Herlitzius, Thomas; Becherer, Uwe and Teichmann, Jens

Knife Sharpness on SPFH – Basic Research

Knifes on Self Propelled Forage Harvesters are wear parts that usually last a season. Knife condition is important for the quality of cut and the power consumption, which is watched by the operator, who decides at what point in time to start the automatic grinding cycles to re-sharpen the knifes of the cutting drum. Based on the actual knife wear the operator has also to define the duration of the cycle. Field research reveals that operators judge the wear differently and partly incorrect, which causes a non-optimal balance between cost of spare knifes, cutting quality and power consumption. The article describes how knife wear can be defined in terms of cutting edge radius, which was evaluated in its relation to wear in lab and field tests.

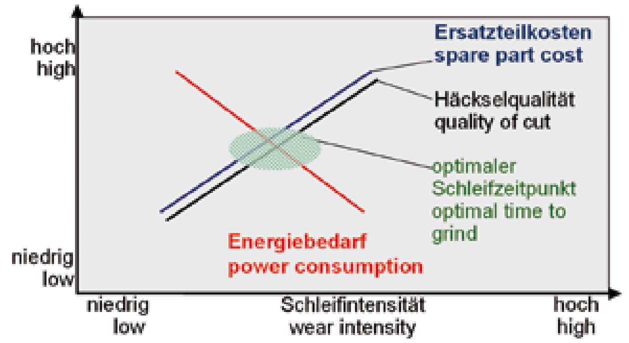
Keywords
Cutting principles, forage harvest, forage harvester knife, knife wear

Abstract
Landtechnik 64 (2009), no. 2, pp. 131 - 133, 5 figures, 2 tables, 4 references

The Self Propelled Forage Harvester (SPFH) is of big importance for the harvest of silage. In grass harvest Self Loading Wagons are strong competitors, however, corn harvest is the major domain of SPFH because of productivity and efficiency. The volume of the global market for SPFH ranges currently between 2000 and 2500 units. The most powerful machine with an installed engine capacity of 750 kW is the Big X from Krone. Today SPFH can process up to 200 t of material per hour. The increasing importance of biomass to energy conversion is creating more needs and requirements for an efficient processing of biomass. In 2008 1.25 Mio. hectares were used for growing of energy plants in Germany. Bio-fuel had a 6.3 % share in total fuel consumption in 2006 and the German government is planning to lift up the ratio to 8 % in 2015 [1]. Taking all predicted usages of biomass to energy conversion into account it could become true that one third of Germany's arable area will be used for energy plants in 2020 [2].

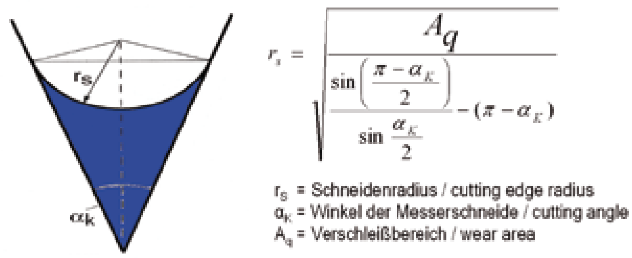
Re-sharpening of the knifes to control knife condition is important for the quality of cut and the power consumption, which is watched by the operator, who decides at what point in time to start the grinding cycles to re-sharpen the knifes of the cutterhead. The whole knife sharpening procedure and the shearbar adjustment is completely automated using modern electronics and sensors. However, the decision when to start and how extensive to sharpen is depending on the operator and his ability to judge the actual wear status of the knifes. Existing limitation of operator skills making this decision is creating the demand for fundamental knowledge about the dependency between cutting quality, power requirement and cost for spare knifes to optimise these parameters economically. **Table 1** shows average monetary values for representative SPFH and **Figure 1** explains the task of optimisation of operational cost and forage quality.

Fig. 1



Challenge of balancing operational cost and forage quality

Fig. 2



Model of knife wear based on knife geometry

Theoretical model of knife wear and lab tests

Knife wear on SPFH is defined as the abrasion and removal of material at the tip of the cutterhead knife. It is known that cutting force increases with an increasing angle of the knife-edge. There is a multitude of influences on real knife wear in field conditions causing uneven material abrasion. For example, impact of foreign objects and inhomogeneous metal properties create wear patterns that do not fit into the volumetric abrasion model. The idealized model defines the removal of material based on knife geometry. Heinrich posted the hypothesis that the change of cutting edge radius can be brought into a relationship with the actual wear of the knife [3], where the radius is directly dependent on the change of the angle of the cutting edge as shown in **Figure 2**.

A lab test stand was used to analyse the wear behaviour of a knife experimentally. According to the theoretical model, the change of the knife-edge radius r_s was sampled over the test period of one representative knife wear cycle. The test stand realises a knife segment rotating with 1230 rpm through a continuously falling homogeneous haze of quartz sand with a defined granularity. Sample positions for cutting-edge radius are set at two places of the circular path of the knife exhibiting track speeds of 32.8 m/s and 36.7 m/s. **Figure 3** plots the 21 sampled knife radii taken in a test run lasting for 90 minutes. The growth of the radius at a constant abrasive load during the test time can prove the theory of correlation of radius and removal of material volume at the tip of the knife.

Evaluation of real knife wear in field conditions

Following the confirmation of the wear hypothesis in lab tests the investigation of the wear behaviour in field conditions is the next step. Three runs of wear measurements were executed on a contractor's SPFH to evaluate the wear progress of knifes between the states "sharp" and "dull". In addition two operators were observed for five days in their ability to re-sharpen knifes according to their operation (**Figure 4**). Whenever the driver decided to re-sharpen radius samples of the knifes were taken before and after the grinding procedure. **Table 2** lists the characterization for each of the operators.

As seen in **Figure 4** operator B has a substantial problem to estimate the real existing wear and therefore produces sharper knifes than required for quality and power efficiency causing faster than necessary consumption of knife material. Similar conclusions were drawn in other evaluations from Neuhauser [4].

Figure 5 shows the results of a continuous knife radius sampling on the one machine that was observed for three re-sharpening cycles. In a representative manner it becomes obvious that knifes wear our very differently over time and the operator again has difficulties to judge an optimal and repeatable point in time to re-sharpen. Variation of radius samples was significantly greater compared to the lab results, which is mainly affected by impact of small foreign objects overlaying the wear process. However, the characteristic behaviour found in the lab can be proven in field conditions as well.

Conclusion

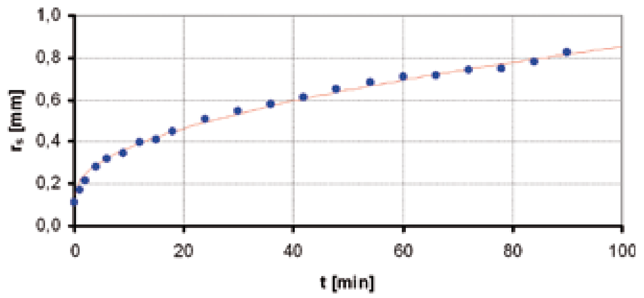
Lab and field tests can prove the hypothesis that knife wear on a SPFH cutterhead exhibits a degressive characteristics of an increasing radius at the knife tip as a function of material abrasion. Based on this behaviour an optimization of sharpness and life time of a knife can be done. In practice the wear process deviates from the idealised process under lab conditions. Main factors of variation are forage condition, forage moisture and damages from foreign objects. Further field tests are necessary to validate and confirm these preliminary results with an emphasis on evaluating the systematic effect of the material conditions on the wear process.

Table 1

Cost figures for a Self Propelled Forage Harvester

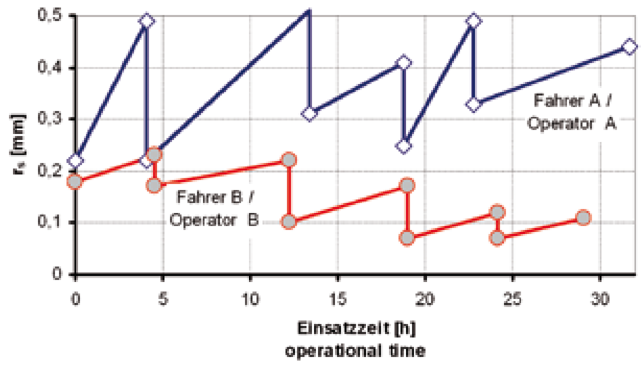
Anschaffungskosten	215.000,00 €
Maschinenkosten Vorsatzkosten	160 € / ha 10 bis 15 € / ha
Energiebereitstellung - Kraftstofftank	1.000 l Fassungsvermögen entspricht 1.000 bis 1.400 € / Tankfüllung
Ersatzteilkosten durch Messerverschleiß	500 … 1.500 € / Messersatz

Fig. 3



Change of cutting edge radius during operation

Fig. 4



Operator behaviour of grinding knifes

Literature

[1] Bundesministerium für Ernährung, Landwirtschaft und Verbraucherschutz http://www.bmelv.de/cln_045/nn_1081138/DE/081-NachwachsendeRohstoffe/Biokraftstoffe/BiokraftstoffeDatenFakten.html__nnn=true

[2] Bundesministerium für Ernährung, Landwirtschaft und Verbraucherschutz http://www.bmelv.de/nn_1021300/DE/081-NachwachsendeRohstoffe/AussagenBioenergieUndNaWaRo/FlaechenNutzungskonkurrenz.html__nnn=true

[3] Heinrich, A.: Grundlagen für ein Messsystem zur Bestimmung des Verschleißzustandes des Häckselaggregates eines Feldhäckslers, Dissertation, TU Dresden, 2007

[4] Neuhauser, H., K. Wild und J. Mitterleitner: Standfestigkeit von Häckseltrommelmessern. Landtechnik 54, (1999), H.5, S. 294 – 295

Table 2

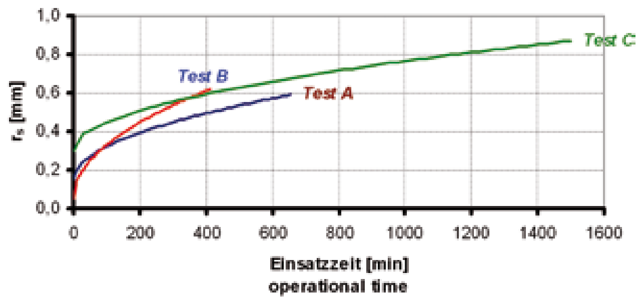
Operator behaviour and wear evaluation

	Fahrer A	Fahrer B
Erntegut	Gras	Gras
Schleifzeitpunkt	immer mittags geschliffen	immer morgens geschliffen
Wahl des Schleifzeitpunktes	Fahrer entscheidet selbst über die Schleifintensität	Fahrer entscheidet selbst über die Schleifintensität
Bewertung	Messer wurden gleichmäßig „stumpf gefahren“, Schleifintensität wurde gut an die vorgefundene „Messerunschärfe“ angepasst	Messer waren zu jedem Zeitpunkt scharf, vordefiniertes Schleifverhalten, das den gegebenen Verhältnissen nicht angepasst wird

Authors

Prof. Dr.-Ing. habil. Th. Herlitzius ist Leiter des Lehrstuhles Agrarsystemtechnik, **Dipl.-Ing. Uwe Becherer** und **Dipl.-Ing. Jens Teichmann** sind wissenschaftliche Mitarbeiter am Lehrstuhl Agrarsystemtechnik, Institut für Verarbeitungsmaschinen und mobile Arbeitsmaschinen der TU Dresden, 01062 Dresden; E-Mail: herlitzius@ast.mw.tu-dresden.de

Fig. 5



Change of cutting edge radius during operation