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SURVEY ON THE CHARACTERISTICS OF ASSEMBLY PARTS UTILISED BY FLEXIBLE SYSTEMS IN THE MANUFACTURING PROCESSES OF LOW WEIGHT AND VOLUME GOODS

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ABSTRACT
One of the major applications of flexible and automated assembly systems are the assembly of parts with low weight and volume –light parts-, in order to build products for the general consumption. The general consumption goods are usually produced in long series and aim to a general public with similar needs. In this context, the light parts follow several general patterns that make possible to cluster them and therefore to treat them as a groups in many engineering appraisals. The purpose of this work is to study some general patterns followed by the light parts, in terms of physical characteristics, as well as to summarize the most used approaches in industry to deal with parts disposition and preparation for assembly processes. The results of this study facilitate the specification, design and evaluation of flexible assembly systems, as well as depict and sort the parts apparent disparity on the assembly industry.
Keywords: Assembly and disassembly, flexible manufacturing systems, production systems.

1. INTRODUCTION
The majority of assembly processes performed for the production of general consumption goods in industry have to deal with the assembly of small parts with low weight and volume, from now onwards, light parts. The corresponding assembly processes usually involve operations such as inserting, drilling, pasting, screwing or bolting parts; thus enlarging the apparent disparity of the light parts assembly processes.

Notwithstanding, the assembly processes of general consumption goods account for a huge share of the global industry comprising fully-automated assembly lines, hybrid manual-automated assembly lines and fully-manual assembly processes. In this context, the optimum design and development of efficient assembly lines can only be achieved with a deep understanding of the underlying processes. To achieve this, it is necessary to portray the main characteristics of the assembly parts.

The objective of the present study is to analyse the properties of the light parts paying attention to characteristics such as degree of rigidity, maximum and minimum dimensions and volumes, geometrical shapes, tolerance ranges and weight. In addition, the study covers the main possibilities in physical disposition of light parts in the industrial assembly lines. The survey covers the results from a diverse range of 580 different light parts coming from several goods manufacturers in the fields of the electrical appliances and the electrical supplies.

2. CATEGORIES AND VARIABLES

Some four categories have been chosen to describe the light parts. For each of these categories, it has been defined a set of specific variables in order to classify the characteristics of each particular light part and, accordingly, compute the statistic sample derived. The categories and variables defined in each category are as follows:

- Degree of rigidity: Deformation under normal manipulation, deformation during the assembly and deformation resultant from the assembly.
- Geometrical shape: Qualitative geometry of the part's shape.
- Dimensions and weight: Dimensions of the maximum part projections, part's weight.
- Tolerance requirements: Manufacturing tolerance range and material.

3. MEASURES AND ANALYSIS OF THE RESULTS

The study of the degree of rigidity of the parts demonstrates that most of the light parts in the study (82,76%) do not deform during the normal manipulation and transport, as shown in Figure 1. Also, a 53,45% of the parts in the survey are not deformed during the assembly process (Figure 2). However, most of the parts that are deformed during the assembly operations remain deformed once the assembly is completed; either plastically or elastically.

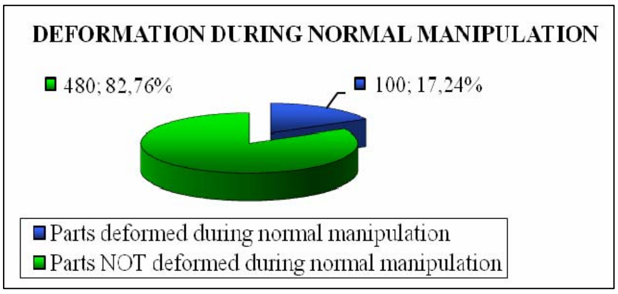
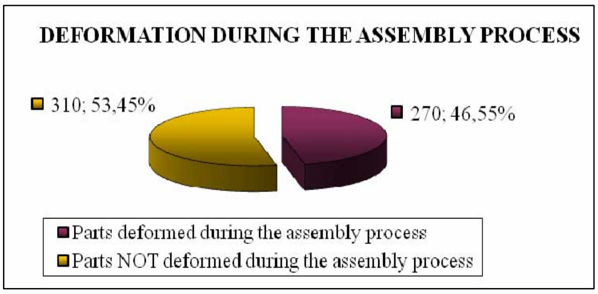
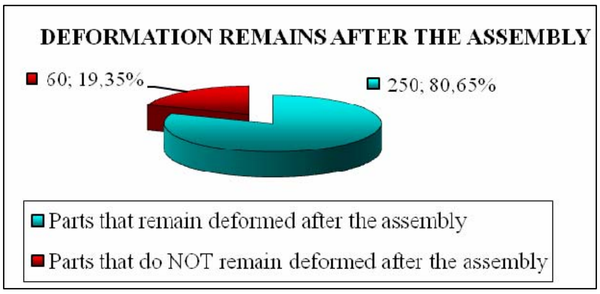


Figure 1. Pie chart of parts deformed during normal manipulation





Figures 2 and 3. Pie charts of parts deformed during the assembly process. For the parts deformed during the assembly process, percentage of parts that remain deformed after the assembly

The qualitative study of the parts geometry reveals that the majority of the parts have shapes that assimilate to cylinders, prisms or open-edge forms (T/P/L/U). As shown in Figure 4, other common part geometries are rings, flat thin geometries and wires.

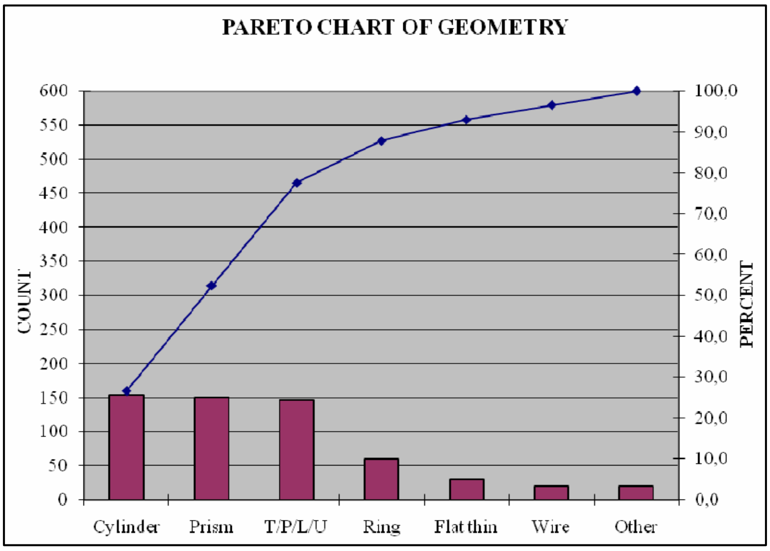


Figure 4. Pareto diagram for the different geometries of the light parts

The parts' maximum and minimum dimensions projected in X, Y and Z axis serve to estimate an average for the volume occupied by light parts. The results of the statistical analysis for the projected dimensions study can be found in Table 1, indicating the means for the maximum and minimum dimensions -36,26mm and 15,02 mm respectively. The largest projection dimension considered for a light part is 285 mm.

Table 1. Relevant statistics for the maximum and minimum dimensions of the parts in the study

Variable	**Mean**	**StDev**	**Minimum**	**Q1**	**Median**	**Q3**	**Maximum**
Max dimension [mm]	36,26	46,13	7,00	12,00	21,00	40,25	285,00
Min dimension [mm]	15,02	28,33	0,20	6,00	8,00	14,85	210,00

The results of the study of the parts' weights can be found in Table 2. From this table it is possible to observe that the average weight is 20,9g. The complete results also show that the 46,55% of the pieces in the survey weights less than 1g.

Table 2. Relevant statistics for the weights of the parts in the study

Variable	**Mean**	**StDev**	**Minimum**	**Q1**	**Median**	**Q3**	**Maximum**
Weight [g]	20,9	92,6	0,5	0,5	1,0	4,0	626,0

The manufacture tolerances in pieces made of plastic are not very demanding; in particular, the common tolerance interval ranges vary between IT 11 and 12. In the case of metallic parts the tolerance interval is reduced to absolute values between 60 and 90 microns.

The materials composition of the parts in the survey it is important in order to determine the maximum acceptable working conditions by the lineal elasticity module and the fluency stress limit. The results from the survey demonstrate that the predominant materials in the light parts sample are PP, steel (steel sheets in the majority of the cases) and brass. The rest of materials user are mostly plastic such as PVC, ABS, PE, POM and PS as shown in the Pareto Chart depicted in Figure 5.

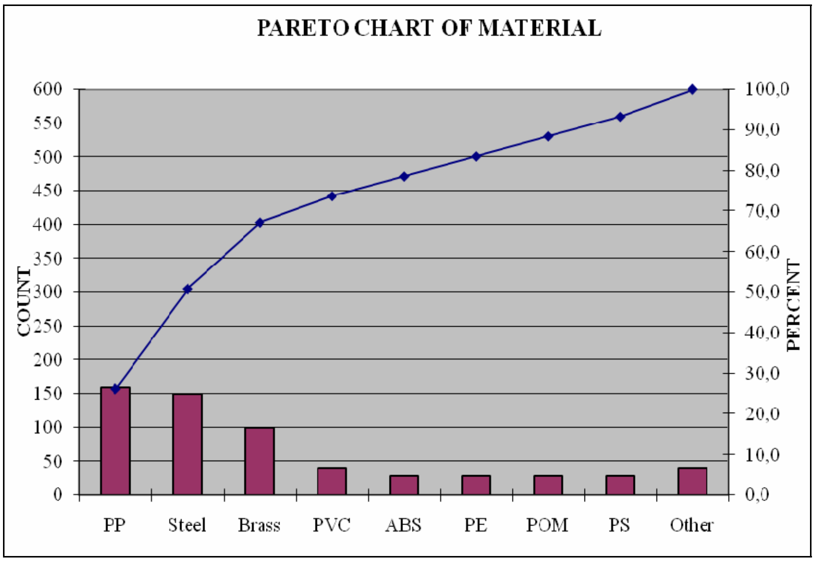


Figure 5 Pareto diagram for the different materials of the pieces.

4. PARTS DISPOSITION IN THE ASSEMBLY LINES

The methods of disposing light parts in assembly lines to perform assembly processes and related operations –as mentioned in the introduction- depend highly on criteria such as the ease of the internal transport, the economisation of the storage space and the specific needs of the operations.

As a result from the present study, the three main part disposition methods for light parts used in industry are:

- Pallet disposition: It is a completely deterministic parts disposition as each part has a precise position and orientation. Some pallet dispositions have the shape of a part negative. This presentation usually eases the part transport as the pallet can be the conveying element for the parts into the factory and until the assembly is completed. The pallet disposition is often used for parts with dimensions and weights relatively medium-high (bearing in mind the considerations of light parts).

- Random disposition: It is a non-deterministic parts disposition method in which the only information available is the volume of the bin that contains the parts. Therefore, parts position and orientation are unknown. This disposition method is often used in manual assembly lines and it can only be implemented in automated assembly processes when including separation devices, for instance, vibration elements.

- Single uncertain disposition: It is a parts disposition method in which parts are not deterministically positioned and orientated but approximately. A clear example of this is the use of automatic conveyors between two assembly stations. These parts disposition are usually used as buffers and can alternatively be implemented in manual, manual-automated and fully-automated assembly lines.

5. CONCLUSIONS

The utilisation of light parts is a spread fact in the production industry of general consumption goods. When treating the light parts as a group, it is found that the majority of the parts do not deform during the normal manipulation, although nearly half of them deform during the assembly operations. In addition, the majority of the parts deformed during the assembly remain deformed in the final product.

The most frequent geometries are cylinders, prisms or open-edge geometries. The 75% of the parts (Q3) have maximum dimensions below 40,25mm and weight less than 4g. The materials most utilised are Polypropylene, steel and brass, followed by other plastic materials (PVC, ABS, PE, POM and PS).

Finally, the results of the characterisation of light parts utilised in assembly processes finds that the part disposition methods in industry can be classified into three main groups: pallet disposition, random disposition and single uncertain position. The decision between one sort of disposition and another depends highly on rationalities such as the ease of the internal transport, the economisation of the storage space and the specific needs of the operations.

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