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GUIDE TO ROBOTICS IN PACKAGING PLANTS FOR FOOD & BEVERAGE

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goals

REPORTING AN OVERVIEW OF ROBOTIC SOLUTIONS FOR FOOD & BEVERAGE PACKAGING

HIGHLIGHTING DESIGN CHOICES AND PERFORMANCES OF DELTA ROBOTS

PROVIDING INDICATIONS ON SIZING, SAFETY AND MAINTENANCE OF A ROBOTIC ISLE

Introduction: robotics in Smart Factory and Industry 4.0 contexts

The third industrial revolution was characterized by the use of electronics and IT (Information Technology) through the availability of industrial robots and computers. With the aim of further automating manufacturing, the fourth industrial revolution, or Industry 4.0, provides for the use of smart, interconnected and web-connected machines. The technological goals pursued by Industry 4.0 are implementing a connection between physical and digital systems, carrying out complex analysis through Big Data and being able to perform adaptations in real time.

This scenario, characterized by a strong interconnection and integration of different technologies, is commonly indicated with the Smart Factory expression. Worth noticing how one of the enabling technologies of Smart Factory and Industry 4.0 is the adoption of “advanced manufacturing solutions” based on the systematic use of advanced, industrial collaborative robotic systems, interconnected and quickly programmable.

Role and use of robots in food & beverage packaging lines: Delta robots

If we consider the food & beverage (F&B) industry, the adoption of Industry 4.0 enabling technologies, such as precisely “advanced manufacturing solutions”, represents a strategic choice to comply with the stricter and stricter requisites imposed by the market, in terms of both product quality and safety and of manufacturing flexibility. From this point of view, the growth of the eCommerce, which is precisely based on the variable assortments of online shops, represents a strong boost for the implementation of increasingly flexible automated solutions. In the F&B sector, one of the most suitable production phases for the adoption of advanced manufacturing solutions is robotic packaging. This application needs the use of robots that can perform pick-and-place movements at variable speeds and frequencies, with many pieces moving on a conveyor belt at a frequency of hundreds of components per minute. The most suitable robot typology for this kind of tasks is notoriously the Delta one. Due to the parallel kinematic structure, Delta robots stand out for an intrinsic structural advantage in terms of performance and flexibility, which makes them ideal candidates for high-speed packaging and pick-and-place applications.

Other existing robots can achieve high rates, for instance serial SCARA robots, but generally they cannot reach the same speeds and endure the same rates as a Delta robot's ones, without running into problems of overheating or excessive stress of motors. Therefore, currently, over 30 years after their ideation, Delta robots have imposed themselves as a structural paradigm for the execution of pick-and-place and sorting tasks, and in all applications at high speed and with reduced loads.

Design choices for high performances

In its standard configuration, the structure of a Delta robot provides for the use of 3 high-torque electric servomotors, mounted on a stiff bearing structure. The presence of 3 motors allows the arbitrary positioning of the end-effector in the three-dimensional Cartesian space, but anyway inside the robot workspace. On the shaft of each motor, perpendicularly to its rotation axis, a link is mounted. The 3 main links are in their turn connected with very light connection links, made of carbon fibre and arranged as a parallelogram; in their turn, they are connected with a central platform. The joints placed at both extremities of parallelogram-shaped links are generally spherical and passive. The end-effector can be directly mounted on the central platform, or an additional motor can be housed inside it. Depending on the application, many Delta robots can be equipped with a fourth rotation axis to allow orienting the object around the Z- Cartesian axis, once this has been grasped by the robot.

The main characteristic of the parallel kinematic structure of a Delta robot is represented by generally heavy motors fixed to the bearing structure and then far from the end-effector. This solution results in very light and fast mobile parts but it increases the torque demanded to motors due to the effect of the moment generated by the product weight on them, and therefore it decreases the overall payload of the robot. There is in fact a well-known “trade-off” between the speed of the end-effector and of handled load, which is typical of this robot typology:

in order to increase the wrist speed, it is necessary to diminish the handled load.

For medium-low loads, that is to say in a range that goes from 1 kg to 8 kg, motion skills of a Delta robot - in terms of number of cycles per minute, speed of the end-effector, positioning and repeatability accuracy - generally exceed the ones of a serial robotic handler with the same payload. The range of possible movements and the workspace are however smaller compared to a handler featuring 6 or 7 degrees of freedom. Delta robots can in fact move freely inside a narrower workspace, especially in terms of possible stroke along the vertical axis.

Important sizing factors

The sizing of a robotic isle housing Delta robots needs taking numerous factors into account. The choice of robot performances and the number of robot installed in the packaging isle mainly depend on the manufacturing volume, then on the required cycle frequency and, finally, on the product mass to be handled. The shape factor and the reachable workspace are variables strongly influencing the final layout of the robotic isle.

Another relevant factor is the choice of the gripper. Some Delta robots can produce very high accelerations of the gripped item, therefore if the gripper cannot exert a sufficient gripping force, the product can get out of the robot's grip. Therefore, it is important to choose a gripper that can assure the grip maintenance even if it is subjected to the accelerations needed by the specific application. The gripping devices more commonly adopted are suction cup grippers, due to the quick actuation and to the high repeatability, or mechanical grippers, for instance pliers, more suitable for products with porous or rough surfaces, to the detriment of a reduction of the cycle time, not only because of a bigger load on the wrist, but also of the necessary time for opening and closing, in the pick and place phases respectively.

Vision systems

The nature of the applications for which Delta robots are conceived, that is to say the pick-and-place of many products that move on a conveyor belt at a frequency of hundreds of parts per minute and at random, needs the integration of a vision system to determine exactly the position of the object that will be picked by the robot. Moreover, advanced algorithms can recognize the product typology, depending on the shape, the colour and the assortment, and can distinguish a product that can be gripped from a defective one according to the information provided by 3D vision sensors and standard RGB cameras.

In case of a robotic isle with a battery of robots, that is to say where several robots execute simultaneous gripping from the same line, the PLC involved in the isle control can be suitably programmed for using the information coming from the vision system in order to schedule picking actions and to optimize the operation time of each robot. Concerning this, it is important to underline how the programming and the control of a Delta robot are almost completely similar to the ones of an industrial robot controlled in position. In general, an operator experienced in industrial robot programming can be able to programme the motion of a Delta robot. Many manufacturers use in fact the same programming language and often also the same software environment.

Safety and maintenance

Safety requirements for Delta robots do not differ from those for a common industrial robot. It is in fact necessary to mount some protective barriers, generally of Plexiglass, around the robotic isle. Some "open", i.e. barrier-free, layouts are anyway possible for those particularly extended manufacturing lines, where the operator cannot go close to the robot. A highly relevant safety aspect for Delta robots concerns possible failures of the gripper, both mechanical or suction cup type. Given the high handling speeds, in case of failure the gripped product might escape from the robot's grip and be hurled in uncontrolled manner and at high speed against an operator: hence the importance of protective barriers to delimit the robotic isle.

Moreover, it is important to point out how the food & beverage industry, which is characterized by high volumes and very severe safety and hygiene regulations, demands for the maintenance of very high cleanliness standards to producers. Equipment must in fact be washed and the exposure of food products (not protected by film) to possible contaminating agents, such as lubricants, metal or plastic fragments and powders, must be avoided. Due to the "open" kinematic structure of Delta robot, motors can be easily insulated by casings, and many models are available with protection class up to IP69K, so permitting the robot to be subjected to high-pressure and high-temperature washing.

The "open" structure of Delta robots provides also a notable maintenance plus. Such structure is in fact easily accessible for an operator who executes repair and maintenance interventions. Concerning this, owing to fast and repetitive motions to which they are continuously subjected, spherical joints and attachments that connect parallelogram links one another are subjected to wear and need a periodical replace-

ment. Assuming a Delta robot is operating under nominal conditions, the parts most subjected to wear are also the springs and washers placed on connection links that constitute the parallel mechanism. These components are usually inexpensive and easily replaced in short times, so avoiding too long idle times of the line.

Another component that needs periodical replacement (once every six months on average) are ring insulators, generally of nylon or Delrin, which act as friction bearing for each servomotor. Insulation rings can typically reach one million of cycles before needing a replacement. Main motors are not homogeneously subjected to wear. The wear status depends on the type of motion they must perform, but generally the three upper motors work inside a symmetric workspace. Like in most of industrial robots, the three main servomotors are of brushless type: one of the most reliable solutions for fast start-stop motions. Since there are no brushes inside this motor typology, but only a rotor that moves inside stator windings, the components subjected to wear are almost absent.

Last frontiers of Advanced Robotics: some examples

Among the examples of robotic solutions of advanced manufacturing in the food & beverage sector we can indicate Delta Triaflex robots by CAMA Group, the Italian Group specialized in the production of robotic isles for automated secondary packaging. Delta Triaflex robots, available in different sizes with a workspace with diameter variations from 100 cm to 150 cm, show a typical three-axis configuration, with possibility of a fourth axis that enables the product rotation once grasped. Made of carbon fibre, these very fast robots are suitable for use in pick-and-place applications with low loads and they can comfortably exceed one hundred grips per minute. In line with the typical technological interconnection spirit of Smart Factory and Industry 4.0, CAMA pays particular attention to the integration of computer vision functions on board of its robots.

Delta Triaflex are in fact equipped with vision systems, supplied by primary manufacturers, able to distinguish autonomously various product typologies for the utmost flexibility in the packaging composition, as demanded by the eCommerce.

A battery of Delta Triaflex robots equipped with vision system can recognize, select, pick up or sort in the package, quickly and with high efficiency, up to 2,000 products per minute that slide at random on the conveyor belt. Delta Triaflex robots can load products also from vertical racetrack and can be used to load cartoning and sleeving machines.

CAMA pays utmost attention to the design of gripping heads aimed at allowing fast interchangeability without needing the use of tools. Depending on applications, Delta Triaflex robots can be equipped to perform gripping with pliers or with suction cups and can manage over 2,000 products per minute very quickly. Cables and communication systems are integrated inside robot arms to preserve their structural cleanliness and to avoid they interfere with the high-speed motion of the mechanical structure. Finally, although they work in the secondary packaging, with products that should be already protected by films, Delta Triaflex robots are prearranged to be subjected to washing according to customers' demands.

Conclusions

One of the enabling technologies of Smart Factory and Industry 4.0: “advanced manufacturing solutions”, provides for the extensive use of industrial collaborative robots, interconnected and quickly programmable. The adoption of such enabling technology in the food & beverage industry, and especially in the secondary packaging phase, represents a key factor for the compliance with manufacturing flexibility requisites imposed by the current market. Delta robots hold a primacy in this sector. Parallel kinematic architecture provides high mechanical advantage in terms of motion performance and accuracy. These specifications, combined with the functions provided by an integrated vision system, confer characteristics of autonomy, adaptation and flexibility to a robotic isle.

Keypoints

- Motion performances of Delta robots make them the ideal candidates to perform pick-and-place tasks for the food secondary packaging.
- The integration of a vision system allows conferring utmost production flexibility to the robotic isle.
- The choice of the gripping system is one of the key factors for the sizing and the safety of a robotic isle with a battery of Delta robots.