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DESIGN AND DEVELOPMENT OF A NEW HARD LOCK SYSTEM

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1. Introduction

Most of the Italian companies have till now been able to remain competitive in the market by developing the manufacturing automation and by re-organizing the product lines, attending to the reliability and the quality of the product, and beating competition mainly on the price front.
This strategy is now revealing its limits since the emerging countries can easily win the price competition because of the low cost of unskilled work.
It is necessary to appeal to a resource which has always been the development engine, i.e. the ability to innovate products. Innovation means finding new ways of fulfilling needs by improving the product with added value of creativity and invention [Basadur 1995], [Higgins 1990], [Henderson 1990].
In the paper the design process, from the idea to the manufacturing aspects, with all the technical and technological problems, to develop a new competitive antitheft is described.
Beyond statistics and official selling data, it is easy to notice that the use of scooters and motorbikes is constantly increasing. This means that the need for antitheft devices is increasing as well. The lock system's market for motorbikes is more and more shifting towards a flight to quality because end-users have now understood the importance of choosing products which guarantee more security to one's own means of transport. This implies the increase of volumes and medium quality of sold devices.
After careful estimation of the limits of the four most widespread types of mechanical antitheft devices now available on the market (Table 1[1]), the authors propose a new antitheft which contains not only the strengths of former types of devices, but is able to exceed their limits.

Table 1. Antitheft: Qualitative Evaluation

Antitheft Types	Strenght	Size	Weight	Easy-to-use	Security Level
Chain locks	++	– –	– –	+–	++
Cable locks	++	– –	–	+ –	+
Brake-disk locks	+–	++	+	+	–
U-padlocks	+	–	+–	+–	+

By adopting recent CAD & CAE systems and RP (*Rapid Prototyping*) technologies the main design steps through which an efficient, low-weight, compact-size, and easy-to-use antitheft for motorbikes (named BlockIT®) was patented (patent n.NA2005A000037) and made, are described.

[1] Table 1 has been drawn up in order to have a concise outline of the relevant state of the art. Chains lock, cable locks, brake-disk locks and U-padlocks have been evaluated according to the shown five parameters.

2. Design process

Through the years the role of the design engineers is changed. Nowadays they are part of a complex network which goal is still to release a marketable product but in a shorter time and with higher value/cost rate, higher reliability and aesthetic charm.
To get these performances it was necessary to give more importance to the formalisation of the engineering culture, bridging it strongly to the scientific research and then splitting it in some specialisations.
The same design process can be subdivided in different steps in which the engineer makes several types of intellectual activities. A classic general design scheme where the actions are organized sequentially with well-defined logic criteria is shown in Figure 1.

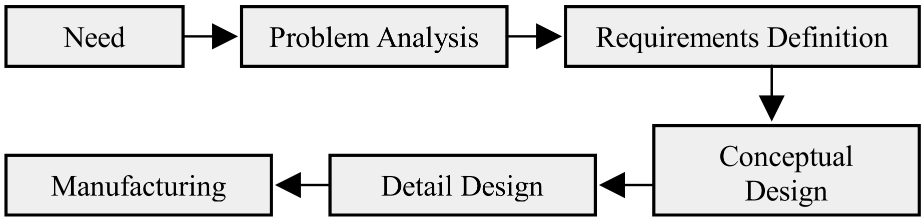

Figure 1. Design Process

Given a "need", the product able to satisfy it is designed. In the "problem analysis" the features and properties of the need are established and, with the "requirements definition" the boundary conditions to be respected are defined. In the "conceptual design" phase the general architecture of the object is created through simplifications and schematization of some macro-elements.
The design becomes more and more precise by some functional schemes, still developed at a level which allows to individuate a technical solution based on its ability to satisfy the needs with the imposed specifications. In the final "detail design" phase the detailed aspects that improve the product features are defined.
This general design scheme, which ends releasing the working drawings, now has to be changed and enlarged to take into account that most design actions are much more efficient – they analyze much more design alternatives in less time – when they are supported by software tools for structural, functional, and manufacturing simulation, and sometime programs for aesthetic and ergonomic evaluation of the product by RP and VR techniques.

2.1 Need analysis

The registrations of new motorbikes and scooters in Italy from 1997 to 2004 are increased of about 330% (Figure 2) causing to have actually more than 4.5 million units running[2].
The large circulation of two-wheels vehicles together with the recent fast growth sales caused a parallel development of security systems against theft.
About twenty years ago the first lock system specific for motorbikes was sold. During years most types of antitheft made for any motorbike model become almost an exclusive product of resellers of motor-vehicles accessories.
Most antitheft models for motorbikes, except the electronic ones, may be technically classified in: chain locks, cable locks, brake-disk locks, U-padlocks. Differences may be found not only in the security level, but also in the following aspects: easy-to-use, lightness, size and shape design, which are no longer negligible elements to be considered when buying lock systems.
Chain and cable locks are actually the most sold security systems and they protect motorbikes also against raising, but they are bulky and hard to use. Brake-disk locks and U-padlocks are, instead, much easier to apply, more compact, and they are used often for brief stops.

[2] Based on official data of the Italian Ministry of Public Transport.

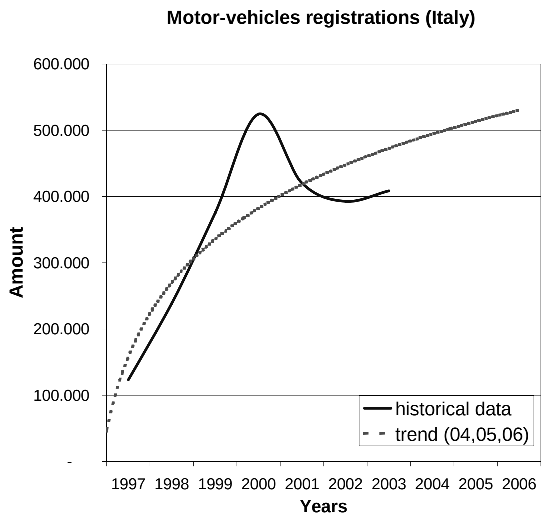

Figure 2. Motor-vehicles registrations in Italy

The lack of national specific standards on the minimum features that an antitheft should respect has given to several manufactures the possibility to make and deliver on the market many types of lock systems, even not efficient at all.
The evaluation of the safety level of the product – in terms of anti-sawing, anti-cutting and so on – is made by the same manufacturer, and this has caused during years to have very cheep systems in this market segment. The customer who does not have any experience and evaluation parameters when buying antitheft systems often is only addressed by the seller.
The authors, starting by these issues, analyse features and proprieties that a new lock system must possess and establish functional requirements and boundary conditions to be respected.

2.2 Conceptual design by CAD/CAE/RP techniques

The first design process phases are those more conceptual and general but at the same time the most critical as they have strong influence on the downstream phases. At this level of the design process it is relevant the capacity to demonstrate the creativity and the innovation which makes the difference between the smart engineer and the medium one.
In the present work the initial conceptual design phase was supported by the recent CAD-CAE-RP technologies which allow to develop, verify, test and manufacture any prototype in a very short time, so affecting strongly design and production costs.
The simulation phase of an antitheft system for motorbike consists, among others, in verifying on the virtual prototype the easy assemblability, and the evaluation of the strength characteristics, for example in terms of anti-cutting and anti-drilling.
The Rapid Prototyping technologies, to be used as last verifying activity before releasing the prototype for the manufacturing phase, represent another final important step of the design process able to strongly reduce the time-to-market.

2.2.1 First design solution

The actual market of the motorbike locks is very wide and many products are usually characterised by a good safety level (anti-sawing, anti-cutting, etc.) combined with not negligible weight and size, or by small size but easily to remove. Figure 3 shows some lock models for motorbikes.
The initial idea was to develop a product unavailable on the market to lock the wheel chain of the motorbike with an appreciable design, high safety level, reliable and easy-to-use (one-touch model). Similar already available products are designed to lock only the brake-disk.

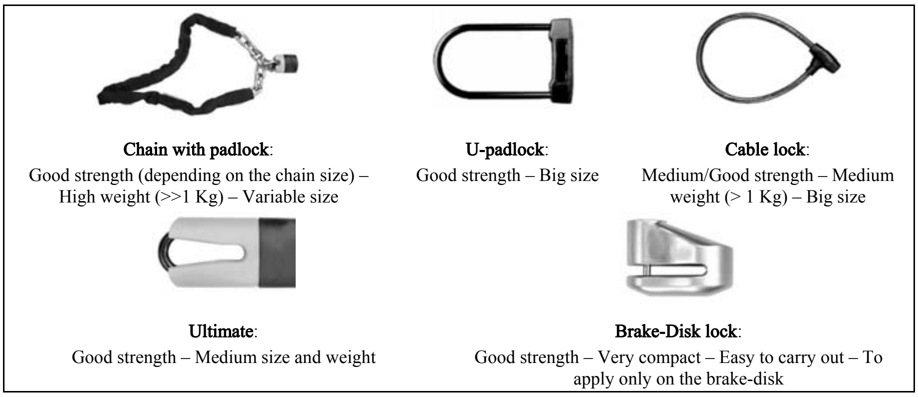

Figure 3. Some mechanical locks for motorbikes available on the market

Several design solutions were analysed to look for the shape able to characterise the product and with new technical solutions. The geometry features of the main wheel chains (Figure 4) were analysed to design a product able to lock more chain elements at time with 3 pins as shown in Figure 5.

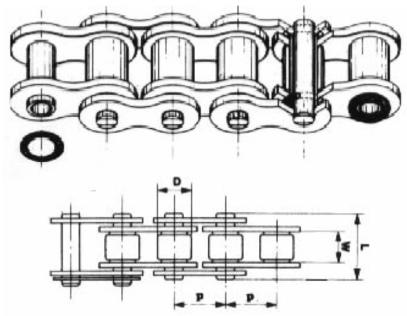

Figure 4. Geometric parameters of wheel chains

Figure 5 also depicts the first virtual locks prototype (created in Solid Works CAD environment [Solid Works SE 2004]) and its RP model (made with SLA 3500 system by 3D Systems).
The designed wheel chain lock, named BlockIT®, is a very compact and fashionable semi-automatic mechanical system based essentially on two components. An internal compression spring acts pushing up the top component when the lock is opened. The mating edges all around the components are designed to prevent anyone from the use of external levers, when the chain lock is closed (Figure 6 left). Moreover, the use of the key is necessary only to open the system, whereas it is enough a simple pressure by hand to close it as shown in Figure 6 on the right.
The high security level of the designed lock is guaranteed by the robustness of the system (both components collaborate to any external action intended to separate or break them, and not by the keylock), and by the bulbous shape of BlockIT that makes very difficult any drilling action.
Other its useful features are the very small sizes and the low weight (about 500 gr.).
Analysing this design solution the following drawbacks come out:

1. it locks only the wheel chain, then
2. it can be used only on motorbikes with wheel chain, and
3. even though very safe, this antitheft may be inactivated by removing the wheel chain.

2.2.2 Second design solution

In the second design solution, still keeping all functional and strength features of the previous solution, the above drawbacks are removed by extending the application of the proposed antitheft to lock more than wheel chains only. By substituting the three pins with only one (in central position, bigger and unreachable when the lock is closed), the same solution may be used to lock chains, brake disks, crown gears, and as universal padlock (Figure 7). With respect to the first solution, the weight, yet comparable with other commercial solutions, is changed from 500 gr. To about 950 gr. To take into account the bigger thickness of the motorbikes' disk to lock (42 mm).

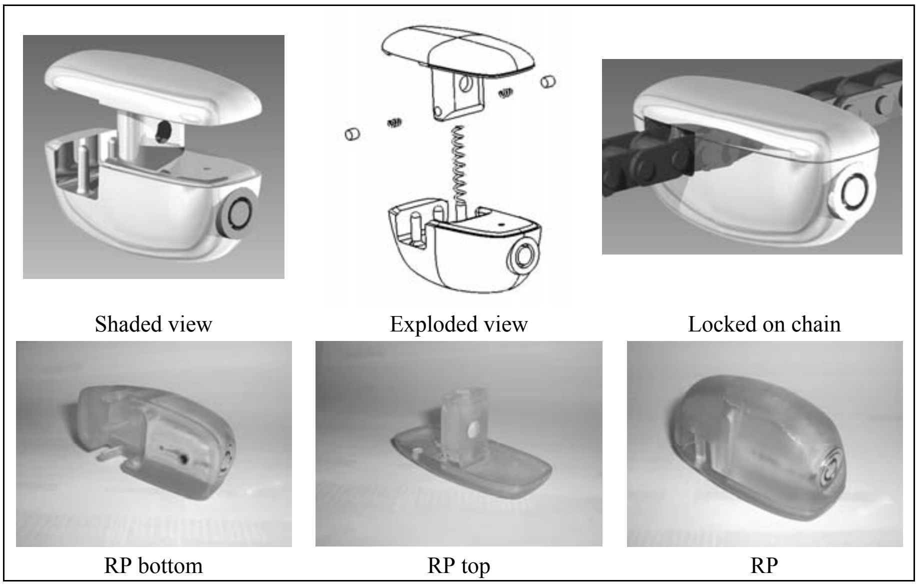

Figure 5. First design solution: virtual prototype and RP model

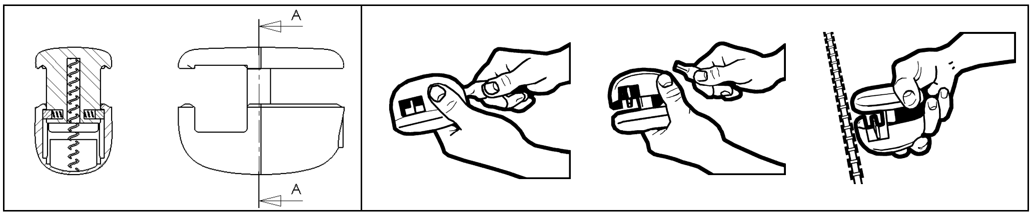

Figure 6. Internal compression spring (left) and easy application of the chain lock (right)

2.2.2.1 Strength analysis

Having the virtual prototype of the lock system it is possible to make any CAE analysis to test it in terms of strength, deformation and so on. A FE analysis was performed under static load conditions to evaluate the critical area of the prototype [Cosmos 2004]. Figure 8 shows some tests (von Mises equivalent stress distribution) made for both components analysed separately, assigning the material proprieties corresponding to a AISI 1040 steel. While the top component has an ultimate strength corresponding to a load of 6800 N, the bottom component has an ultimate strength corresponding to a load of 11700 N. The central pin has, instead, a failure at 14800 N. We may estimate the resultant load capacity of the whole lock system to be more than 10000 N, which is an appreciable security level.

2.2.2.2 Last design solution

The previous design solution with respect to the first one has an evident lack due to the big fixed space between the two components even when the lock is closed: it may be easily attached with an external lever, or the pin sawed.

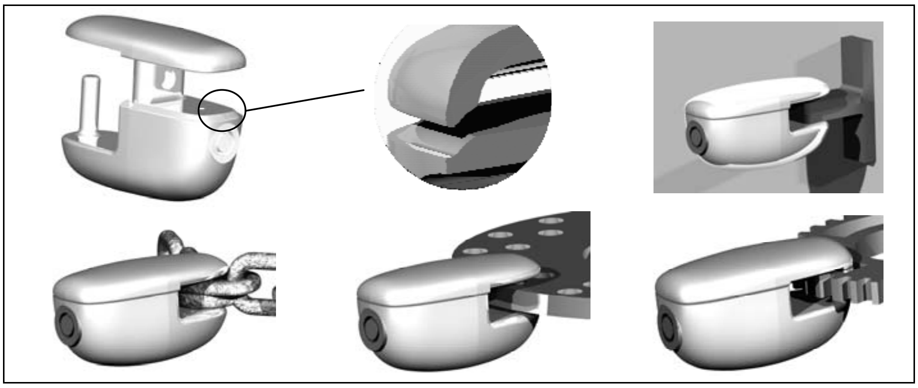

Figure 7. Second prototype to be used as padlock and locker for chain, disk and crown gears

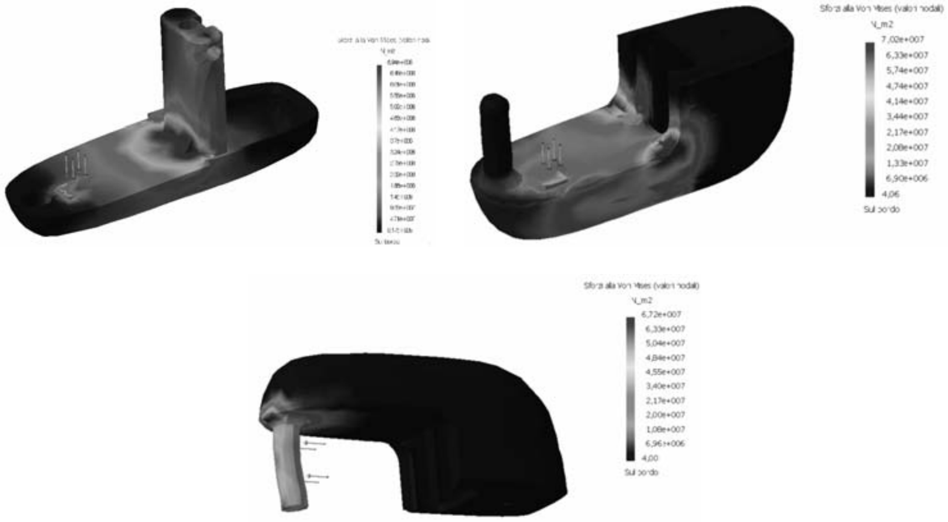

Figure 8. Von Mises stress distribution of the second design solution

To overcome these problems we have proposed a new design solution which allows to lock the system in two different positions depending on the thickness of the object being locked. Now this system may be properly used as brake disk lock, chain lock, crown gears lock, all with different thickness, and as universal padlock (Figure 9). To protect it from the use of levers applied on the lateral sides, these were reinforced.

2.2.2.3 Strength analysis

As in the previous solution, a strength analysis was performed on the last design solution. Figure 10 shows the von Mises equivalent stress distribution for both components (assuming always the AISI 1040 material properties). The shown distribution corresponds to the ultimate strength reached for the top and bottom component respectively under a load of 9200 N and 14500 N. The stress distribution for lateral sides is shown as well to guarantee the lateral strength of the prototype (under a load of 14800 N).

3. Manufacturing phase

The final model was designed to still be within 950 gr. as the previous solution, without sacrificing the whole strength.

Figure 9. Some configurations of the final design solution

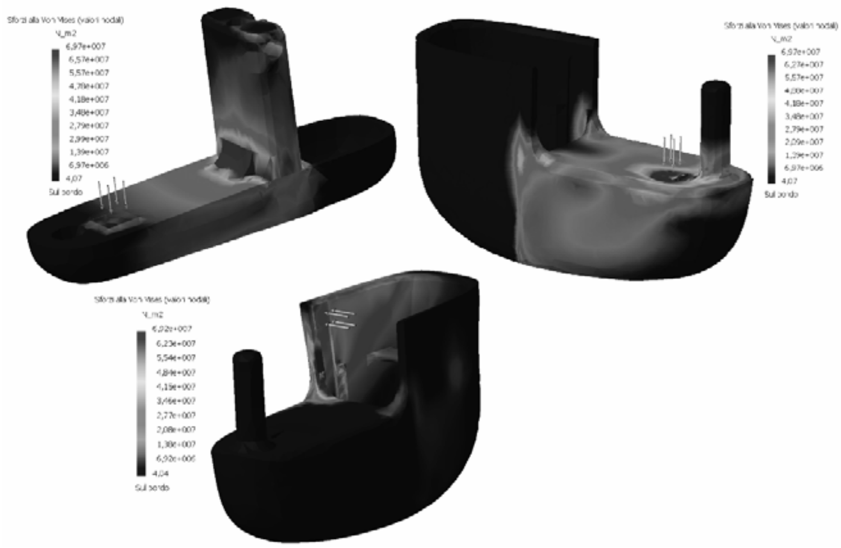

Figure 10. Von Mises stress distribution of the last design solution

It will be manufactured in AISI 1040 heat-treatable steel by lost-wax casting at very competitive price (Figure 11). For some specific features of the product the lost-wax casting manufacturing process has been chosen as it offers some advantages with respect to hot-pressing and metal shaving machining processes when manufacturing many pieces. In particular, as to make lighter the bottom component of the lock system it was designed as shell-wise part, the lost-wax casting process is the appropriate manufacturing process to adopt. Moreover, it offers a quite accurate solution as the tolerance range is generally within the 0.5% of the nominal size, as shown in Table 2. Tighter tolerances can be made available for a few selected design features. In many cases the casting may be assembled as it is. In our case, at the end of the process the component needs to be drilled and treated by nickel coating process before assembling it. The assembly process is very easy to carry out because of few components, and it does not require specific skilled operators, so the assembly costs are very limited.

4. Conclusions

In this paper the simple design approach has been adopted based on the consideration that most innovations do not come out from a total invention, but often from the new application of design solutions already developed. Here, a new model of hard antitheft is presented completely designed, developed (and patented) and manufactured at the University of Naples and Cassino, Italy.

It has weight and size very limited and some important features such as easiness to handle, high strength and high versatility; all this makes it an exclusive product of its type.

The integrated use of the CAD/CAE and RP techniques made possible to analyse three different solutions in a very short time. The final product, made in AISI 1040 steel, is going to be manufactured and distributed in Europe by BULLOCK® in 2006.

Table 2. Precision grade for lost-wax castings

Dimensions (mm)		Precision Grade	
		MD 1	MD 2
from	to	Tolerance range	Tolerance range
--	6	± 0,10	± 0,08
6	10	± 0,12	± 0,10
10	14	± 0,15	± 0,12
14	18	± 0,20	± 0,14
18	24	± 0,25	± 0,17
24	30	± 0,30	± 0,20
30	40	± 0,36	± 0,25
40	50	± 0,42	± 0,30
50	65	± 0,49	± 0,35
65	80	± 0,58	± 0,42
80	100	± 0,68	± 0,48

Figure 11. Manufactured lock made by lost-wax casting

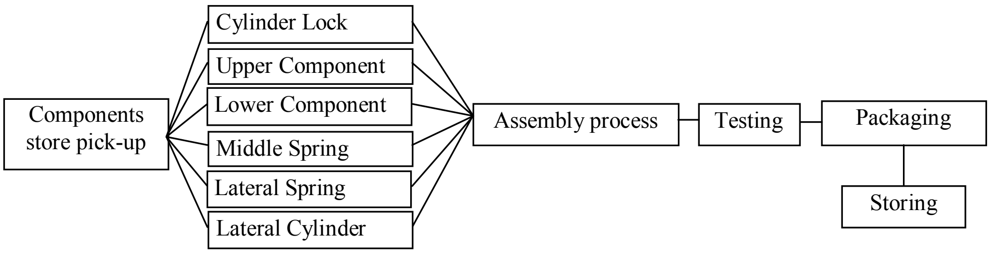

Figure 12. Production process general scheme

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