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Designing Conveyor Line Work Places

Processing Vegetables

Grading and processing technology is becoming more and more efficient. The man-machine interface in modern sorting and processing plants needs an optimal design to completely exploit the existing machine potential. Through applying the results from motion analysis, the quantitative influences of selected design parameters are shown. The considered work place is designed to be labour-saving as well as ergonomically. A reduction of the work load and a better performance prove the positive influence of both design principles.

The capacity of modern sorting-, washing- and processing-machines in fruit and vegetable production is more and more limited by the human being, as certain processes, e.g. placing the products on the conveyor belt, are still done by hand. E.g. up to 30.000 asparagus spears per hour can be sorted optically, placing the same amount onto the conveyor belt - by the usually two to three workers - is not possible without further aid. Thus, the need for adequate solutions is rather urgent .

Besides optimal work place design through appropriate height of tables, optimal illumination of the area of work and sensible arrangement of the products to be placed on the conveyor belt, also its speed influences the result of work. These aspects at the man-machine interface have been examined at the ATB applying a three-dimensional system of motion analysis.

Work places at the conveyor belt

The worker at the conveyor belt has an extremely limited scope of decision and behaviour, the task being repetitive and monotonous.

Generally the driving aspect of a conveyor belt has a performance-enhancing effect, but at a certain point a maximum is reached. If the speed of the conveyor belt is too high, errors and stress may occur, and it is regarded as unpleasant.

The system of motion analysis helps to show in how far this subjective feeling demonstrably corresponds to a decreased performance.

Experimental structure

Several design variations at a conveyor belt for cutting leek and its transport to washing were examined by motion analysis. By means of a camera system (3) informationally valuable points of the worker's body, marked by infrared light-emitting diodes, are tracked during the process and evaluated through their three-dimensional room co-ordinates. The recording frequency amounts to 50 Hz, divided by the number of points to be recorded. Sticks of willow, which are equivalent to leek in their length and diameter, served as experimental material.

Quantitative effects of the height of the conveyor belt, of its speed and the influence of grasping distances on the flow of work were examined.

The willow sticks were placed on the conveyor belt in a standing position. They were to be taken from a box with both hands and then put onto the belt by the right hand, one

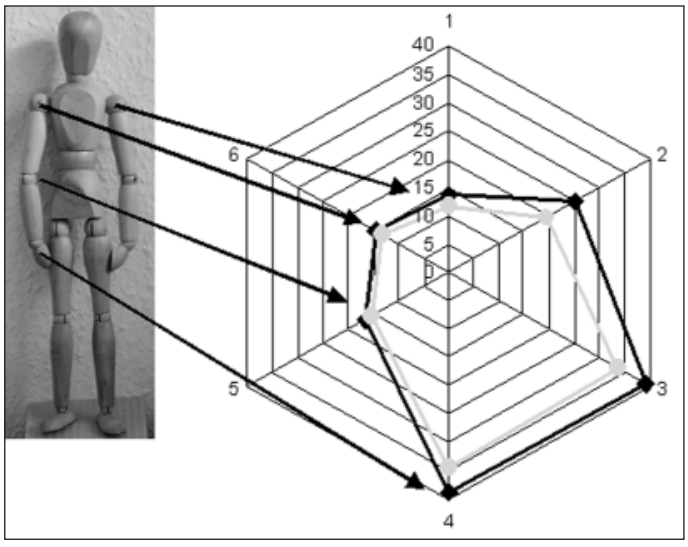

Fig. 1: Sum of motions (in m) of the upper extremities at two different working heights at a conveyor belt (height 95 cm: grey; 90 cm: black)

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Keywords
Work place design, motion analysis, ergonomics

after the other into single compartments. The occupation can be characterised as easy work with normal vision demands. The recommended height of the working surface is at 15 cm below elbow height. The average elbow height of men is 110 cm and of women 105 cm [2]. More detailed information, which goes beyond these general ergonomic considerations, can be taken from the DIN 33406 (German Industrial Standard). This standard describes the design of work place dimensions in the production sector depending on the respective task.

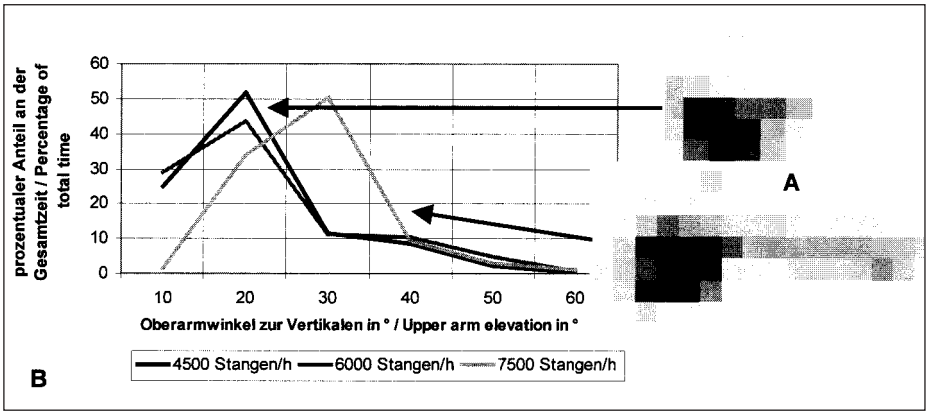

Fig. 2: Working area (A) of the right hand and analogous upper arm lifting at different conveyor belt velocities (B)

Results

Performances in placing the willow sticks varied significantly. The test persons put on between 3000 and 5500 pieces/hour, with an average of all variations being 4500 sticks in one hour. During a working day a person thus moves 3,2 t of leek. Measurements of the pulse frequency have shown that this occupation demands rather little physical effort, which during the whole time is within the range of aerobic oxygen supply. The absolute values of the pulse frequency clearly reflected the physical fitness of each of the test persons and shall not be considered further.

Via the regulation of motor rpm , three different machine performances were simulated (4500/6000/7300 pieces per hour). A performance of 4500 pieces/hour requires just one worker. In the experiments nearly every compartment on the conveyor belt was filled. The two higher velocities require more than one worker to continuously fill all compartments.

Within the scope of motion analysis the sum of motion, which is calculated from the sum of the length of all straight segments recorded, functions as a descriptive variable for the comparison of two design variations. This measure has already been used as a comparison in former motografic measurements via long term exposures underlaying the scenes/pictures with scales [1]. Of course, accuracy is much higher within the scope of digital measurement. In most cases the sum of motion is determined for the hands, as the major objects of interest. The motion of the head proved to be informative as well, provided that the motions offer a minimum of activity.

As an effect of an inadequately low working surface the test persons suffered from pains in the lower back and neck regions. A measurable effect was an increased sum of motion due to the unfavourable work place design (*Fig. 1*).

In another experiment the allocation of the products was changed. The sum of motion increased, when the hands took the leeks out of the box standing on a lower level. The worker had to bend down to reach the products, thus head movement nearly doubled. Nevertheless, the performance could be kept on a constant level. The additional effort was compensated by a higher speed of motion, resulting in an increased work load.

The results at different machine performances varied among the test persons. One person showed a clear shift of the working area of the hands, following the direction of the belt movement at high speed, resulting in an increased virtual distance between product allocation and placement. The completing of the compartments becomes more and more unlikely, the worker is stressed. Due to the shift of the main working area of the hands, the arms had to be opened wider, measured by the elbow extension (*Fig. 2*). The other test persons showed a higher performance at a higher speed. These interpersonal variations underline an existing performance potential which could be fully used through training on the job and they point out the necessity of regular controlling.

Conclusions

Minimal grasping distances, ergonomic design and an even distribution of the products accelerate the process of placement. The artificially increased distance between product and belt was not noticed in the overall time needed for the process, but the sum of motion was significantly higher, also increasing the work load. The head movement explicitly increased due to the necessary trunk inclination towards the products. According to prEN (Draft European Standard) 1005-4:2002, a frequency of ≥ 2 / minute for trunk inclination is not acceptable. This lack seems quite obvious, but nevertheless there can be found numerous examples for it in practice. It can also be questioned, whether the noted compensation would be put into practice during a whole shift with normal workers, exposed to monotonous and repetitive work. The pre-processing sector should get the same attention and technical support, because it is the interface influencing the performance of the whole system. The results of the motion analysis show the potential of ergonomic and efficient work place design.

The effect of different machine performances depends on the person. The speed of the belt movement can increase the individual work pace up to a personal performance limit. A high speed causes stress and can reduce job satisfaction.

The proven increase of the sum of motion caused by the inadequately low working surface points out the importance of individual adjustment.

Looking at the existing washing and sorting techniques, the gap between the comfort for the user and the achieved quality constantly widens. The machine performances rapidly develop whereas the pre- and post sectors are neglected.

	Variante 1 Person A	Variante 1 Person B	Variante 2 Person B	Variante 2 Person A
Sum of motion	13,30 m	8,96 m	23,84 m	23,82 m
Speed	0,15 m/s	0,10 m/s	0,26 m/s	0,26 m/s

Table 1: Comparing head movement of two variants of product supply and the same performance level

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