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Comparison of a mobile scraping system with a fixed one for removal of liquid manure

Productivity of work processes and their automation are important factors in modern milk production. Robotic systems for cleaning slats are self-sufficient and very flexible. In the investigation a slat-cleaning robot is applied for cleaning different areas of solid flooring and its efficacy compared with that of a fixed cable-and-blade system in terms of functionality, route configuration and cleaning performance. Especially important in this respect are the dimensions of the scraper and that of the liquid manure removal channel.

Keywords

Liquid manure removal, solid flooring, slat-cleaning robot, animal health

Abstract

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Animal well-being in modern cow housing is an important farm management factor. Only healthy and contented animals can produce high performances in lactation and reproduction. Several factors contributing to the well-being of the animal can be understood under the term cow comfort. Alongside the comfort of the lying areas, housing climate and opportunities for free movement are important. Cleanliness of movement areas can also be mentioned in this respect [1; 2]. Clean flooring areas mean drier hoofs and reduction of hoof disease [3].

Modern agriculture is characterised by fluctuating yields and returns with the background influences of cost developments and work efficacy. Milk production is very time-intensive whereby the biggest factors in this respect – milking time, feeding and manure removal – devour up to 60 percent (%) of the working time [4]. The target in cow management is to keep work time to 35 hours per animal while maintaining optimum herd care. The basis for this singles out work efficacy and efficiency as important parameters. One solution in this respect is automation of work processes as has been indicated in recent years with the introduction of automatic milking systems. A trend is the continued increase in automation of feeding and manure removal. Housing for the majority of cows moves increasingly towards non-restraint housing systems in buildings that feature various manure removal procedures. The most widely flooring features slats and solid flooring. Both approaches have advantages and disadvantages whereby the trend where cow movement passages are over 50 m (m) runs to solid floors with fixed cable-and-blade scraping systems for removing the liquid manure. The aim in such cases is to remove solids and urine as quickly as possible from the vicinity of the animals [5]. Cleanliness and hygiene play a large role in modern herd management.

Mobile slat-cleaning robots scrape and clean the slatted flooring in loose housing. They are not confined to rail tracks and can also clean connecting passages and milking parlour collection areas. Advantages of the system are the capacity for scraping several times per day and high operational flexibility of up to 18 hours.

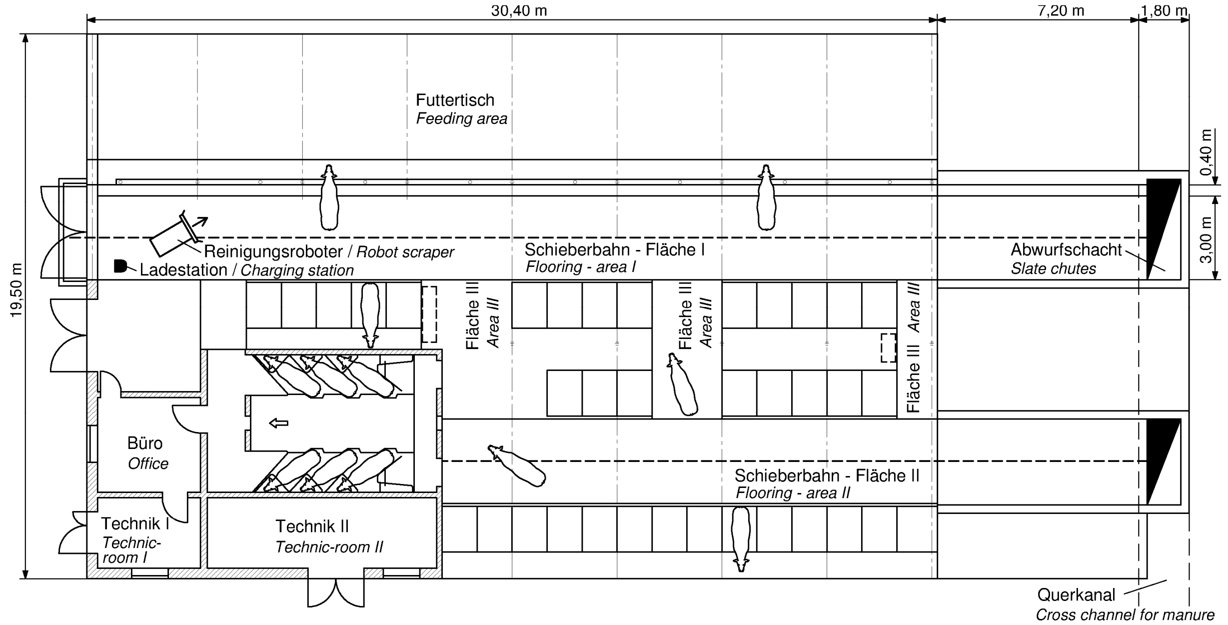
Many dairy farms utilise this flexibility on slatted flooring whereby there exists questions about operational suitability of the robots on solid-floored collection areas and other solid floored areas.

A fixed scraping system was compared with a mobile one for removal of liquid manure with regard to functionality, cleaning efficacy and route configuration with results backed-up by and animal observation.

Material and methods

In order to test the equipment under practical conditions, a dairy farm was selected with three-row cubicle house and integrated herringbone milking parlour with attached roofed feeding area, the complex being erected in 2006. Housed in the solid-floor building were 38 milking cows with manure removal via fixed cable-operated folding scraper blade. Although the number of 38 cows seems to be small, the results are comparable to the numbers, which one gets out of big cow herds. The reason therefore is the relationship between flooring areas, passing areas and manoeuvre areas are nearly the same and the dimensions of these areas hits more than the pure cow number.

Fig. 1



Trial housing area overview

In a preliminary trial the amount of manure produced over 24 hours was determined with three separate days measured. The manure amount was measured on each day at 8 am and 8 pm. The periods between measurements of almost 12 hours permitted defecation behaviour to be determined right through the period. Area I subject to scraping was 112.5 square metres (m2) and situated between feeding area and the nearest cubicle row. Area II ran down the house in-line with the parlour and covered 52.5 m^2. There were three transverse passages between the main movement areas and these totalled 32.9 m^2 and represented area III. (See **figure 1**).

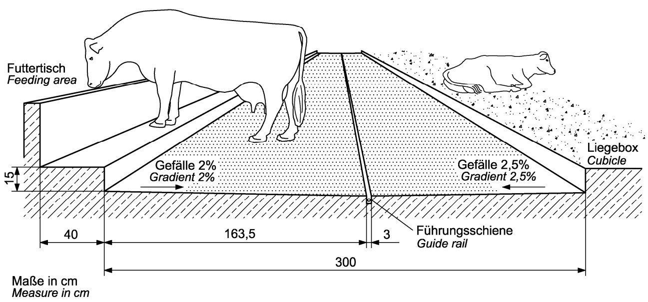
The movement areas were concrete-surfaced with brushed finish and the main passages had an unsymmetrical surface with a fall of 2 % and 2.5 % to the almost mid-positioned groove for the scraper blade cable, which you can see in **figure 2**.

To increase cow comfort the deep litter cubicles had bedding of lime and straw.

Applied was a compact-design slat-cleaning robot with a scraper blade width of 130 centimetres (cm) that can be seen in **figure 3**. The capacity of the small blade is 25 kilograms (kg) of fresh (FM) liquid manure.

With the smallest scraper blade the robot weight is 455 kg, with up to 60 % of this bearing on the front axle. The machine runs on a three-wheel system with the front axle providing both drive and steering. An electric motor powers the mid-positioned front wheel that has a steering angle of maximum 95 degrees to each side. Travelling speed is about 4 m per minute. In the scraping process the machine orients itself on transponders sunk into the floor every three to five metres. The blade side flaps are not rigid but instead are pressed outwards by a compression spring. These flaps are linked to sensors via a rod.

Fig. 2



Profile of movement area I

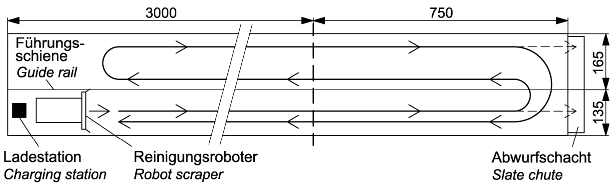
Fig. 3

Design of the mobile manure removal machine "slat-cleaning robot" (foto: TUM)

When travelling alongside a wall these sensors help calculate the actuating angle of the robot to the edge of the passage. The robot automatically continuously adjusts its steering angle so that it can be driven precisely along a bordering wall without human intervention.

The charging station for the slat robot was positioned near the cow movement area so as not to unnecessarily lengthen travelling times. The charging station served as starting point for the route configuration used in the investigation. A number of routes were investigated for pushing manure to the removal channel. Each route was programmed into the system and was followed by the robot every 1.5 to 2 hours with variants investigated over three days. Variant 1 is illustrated in the following diagram.

Fig. 4

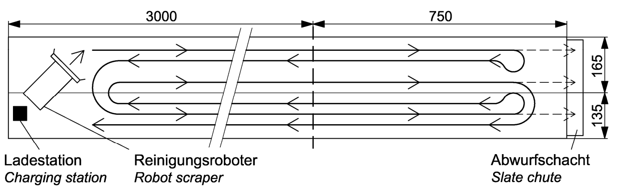


Overview of route configuration of variant 1 with dimensions in centimetres (scraper route area I)

The robot pushed the liquid manure down past the cubicle row into the manure removal channel. There followed a 180-degree turn and the robot drove back the length of the building. It again turned at the level of the charging station making another journey back to the removal channel, this time along the edge of the feeding table. The last turn took place along the edge of the removal channel and then back to the starting point.

Variation 2 featured a driving route adjusted so that the same track was followed by the slat- cleaning robot for inward and outward journeys. (See **figure 5**) For this variation the blade was enlarged to give a holding capacity of 75 kg liquid manure.

Fig. 5

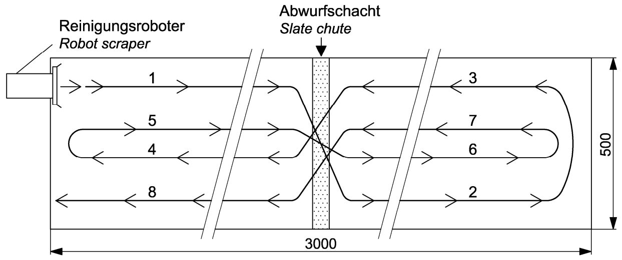


Overview of route configuration of variant 2 with dimensions in centimetres (scraper route area I)

The slat robot was applied in the three-row cubicle house in the scraping area I covering 85.5 m². This area comprises the total scraper area I minus the robot parking area and the area around the removal channel. The trial period was limited to 12 hours per day. In order to determine the degree of cleanliness left by the scraper in the movement areas, the amount of liquid manure remaining in the passages, in the area of the removal channel and the charging station was recorded and the result compared with the performance of the fixed folding scraper system.

To test the application potential of the mobile slat robot on level and solid-floored parlour collecting areas a trial comparison took place on a net area of 150 m² in a functional exercise yard adjacent to a row of cubicles. This trial was named as variant 3. The blade volume was increased as in variant 2. The liquid manure to be cleared was comparable with that in variants 1 and 2. Within the trial period of 12 hours a total of three cleaning journeys took place. The routes were selected so that the liquid manure was pushed into the removal channel that ran across the middle of the exercise yard and was covered by a grating. The route of the robot ran obliquely over the grid to offer effective disposal of the collected manure through the grid. See **figure 6**.

Fig. 6



Overview of the route followed in variant 3. Dimensions in centimetres (exercise yard)

To determine the degree of cleanliness achieved in variant 3 on the movement area, the amount of liquid manure left on the area and around the removal channel was recorded as with variants 1 and 2.

Results and discussion

In the preliminary trial the amounts of liquid manure produced daily were determined via three repeated daily measurements. The almost 12-hour measurement periods permitted the respective manure production for the whole day to be determined. See **table 1**.

It was determined that average production of excrement per cow was 59.8 kg fresh mass (FM) with dry matter content of 12.1 %. A slight gradient on surfaces meant that liquid could run off, leading to relatively dry liquid manure. The average amount produced per m² worked out at 13.3 kg fresh mass (FM). One reason for the uniform distribution of excrement amounts in the day and night phases could have been the single feeding time in the evening. The larger amounts of manure deposited directly behind the cubicle beds led to high demands on the slat-cleaning machine, especially when one considers the four-hour charging phase during which the machine can-

Table 1

Overview of liquid manure production over 24 hours

	Kotanfall Nachtphase *Excrement amount night* kg FM	Kotanfall Tagphase *Excrement amount day* kg FM	Kotanfall/24 Stunden *Excrement amount/24 hours* kg FM	Kotanfall/Fläche *Exrement amount /area* kg FM/m²
Fläche I *Area I*	559,9	567,7	1 127,6	13,2
Fläche II *Area II*	526,4	534,9	1 061,3	20,2
Fläche III *Area III*	28,9	54,3	83,2	2,5
Kotanfall gesamt *Liquid manure total*	1 115,2	1 156,9	2 272,1	13,3

not remove manure. The slat-cleaning robot was applied on the scraping route area I, net area 85.5 m². In that liquid manure production over the period was relative uniform, and with the background of animal observation, the investigation period was limited to 12 hours per day.

In variant 1 the blade width of the slat-cleaning robot meant repeated journeys were required to push the liquid manure in the direction of the removal channel. This variant cleaned the area unsatisfactorily in that a very large amount of liquid manure was left, being lost from the blade during return journeys to the removal channel and during turning manoeuvres.

In average of three days of the attempt, there was in 12 hours 700 kg manure in variant 1 with a standard deviation of 31 kg and a dry matter of 11%.

Only just below 50 % of the liquid manure produced could be transported out of the housing in this variant.

Variant 2 was characterised by the larger blade used and by the alternative route configuration with each scraper track followed in two directions – along the housing and back to the removal channel. This resulted in a substantial reduction in the amount of manure left behind on the floor, as can be seen in **figure 7**.

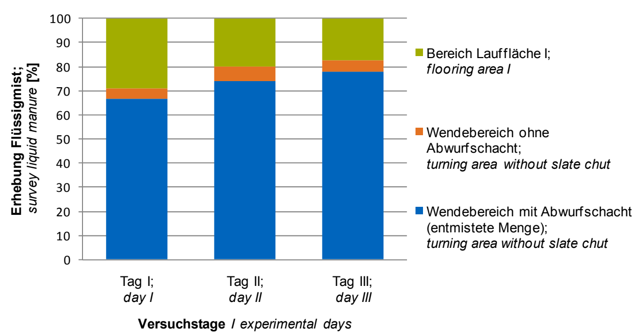
In average of the three days attempt, there came up in 12 hours 673 kg manure with a standard deviation of 49,9 kg. The transportation quote was in average 491,4 kg manure out of the cow barn, which is 75 % of the manure.

An average up to 75 % of the liquid manure could be transported out of the house and 21 % left on the floor. The largest amounts were clearly left in the vicinity of the cable groove for the fixed blade cable. The rigid scraper blade meant that this area could be reached only with great difficulty. Up to 4 % of manure was left lying through spilling at the U-turns made in the area of the charging station.

In variant 3 the slat-cleaning robot was applied in an exercise yard. As with variant 2, the scraper blade volume capacity was increased.

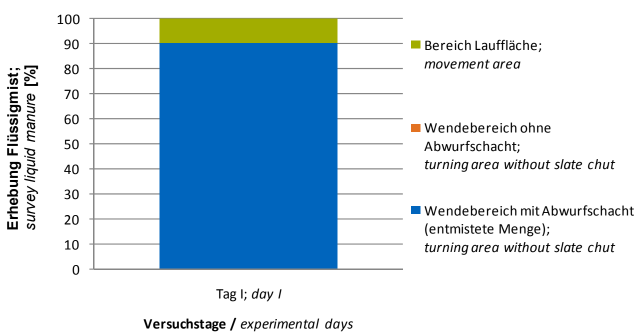
In 24 hours liquid manure production totalled 650 kg, almost equalling the amount in the trial movement areas.

Fig. 7



Cleaning results in percent for variant 2 (scraper track area I)

Fig. 8



Cleaning results in percent of variant 3 (exercise yard)

Almost 90 % of the liquid manure produced was pushed into the removal channel by the mobile slat-cleaning robot. See **figure 8**. The remainder liquid manure from 79,8 kg was left lying at the respective ends of the exercise yard, the areas where the robot directional changes were carried out.

The robot's own weight ensured sufficient downward pressure on the flooring for transportation of large amounts of excreta and cleaning of the investigated areas.

The behaviour of the animals could be observed in all the trials. After a phase of familiarisation the slat robot was accepted by the animals, which moved out of the way on its approach.

The cleaned areas were clearly visited and frequented more often by the animals.

Conclusion

- The applied slat-cleaning robot is functionally reliable and its pushing power can be applied on both slatted and solid floors within cow houses.
- The dimensioning of the blade, the configuration of the cleaning routes and the position of the manure removal channel all had an influence on the cleaning efficacy on the investigated flooring areas.
- The bigger the shield of the slat-cleaning robot, the less transits per square metre are necessary. However it reduces the flexibility of the robot. Further investigations in this research field have to be done.

Literature

[1] Alsing, I. (2002): Lexikon Landwirtschaft. Stuttgart, Eugen Ulmer Verlag, 3. Aufl., S. 442
[2] Weiß, J.; Pabst, W.; Strack, K.; Granz, S. (2005): Tierproduktion. Stuttgart, Parey Verlag 13. Aufl.
[3] Fiedler, A.; Maierl, J.; Nuss, J. (2004): Erkrankungen der Klauen und Zehen des Rindes. Stuttgart, Schattauer Verlag
[4] Schick, M. (2010): Steigerung der Effizienz in der Milchviehhaltung, Optimierung arbeitswirtschaftlicher Arbeitsabläufe im Betrieb. ALB-Fachtagung, Hohenheim Stuttgart
[5] Steiner, B.; Keck, M. (2000): Stationäre Entmistungsanlagen in der Rinder- und Schweinehaltung, Technische Ausführungsdetails und die richtige Handhabung entscheiden über die Funktionssicherheit. FAT-Bericht 542/2000, Hg. Eidgenössische Forschungsanstalt für Agrarwirtschaft und Landtechnik, Tänikon-Schweiz (FAT)

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