Study on the Pneumatic Actuation of Gripping Systems

DOINA ȚĂRLIMAN (NEGREA), TUDOR DEACONESCU
Industrial Engineering and Management Department
Transilvania University of Brașov
29 Eroilor Bd., 500036 Brașov
ROMANIA
doina.negrea@unitbv.ro, tdeacon@unitbv.ro

Abstract: Constructive optimisation of industrial robot gripping systems has been addressed in numerous studies. The present paper analyses the main actuation variants of gripping systems, with an emphasis on pneumatics. Further discussed is the possibility of including artificial muscles actuated by compressed air into the construction of such systems. The paper also presents some constructive variants of gripping systems actuated by pneumatic muscles, as well as the associated diagrams describing the operational behaviour of these actuators.

Key-Words: Industrial robots, gripping systems, pneumatic muscles

1 Introduction
Besides the more or less evolved mechanisms mimicking human motions devised before the early 1900s, the worldwide explosive industrial development including information technology and its deployment in the control of working equipment has triggered, as a natural consequence, the creation of robots.

The first robot with industrial applications was built as late as 1962 by Unimation™ and was implemented at General Motors. In the ensuing years robots have known swift development, particularly in Japan and the US, to date being present in practically the entire global industry. According to the International Federation of Robotics (World Robotics 2012), the year 2011 has represented a peak of global robot sales, exceeding the preceding year by 38%, considering a total of 166,028 units. The main markets were Japan and South Korea, while the most significant per cent increase, between 39% and 51%, was recorded in China, the USA and Germany. The graph in Fig. 1 illustrates the dynamics of global robot production sales [1].

As can be noticed, the above definition identifies the gripping system as an important component of an industrial robot. The gripper is the end-effector of a robot and is typically not included in its “anatomy”.

The paper will further analyse the current state of gripping systems construction, with an emphasis on deploying pneumatic muscles as means of actuation.

2 Gripping Systems
2.1 Definitions, classifications
From the multitude of functions of the human hand, gripping stands out as the most important. According to the definition provided by the Romanian Language Dictionary, gripping is “the hand’s action of seizing by means of fingers, claws, tweezers etc.” [3]. While the gripping ability of limb extremities can also be found in animals (e.g. lobster
claws), it reaches its highest functionality in humans. Thus adequate combining of the independent motions of finger phalanges allows seizing, holding, displacing and releasing of various bodies.

The human gripping function entails a sequence of phases, starting with selecting the seizing modality, followed by the actual gripping and concluded with the control of the manipulated object. A wish, generated internally or externally, triggers reactions in the brain and at visual level. Consequently to such reactions the hand is positioned close to the targeted object, which it subsequently seizes and further carries out the programmed task. Figure 2 presents the command flows of a human hand gripping action[4].

Fig. 2 Command flows of a human hand gripping action

In robotics gripping means contact of the effector element of a robot (the gripper) and a body in view of its manipulation. Grippers are those components of robotised systems that facilitate the temporary contact with the manipulated object, thus ensuring its position and orientation during transport and assembly.

The term gripping is used not only for situations describing an actual mechanical “seizing” of an object by means of fingers, but also for the retaining of a body by means of vacuum, a magnetic or electrostatic field, by adhesion, etc.

The main functions of gripping systems depend on the specific applications they are part of and include [5]:

- temporary maintaining of a final position and orientation of a body in relation to the manipulation equipment;
- firm holding of the gripped object under static conditions (under the action of its own weight), dynamic conditions (in motion, during acceleration and braking) or when subjected to the action of external forces (cutting forces, torques);
- determining and modifying the position and orientation of the object depending on the concrete requirements of the application, etc.

In order to carry out the above functions, a gripping system needs to include the following main components:

- an energy system, meant to provide the type and quantity of energy required by the gripper;
- a mechanical execution system that carries out the actual gripping task;
- a system of sensors and transducers, meant to collect information (forces, displacements, accelerations etc.) and to transmit these to the control system;
- an information processing and control system that receives the signals coming from the sensors and transducers, processes these and consequently issues the necessary commands to the energy system.

2.2 Actuation of the gripping systems

The actuation motors of grippers need to satisfy the main requirements for such a system, like: ensure a sufficient gripping force, as well as accuracy, reliability, flexibility and compliance, etc. Depending on the type of energy utilized for actuation, such motors can be electrical, hydraulic, pneumatic or non-conventional.

Electric motors are often used in the construction of gripping systems due to their simple control. Hydraulic, linear or rotating motors are used in applications the entail high gripping forces, while pneumatic actuation lends itself for applications with smaller necessary forces.

Further analysis focuses on the pneumatic actuation of gripping systems, with an emphasis on the possibility of using artificial muscles actuated by compressed air.

3 Pneumatic actuation of gripping systems

This type of actuation is frequently used for gripping systems, due to its advantages:

- simple control schemes;
- possibility of system overloading;
- easy maintenance;
- environment-friendly working medium;
- easily adjustable torques, speeds and forces, by means of simple devices;
pneumatic transmissions allows damage-free frequent starting and stopping, as well as sudden changes of direction;

compliance etc.

The structure of a pneumatic actuation system generally includes a source of compressed air (compressor), an air preparation system (filter, pressure regulator, and lubricator), adjustment and control elements of the pneumatic quantities and final consumers (motors) that transform the input pneumatic energy into useful work.

Festo AG & Co. of Germany is one of the most important manufacturers of pneumatic gripping systems. Grippers offered by Festo are of parallel type, with two or three brackets, of angular type, with a membrane or vacuum-based. Figure 3 shows examples of such gripping systems [6].

Fig. 3 Pneumatically actuated gripping systems

A pneumatic motor of relatively new type is the pneumatic muscle. It is defined as an elastic system with a contracting membrane, which, when fed compressed air increases its diameter and shortens its initial length.

Artificial muscles benefit from a number of characteristics that render them extremely useful for robotized applications, such as: small dimensions, impact shock damping capacity, easy connecting, high energy efficiency, contraction force similar to that generated by biological muscles, etc.

Currently the pneumatic muscle with the most competitive features is the one manufactured by Festo, Germany.

Fig. 4 Festo pneumatic muscles

The main component of this type of muscle is a flexible tube within a sealed envelope made from non-elastic fibres displayed by a diamond pattern, thus yielding a 3D mesh. Compressed air fed to the pneumatic muscle will cause its radial and axial deformation and generate a longitudinal traction force.

Pneumatic muscles behave similarly to mechanical springs, as the developed force is at its maximum initially and the falls towards zero with increasing deformation. Upon pumping compressed air into the muscle, it shortens while its diameter grows, as illustrated in Fig. 4. The length of the stroke depends directly on the level of the feed pressure.

The difference between the length of the relaxed muscle and the one obtained consequently to the feeding of air at a non-null pressure represents the conducted stroke. The maximum stroke achievable by a pneumatic muscle is of about 20% of its relaxed (no-load) length.

The constructive structure of Festo pneumatic muscles endows them with a range of special features:

- pneumatic muscles can be produced in a large range of dimensions (lengths and diameters);
- their structure can be compared to that of a human muscles under the aspect of form, characteristics and performance;
- they are very flexible and fine-textured to the touch;
- safe operation;
- silent, smooth motion throughout the working cycle;
- reduced friction forces;
- small manufacturing cost;
- excellent operational behaviour in explosive or high humidity environments.

A few variants of gripping systems with pneumatic muscles are known, two of which are shown in figure 5 [6].

Fig. 5 Pneumatic muscle actuated gripping systems
The first gripper, developed by Festo and called Power Gripper, was inspired by the way birds use their beaks to seize and hold objects. The motor is a pneumatic muscle and its construction is based on Watt linkages. The system has a good developed force–to–eigen weight ratio, due to the included light motor (pneumatic muscle).

The second system presented in Fig. 5 is a parallel gripper of DMSP-HGP-SA type actuated by two pneumatic muscles. It is designed for pick and place applications in environments with high dust contents.

Figure 6 shows two further variants of pneumatic muscle actuated gripping systems, a parallel and an angular one [7, 8].

![Fig. 6 Parallel and angular gripping systems actuated by pneumatic muscles](image)

In the first constructive variant a transversally positioned pneumatic muscle actuates the brackets. It is controlled by a 5/3 proportional valve. The brackets carry out a linear motion with a maximum stroke of 5 mm, and generate a force of 50N. It needs be pointed out that the casing includes the actuation elements of the two brackets, as well as the control valve of the pneumatic muscle. The thus obtained compact and light structure is easily placed on a robotized system.

In the second constructive solution the pneumatic muscle actuates two rotating fingers. The resulted construction is somewhat longer, but equally light as the previous one.

The same type of pneumatic muscle was used in both constructions, of 10 mm diameter and 40 mm length. The dynamic behaviour of this muscle was described by means of ProPneu software developed by Festo. Figure 7 shows the displacement of the free end of the muscle while being fed compressed air (position versus time), as well as the variation of speed and acceleration.

![Fig. 7 Characteristic diagrams of the pneumatic muscle](image)

### 4 Conclusions

Pneumatic actuation in form of linear pneumatic motors is one of the most utilized solutions in the construction of gripping systems. Over the last years an alternative to such motors materialized with the development of pneumatic muscles, which offer a large number of operational advantages. Pneumatic muscle actuated mechanical systems have known increasing industrial development. It is within this context that research needs to focus on in-depth study of performance and behaviour of pneumatic muscles.

The present paper has presented the current state of the construction of industrial robot gripping systems. In addition to an analysis of the main variants of pneumatic gripping systems utilized in industrial robotics, the paper presents a number of constructive solutions of pneumatic muscle actuated grippers with brackets.

As a conclusion of research conducted so far, it can be asserted that due to their evident benefits, pneumatic muscles represent a viable alternative for the construction of modern gripping systems.
References: