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DEVELOPMENT TRENDS IN ASSEMBLY AUTOMATION AND FLUID POWER

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Abstract: Automation of handling and assembly covers areas such as technology of handling and assembly, Robotics and Machine vision, which all together constitute a fully automated solution. These areas can be called the Robotics and Automation, and are highly influenced by Fluid power elements and systems. When trying to predict the future trends of development in robotics and automation, we must first assess the current state and trends of development and based on that, estimate future development. This article discusses some of the trends that drive the development of robotics, automation and fluid power while trying to identify trends that coincide with development efforts. Noteworthy is also data that provides an insight into how economic crisis has affected the development trends in automation of handling and assembly, and how automation has helped industrialized countries to overcome the crisis. Nowadays, the emphasis is on "green automation", the topic also described in the article.
Keywords: robotics, automation of handling and assembly, fluid power, digital valves, development trends, green automation, efficiency of systems

1. INTRODUCTION

As in other areas of industry, a driving engine of the future development of robotics and automation represents a market, its requirements and needs on one hand and technological possibilities on the other hand. In the past few years both have undergone a significant change under specific economic circumstances, which are still ongoing.

Influenced by a globalization and increasing market dynamics in recent years, business environment is forced to work in increased competition. Manufacturing companies have to cope with new challenges. Therefore an increase of productivity, a reudction of wastes and costs and shortening of a lead time is a main principle of all successful "players" in the world market. Automation can here play a prominent and important role at all levels and in every step towards a success [1, 2].

Robotics and Automation can contribute to a success mainly due to the rapid development in information technology (IT). While a decade or a bit more ago the automation was somehow "locked" to itself and was self-sufficient, it has fully opened now, and is based on technologies that are used also in other areas. In fact, robots have become standard equipment in modern manufacturing sites, providing fast and reliable routine operations. Consequently boundaries between different areas, due to incompatible software, have somehow disappeared. This enables integration of different needs in the value chain. The approach leads to the reduction of development costs of automated handling and assembly systems. However, we cannot ignore the life expectancy issue of information technology products, which may be even shorter than one year. From this perspective, we cannot achieve life time of automated system of 20 years without any intermediate updates of information technology products [3, 4].

The paper gives a brief overview of the situation and trends in the field of automation of handling and assembly or robotics and automation and in the field of fluid power. It draws attention to some particular emerging technologies that show right direction to those who plan automation, handling and assembly systems, staying on the right track and leading in the direction in which we should be thinking.

2. SITUATION IN AUTOMATED HANDLING, ASSEMBLY AND FLUID POWER

When we discuss the situation in the field of automated handling and assembly as well as fluid power technology, we cannot ignore the financial and economic crisis affecting this area. We somehow prefer to follow Germany's example, which is (at least for Slovenia) our major economic partner. As Figure 1 shows, volume of handling and assembly business in Germany in 2009 decreased (excluding exports) for 35%, to a level achieved in 2001/2002 [1].

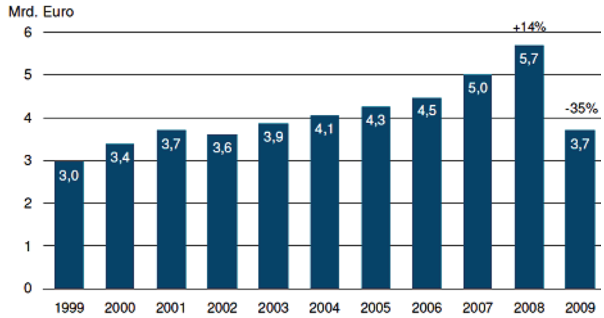

Figure 1. Impact of financial and economic crisis on the scale of business [1]

If we consider only scale of business in Germany, it has increased in the past three years for 14% in 2010 up to 42% in 2011 and 2012. However, the volume of business in the field of robotics and automation, including exports, shows a slightly different picture. Growth in the year 2010 is 5% and grew up to 37% in 2011 and continued with the same rate in 2012 [1, 2]. This means that German economy actually recovers faster than the rest of the world. For this sector this is the most important information.

Based on statistical data [1, 2, 3, 4, 5, 6] we can conclude that industrialized countries investing more in automation of production processes in general, are recovering from the economic crisis more quickly. This demonstrates the importance of automation of handling and assembly, which should not be disregarded, when we talk about economic recovery in different states and regions. Industrial handling, assembly, robotics and fluid power will play an important role in future industrial development. In particular, the use of intelligent automated systems will become a strategic factor of cost efficiency, productivity and overall success in industrialized countries. This is less industrialized countries should follow as an example.

Automation of handling and assembly in manufacturing processes in general is one of the main principles of attracting and retaining manufacturing advantages and competitiveness in the global market. Established world economies such as Japan, USA and many other EU countries, in order to retain global competitiveness, base their production on automation, despite the high costs of wages. Moreover, the most modern and intelligent automation provides stable production processes and high quality finished products. Modern intelligent automation also enables efficient use of energy and resources; consequently it enables so-called green automation. Especially in difficult economic periods, it is important to automate manufacturing processes to ensure the production of high quality products at a low price. Competitive advantage can be achieved only if response to market requests and demands is quick and at the same time products are of high quality. According to the assessment of the OECD, this flexibility is probably one of the reasons for quicker recovery of industrialized countries from the economic crisis, as was

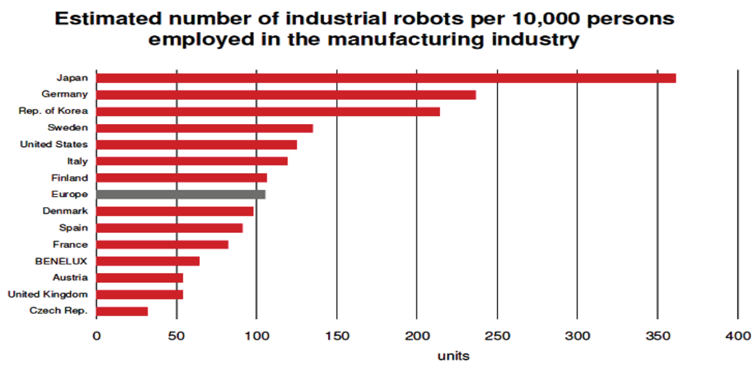

Figure 2. Estimated number of robots per 10.000 of employees [6]

expected at the beginning of the crisis.

According to IFR (International Federation of Robotics) [6] study on the prevalence of automation in the world, only one-third of companies use industrial robots in the process of quality control. Thus, in Eastern Europe as well as in Asia, excluding Japan, South Korea and Taiwan, there are less than 50 industrial robots per 10,000 employees, which is also evident in Figure 2. The density of robots is however a main indicator of the level of automation.

In industrialized countries, automation is introduced in order to increase efficiency, which is one of the most important factors for the decision. In other countries where the automation is at a lower level, robotics and automation affect the success of the company for other reasons: requirements for products quality and precise handling of micro components are the main arguments for the introduction of automation even where the costs of automation are comparable to costs of low wage workers.

Today's level of automation in the world assures the following [5, 7, 8, 9]:

- production becomes or remains competitive despite salaries' increase,
- high level of productivity,
- best price of products because of optimal quality,
- high degree of innovation in production and end products,
- efficient production in terms of use of resources etc.

In the future, automation will provide the following perspective options:

- the production for demanding customers will be possible globaly with high quality and safety criteria,
- besides increase in productivity with decrease of costs the emphasisze will be in safety, quality and flexibility of production processes,
- high precision and miniaturization of products,
- cheaper automated high-volume production in comparison to hand-held large-scale production.
- high-tech products will require high-tech manufacturing etc.

3. TRENDS

Important trends in the field of automation and assembly do not change overnight, but remain unchanged for a long time. For some time already we can notice the trend of automated handling and assembly processes in growing number of companies which incorporate standardized, but variable modular systems that provide the optimal ratio between flexibility and profitability. With smart planning of automation handling and assembly processes, we can combine automated and manual processes in combined flexible manufacturing solutions.

One of the important advantages of flexible modular systems is that they allow companies a successive investment in new equipment. In the initial phase the user is satisfied with minimal system configuration of the production. With increasing number of products and types of variants, the basic system can be upgraded and extended, and thus adjusted to the new manufacturing requirements.

Consequently it is essential to implement the necessary flexibility in the initial design of automated systems and thus enable ability for incremental changes and upgrades. In this way it is possible to spread the investment over a longer time period and the automated systems can be updated gradually and at any time to the most appropriate and advanced solutions [6]. With such an approach we ensure the sustainability of automated systems and their variability, which is an assurance that the device retains its value and provides return of the investment costs and creates profit.

Beseides the introduction of LEAN production, one of the important trends in automated assembly is the efficiency of the production process and therefore of the company. For the definition of the performance of the company or services the appropriate criterion must be defined, which allows the assessment or classification of different approaches to the optimization of the production process. Such a criterion is Overall Equipment Efficiency (OEE) [7]. This criterion tells us how effectively the implement equipment is used.

In Figure 3, we can see those parameters which have impact on the profits of the production company owner and are a result of the company organization (graph doesn't take into account parameters such as market conditions, variety of products, etc.). Parameters influencing the cost side are mainly maintenance costs.

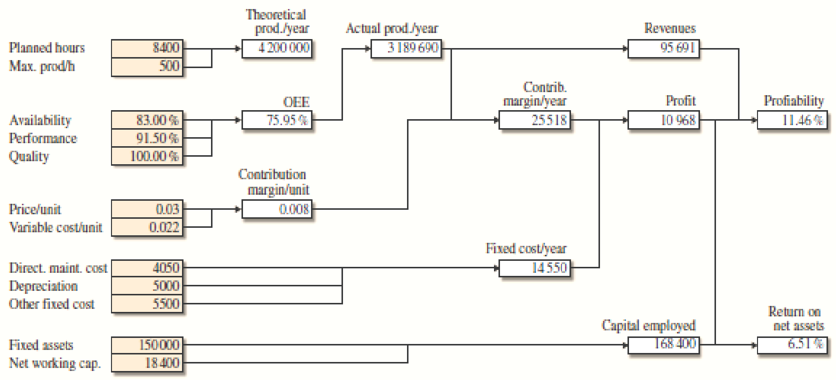

Figure 3. Overall equipment efficiency [7]

From the organization and quality of maintenance in the company (which is extremely important) depends availability, efficiency of the equipment or the reliability of its performance as well as production quality, which must be at the highest possible level. The availability and equipment efficiency is also influenced by the flexibility of automated systems and their architecture or redundancy. The price of the product is of course affected also by the operating costs.

In addition to the above trends, they are still current following guidelines in developing automation and assembly [4]:

- Flexible handling and assembly equipment for variable handling and assembly tasks - shortest possible time of shift.
- The modularity and reconfigurability of the systems even for small series and quick-change product features (flexibility of process and quantity).
- A high level of functional integration of different technologies with machine design to reduce length of the production chain.
- Flexible implementation of available system components including peripheral characteristics (process connection, operation, installation).
- New forms of co-operation with customers – integration of the customer as a partner enables value-added and the common development of the product.
- Transparency of the entire trade chain and life of the product, both for the customer and for the manufacturer.

Minimizing the cost of production is still in the very center of attention. There was a lot of discussion about the so-called "Lean manufacturing", and about lean production systems in recent years. With the help of lean manufacturing philosophy, production companies can optimize the performance, raise productivity and considerably reduced the cost of production as well as increase the profit. In the practice the best assembly can be achieved through the philosophy of "lean production" - never completed continuous improvement of the product and production process.

Those countries which are industrially less developed and therefore more vulnerable in terms of economic and financial crisis should especially support concrete steps of lean manufacturing introduction and lean into their companies. This measure would cost just a few percentage of the amount government usually is spending on high-tech research and the result would be at least double the added value in a very short time.

Also Design For Manufacturing and Assembly – DFMA is one of the methodologies and tools which will enable products and processes to remain "lean" from the beginning with the reduction of short-term costs and improving long-term profitability. The aim of DFMA is to get optimal handling and assembly process, which is achieved through the use of sophisticated software in the early stage of the planning and designing of the product. Herewith we reduce the number of components and simplify the handling/assembly process and maintenance as well as improve the quality of products [4].

In doing so, we must not forget the concurrent Engineering, which is the essence of success in using DFMA methodology, where close cooperation between all factors in the product life cycle (designers, constructors, vendors, users, manufacturing and assembly specialists, etc.) is crucial and in early stages of product design. Only in this way it is possible to effectively reduce production costs, improve efficiency of the process, consider all the alternatives and achieve consensus of all partners in order to shorten the production time of the product at improved quality.

Concurrent Engineering and the exchange of CAD data is becoming increasingly important in participation of producers and users of assembly systems [4, 7, 9]. This approach, implemented already in the early stage of development of handling and assembly systems enables shortening of the time to market for the product, high assembly process reliability, shorter cycles, etc.

At the introducing sensorics (sensors) in automated systems it is very important to simplify the use and the integration of sensors in systems, miniaturization of sensors while increasing functions and their robustness, simplified configuration, parameterization and diagnosis, increased intelligence of sensors and implementation of a standardized communication "IO-link" which eliminates bottlenecks between the control and the process level [10].

A lot have been discussed in the last few years about the environment and preserving our mother earth for future generations, therefor at this point we should mention the so-called "Green Automation". This initiative is being developed mainly in Germany, but also elsewhere in the world. The initiative derives from the following findings and goals [1]:

- the importance of robotics and automation in protecting environment and resources,
- efficiency, reduction of the energy consumption and material resources already in the manufacturing of the products without affecting flexibility, production capacity of products, etc., which can be achieved by innovative techniques of automation,
- the development of such control methods, which allow handling and assembly devices to consume only as much energy as required in the given frame of the production process,
- fast transfer of new technologies which lead to lower consumption of energy and resources from laboratories to the industrial environment.

It is also important to mention some concrete narrowly focused trends in automated assembly and handling, which are probably conditioned by the economic crisis [8]:

- Fine-Tuning of drive technologies, controls, etc. is for the first time in the forefront of manufacturers of machinery and devices. This means that the focus is on improvement and optimization of existing controls and drives in machines and devices, not in replacing them with other technologies.
- Energy efficiency drives – increasing number of companies decide for this measure. Concrete measures represent a shift from the use of electric motors with constant speed to the use of motors with variable speed with using of frequency converters, energy-saving three-phase motors in accordance with IE1 to IE3 (IEC 60034-30), etc..
- Controllers and servo-drives from one source.
- Increased use of linear actuators.
- Filed Buses and Ethernet: increased optimization of I / O modules, replacement of the classic Field Buses with Field Buses within the Ethernet, widespread introduction of Ethernet etc.
- Increased introduction of IT links (7 to 10% of annual growth).
- Increased introduction of RFID (10 to 14% of annual growth).

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Intelligent, reconfigurable automated handling/assembly systems with a high degree of flexibility and autonomy will be increasingly influenced by robotics and robots. Industrial robots deliver already nowadays high quality and cost-effective manufacturing, assembly, logistics and tending support in all major branches of industry, which will be only more pronounced in the future [6]. Figure 4 shows the number of supplies of industrial robots for individual years in the world and forecast for the future. Despite the fall in 2009, the number of industrial robots in the world increase.

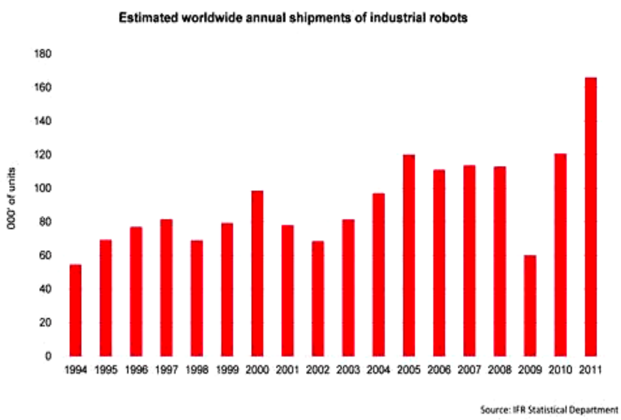


Figure 4. Global annual supply of robots [6]

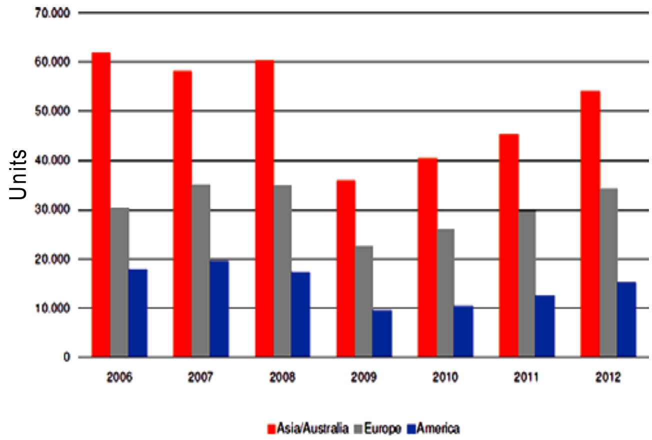


Figure 5. Percentage of industrial robots in world regions and years [6]

At this time Europe (in addition to Japan) is leading in the introduction of robots in an industrial environment [6]. Figure 5 shows te share of industrial robots in operational use in the world by regions and years.

A retrospective view on robotics covering the last few years reveals substantial changes in terms of market and technology drivers [8, 9, 11, 12, 13]. Recently, manifold trends have changed the shape, the performance and the fields of application of modern robotic systems. Although industrial robots have reached a high degree of maturity by now, robotics systems nevertheless achieve a steadily increasing level of overall performance. This is partly due to improvements of robot systems themselves, but additionally it is also strongly driven by improvements of peripheral devices and equipment such as improved gripper systems, tooling, and the like. While in the past, robotic companies had to develop most of their hardware by themselves, they will more and more benefit from developments driven by other high-tech areas such as mobile communication, game consoles and the like in the future. Even though an adaptation of these components will often be necessary before they are applicable to industrial robot systems, the overall costs for implementing new technologies into robot systems will be in many cases considerably reduced compared to pure in-house developments as they were standard in the past [14].

The flexible robot cell concept was developed and patented by the University of Applied Sciences, Aschaffenburg (Figure 6). Because of reduced lot sizes and an increasing number of product variants, the flexible robot cell can adapt to new products very quickly and in a simple way [14]. Instead of having the peripheral equipment individually adapted to a specific product range and being permanently fixed within the robot cell, the flexible robot cell concept integrates the robot periphery into task-specific modules (e.g. welding modules, grinding modules, measuring modules,…). These modules have a detachable mechanical connection to the cell floor. Furthermore all electrical, network and fluidic connections of a module are combined in a single, standardized connector. If a production change requires a reconfiguration of the robot cell, modules can easily be detached and removed from the robot cell. New modules can be configured and tested outside the robot cell. The installation of a pre-configured module in the robot cell takes only a few minutes, thus reducing production down-time to almost zero. The locking of the modules within the cell is achieved by a centralized, pneumatically-driven locking mechanism.

The connectors which are used to link the modules with the cell are electrically coded. By this means the overall system controller permanently has all relevant information about the cell such as the type of modules inserted, the number of modules loaded in the cell and their location within the cell grid.

The modularized cell concept offers some significant advantages, such as:

– easy setup,
– easy reconfiguration,
– ultra-fast adoption to new products (reduced change-over time),
– minimal downtimes for maintenance,
– standardization of components,
– easy upgrade for cells etc.

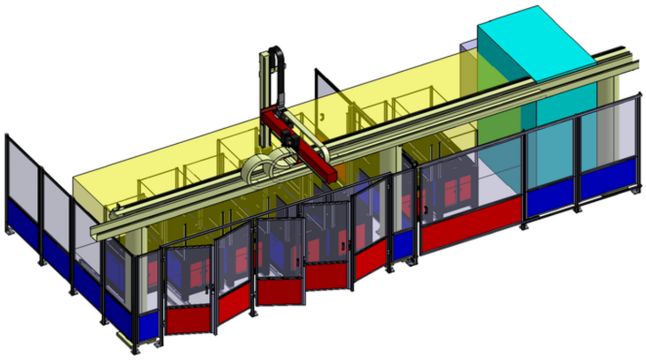


Figure 6. Modularized Robot Cell [14]

Other important trends in the development of industrial Robots are [9]:

– Small robots with a large range in safe space.
– Robots with lightweight construction - the use of lightweight materials enable energy savings.
– Robot vision for optimum quality control.
– More intelligence, less "plug and play" applications.
– Easy operation and programming of robots simplify their use.
– Improved sensors enable the use of robots outside safe areas.
– Advanced human-robot collaboration and control (algorithms and sensorics for human safety, avoidance of human and robot damages etc.).
– Achieving energy efficiency through innovative methods of robot control.
– Increasing number of installed force-/torque, acceleration, hybrid sensors etc. will e.g. extend the fields of application for robots from simple position control tasks to force-sensitive interactions with shorter cycle times, greater flexibility, increased overall sensitivity etc. Multisensory perception still means a big challenge in terms of data processing and interpretation but it also offers interesting perspectives towards sensitive robot systems with a higher level of autonomy. Combinations of vision, laser and photoelectric sensors will provide a reliable mapping of the robot's environment and will - by this means - allow for more precise, more flexible and safer robot operations [14].

The increasing computing power of modern robot controllers will allow them to assimilate control tasks which are nowadays still generated off-line or in separate controllers. Figure 7 illustrates an example for such a task integration which was achieved in the framework of the LARISSA research project [15].

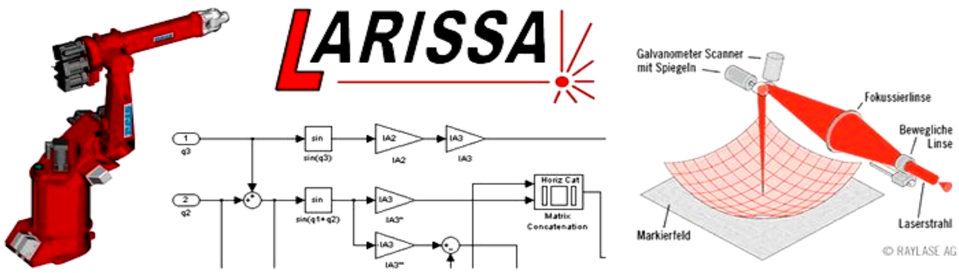


Figure 7. LARISSA-Project: Robot, Algorithms and the Laser Deflection Unit [15]

As presented in the Figure 7, the formerly separate control of the laser deflection unit has been integrated into the main controller of a robot system. As a result, the separate controller became obsolete, saving significant system costs. Furthermore, the integrated control of the robot arm and the laser deflection unit allowed for a significantly better coordination of the robot and deflection mirror movements, increasing the performance of the overall system – in a typical application - by the factor of five [15].

However, robot controllers are not only likely to become more powerful in the future. They will also become more user-friendly and smarter in the way how they handle standard and exceptional situations. Based on the increased computational power, robot controllers will include more self-calibrating and self-tuning capabilities, allowing them to adapt to changes in their setup, work load and the like. Also fault detection and fault tolerance of future systems will be significantly higher compared to current systems [14].

Finally, it is likely that the trend towards the integration of more powerful and versatile communication protocols and interfaces will continue. This will include new and open standards, many of them allowing future systems to link themselves with a multitude of different components from varying suppliers in a "plug and produce" fashion. Besides classical bus interfaces, future systems will presumably support open and non-industry communication standards (such as: GSM/UMTS/WLAN/…) allowing remote operation and diagnosis via local or telematics interfaces [16].

In addition to the already established trends such as maintaining flexible robots, the further development of robots will be focused in the socio-economic impact of robots, in cooperation of man, robot and environment and thus removing now necessary safety curtains. Also the development of effective and affordable intelligent grippers is an important trend in the robot development, which leads to the reduction of working cycle times of the robot [9]. More details including 10 techniques for of the reduction of the duty cycle of the robot, which is also dependent on conveyors, process time, machine vision, grippers, operators, etc. can be found on the following website: *http://www.assemblymag.com/Articles/Web_Exclusive/BNP_GUID_9-5-2006_A_10000000000000851129*.

The development of intelligent, efficient, affordable, modular, flexible, rigid and lightweight grippers with the option of auto-calibration is, and will certainly be the R&D trend in the future.

Machine vision system will be ever more often used for a robot control and other automated systems, final and intermediate control in the assembly, identification of products, etc. The use of robotic assembly systems with machine vision and with the ability to grip the components and implementation of robotic assembly operations in unstructured environments with randomly positioned objects is a trend that will remain and increase in the future [4].

In addition to these current trends there are additional trends in the development and use of machine vision [7, 8, 10, 11, 13]:

- Compact, integrated components will enable space-saving.
- Intuitive operation and configuration.
- Simplified integration of machine vision through the development of standards for interfaces.
- Improving the capacity - (CPUs, cameras etc.).
- The increasing use of standard software libraries.
- Many new, non-industrial applications.
- Increasing the use of 3D machine vision.
- Increasing the use of "Low-cost" vision systems.
- Increased interest in general systems of machine vision, which can be configured by an end-user.
- The increased demand on digital cameras and single components – not so much on the systems.

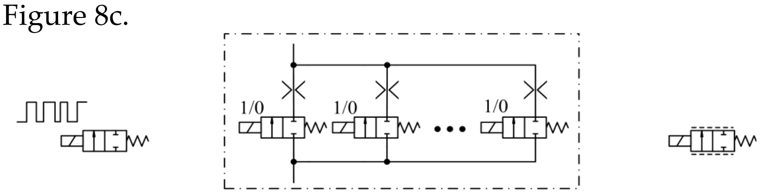
Looking into fluid power systems they consist of the generator of power, the conductive part like pipes, valves and accessories and of the actuator consisting of cylinders or rotating motors. Although developments with speed adjustable electric motors in some areas allow the elimination of proportional valves in the signal and power circuit, valves can still be considered as the heart of fluid power solutions. Any valve needs an electro-mechanic transformer and modern valves today incorporate digital drive and control electronics as well as sensors for pressure, flow and spool displacement. It is easily understood that valves comprehend all features of a mechatronic system.

Due to ever growing demands for smaller valves with better dynamic properties, lower energy consumption and increased fluid flow capacity, the use of piezoactuators as control elements in valves is becoming ever more interesting. To obtain optimal results also the advantages of other technologies, like microelectronis and sensorics are used. The main obstacle to use piezoactuators as control elements for valves represents their extension, which is too small for a direct control of a sliding spool of a hydraulic or pneumatic valve, therefor piezoactuators should be combined together with an extension amplifier. For the applications in the assembly automation the important advantage that piezoactuators can offer is the possibility to have the actuator, force sensor and the position sensor in one piece [17].

Hydraulic servo valves, as the main elements of today's high-dynamic dynamic systems, in spite of advanced optimization methods and the use of advanced actuators achieve operating frequency up to 800 Hz at -3 dB [18]. Not only the stagnation in the achieving of the further increased dynamics of hydraulic servo valves but also very expensive manufacture of servo valves sensitive to failures and high energy consumption has brought us in the last decade to an alternative and promising digital valve design as an alternative to the existing servo valves [17, 19].

Figure 8a presents the implementation of the switching controlled two-way valve. It controls the average flow area by the high frequency modulation and the pulse-width modulation (PWM) is the most common approach. In theory, the average flow area can have any value, but finite valve dynamics limits the smallest and biggest possible duty ratio. Controllability depends also on the switching frequency. Low frequency improves controllability of the average flow area, but increases pressure pulsation. Careful system design and/or damping devices are normally needed to suppress noise [17, 19].

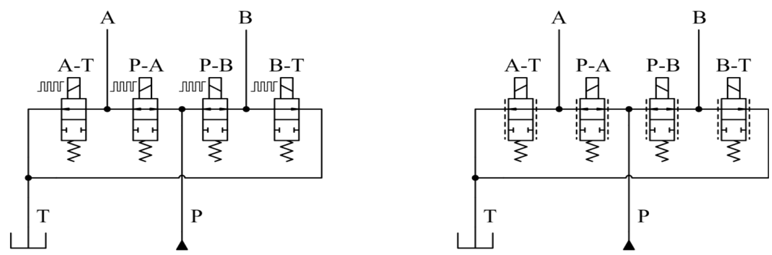
Figure 8b shows the parallel connected implementation of the two-way valve. The name DFCU (Digital Flow Control Unit) is used for this kind of valve assembly, and the simplified drawing symbol is shown in Figure 8c.



(a) (b) (c)

Figure 8. PWM controlled on/off valve (a), digital flow control unit – DFCU (b) and the simplified drawing symbol of the DFCU (c). Orifices are used to match flow capacities of valves in (b) [17,19]

The flow area of the DFCU is the sum of the flow areas of the open valves. Two factors determine the steady-state characteristics: the number of parallel connected valves N, and the relative flow capacities of the valves.



(a) (b)

Figure 9. Implementation of distributed four-way valve by [17, 19]

Binary coding is the most common method and the flow capacities are in ratios of 1:2:4:8 etc. Other coding methods include Fibonacci (1:1:2:3:5 etc.) and pulse number modulation (1:1:1:1 etc.). Independently on the coding, DFCU has 2N opening combinations, which are called states of DFCU. Each state has different flow area in the binary coding while varying degree of redundancy exists in the other coding methods. Essential difference to the switching valve is that DFCU does not require any switchings to maintain any of the opening values. Switchings are needed only when the state changes.

Figure 9 shows how to implement the digital hydraulic four-way valve. The approach is the same as in analogue distributed valve systems: each control edge can be controlled independently contrary to traditional four-way spool valves. However, the implementation of fast, leackage free and bi-directional valves is easier in the digital environment.

One of the biggist challenges in the digital valve technology is the actuator which must have the ability to swith on and off very fast and the control electronics to support such fast switching of the valve. As only few commercial control electronics are available, it is necessary to develop new control technology and algorithms for a very fast swithcing digital valve, which reaches the response time under 1 ms. Such very fast switching digital valve with fluid flow up to 80 l/min and with a response time of around 0.1 ms has been developed in the laboratory LASIM, Faculty of Mechanical Engineering, University of Ljubljana [17]. It is a piezo driven and the fatstest digital valve known so far.

4. CONCLUSION

This paper provides an overview of situation and trends in the field of automated handling, assembly, robotics and fluid power, especially digital control valves. It can be concluded that the intelligent, flexible, modular designed automation with the introduction of hybrid technology and robotic autonomous systems with ecological focus is response to the many dilemmas of our time in automated assembly, robotics and fluid poewer.

The digital technology in fluid power offers several new ways to implement highly efficient hydraulic systems. All functions can be implemented by simple on/off valves and fixed displacement units. The side effect is that control code becomes complicated because it implements all the functionality.

The biggest obstacle of the application of digital fluid power is the lack of commercial valves. Therefor there is an urgent need for good new digital valves, valve packages and control electronics.

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