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DESIGN OF A TOTE EXTRACTOR IN SMALL PARTS STORAGE SYSTEMS

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Abstract: Order picking and replenishment are usually the most important costs incurred in warehousing next to inventory carrying costs. To reduce labor-intensive functions automated storage and retrieval machines have been developed with various load handling mechanisms arranged on the shuttles. Basic principles are load lifting tables, extractor and gripper devices for the storage/retrieval movements into or out of a storage rack position. In this paper we describe the design and functions of a tote extractor to handle unit load totes with VDA-containers in automated small parts storage systems.

Keywords: *Automated Storage and Retrieval System (ASRS), extractor mechanism, unit load handling device*

1. INTRODUCTION

Small part storage systems are usually operated with unit load totes. Many standardized tote types of size 400 x 600 mm are available, but in the automotive industry the VDA-KLT container is most widely used [1]. It offers special design features for handling, stacking, conveying and storing functions.

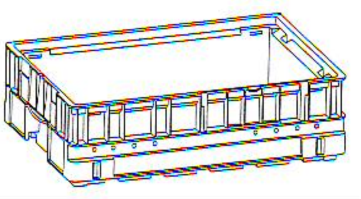

Figure 1. VDA-KLT container

Optimal space utilization is possible, if an extractor is used for retrieving and storing the totes by means of an automated storage/retrieval system (AS/RS). For this purpose a novel design of a unit load extractor according to Figure 2 to handle VDA-KLT totes has been developed, manufactured and tested at the Institute of Material Handling and Logistic Systems at TUG Graz University of Technology [2]. A unique electro-mechanical drive operating with two pairs of chains and hooks engaging in the front slots of the container enable to facilitate the full storage/retrieval cycle moves with only one EC-servomotor in both directions.

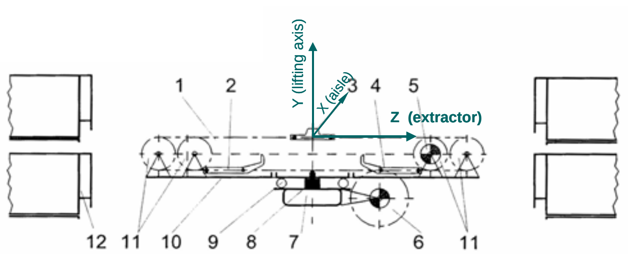

Figure 2. tote extractor

After conceptual studies comparing several alternatives the extractor was developed, designed and simulated to study power demand and functional issues. Figure 3 illustrates the benefits of the extractor-design.

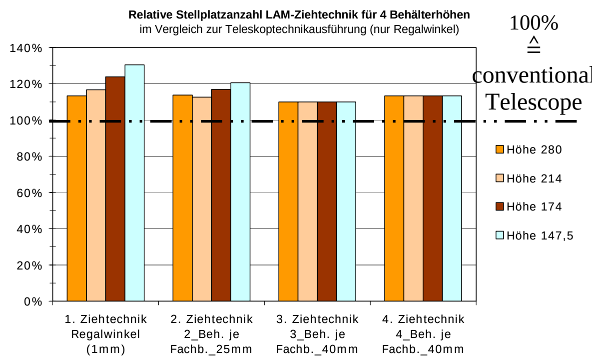

Figure 3. increased space utilization by extractor-unit

Storage space benefits between 10% and 30% can be achieved compared to a conv. telescope depending on the container arrangement in the storage rack.

Extensive tests with a prototype manufactured at our laboratory proved the device to be compact, light, safe and reliable. A special servo-drive technology in connection with a brake/clutch device reduces costs, as only one electronically commutated drive motor is needed to perform all functions for a load cycle.

In this paper we present first a overview about the total Automated Storage and Retrieval System “AKL 25/50kg” second the basic functions and working principles with an introduction of the operating characteristics of the extractor mechanism. In the third section we describe the design concept of the extractor mechanism. In the fourth section detailed information about the experimental prototype investigations are presented. The fifth section contains aspects and results from theoretical simulation tasks.

The last section presents a summary and final conclusion of the product development.

2. EXTRACTOR MECHANISM OF AS/RS

2.1 AS/RS "AKL 25(50)"

Table 1 below lists the technical data and the design specifications of the AS/RS "AKL 25 (50)" developed at the Institute of Material Handling and Logistic System, Graz University of Technology.

Table 1. design variants "AKL 25/50"

axis→ ↓ data	aisle (X)	lifting (Y)	picking (Z)
rack dimensions	**30m**	**6m (10m)**	**single deep**
picking unit (telescope, extractor)	-	-	telescope
	-	-	**extractor**
load dimension (WxHxL)	0,4m	variable	≤ 0,6 m dep. picking unit
rack pitches (X,Y,Z)	dep. picking unit and container		0,7m aisle gage
payload	**25** (50) kg		
throughput cycles	**120 dc/h (FEM 9.851)**		

2.2 Basic functions of the extractor unit

The basic functions of the extractor device in connection with an AS/RS are described as follows:

The extractor is fixed on the shuttle of the AS/RS and is moved at the appropriate vertical position in front of a storage slot (Figure 4).

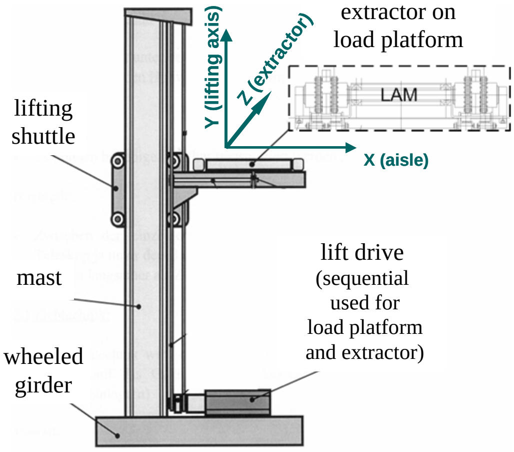

Figure 4. small parts AS/RS

First the gap between the racks and the extractor is according to Figure 2 closed by a short horizontal movement of the sliding base carrying the tote on two pairs of chains. During a storage move the chains operate like a chain conveyor and move the container in its storage position in the rack. Hereafter the hooks disengage from the container slots and by switching a clutch/brake device the sliding base is moved backwards to its central position in the aisle.

A retrieval operation starts with moving the sliding base towards the storage rack in order to close the gap between the tote and the extractor. The next operation in engaging the hooks between each pair of chains with the front slot of the VDA-KLT tote. This is a critical move needing high positional accuracy which here is facilitated with a servo-drive. With the next move the hooks pull out the tote from its storage position until the front edge of the container reaches the chains. Finally the device works as a chain conveyor carrying the toe in its central position on the extractor device.

The following velocity time diagrams exhibit the basic cycles for pick and drop operations in Figure 5.

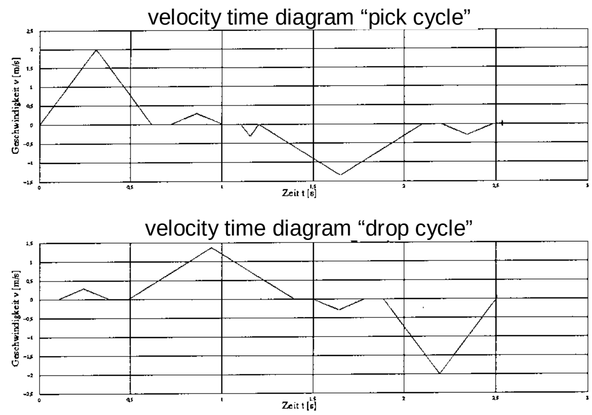

Figure 5. velocity time cycles

2.3 Design description

A schematic picture of all drive components for the extractor is shown in Figure 6. A central control unit coordinates the simultaneous control of three axes x, y, z. Individual servo-drive controllers are allocated to the individual axes.

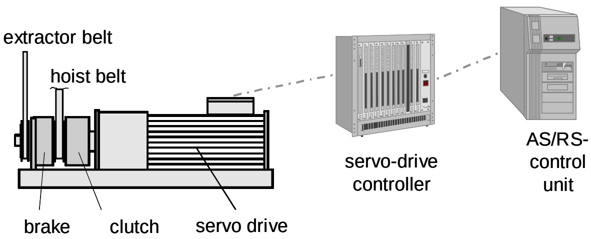

Figure 6. drive components of the extractor

In our case there is only one servo-drive in operation for lifting and extraction, as the y- and z-axis never operate simultaneously and thus one common drive is sufficient to perform both functions.

A similar concept is used when operating the extractor mechanism. As shown in Figure 7 a bottom chain wheel engages in the lower chain serving like a tooth rack when it is blocked by a brake in the main front shaft. This causes the 50 mm gap to close between the AS/RS and the storage slots.

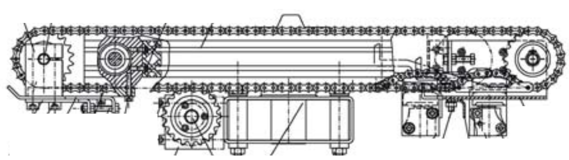

Figure 7. extractor unit

After releasing the brake when the gap is closed the chain pulls the tote with two hooks from its storage position to a central position on the load table. Hereafter the 50 mm gap is opened by retrieving the load table to its base position.

2.4 Prototype - investigations

The development/design project has been included two prototypes. First a prototype for the standard-design “telescope 50kg”, including all axis and devises (rack dimensions 6m high and 22 m long). This prototype ran nearly 10.000 hours in a continuous operation.

The second device has been designed for testing the extractor unit. This prototype includes the standard mast (reduced height), the standard lift shuttle, the extractor unit and one rack column. Figure 8 shows a picture of the realized extractor unit, as mentioned and described at Figure 2.

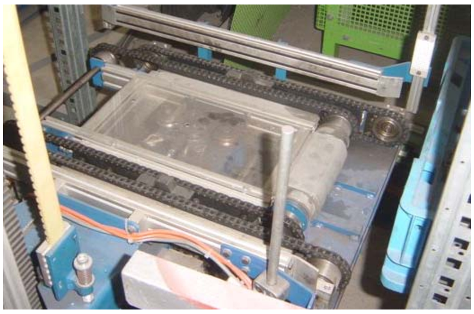

Figure 8. tote extractor (AS/RS “AKL 25”)

The general aims of the investigations were the verifications of reliability and durability. Therefore automated function and endurance tests were designed and carried out. The extractor concept, the design and the construction were approved - without any restrictions. The next two figures show important aspects of specific tests. The results meet the high demands on velocity motion sequence and positional accuracy of z-positioning (tote in rack).

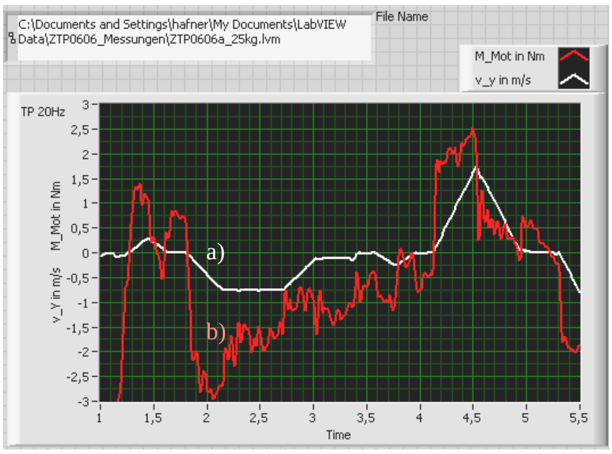

Figure 9. measurements at servo-drive a) *v* b) *M*

Figure 9 shows two graphs of the servo-drive during a drop cycle: a) speed *v*=f(t) b) torque *M*=f(t).

As mentioned in section 2.3 one single servo-drive (closed loop controlled) is used for three high dynamic sequential operating axis. Two force-fit based electro-mechanical switching units realize the different power connections. There was to answer the important question about the repeatability of the Z-positioning.

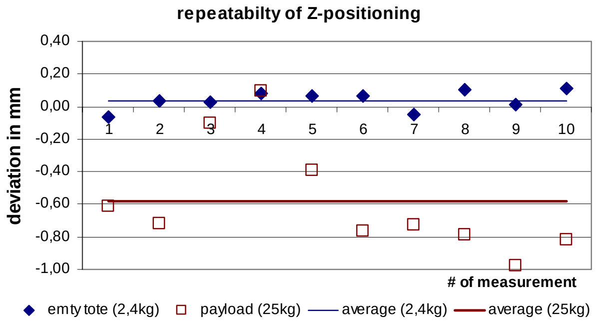

Figure 10. deviation of z-positioning (container in rack)

Figure 10 illustrates the test results for minimum and maximum load. Ten repetitions of automated drop cycles on the test rig were done twice. The first series with a empty tote (2,4kg) shows a deviation-band of ±0,1mm. The second test series, for the payload (25kg), gives a max-min-range of 1,0mm (average of -0,59mm).

2.5 Theoretical modelling and simulation

For the optimization of the motion sequences and detailed studies e.g. about different system heights a ITI®-SIM model [3] is in use and further development. Figure 11 contains the main elements of the mechanical coupled axis lift shuttle (y), z-platform (z_T) and z-extractor (z_K) - see (Figure 4), (Figure 6) and (Figure 12) too.

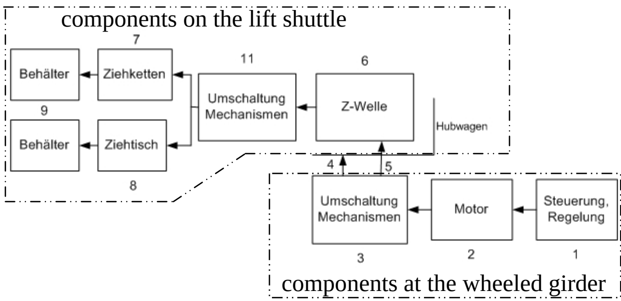

Figure 11. schematic diagram of the mechanical coupled drive-shuttle-platform-extractor units

Studying Figure 9 we see that the high-end closed-loop controller in connection to the servo-drive supports a nearly optimal velocity diagram. The stiffness and the eigenfrequencies of the electrical and electronically drive components are much higher than the relevant ones of the mechanical structure, i.e. we are allowed to neglect the electrical drive parts in modeling.

The ITI®-SIM model shown in Figure 12 represents the main structures of the mechanical components a) of the lift shuttle (y) and b) of the platform (z_T) and extractor (z_K).

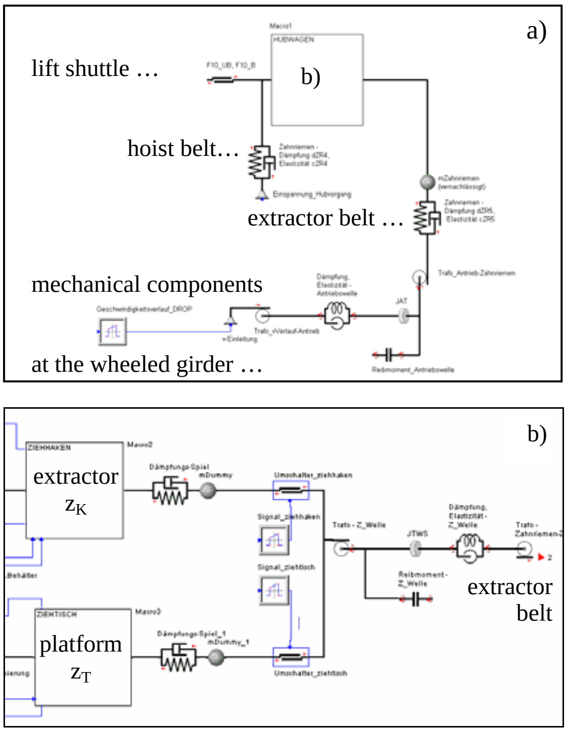

Figure 12. a) main structure b) subsystem extractor

As an example for simulation studies Figure 13 offers the velocity diagrams for a drop cycle. Shown are the graphs for the servo-drive v_{drive}, the platform v_{ZT} and the extractor v_{ZK}.

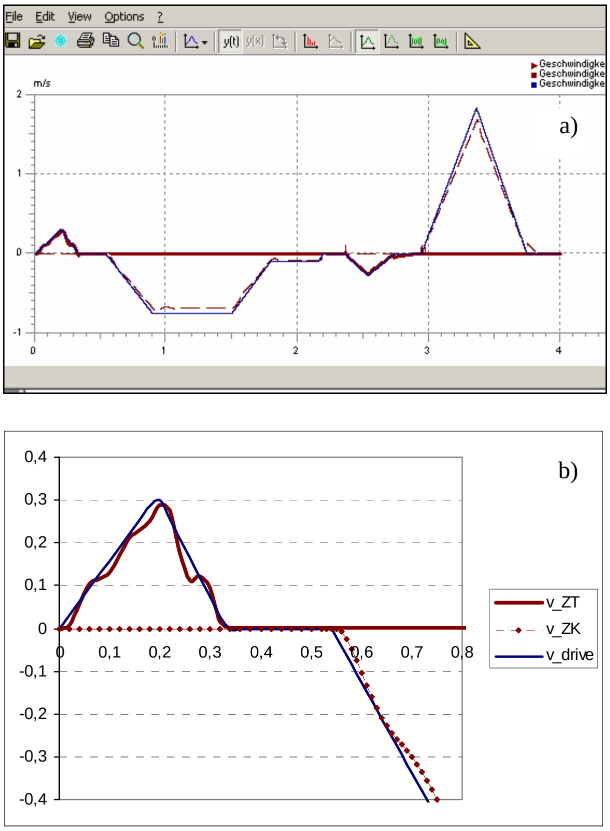

Figure 13. simulated velocities (v_{drive}, v_{ZT}, v_{ZK})
a) drop cycle b) detail

The simulated velocity graphs in Figure 13a for a drop cycle show a good compliance with the measured data from Figure 9.

3. CONCLUSION

In this paper we have presented a new extractor-design (Figure 2) for a load handling mechanism attached to the lifting shuttle of a small parts storage system AS/RS (Table 1) (Figure 4).

The new design-concept (section 2.3) was the gate to the advantages as follows. Figure 3 showed the increasing space utilization of the extractor-solution (up to 130%) in reference to a conventional telescope-technique. A high throughput and high positional accuracy was realized by the use of a closed-loop controlled EC-servo-drive unit (Figure 6). The multi use of the servo-drive for the three sequential operating axis saved money.

The prototype investigations (section 2.4) approved all requirements like reliability, durability, repeatability of positioning.

In section 2.5 we presented demands, goals, approach and solutions of additional theoretical investigations (modeling and simulation) for the optimization of controlled motion sequences and further design (parameter) studies.

Finally we are able to say the developed extracter-design for VDA-KLT totes [1] comprises relevant advantages and is ready for industrial use.

4. ACKNOWLEDGEMENT

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Sponsor:
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5. REFERENCES

[1] VCA-KLT container, DIN 30820

[2] J. Oser and K. Reisinger, Extractor device, patent # DE 19532641

[3] ITI®-SIM Simulation (v3.5), ITI® GmbH

6. NOMENCLATURE

v	*velocity*
M	*torque*

axis of the AS/RS (Automated Storage/Retrieval Syst.):

x	aisle
y	lifting axis
z_T	platform, horizontal sliding base towards rack
z_K	extractor, pairs of chains