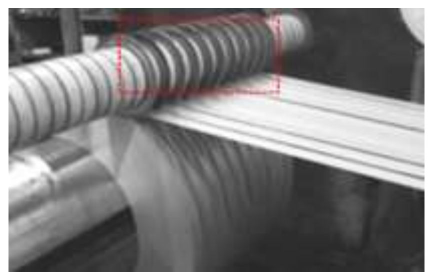


Fig. 2 Slitting process

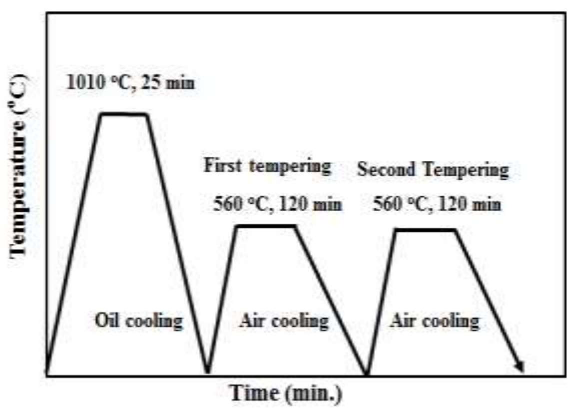


Fig. 3 Heat treatment conditions

RESULTS AND DISCUSSION

Fig. 4 shows a damaged part of the slitting knife. The circle shows the edge of the slitting knife and outlines the damage to the material in contact with the steel sheet. The damaged area exhibits a spalling pattern from the vibration caused by contact with the upper and lower molds. This degraded the hardened layer of the surface with repetitive cutting action, and was peeled off by an external shock.

Fig. 5 is the SEM observation result for Fig. 4 and illustrates the damage from the impact caused by rotation. Peeled parts containing a lot of defects and impurities were observed, confirming deep flaws in the longitudinal direction, which is typical in spalling damage.

The microstructure of the damaged portion of the slitting knife and the base material at the edge were observed to investigate the peeling phenomenon caused by wear.

Fig. 6 shows the structure in the base material with and without damage. Generally, toughness is lost by quenching and regained by tempering. The base material formed a tempered-martensite structure with high strength and toughness, but the the damaged part shows a somewhat coarser spheroidizing structure. Therefore, the material was changed from a martensite structure to a spheroidizing structure with degradation. Due to the spheroidizing structure, peeling occurs easily with an external impact.

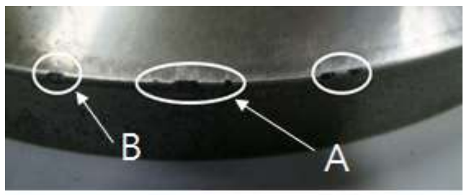
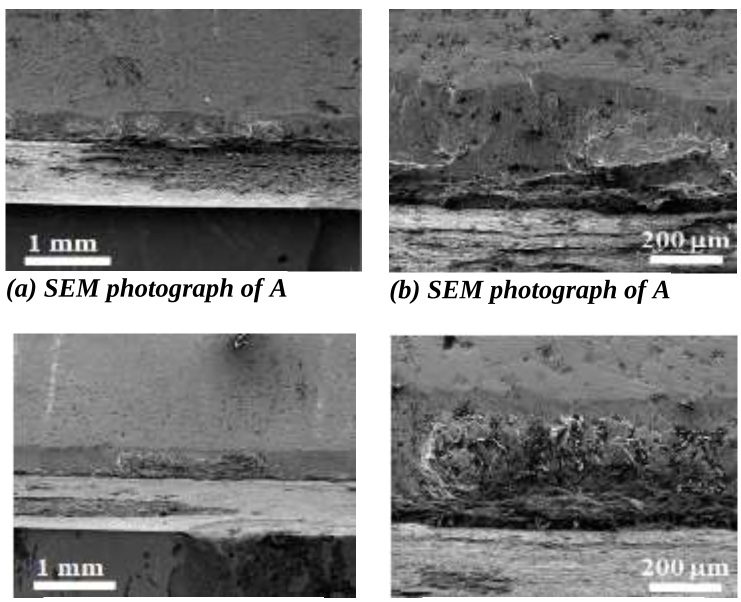


Fig. 4 Spalling failures at the slitting knife edge



(a) SEM photograph of A *(b) SEM photograph of A*

(c) SEM photograph of B *(d) SEM photograph of B*

Fig. 5 SEM photograph of spalling failure parts from Fig.4

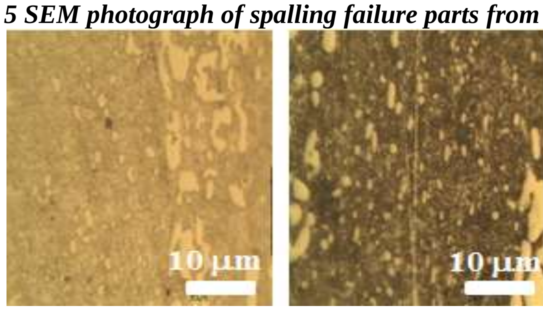


Fig. 6 Microstructure observation of spalling failure part and base metal

A wear test was conducted on the inside (a portion close to the radius of the slitting knife), surface and damaged parts (knife edge) of the slitting knife. Fig. 7 shows the wear loss and the friction coefficient of the damaged part.

Fig. 8 shows the average wear loss and the average friction coefficient obtained from the three areas subjected to wear tests. Specimens became damaged as the slitting knife was used over a period of 1 year. Therefore, the friction coefficient and wear loss at the knife edge was slightly larger. The friction coefficient and wear loss of the heat-treated surface was small while the inside showed larger damage than the polished edge because of cutting. Tables 1 and 2 show the mean, standard deviation (STD), and coefficient of variation (COV) according to mathematical statistics.

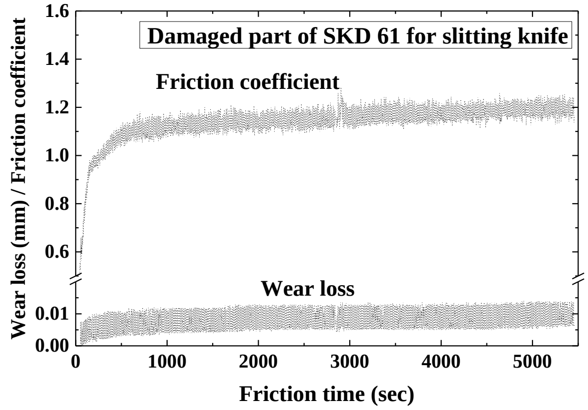


Fig. 7 Wear loss and friction coefficient according to friction time

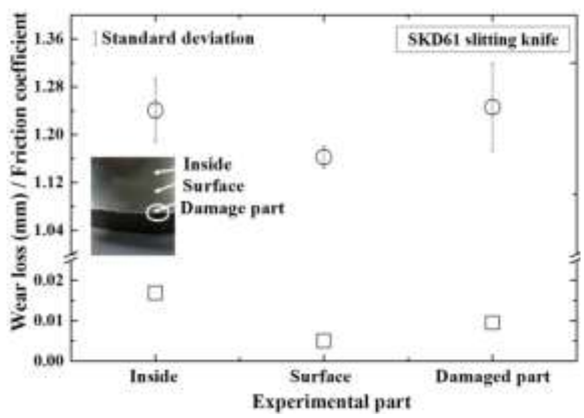


Fig. 8 Wear loss and friction coefficient according to experimental part

Table 1 Estimated parameters of wear loss

	Mean	Standard deviation (SD)	Coefficient of variation (COV)
Inside	0.0169	0.00085	0.050
Surface	0.0050	0.00071	0.141
Damage Part	0.0095	0.00310	0.326

Table 2 Estimated parameters of friction coefficient

	Mean	Standard deviation (SD)	Coefficient of variation (COV)
Inside	1.241	0.053	0.043
Surface	1.163	0.018	0.015
Damage Part	1.246	0.073	0.058

Fig. 9 shows the mean Vickers hardness measured at each location. The mean value of the Vickers hardness was approximately 760 and 687 Hv on the inside and the heat treated surface, respectively. On the other hand, the corresponding values on the surface of the damaged side and the damaged part were 530Hv and 493 Hv, respectively. The damaged part showed the smallest value. This is because the peeling occurred from shock due to repetitive cutting operation.

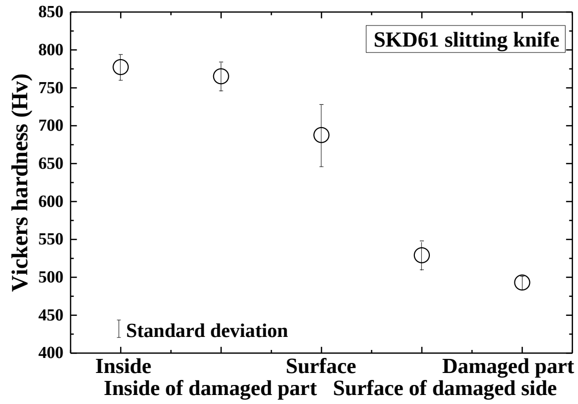


Fig. 9 Vickers hardness according to specimen conditions

In the strength evaluation of ceramics, as a brittle material, a probabilistic evaluation considering the variation distribution is important in order to improve the accuracy of the assessment. In addition, it can be seen that Vickers hardness is not a determined value, and statistically changes. Accordingly, considering the ease of analysis and the weakest link assumptions, a Weibull statistical analysis needs to be applied as a two-parameter Weibull distribution as shown below.[14]

$$F(x) = 1 - \exp\left[-\left(\frac{x}{\beta}\right)^{\alpha}\right]$$

Here, α is the shape parameter, which refers to the variability of the probability parameter, and β is the scale parameter indicating the characteristic lifetime, which has a failure probability of 63.2%.

Table 3 Estimated Weibull parameters of Vickers hardness

	ⓐ	ⓑ	ⓒ	ⓓ	ⓔ
①	52.54	784.88	777.3	16.78	0.022
②	47.21	773.53	765.2	19.10	0.025
③	19.41	705.30	687.6	41.27	0.060
④	34.94	536.64	529.0	18.99	0.036
⑤	71.62	496.64	493.1	8.32	0.017

ISSN: 2277-9655
Impact Factor: 4.116

Note: ⓐ Shape parameter, ⓑ Scale parameter, ⓒ Mean, ⓓ Standard deviation(SD), ⓔ Coefficient of variation (COV), ① Inside, ② Inside of damaged part, ③ Surface, ④ Surface of damaged side, ⑤ Damaged part

Table 3 shows the shape parameter and the scale parameters of the Weibull distribution function estimated from the Vickers hardness of the as-received specimen and healed specimen. The table also shows the average, standard deviation (STD), and coefficient of variation (COV) according to mathematical statistics.

Fig. 10 shows the Vickers hardness according to the Weibull probability. Since hardness is expressed as a straight line, it can be seen as applicable to the Weibull probability distribution. The Vickers hardness of the damaged specimens (△, ▷) was significantly lower than that of the inside specimens (○, □). The value for the surface specimen (◇) was higher than for the damaged specimen (△, ▷), but was lower than for the inside specimen (○, □). This is caused by degradation due to use.

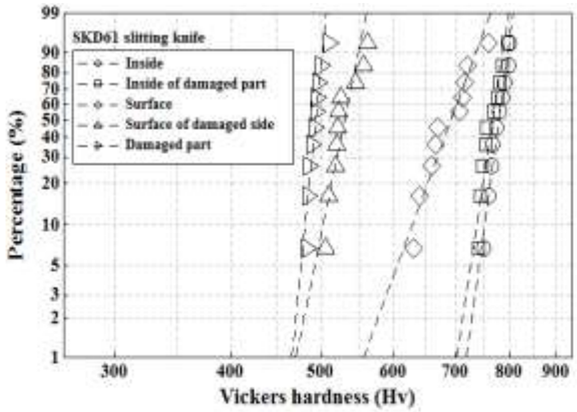


Fig. 10 Weibull plot of Vickers hardness values

CONCLUSION

Analysis of the damage to a slitting knife used to cut steel sheets for automobile parts was performed. The results obtained are as follows. Spalling of the edge portion occurred by degradation during use over a long period of time. Rough parts from damage appeared in the specimens because the slitting knife was used for 1 year. The friction coefficient and wear loss at the damaged part of the knife edge was slightly larger from shock due to repetitive cutting operations. The Vickers hardness followed a two-parameter Weibull probability distribution.

REFERENCES

[1] K. T. Kim and Y. S. Kim, "Effects of Counterpart Materials on Wear Behavior of Thermally Sprayed Ni-based Self-flux Alloy Coatings", Journal of The Korean Society for Power System Engineering, Vol. 11, No. 4, pp. 92-97, 2007.
[2] http://www.swhitech.com/main/
[3] M. E. Merchant, "Mechanics of the Metal Cutting Process. I. Orthogonal Cutting and A Type 2 Chip", J. Appl. Phys., Vol. 16, pp. 267-275, 1945.
[4] W. S. Cho, “Martensitic Transformation and Mechanical Property of Abrasive Resistance Alloys with Heat Treatment Conditions”, A doctor`s Thesis, Chosun University, Jeonnam, Korea, 2009.
[5] K. T. Han and J. K. Seo, "A Study on the Slitting Working by Finite Element Analysis", Journal of The Korean Society for Power System Engineering, Vol. 5, No. 3, pp. 56-63, 2001.
[6] H. Puls, F. Klocke and D. Lung, "Experimental Investigation on Friction under Metal Cutting Conditions", Wear, Vol. 310, Issues 1-2, 15, pp. 63-71, 2014.
[7] P. Hedenqvist and M. Olsson, "Sliding Wear Testing of Coated Cutting Tool Materials", Tribol. Int., Vol. 24, pp. 143-150, 1991.
[8] J. C. Miranda and A. Ramalho, "Study of the Effects of Damage Accumulation on War", Wear, Vols. 330–331, pp. 79–84, 2015.

[9] H. J. Kim, J. D. Kim, S. W. Koh and Y. S. Kim, "Impact and Wear Behavior of Side Plate of FRP Ship", Journal of The Korean Society for Power System Engineering, Vol. 13, No. 6, pp. 123-128, 2009.

[10] I. Ucun, K. Aslantas and F. Bedir, "An Experimental Investigation of the Effect of Coating Material on Tool Wear in Micro Milling of Inconel 718 Super Alloy", Wear, Vol. 300, Issues 1–2, pp. 8-19, 2013.

[11] A. C. Cohen, "Maximum Likelihood Estimation in the Weibull Distribution Based on Complete and on Censored Samples", Technometrics, Vol. 7, pp. 579-588, 1965.

[12] K. W. Nam, S. J. Kim and D. S. Kim, "Weibull Statistical Analysis on Mechanical Properties in $ZrO_2$with SiC Additive", Transactions of the KSME A, Vol. 39, No. 9, pp. 901-907, 2015.

[13] S. J. Kim, D. S. Kim and K. W. Nam, "Determining Mechanical Properties of ZrO2 Composite Ceramics by Weibull Statistical Analysis", ", Transactions of the KSME A, Vol. 39, No. 10, pp. 955-962, 2015.

[14] W. Weibull, "A Statistical Distribution Function of Wide Applicability", ASME J. Applied Mech., Vol. 18, pp. 293-297, 1951.