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Innovative systems of movement of elements and subassemblies used in kitchen furniture for people with reduced mobility

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Abstract: *Innovative systems of movement of elements and subassemblies used in kitchen furniture for people with reduced mobility.* The article presents innovative design solutions developed by the domestic company JATI, solutions that enhance the functionality of kitchen furniture intended for the elderly and wheelchair users, as well as a solution allowing for the installation of wall-mounted cabinets in the case of partition walls with insufficient load-bearing capacity. The design solutions concern: a top kitchen cabinet that can be lowered and brought closer to the user, a drawer beneath the countertop that can be pulled out and lifted upwards, as well as a system for raising and supporting a large countertop with attached components. These solutions were analyzed using analytical methods and empirically tested to determine their technical and user-related parameters. After developing the solutions, they were registered as original utility designs.

Keywords: furniture fittings for disable people, moving system for kitchen box furniture, moving system for heavy top panel with subassemblies, kitchen furniture, furniture for users wheelchairs

INTRODUCTION

Among the users of kitchen furniture are individuals with limited mobility, who move using wheelchairs, or elderly individuals with limited vertical reach, both upper and lower. Additionally, there are kitchen furniture users who, for instance, have experienced accidents or sports-related injuries that have led to the need for wheelchair use. However, these individuals are professionally active, often with a high socioeconomic status, and they desire to maintain full independence within their living spaces. Furniture companies operating in the kitchen furniture manufacturing sector strive to adapt their offerings for this group of customers. They provide options from a higher price range that come with enhanced functionality, achieved through the use of accessories that increase furniture mobility.

Publications addressing the issues of designing buildings and interiors, specifically kitchens, for people with disabilities include works by Bola et al. (1991), Omelańczuk (2003), Meyer-Boha (1996), Skardzińska (1980).

There are authors who address the issues related to the functionality of kitchen furniture for individuals using wheelchairs, with a special focus on the vertical reach of users. For example, Hrovatin et al. (2015) discuss this topic.

Other authors concentrate on the challenges of older individuals using kitchen spaces. Maguire et al. (2014) focus on elderly individuals who also have limited mobility, with a specific emphasis on safety aspects of using kitchen equipment. Hrovatin et al. (2012) delve into the safety aspects of kitchen equipment usage, while Kumashiro (1997) explores the aspects of work performed by wheelchair users in kitchen environments.

Less common are publications concerning technical solutions that facilitate the use of kitchen equipment by people with disabilities, such as Jaranowska (1992). There is a lack of contemporary publications addressing the technical aspects of solutions that enhance the comfort of kitchen use for individuals with limited mobility. This publication fills that gap.

In the offerings of companies supplying fittings and furniture accessories, examples of ready-made solutions for use in kitchen furniture can be found. For instance, in the product lineup of Häfele company, there is a system called DIAGONALHEBER DIAGO 504 (Fig. 1), which allows for lowering and bringing closer to the user the cabinets above the worktop. The design consists of two frames connected by four swivel-mounted connectors. The rear fixed frame is attached to the wall using screws and dowels of the toggle type. The front movable frame is used to attach the cabinet, its lower and upper cornices, using screws. The drive of the system is provided by a linear motor rotationally mounted to the movable frame. The solution is offered in two dimensional variants, intended for cabinet bodies with widths ranging from 600mm to 1100mm and for cabinet widths from 1200mm to 1800mm. The maximum load-bearing capacity of the cabinets, expressed in kg, for the presented variants is 50 kg and 95 kg, respectively. Unfortunately, this solution is not without flaws, as highlighted by the mechanism supplier in the description of the conditions for using the mechanism, where even and symmetrical shelf loading is recommended.

Fig. 1. System for cabinets above the countertop allowing for lowering, bringing them closer to the user, and lifting.
Source: Internet, https://www.rehadat-hilfsmittel.de/de/produkte/bauen-wohnen/moebel-und-tische/ (access 01.08.2023).

The company Granberg offers other mechanisms for lowering and raising cabinets above the countertop, known as the Verti system and the InDiago system.

The Verti system (Fig. 2) allows for swift and quiet lowering of shelves with contents, without the need to open the doors. After the shelves are lowered, there is a clearance zone under the lowest shelf. The system can be easily installed in existing cabinets with a height of 700mm and above, and widths ranging from 400mm to 1000mm. The system features pinch protection for objects located under the cabinet.

The InDiago system (Fig. 3) allows for lowering shelves with contents and bringing them closer to the user of the furniture, combined with automatic door opening. The system can be installed in existing cabinets with a height of 700mm or 850mm and widths ranging from 500mm to 1000mm. The system features protection in case of encountering resistance during downward and forward movement.

Fig. 2. The VERTI lowering and raising system by GRANBERG.
Source: Internet: https://www.granberg.se/en/our-products/accessible-kitchen/lifting-systems-wall-cabinet/verti (access 01.08.2023)

Fig. 3. The InDiago lowering and raising system by Granberg.
Source: Internet: https://www.granberg.se/en/our-products/accessible-kitchen/lifting-systems-wall-cabinet/wall-cabinet-lift-diago/diago (access 01.08.2023).

In the case of a ready-made solution for lifting and lowering countertop surfaces, you can come across a fitting named Baselift 6300/6310 (Fig. 4), offered by Granberg company. This fitting is used for raising a small countertop, and there are also fittings available for lifting larger countertops with attached kitchen components for single-row and L-shaped kitchen layouts (for lifted corner units). Another solution available in the European market for lifting long countertop surfaces is the hardware system named Sidelift 6400 by Granberg company

(Fig. 5). The height of the countertop relative to the floor ranges from 700 to 1000mm. The system has a weight capacity of 400kg. Two lifters are used in the system.

Fig. 4. Countertop lowering and raising system, e.g., with an installed induction cooktop, Baselift 6300/6310 by Granberg company.
Source: Internet: https://www.granberg.se/en/our-products/accessible-kitchen/lifting-systems-worktops/baselift-6300-6310/

Fig. 5. Sidelift 6400 Countertop Lowering and Raising System, e.g., with an installed sink, induction cooktop, drawer component, by Granberg company.
Source: Internet: https://www.granberg.se/en/our-products/accessible-kitchen/lifting-systems-worktops/sidelift-6400/ (access 01.08.2023).

No drawer slide system combined with lifting was found on the market. Only a type of pull-out mechanism was encountered, which lifts and extends a plate element to create additional surface in front of the worktop (Fig. 6), available from Häfele. These pull-out mechanisms are characterized by a horizontal load capacity of 8-10kg. Electric drawer opening support mechanisms like Blum's SERVO DRIVE (Fig. 7) can also be found. However, this is a mechanism for horizontal extension without lifting the drawer with its contents upwards.

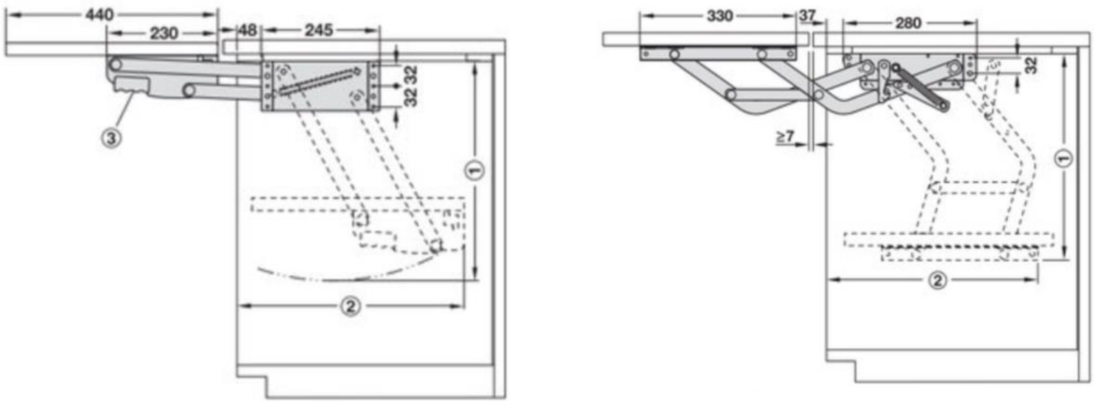


Fig. 6. Hand-pulled and lifted pull-out systems installed in the cabinet body of a kitchen unit. Solution from Häfele company's catalog. Source: Häfele company catalog 2017.

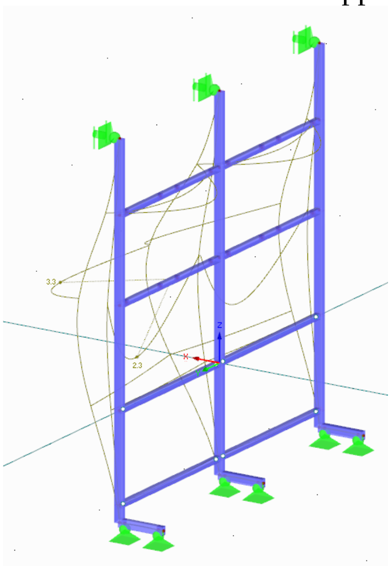
Fig. 7. SERVO DRIVE system for electronically assisted drawer opening in kitchen furniture, from Blum company's product offerings. Source: Blum company catalog 2022/23.

MATERIALS AND METHODS

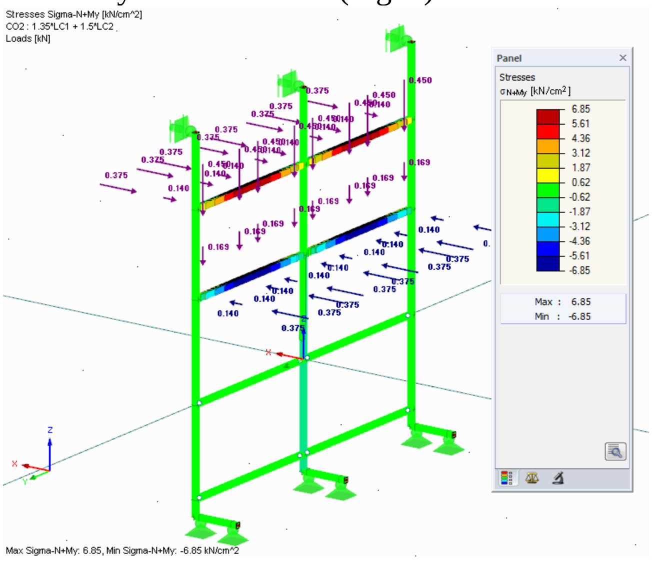
At JATI company, as part of the project, the design team under the direction of Dr. Eng. Tomasz Wiktorski conducted not only a functional analysis but also a detailed technical analysis of the existing European market systems for cabinets that can be lowered and raised above the countertop (wall-mounted), systems for lifting the countertop along with attached components like cabinets, sinks, and induction cooktops, as well as available mechanized drawer extension systems and extension systems combined with lifting elements. The analysis of existing solutions allowed for defining guidelines and principles for designing systems that would exhibit improved technical and user-related parameters. One of the conclusions drawn from the analysis was the need to create a load-bearing frame structure for attaching mobility-enhancing systems to kitchen furniture. This was to be done in a way that these systems could be applied in rooms with partition walls of limited load-bearing capacity, facilitating the installation of cabinets above the countertop.

Under the project assumptions, a single-row kitchen layout was chosen as the functional layout for which all systems were designed.

Designs were developed for load-bearing frames spanning between the floor and the room's ceiling, made from wood, aluminum, and steel. In each material variant, the cross-sections of the elements were diversified. Additionally, designs for upper fastening and stabilizing feet were created. For each material variant, analyses/simulations of deflections of load-bearing beams and stress analyses in the elements were performed (Fig. 8). Prototypes of selected frames made from different materials were also created. These prototypes underwent empirical testing as well, assessing their stiffness (deformations) under applied forces. The stiffness of the upper fastening and the connections between vertical and horizontal beams were also examined. Ultimately, after analysis, a steel frame was selected, and the fabricated prototypes of frames, made from various materials, were subjected to loads to determine real element deflections under applied loads and to verify frame stiffness (Fig. 9).



Simulation of deformation in the steel structure.



Simulation of the frame's load, which accurately depicted the magnitude of stresses in the frame's elements.

Fig. 8. Sample diagrams from the analysis of deformations and stresses in the designed frame.

Another goal of the design work was to develop a lifting and lowering system for upper cabinets, designed to bring the cabinet closer to the user. This system is intended for cabinets suspended above the countertop surface. The system includes a selected DC linear motor. The system is sensitive to resistance during movement, leading to automatic stoppage when resistance is encountered. It is worth noting that the system is designed to handle asymmetric cabinet loading, and it is lighter than comparable products on the market, weighing only 20kg. Additionally, the system is designed for easy installation onto the load-bearing frame structure. Unlike existing market solutions where symmetric cabinet loading is recommended, this system allows for asymmetric loading.

Preliminary analyses of the designed system were performed using computer software, and a prototype of the cabinet was tested in laboratory conditions, subjecting it to both symmetric and asymmetric loads (Fig. 10).

Fig. 9. Empirical testing of frame stiffness and element deflections using weights in a situation simulating the suspension of the cabinet lifting and lowering system.

Fig. 10. Schematic diagram of the upper cabinet mechanism, side view of the prototype mechanism with the cabinet, cabinet with the mechanism during tests with asymmetric loading.

As part of the project, a system for lifting the countertop surface was designed. The countertop surface for kitchen furniture can be made from various materials used in kitchen equipment, even those with lower bending strength and stiffness. Attaching the countertop element to a steel frame ensures its strength and stiffness. The first version of the countertop lifting system, during empirical testing, exhibited unacceptable deformation of the countertop (Fig. 11, top). In the second version, a reinforced frame for attaching the countertop was used, providing sufficient stiffness (Fig. 11, bottom). Additionally, the second solution incorporated two additional vertical lifters/actuators under the countertop surface, which positively influenced the load-bearing capacity of the system and allowed for asymmetric loading of the countertop with a weight of 300kg. The countertop is positioned at a height of 610mm in the lowered position and is raised to a level of 910mm.

Another design was developed for a drawer with both extension and lifting functionality. This is an original solution developed at JATI company and not commonly found in the offerings of other hardware and furniture companies. The schematic of the drawer and the physical implementation of the system are shown in Figure 12. The system employs two actuators - one for extending the drawer using selected ball-bearing slides and another actuator for lifting the drawer, along with its contents, upwards. The fabricated prototype of this system was also subjected to tests assessing its deformations, strength, and capability for asymmetric loading.

As a result of the design work, several structures were developed: load-bearing frame, lifting and lowering system for upper cabinets, lifting and lowering system for the countertop, and a drawer extension and lifting system (Fig. 13). The prototype of the integrated systems underwent cyclic load tests simulating years of system operation. Cyclic loads were applied ranging from 100 cycles to 1500 cycles in increments of 100 cycles. After each cycle, clearances and deformations in various directions were measured, and the acoustic comfort of the systems' operation was subjectively evaluated.

A prototype kitchen incorporating these new systems was created and evaluated by users in terms of functionality and safety. However, these aspects of the research are presented in the publication by Kaczor et al. (2023).

Fig. 11. Countertop lifting system during load testing. At the top, the first version of the system without a frame for attaching the countertop, and at the bottom, the second version of the system - the final version, with a sturdy frame for attaching the countertop element.

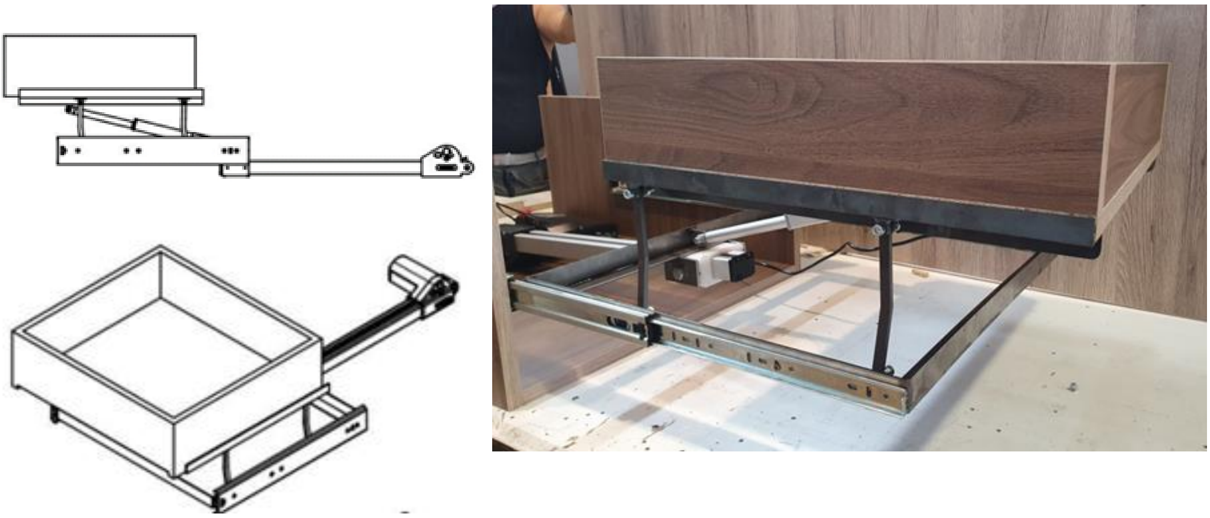


Fig. 12. Drawer extension and lifting system. On the left side, schematic diagrams illustrating the mechanism's operation, and on the right side, the physical implementation of the project.

Fig. 13. Integrated structures: load-bearing frame, lifting and lowering systems for two upper cabinets (above the countertop), lifting and lowering system for the countertop, and drawer extension and lifting system under the worktop.

RESULTS AND THEIR ANALYSIS

The results of the analysis and research on the initially proposed construction variants allowed for their development and refinement. The designed load-bearing frame and systems for the hanging cabinet, countertop, and drawer under the countertop were improved. It's important to emphasize that the systems were tested and refined using asymmetric loads, which presents a more challenging simulation of real usage conditions.

The empirical testing of the final prototype, subjecting it to cyclic loading, provided insights into how the systems would perform under prolonged usage conditions, simulating long-term kitchen equipment use.

Comparing the deformations and stiffness of the final load-bearing frame constructions made of wood, aluminum, and steel led to the selection of steel as the practical solution. The load-bearing capacity of the steel frame is around 600kg.

Testing of the hanging cabinet lifting and lowering system above the countertop, loaded symmetrically and asymmetrically, with loads exceeding normal usage (60kg), demonstrated correct operation of the construction and an acceptable level of deformation after numerous load cycles.

The testing of the countertop lifting and lowering system also showcased its reliability during cyclic movements with symmetric (300kg) and asymmetric (150kg) loading. Minor deformations that appeared after multiple cycles did not pose any problems for the system's functionality. The implementation of a robust frame for the countertop completely eliminated its previous bending, which was noted in an earlier variant (deformation at 45mm).

Furthermore, the tests on the drawer extension system, combined with lifting under load (20kg), also demonstrated the efficiency of the system after multiple load cycles, showing acceptable levels of deformation.

CONCLUSIONS

The highest level of innovation is represented by the drawer extension system combined with lifting. According to the market analysis conducted by JATI, as of today, no European companies offer such solutions.

The designed and manufactured lifting system for cabinets suspended above the countertop is resistant to asymmetric cabinet loads, as verified empirically. This feature distinguishes the new system developed by JATI from the systems available on the market.

Regarding the countertop lifting system, it is important to highlight that it enables the use of a rigid countertop made from various materials, solidly supported by a reinforced frame construction. The increased number of lifters, up to four in the system, provides an advantage in terms of the load-bearing capacity of the countertop compared to competing products.

The load-bearing frame construction, spanning between the floor and ceiling of the room, for hanging and supporting lifting systems, allows for a solid and rapid system installation, particularly for hanging cabinets. This is in contrast to solutions available on the market, which require wall mounting and can be more cumbersome. The load-bearing frame also provides the flexibility to use the systems even in kitchens with partition walls of limited load-bearing capacity and connection capability.

The designed systems require testing and observation under real-world conditions to validate their functionality.

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Streszczenie: *Innowacyjne systemy ruchu elementów i podzespołów zastosowane w meblach kuchennych dla osób z ograniczoną sprawnością ruchową.* W niniejszym artkule przedstawiono innowacyjne rozwiązania konstrukcyjne wykonane w krajowej firmie JATI, rozwiązania zwiększające funkcjonalność mebli kuchennych przeznaczonych dla osób starszych oraz poruszających się w wózkach oraz rozwiązanie umożliwiające montaż szafek wiszących w przypadku ścian działowych o niewystarczającej nośności. Rozwiązania konstrukcyjne dotyczą: szafki kuchennej górnej opuszczanej i przybliżanej do użytkownika oraz szuflady pod płytą wierzchnią wysuwanej i unoszonej do góry a także systemu do podnoszenia, podtrzymania dużej płyty wierzchniej z dołączonymi podzespołami. Rozwiązania te analizowano metodami analitycznymi oraz testowano empirycznie w celu określenia ich parametrów techniczno-użytkowych. Po opracowaniu rozwiązań zastrzeżono je jako oryginalne wzory użytkowe.

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