Designing and optimizing extractors for automated dispensers

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Abstract. Currently, the process of manufacturing the goods and then distributing them to the customer is constantly optimized, accelerated and automated. For these aspects, goods handling and automated storage play a key role. This article focuses on designing and optimizing the mechanisms that are parts of vending machines. Both static and dynamic models of mechanisms are presented, also the thesis describes the configuration and operating principle of given mechanisms. The mechanisms have been designed to handle for instance boxes, reliably and precisely, they were subjected to dynamic analysis. Several principles of the various mechanism are presented. After this, the functionality of some mechanisms was verified by analysis. These models of extractors can be used in food dispensers, vending machines in libraries, pharmacies, and stores of specific goods. The presented mechanisms are particularly suitable for medicine dispensers and pharmacy environments.

1. Introduction
Currently, the process of manufacturing the goods and then distributing them to the customer is constantly optimized, accelerated and automated. For these aspects, goods handling and automated storage play a key role. This article focuses on designing and optimizing the mechanisms that are parts of vending machines. Both static and dynamic models of mechanisms are presented, also the thesis describes the configuration and operating principle of given mechanisms. The mechanisms have been designed to handle for instance boxes, reliably and precisely, they were subjected to dynamic analysis. Several principles of the various mechanism are presented. After this, the functionality of some mechanisms was verified by analysis. These models of extractors can be used in food dispensers, vending machines in libraries, pharmacies, and stores of specific goods. The presented mechanisms are particularly suitable for medicine dispensers and pharmacy environments [4, 5].

2. Methodology
As the proposed mechanisms are designed primarily for vending machines and pharmacies, specific requirements that are part of the environment need to be taken into account. Handling mechanisms are primarily intended for supplying and dispensing objects. When designing extractors, it is necessary to pay attention to the shape, weight and other associated operations. Figure 1 shows the division as well as the intended application of the mechanism.
When designing, it is also necessary to take into account the principle of the equipment to work. In most cases, these are mainly the principles: pneumatic, electromechanical and hydraulic. In our case, we exclude hydraulic operation. Disadvantages have far outweighed the advantages of the hydraulic system. Especially because of costly operation of the system, the presence of dangerously high pressures, pollution caused by leakage. When designing the mechanism for supplying the dispenser and for dispensing objects from the dispenser, it was mainly based on the shape diversity of the medicines. For this purpose, we have communicated with pharmacists and worked closely with pharmacies, conducted a survey, and developed an extensive list of the most widely sold drugs. Pharmacies have been involved in the research to provide us with their data [5].

It has also been shown that the marketing of drugs and, in particular, their species is different from the season. For these aspects, a consensus has been created that meets market requirements.

Partial goal of data collection was also input conditions for solving problematic packaging forms of some types of drugs. As can be seen from Figure 2, in particular the irregular shapes of the vials and bags.

It has also been found that it is not possible to automate the sale of all kinds of drugs in the present automated device. According to the drug sales list, a formula has been created according to which the design of extractors has started.

If a given type of drug has not exceeded a certain threshold of sell ability (constant $K$) and the shape of the packaging has been complicated, it has been classified as non-automated and must be stored manually, see Figure 1. In general, drug vending machines can automate the sale of 80% of the drugs offered on the market. However, this number may increase over time as mechanical principles are constantly innovated, and drug manufacturers will also consider the shape and packaging of the drug. However, we expect that within a few years we will see more than 90-95% of all drugs automated. Nevertheless, the processes mentioned above need to be carried out [5].
Following the analysis of the drug market, the development of mechanisms for the drug dispenser was started. The fully automated drug delivery system is characterized by the fact that it can automate the supply and delivery of drugs. This means that one supply extractor takes care of the supply and one extractor ensures the dispensing itself. The machine we developed is based on two parts. In the back, there are shelves in the horizontal direction. These shelves balance stocks and serve as a temporary store. In front of the dispenser, there are shelves that have the character of a gravity rack. The shelves are installed at an angle of 30°. In the following chapters, we analyse the supply extractor and the dispensing extractor.

**Figure 2.** Medicine division by shape and methods of the gripping.

**Figure 3.** Schematic movement of the medicine across the machine.
Figure 3 schematically shows the movement of the medicine in the dispenser. The medicine comes through a conveyor belt to pick it up by supplying extractor and then the supplying extractor stores the medicine in the shelves. From the front shelves, the vending dispenser extracts the medicament, and through the dispensing site, through the pipeline, enters the pharmacist's work area.

3. Conceptual design of a supply extractor
We have selected a conveyor to deliver drugs to the dispenser. The conveyor can be made in various designs, depending on the customer's request. The drugs are deposited on a conveyor and passed through an optical gate, where their bar code is scanned, and the data is recorded into the system. The following systems have been proposed for the collection and subsequent incorporation of drugs [4].

3.1 Supply extractor with suction pad and scissors mechanism
One of the first proposals was to use a suction cup and a scissors mechanism. In another concept, we have replaced the scissors mechanism with a pneumatic piston. The advantage of this solution lies in its simplicity of design, predictable life. However, the big disadvantage is the small number of medicines per hour, because we are able to grab only one box. Another drawback is that the position of the suction cup must be oriented as low as possible to the conveyor because there is a risk that the suction cup will not catch the object, especially small boxes. Thus, the versatility of the device can be more difficult than with other prototypes. The forces that need to be overcome are very low since the drug box only slides over the pad, where friction is considered (k = 0.1, between pad and box). Thus, only the self-weight and weight of the suction cup acts on the scissors stroke. In addition, this mechanism is supported by auxiliary guide, see figure 4 [1].

![Figure 4. Schematic view of extractor with suction cup.](image-url)
3.2 Extractor with forks and slider
We have tried to eliminate the shortcomings identified in the concept above by using other, in particular more universal mechanisms. We went to a full electromechanical drive. There are 4 electric motors on the extractor. One of them provides rotational movement of the extractor around itself axis. The gripping of the boxes is ensured by the so-called forks that move along the side guides. The motion is provided by the motor which produces the torque on the threaded rod. The principle of function and the individual elements of the mechanism can be understood from the following figures [4].

The advantages of using this system lie in the higher capacity of the stored medicines. 1 to 3 boxes at a time can be grasped. This system is much quieter. Plastic lines are used for several reasons. There is no need to lubricate them with an external lubricant, which means a cleaner and more hygienic environment. They are on the order of 50% lighter than steels, without stiffness and strength. They have a better predictable life [1, 4, 5].

![Figure 5. Main functional mechanisms of the fork extractor.](image)

![Figure 6. Von Misses strain at force 80 N.](image)
We made a simulation calculation of the design of the fork clamp force. Based on the calculation we propose to use a force of \( F = 80 \) N per one fork, see figure 6. As the fork material, S235 was chosen with Young's modulus of \( E = 210,000 \) MPa and a Poison number of 0.3, and the paper was chosen as the homogeneous material with Young's modulus of \( E = 10,500 \) MPa and Poison number of 0.35. When a force of about 500N is applied to a fork, the box begins to deform, see figure 7 [2, 3].

![Figure 7. Von Misses strain at force 500 N.](image)

Figure 8. The process of inserting the medicine (a), the process of pull the medicine from the conveyor (b).
4. Conceptual design of dispensing mechanism

Various types of dispensing extractors are used to remove drugs from the front shelves. Medicines can be stored in horizontal shelves, but also in shelves that have the character of a gravity rack and they are stored at the certain angle. If the front shelves are horizontal, we have designed a suction and slip extractor. However, if the front drug shelves were tilted at an angle, we designed an extractor that includes a so-called thumb mechanism. In a particular position in front of the rack, with the ordered medicine at the complete stop of the extractor, the dispensing mechanism is then triggered.

The drug is released from the gravity shelf and lowered into the extractor storage area. If there is more than one medicine order, this cycle is repeated. After collecting medicine from the shelf (which, depending on their size, may be more than five pieces), the extractor moves to the dispensing place. At the same time, the extractor door is opened by reaching the position of the dispensing place and its content is displaced spontaneously through the tube to the selected point at the cash register. Both extractors are designed to weigh up to 10 kilograms [4, 5].

4.1 Design of extractor with thumb mechanism.

The main parts are the kinematic mechanism of the thumb, the engine securing the movement of the thumb mechanism, the actuator opening the door, the structure itself, the cover, supporting and connecting elements, see figure 9. Opening of the door ensures micro-linear actuator. This door opening principle was chosen for the following facts: the door weight is 200 g, on the hinges they perform a simple two-way movement of 90 °. Actuators provide quiet and precise motion control, are effective, have a long lifetime and virtually zero maintenance. The selected actuator consists of a motor, gear and trapezoidal screw [5].

![Figure 9. Dispensing extractor (a), process of releasing the medicine from the gravity rack (b).](image)

The kinematic mechanism of the thumb was subjected to dynamic analysis in Inventor 2018, and one of the outputs was the endpoint trajectory of thumb, see fig. 9. With the help of dynamic simulation, it was possible to analyse the acting forces and the torque needed to ensure the rotational motion of the kinematic mechanism. One cycle lasts 2 seconds, the time it takes for the thumb to go through the entire trajectory from the starting point while removing the box from the gravity shelf. In the analysis, the mechanism was loaded with the heaviest box weighing 450 grams.

As can be seen from the figure 10, the maximum torque required was reached at 1.35 s, when the thumb lifts the box over the edge of the shelf. The value reached 101 Nmm (0.1 Nm), which was one of the data needed to select a suitable engine [5].
4.2 Extractor with a suction cup and slip surface
In addition to the clamp grip, a suction cup and scissor mechanism has been designed to move medicines from the horizontal shelves to the extractor. When the scissor mechanism is lifted, the suction cup grabs the medicine. The medicine is simply pulled by the suction cup. Thus, the scissor stroke only has its own weight, which allows it to be used in such an application. After reaching the maximum contraction point, the drug is released and the inclined plane self-releases to the door.

The storage surface on an inclined plane is sufficient for 2 to 4 packs of drugs. Similar to the previous case, after the storage space has been filled, the extractor is moved by a manipulator on which it is placed at the dispensing points. At the dispensing point, the rear door opens and the medicines spontaneously advance through the conduit.

Figure 10. Graph of torque and cycle time with defined parameters for motor.

Figure 11. Schematic view on extractor with a suction and slip surface.
5. Visualization of the automat
In the figure 12, 13 we can see the design of the cladding, the access door and other supporting elements. The implementation of vending machine is individual and depends on the requirements.

Figure 12. Visualization of the automat.

Figure 13. Visualization of the automat with staff and customer.
6. Conclusion
The article reflects the issue of medicine storage in automated devices. The results of a survey conducted in pharmacies have produced statistics on medicine storage options. It was clear from the results that so far it is not possible to automate the sale of all drugs on the market. In the next section, some of our extractor designs were presented, their advantages and disadvantages were evaluated. We have analysed some of them and discussed their technical principles in more detail. This text can serve as a review article as an inspiration for new solutions and ideas for developing new mechanisms.

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