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Review

A statistical review of industrial robotic grippers

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ABSTRACT

With the recent introduction of ambitious industrial strategies such as Horizon 2020 and Industry 4.0, a massive focus has been placed on the development of an efficient robotic workforce. Amongst all the operations robotic systems can take care of, handling remains a preferred choice due to a combination of factors including its often repetitive nature and low skill requirement. The associated demand for grasping tools has led to an ever increasing market for manipulation end-of-arm tooling from which a handful of industry giants have emerged. Based on data publicly accessible from the catalogs of several well-known companies, this paper aims at presenting a review on the characteristics of pneumatic, parallel, two-finger, industrial grippers. Included in the specifications under scrutiny in this paper are: stroke, force, weight, as well as a performance index referred to as the C-factor. This last index is a combination of three of the aforementioned characteristics and has been proposed in the literature as a measure of the efficiency that a gripper is capable of reaching. As will be shown, by analyzing hundreds of specifications it appears that, indeed, the range of C-factors of the grippers built by one company can be often consistently different from these of competitors. Furthermore, an important bias for certain typical specifications can be observed in most of the grippers which seems at odd with the requirement of modern robotic systems. This latter remark will open up a closing discussion proposed in the last part of this paper on the future evolution of grippers based on emerging new products.

1. Introduction

Industrial robotic grippers have a pivotal role in modern automation since they constitute the end-of-arm of robotic manipulators and thus, they are in direct contact with the workpiece to ndled. Grippers as end-of-arm tools have to perform their tasks under demanding requirements in modern mass production because handling operations do not directly increase the market or intrinsic values of the workpieces. Therefore, grasping and manipulation should be achieved not only securely but as fast as possible to reduce cycle times. An important issue is for the output rate of the production lines where robots are used not to be negatively impacted by the handling operations [1]. This requirement for speed becomes a challenge when the workpieces do not have predictable or consistent properties, as for instance in food processing, goods packaging, recycling, or mining industries. The variability of the objects a robot or automated machine have to seize led manufacturers of grippers to expand their catalogs to accommodate this issue and now, commercially available grippers come in innumerable shapes or sizes. Current grippers range from the minuscule to the gigantic. To conciliate all these different products and their various designs also emerged the necessity of tool-changing, i.e. swapping one tool for another, each gripper being able to seize only a limited set of objects. Ultimately, the goal of all robot grippers remains however the same: holding and securing the pose of a workpiece relatively to a (robotic) manipulator so the latter can move this workpiece from one place to the other where it is then released. The development of gripper technology has been closely connected to the development of robotics since the kinematics of robots strongly influence the requirements for the gripper [1]. Considering the wide range of robotic architectures one can find on the market it is not surprising to see the plethora of commercially available grippers that have been developed [2]. However, it is unclear how varied the specifications of all these grippers are and how their performance can be related or even quantified. The range and statistical values of the available specifications of available commercial products have not been previously listed to the best of the authors' knowledge. The aim of this paper is to shed some light on this issue and propose an analysis of what the market currently offers to its customers. While there exist a handful of references reviewing industrial grippers from a general point of view, e.g. [3–8], with a few exceptions such [9] most of them are rather old and consistently focus on specifically targeted applications/aspects, e.g. [10–12], or how the gripping motion is produced instead of what are the actual performances of these grippers in terms of force, stroke, weight,

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power, etc. Again, this review aims at filling that gap by providing actual numbers for these specifications.

An interesting and maybe surprising point to note is that most companies which produce robots do not produce grippers themselves [2]. There are of course a few overlaps here and there but as an industry, gripper and robot manufacturers are generally distinct businesses. Generally speaking, it seems that robot manufacturers and integrators mostly rely on the products offered by gripper companies and only if they cannot find a solution matching their requirements, a custom tool is developed. Now, to see what is the current landscape of industrial gripper technology, one has to find a representative subset of the manufacturers. However, therein lies the first obstacle: ranking these companies by market volume or overturn is not possible. Indeed, little—if any—data is available to the general public and sales' numbers remain sensitive and confidential figures. Furthermore, many companies producing grippers are still privately-owned and do not disclose any financial information. To circumvent this issue, the authors chose to have a look to the names of companies presenting their grippers at industrial fairs and exhibitions such as: the Chicago Automate Fair, Tokyo IREX, and Hanover Messe. Recurring names were selected for this review. It was noticed that several of these companies are from Germany which the authors conjecture is due to the strong automobile production and geographically close European market. Another point noticed is that there is an impressive number of small and medium-sized enterprises (SME) but only a handful of global corporations. The list of companies we selected was crosschecked with the online database Direct Industry using the criteria presented in the subsequent Section and it was found out that with this methodology, almost all the companies offering a significant number of products were obtained.

Processing the entire catalogs of all the gripper manufacturers was an insurmountable task because of the very large number of products each one of them offers. Indeed, even disregarding all vacuum grippers and special custom designs of limited interested outside their target market, e.g. for mechanical diggers or cranes, there are still literally thousands of products. Therefore, the scope of this review was further reduced down to a specific but very common design as will be discussed in Section 2. This will be followed by the presentation of statistical values of the specifications pertaining to these grippers in Section 3.

Subsequently, after this presentation of the raw data, an actual comparison between manufacturers of all considered products can be undertaken and the results is presented in Section 4. This comparison will mainly focus on specifications such as the length of the stroke, gripping force, weight of the gripper without fingers, and maximal length of the finger that can be attached. Furthermore, the C-factor, i.e. a measure of the energy that the gripper is outputting relatively to its mass, has been computed for each of the grippers and will also be discussed in Section 5. Finally, in Section 6, a discussion on the results and the future of industrial grippers is proposed.

2. Scope

In this review, the authors chose to focus on a specific architecture of impactive tool, namely parallel grippers with two fingers and driven by pneumatic energy. The main reason for this is to narrow down the list of devices considered to a manageable size. Furthermore, this type of grippers appeared from a preliminary investigation of manufacturers' catalogs to be the most common one, by far. In order to gather a meaningful list of specifications for the grippers fitting the scope of the review, the authors also chose to focus on the products readily available from these catalogs, i.e. disregard special editions of more typical models such as oversized variants. As a summary, the properties of the grippers considered in this review are:

1. impactive,
2. driven by compressed air (pneumatic),
3. a parallel finger movement,
4. two fingers,
5. out-of-the-shelf (no custom model),
6. no spring or magnetic assistance to the gripper force.

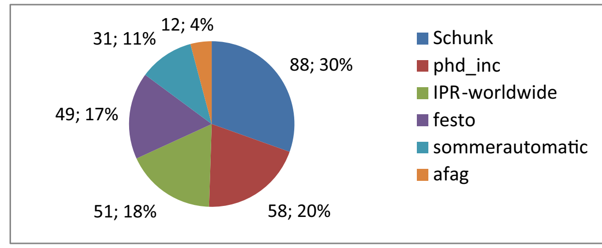

Fig. 1. Distribution of grippers by manufacturer.

An important point to notice is that the analyzed data is only based on catalogs' data and not sales figures for the grippers. Therefore, each gripper in the catalogs is equally considered while one model might actually be a bestseller product. This might appear as a weakness of this review but it does not necessarily introduce a significant bias in the results. Indeed, it appears reasonable to assume that the manufacturers offer the most complete choice of grippers with the most commonly requested features and therefore, a bestseller series of grippers is expected to have several declinations in the catalogs. Considering only catalogs' data does not ensure accuracy and the trustworthiness of manufacturers is assumed when reporting specifications. Understandably, experimentally verifying each specification for each gripper is highly impractical but this limitation must be acknowledged.

After investigation, six manufacturers were chosen for this analysis, namely (in alphabetical order): AFAG, Festo, IPR, PHD, Schunk, and Sommer Automation (recently acquired by the Zimmer Group.) All these companies provide the specifications of their grippers in catalogs publicly available and a compilation was established in a digital database of all their models satisfying the aforementioned properties. Fig. 1 illustrates the share and number of grippers obtained for each manufacturer: 12 for AFAG [13], 49 for Festo [14], 51 for IPR [15], 58 for PHD [16], 31 for Sommer Automation [17], and 88 for Schunk [18]. The grand total of all grippers considered in this review is therefore 289 and the complete list of models used is presented in Appendix A. The nominal pressure that was found for all grippers is 6 bars and thus, this value was considered when establishing the generated force even if they could operate at other pressures.

3. Data analysis

Once all the specifications are compiled, a statistical analysis of the data can be conducted. Accordingly, an overview of the resulting analyzed data is shown in Table 1 which lists minimal, maximal, mean, median and standard deviation of all the selected specifications of the grippers. With these, one can define the ”most average” gripper of the sampled market to have a stroke of 20.8 mm, a force of 1,020 N, and a weight of 3.4 kg. However, if one compares these figures to the median values, the results are noticeably different. Namely, the thusly defined median gripper has a stroke of only 9.5 mm, a gripping force of 320 N, and a weight of 0.6 kg. A significant difference between mean and median values in a statistical analysis indicates that the repartition of the data is not as simple as a bell curve. On closer inspection, this large discrepancy is due in this case to the fact that there is a significant bias toward smaller values for many specifications and especially the stroke. Nevertheless, if small grippers fill the bulk of most of the manufacturers' catalogs, very large products also exist but there are only few intermediate devices.

It should be noticed that in this analysis, the values indicated for the stroke are actually for one finger only, following the standard designation used in the catalogs, but the overall opening and closing ranges of