

Wear Mechanisms in High Speed Steel Gear Cutting Tools

M. Jalali Azizpour, H. Mohammadi majd

Abstract—In this paper, the wear of high speed steel hobs during hobbing has been studied. The wear mechanisms are strongly influenced by the choice of cutting speed. At moderate and high cutting speeds three major wear mechanisms were identified: abrasion, mild adhesive and severe adhesive. The microstructure and wear behavior of two high speed steel grades (M2 and ASP30) has been compared. In contrast, a variation in chemical composition or microstructure of HSS tool material generally did not change the dominant wear mechanism. However, the tool material properties determine the resistance against the operating wear mechanism and consequently the tool life. The metallographic analysis and wear measurement at the tip of hob teeth included scanning electron microscopy and stereoscope microscopy. Roughness profilometry is used for measuring the gear surface roughness.

Keywords—abrasion, adhesion, cutting speed, hobbing, wear mechanism

I. INTRODUCTION

GEAR hobbing is a widely used method in mass gear production. A hob has a large number of cutting edges arranged spirally around the tool body. Gear hobbing remains a cutting technology where high speed steel continues to find wide application in modern manufacturing practices [1], [2]. Gear hobbing has complicated process kinematics; chip formation and Tool wear mechanisms. Many researchers investigated the wear behavior and tool life of turning and milling cutting tools [3]-[6]. To understand the wear mechanisms in Gear hobbing, it is necessary to have a brief understanding of the Hobbing tribosystem includes hob, Gear, Cutting operation and sever contact in the tool-chip interface. Among the various hobbing parameters cutting speed has the most effective role on wear behavior [7].

In this study the effect of cutting parameters on the wear mechanisms of HSS hobs has been investigated at industrial conditions. The type of high speed steel influences the speed that will be used and the wear of hob. Two grades of HSS (AISI M2 and ASP30) are selected for this purpose.

II. EXPERIMENTAL PROCEDURE

The main shaft of a tractor (Fig.1) is selected as gear blank.

F. A. Author is with the production technology research institute, branch of ACECR, Ahwaz, Iran. (Corresponding author to provide phone: +986113358491; fax: +986113358490; e-mail: m_jpour@yahoo.com).

S. C. Author is with the production technology research institute, branch of ACECR, Ahwaz, Iran. Phone: +986113358491; fax: +986113358490; e-mail: majd_ha@yahoo.com).

Table 1 shows the detail of hob, gear and hobbing condition. The vertical hobbing machining Rh6/1623 is used. Cutting speed that has direct relationship with temperature can change the predominant wear mechanisms and wear behavior of hob as well as gear. Scanning electron microscopy (SEM) was used to study the wear of worn surface and microstructure. Stereoscope (Nikon-type 104) was used to measure the flank and crater wear on the flank and rake face. Surface profilometry is used to measure the roughness of gear that produced by high speed hobbing process.

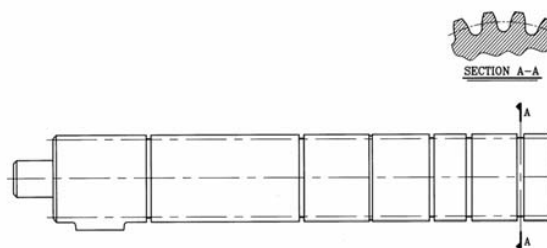


Fig. 1: Main shaft of a tractor as gear blank

TABLE I
HOBBING TRIBOSYSTEM

Gear	Hob	Cutting conditions
		Cutting fluid Telos
Material :21 NiCrMo2	ASP30& M2	Continuous
Hardness :170 BHN	DP = 10	shifting
Spure Gear	1 st	Cut depth: 5.5mm
$d_k=50.8$ mm	$GL=\infty$	Axial feed rate :
$L_{cut}=256$ mm	$D_0=100$ mm	2mm/rev
Number of teeth: 18	L= 100 mm	speed : variable
	Hardness: 65 RC	Climb

III. RESULT AND DISCUSSION

Among the variable hobbing parameters, only the cutting speed can affect the wear behavior strangely [7]. Cutting speed has direct relationship with Tool- chip interface temperature [7], [8]. At lower hobbing speed where the temperature is not high enough, a stable built-up edge (BUE) protects the cutting edge against the abrasive and adhesive wear. However, the formation and rebound mechanism of

BUE Causes a sudden failure in cutting edges in chipping form. The relative motion between Tool and blank at such condition is stick-slip. At higher cutting speeds, this relative motion changes to slip so that the BUE will be unstable to play a wear particle (debris) role, causes three body abrasion wear. Fig.2 shows the SEM topography of BUE in the cutting edge. The segregated carbides and hard partied from tool and blank have the same effects.

As shown in Fig.3 increasing the hobbing speed leads to high abrasion wear. The peak of flank wear is at 65 m/min. At $V=65$ m/min the flank wear is 0.3 mm. in this condition each of the adhesive and abrasive wear is present but the abrasion is the predominant wear mechanism. Fig. 4 shows the SEM topography of the adhesive wear that exists at each condition. This adhesive component often is referred to as mild adhesive wear.

Two body abrasion wear is counteracted with high yield strength (high hardness) as well as large carbide volume of the HSS for three body abrasion [7],[10]. At such condition also, the segregated BUE have a scratch action. The presence of BUE as a thermal barrier layer protects the rake face against the high temperature. At cutting speeds higher than 65 m/min wear particles (debris) begin to soften, and therefore lose their abrasive role at flank wear. Declining in the flank wear curve is because of phenomenon described above. Softening and rebounding of the thermal barrier layer leads to heat transfer from cutting zone to rake face that softens the hob tooth and forms a crater in rake face. This adhesive component often is referred to as mild adhesive wear. If the hob is used upper than its limit of heat resistance, severe adhesive wear may result a large scale plastic flow of surface material in direction of the chip flow. Severe adhesive wear are primarily resisted by HSS material through its high yield strength at elevated temperatures (High hot hardness). At $V=90$ m/min the severe adhesion wear is predominant.

Adhesion wear mechanism is identified by deep craters. The depth of crater increases always proportionally with cutting speed. It will be useful to find an optimum condition in which, the flank wear is decreased but the thermal barrier role of BUE remains exist. We can select $V=50$ m/min or higher cutting speed such as $V=95$ m/min for economic aspects.

Macroscopic fracture of the tool can occur is a rather scarce event. More common it localized chipping of tool edge. Smooth tool surface, high fracture Toughness promoted by fine grained structure of both matrix and hard phased is counteractive tool properties against this wear mechanism. This type of wear can occurs at low or high cutting speeds.

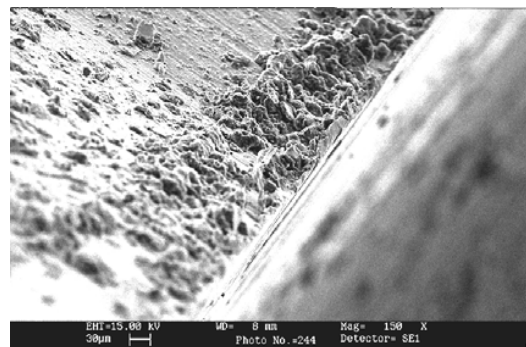


Fig. 2: SEM topography of built-up edge

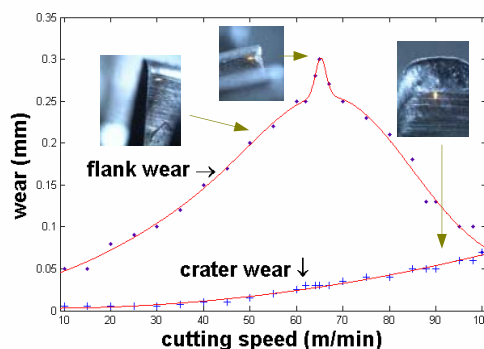


Fig. 3: Flank and crater wear vs. cutting speed

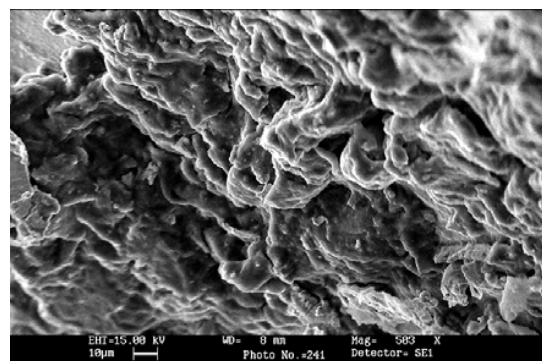


Fig. 4: SEM topography of adhesion wear mechanisms

Fig.5 shows a micrograph of the microstructure from ASP30 hobs. Fig.6 shows a micrograph of the microstructure from AISI M2 steel used as hob material. As can be seen, the microstructure consists of hard particles dispersed in a soft matrix. ASP30 that is the product of Anti Segregation Process has fine carbides as well as homogeneous distribution of carbides through the matrix. Then it is difficult for the particles to segregate from the matrix and hence there will be some debris at the interface. For this reason, abrasive wear in M2 hobs is more severe compared with ASP30 hobs (see Fig.7). High degree of C/V proportion in the chemical composition (such as M42) leads to a reduction in the hardness difference between the matrix and dispersed carbides. It has the same effect on the abrasion as well as adhesion wear. The critical cutting speed in M2 hobs is

reported to be 60 m/min [11]. The hot hardness of ASP30 hob is because of high amount of cobalt in the chemical composition. It means that the ASP30 hobs can be used at high speed hobbing. Moreover, at high cutting speeds, another wear criterion exists. Increasing the surface roughness (Fig.8) of the gear produced at such conditions, limits the cutting speed to be used. Therefore, for optimizing the cutting operation it is necessary to consider the surface roughness of gears as an important criterion. For high speed hobbing, we may use rigid machine tool and blanks with low length to diameter (L/D) proportion.

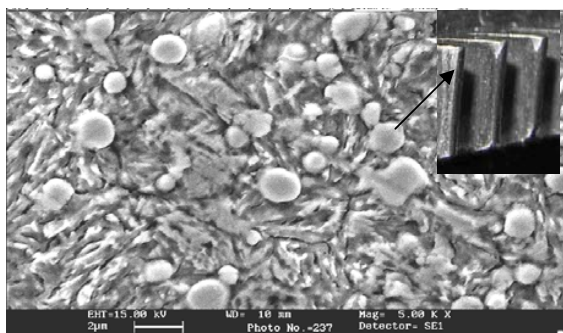


Fig. 5: SEM micrograph of ASP30 hob microstructure

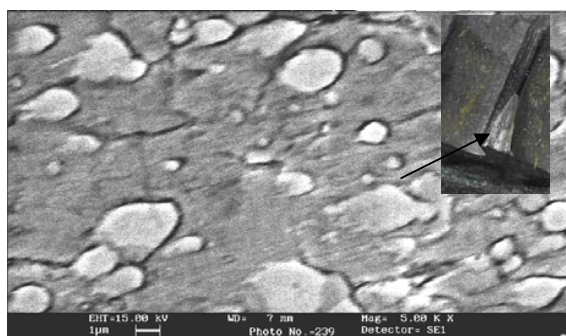


Fig. 6: SEM micrograph of M2 hob microstructure

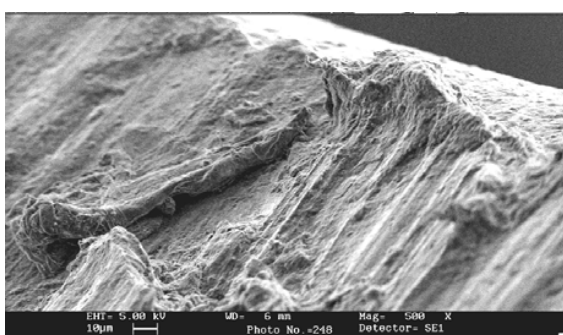


Fig. 7: SEM topography of severe abrasion wear mechanisms of M2 hob

IV. CONCLUSIONS

Wear mechanisms of HSS hobs has been investigated. Tribological and metallurgical analyses are employed for this

purpose. A summary of conclusions is as follow:

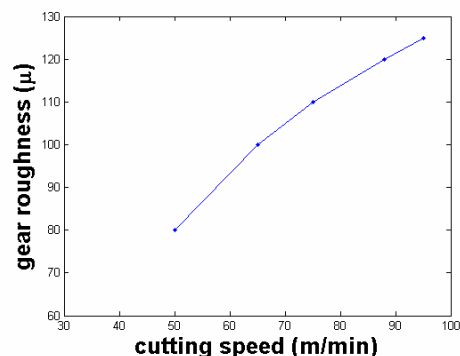


Fig. 8: Surface roughness of gear(μm) vs. cutting speed

- In HSS hobs at moderate cutting speed, the predominant mechanism is abrasion wear at the flank of cutting edge. The maximum of flank wear is at $V=65\text{m/min}$
- Adhesive wear can exist at each hobbing condition but at high speed hobbing the predominant wear mechanism is severe adhesive wear.
- The presence or absence of built-up edge is important to change the predominant wear mechanism.
- The hob made by ASP30 has high hardness, excellent hot hardness and wear resistance compared with M2.
- The grade of tool material can not change the wear mechanism, but wear resistance of hob can be improved by correct selecting of tool material considering cutting condition to be used and machining economy.

REFERENCES

- [1] Tokawa, T. and Nishimura, Y., "High productivity dry hobbing system", Mitsubishi Heavy Industry, *Technical Review*, Vol. 38, No.1, PP. 124-147, 2001.
- [2] Jainlk, C. and Agreval, G., *Metal cutting science and production technology*, McGraw – Hill Publishing company, NewDelhi, 1988.
- [3] Rech, J. and Djouadi, M. and Picot, J., "Wear resistance of coating in high speed gear hobbing", *Wear*, Vol. 250, PP. 45-53, 2001.
- [4] Lim, S.C. and Lee, S.H. and Liu, Y.B. "Wear maps for uncoated high speed steel cutting tools", *Wear*, Vol. 170, PP.137-134, 1993.
- [5] Scherge, M. and shakhvorostove, "Fundamental of wear mechanisms of metal", *Wear*, Vol. 255, PP. 395-400, 2003.
- [6] Haron, O. and subramanian, S.V., "Tribology of tool-chip interface and tool wear mechanisms", *Surface and Coatings Technology*, Vol. 149, PP. 151-160, 2001.
- [7] Soderberg, S. and Hogmark, S., "Wear mechanisms and tool life of high speed steels related to microstructure", *Wear*, Vol. 110, PP. 315-329, 1985.
- [8] Brion, J.M., "Mechanisms of built-up layer formation on turning tools: Influence of tool and workpiece", *Wear*, Vol.154, PP. 225-239, 1992.
- [9] Bhattacharyya, A., *Metal Cutting Theory and Practice*, Jadavpur University, New Central Book Agency, Calcutta, 1998.
- [10] EL-Rakayby, A. M. and Mills, B., "the role of primary carbides in the wear of high speed steel", *Wear*, Vol. 112, PP. 327-340, 1986.
- [11] Joseph, R., *ASM Handbook, Vol. 16: Machining*, American Society for Metals, 9th Edition, 1998.