DEVELOPMENT OF A PARKING DUPLICATOR MECHANICAL DEVICE DRIVEN WITH PULLEY

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***Abstract*—The large increase in the fleet of vehicles in urban centers is causing the problem of the need for parking slots for more and more vehicles in confined spaces. This paper presents a solution to this problem by developing a parking duplicator device that allows parking two vehicles in the space required to park only one vehicle. The solution is to lift one of the vehicles, so that the other once can occupy the space below it. The proposed device presents simple and innovative configuration and drive (with movable pulley) besides the characteristic of being able to be easily manufactured and assembled in series, which provides lower final cost of the product and characterize it, along with its other attributes, as a great invention compared to the similar equipment available on the market, hitherto patented or in the state of the art.**

Keywords— Parking duplicator; Inclined Plane; Second Class Lever; Movable Pulley; Shear Pin;

I. INTRODUCTION

According to a survey of the Polytechnic School of the University of São Paulo (Poli) based on data from the real estate market since 1930, about 25% (or one quarter) of the entire area built in the city is used for parking slots. The large number of vehicles in urban centers, such as in the city of São Paulo with 2.2 inhabitants/car in the year of 2016 [1], has caused the problem of the need for parking spaces for an increasing number of vehicles in reduced spaces. A solution to this problem is found in the parking duplicator device shown in the Fig. 1:

Figure 1. Parking duplicator view showing the cars parked

Already in the 3rd century BC, the Greek philosopher Archimedes presented the concept of the simple machines suggesting objects that facilitate the execution of different day to day tasks and which are the basis for the more complex machines created by mankind throughout history. The device in the present discussion is a combination of four of the simple machines: the lever, the inclined plane, the pulley and the wheel and axle. The parking duplicator discussed in this paper has a simple form, has the property of being manufactured in

an industrial production line, in series, and has as its application field the residential garages (mainly apartment buldings and houses) and commercial garages (such as parking lots and offices).

There are currently some companies in Brazil that produce parking duplicators. Generally speaking, the majority of duplicators found use a hydraulic or electro-mechanical spindle drive system and therefore do not rely on the simplicity of the assembly and the drive of the device proposed here. The present study becomes convenient and necessary since the currently manufactured duplicators do not have the same innovations, drive and configuration presented here and therefore do not display the gains described in this document such as the energy savings required for raising the vehicle associated with the use of a movable pulley (which divides the elevatory force by 2), for example. In this sense, the presented parking duplicator brings a series of innovations to the current state-of-the-art of similar devices currently available on the market.

II. MATERIAL AND METHODS

The project development methodology [2,3] includes the following steps: 1. Definition of the Basic Idea and Design Characteristics 2. Development of a Conceptual Design 3. Dimensioning of Main Components 4. Finite Element Simulations and Refining of the Calculations 5. Elaboration of a Detailed Project, 6. Estimation of the Manufacturing Cost and 7. Development of a Prototype in Reduced Scale and Testing.

Although there are already quite satisfactory and innovative results, the project is still in the development phase, both in the aspect of refinement of the calculations and in the improvement of the mechanical design.

A. Definition of the Basic Idea and Design Characteristics

From the parking problem presented, a basic idea [4] of the project was proposed for the duplicator and proceeded with obtaining, evaluating, discussing and defining the capabilities, performances and basic characteristics of the project. The dimensions of the parking duplicator were based on the Honda Civic 2.0 i-VTEC Sport and the limitations of the application fields for the device. Thus, parameters such as the dimensions of the duplicator, the type of drive, the power and the rate of reduction of the gearmotor were idealized, which were used in later stages such as modeling and stress analysis of the device. This stage also involved the evaluation and discussion of the basic idea regarding functionality, fabricability (unit or series, spectrum of manufacturing processes), maintenance, durability, economic viability, work safety and environmental viability. The duplicator is intended to be installed primarily in rotary parking companies, apartment buildings, homes and offices. The only requirement for its installation is the ceiling of the building, which must not be lower then 3 m.

B. Development of a Conceptual Design

According to the basic concept and the observation of existing equipments, installations, components and structures that are the same, equivalent or similar to the device under study, a conceptual design was developed for the parking duplicator following the characteristics discussed in the first step. It is through the conceptual design that, in fact, a solution to the presented problem was conceived. The CAD softwares SOLIDWORKS® v. 2017 and AutoCAD® v. 2016 were used in the execution of the conceptual design.

C. Dimensioning of Main Components

According to [5, 6] and in order to perform the mechanical dimensioning of the duplicator, the components and parts were separated, considering the influence of the efforts of each element on the other and vice versa. Thus the free-body diagrams were obtained, where the efforts can be defined as actions and reactions. In this way, the stress analysis of the main components of the duplicator was followed. The Fig. 2 shows a simplification made for the analysis of the device, accordig to which all components have been dimensioned:

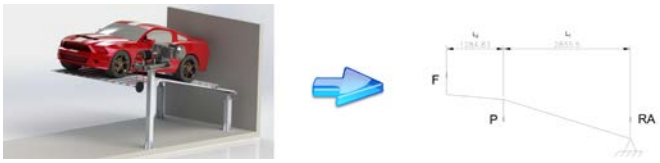

Figure 2. Duplicator and free body diagram showing how the mechanical components were dimensioned (dimensions in mm)

The flexion in the platform is a critical part of the project and three beams that are transversal to the platform resist the flexion. The type of beam is selected according to its resistance module. Once the loads on it are known, the minimum resistance module required for the problem is calculated through the Eq. [1] where M_f is the bending moment, ω_{x0} is the resistance module and σ_f is the permissible bending stress.

$$M_f = \omega_{x0}\sigma_f \tag{1}$$

D. Finite Element Simulations and Refining of the Calculations

Using the software ANSYS® v. 18.0, the main mechanical components will be dimensioned in simulations according to the respective loads [7]. The device dimensioning calculations will then be reviewed and refined in order to validate the simulation results. It is important to realize that this and the following steps are still in progress and therefore not concluded yet.

E. Elaboration of a Detailed Project

The purpose of this step is to transform the generated concept into a product. It contemplates the development of the detailed technical drawings involving each one of the equipment components, in agreement with the results of the dimensioning carried out analytically and with the simulations. As a result of this step, there will be a detailed design that will be used for fabrication, assembly and maintenance of the device. Subsequently, this design will also provide information on the assembly, operation and maintenance manual of the equipment.

F. Estimation of the Manufacturing Cost

From the manufacturing design, a list of materials will be carried out contemplating the materials and quantities necessary for the execution of the project. Through a market survey, the prices of the materials will be evaluated and summed in order to obtain the manufacturing cost of the equipment considering the labor, taxes and a profit margin for the proper commercialization of the parking duplicator. From the manufacturing design, a list of materials will be carried out contemplating the materials and quantities necessary for the execution of the project. Through a market survey, the prices of the materials will be evaluated and summed in order to obtain the manufacturing cost of the equipment considering the labor, taxes and a profit margin for the proper commercialization of the parking duplicator.

G. Development of a Prototype in Reduced Scale and Testing

Based on the drawings, a small scale prototype will be manufactured, which will be tested and the correct corrections will be applied to the detailed design. After completing this step, the assembly, operation and maintenance manual of the equipment will be developed.

III. RESULTS AND DISCUSSIONS

The present study comprises a device for doubling garage slots composed of a lifting platform articulated on a support column and lifted/lowered by a drive assembly formed by a movable pulley and a winch (or a hoist). The Fig. 3 illustrates the conceptual design of the duplicator.

Figure 3. Conceptual design developed for the duplicator

And the Fig. 4 shows the general operation of the proposed device: the first car is parked, lifted, and then the second car is parked below the first one.

Figure 4. Device's general operation

As shown in Fig. 5, the lift platform is intended to lift a vehicle and has a geometry so as to prevent any leakage of oil or water from the top vehicle to reach the bottom one. The platform has a stop in contact with which the wheels of the vehicle should be positioned when parking, preventing the raised vehicle from slipping after lifting the platform. The lifting platform is made of sheet metal which has folds that increase the mechanical resistance of the platform and thus allow the use of a thinner and therefore lighter and cheaper sheet.

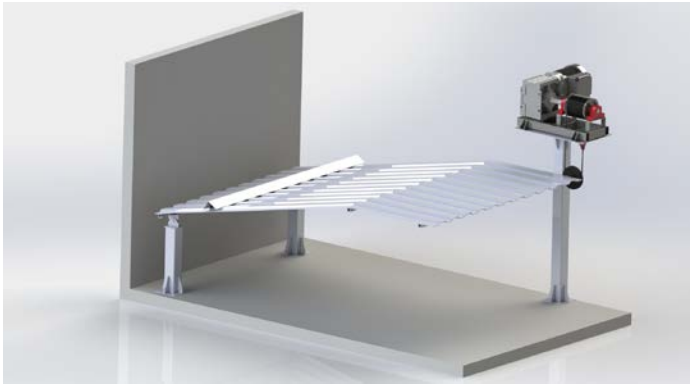

Figure 5. Parking duplicator view

The Fig. 6 shows a side view of the parking duplicator, where the two parked vehicles can be seen. The configuration described here is the basic one for the operation of the system. Other items can be added to it attempting greater security. These include: safety locks that prevent accidental lowering of the platform and miscellaneous sensors, such as those that make it impossible to lower the platform if the space below it is occupied, which interrupts the lift if the vehicle is close to touching the garage ceiling or which interrupt the operation of the platform in case a child or a domestic pet enters regions considered to be dangerous during the operation of the parking

duplicator device. Other possible items are remote actuation devices, handrail on the lift platform, and protection/closure sheets for parts such as steel cable and pulley, which can injure the user in an accidental contact.

Figure 6. Side view of the parking duplicator

The motorized system may also be mounted on the ceiling as shown in Fig. 7, thus allowing an alternative assembly for the device.

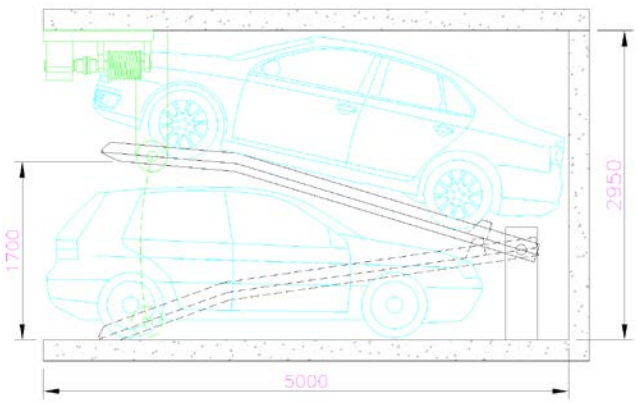

Figure 7. Alternative assembly (dimensions in mm)

After elaborating a brief cost estimative, it is estimated that the device could be marketed for R$ 7,000, including manufacturing cost, taxes and profit margin. It is a cheap device due to its simplicity, being up to three times cheaper than the solutions currently available in the market. And the very simplicity of the duplicator designed ensures its functionality. The device also has the feature of being easily manufactured, transported and assembled in series, which provides lower final cost to the finished product. The Fig. 8 represents this quality showing an exploded view of the joint pillar:

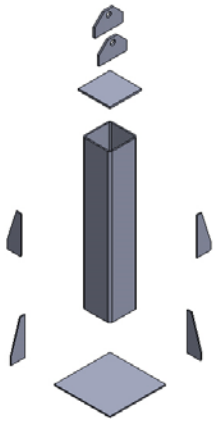

Figure 8. Exploded view of the joint pillar

The obtained result was a simple device that serves as an alternative to be implemented mainly in parking lots, apatment buildings, private homes and offices. A patent application has already been properly deposited under the registration number: BR1020170118142, which enables the full commercialization of the equipment.

Some important technical details of the duplicator are presented in Table 1, where it is important to notice that the heigh of the build must be aproximately 3 m in order to properly accommodate the device:

TABLE I.

Technical Details	
Motor Power	3 hp
Max. Possible Weight	2000 Kg
Height	2950 mm
Lengh	5000 mm
Width	3250 mm

CONCLUSIONS

At the beginning of this study, a solution was sought in saving space for parking cars. A simple and inexpensive solution to optimize parking lots, especially in rotary parking companies and apartment buildings, where parking spaces are limited. Analyzing the evolution of the results, we can see the relevance of the project. The device designed in this article brings a parking solution when verticalizing the use of spaces. The parking duplicator compacts parking slots offering convenience and efficient use of space. It saves time, money, space and simplifies the often tedious task of parking.

In view of these results, it is concluded that the project meets the expected specifications. Through further advances in the project, it will be possible to develop a product that can be used in all urban centers, opening wide parking possibilities.

ACKNOWLEDGMENT

The authors are grateful for the support of BRINELL SERVIÇOS DE PROJETOS E ENGENHARIA LTDA. in the development of the parking duplicator system.

REFERENCES

[1] NEXO Journal. < https://www.nexojornal.com.br/grafico/2016/01/29/A-propor%C3%A7%C3%A3o-de-habitantes-por-carro-nas-capitais>. Acesso em 11 de outubro de 2017.

[2] Ulrich and Eppinger. Product Design and Development. 5th ed. McGraw-Hill Education, 2011.

[3] C. L. Dym, P. Little. Engineering Design: A Project Based Introduction. 4 ed. Hoboken: Wiley, 2003.

[4] J. Tidd, J. Bessant, K. Pavitti. Gestão da Inovação. 5th ed. Porto Alegre: Bookman, 2015.

[5] R.C. Hibbeler, Structural Analysis, 4th ed., Prentice-Hall, Englewood Cliffs, New Jersey, 1998.

[6] S.P. Timoshenko and D.H. Young, Theory of Structures, 2nd ed., McGraw-Hill, New York, 1965.

[7] O.C. Zienkiewicz and R.L. Taylor, The Finite Element Method, 5th ed., vol. 1: The Basis, Butterworth-Heinemann, Oxford, Massachusetts, 2000.