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# DESIGN AND REALIZATION OF A SWIVELLING SEAT FOR A PARALYMPIC RACING BOAT

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***Abstract***: In past few decades, an increased interest in physical disability studies has developed. However, there is a lack of devices and innovations that allow disabled athletes to participate in Paralympic sports properly. In this work, a new, ergonomic swiveling seat used for Paralympic sailing boats has been developed and is compared to the traditional seating system. To increase the performance of the improved seat during a regatta race, a variety of innovative modifications have been introduced; the structural seat design has been developed through 3D simulation; a FEM (finite element method) analysis has also been presented to calculate the real stress and deformation ranges on the structure. Results show significant reduction in the weight of the seating structure, as well as an increase in the seat's movement accuracy, in relation to the design and selection of the actuator. Furthermore, structural modifications make the swiveling system more ergonomic for most disabled users during sailing.

***Keywords***: Ship engineering, disability, 3d simulation, swiveling seat, finite element analysis.

## Introduction

Paralympic sports have seen an exponential increase in participation in the last few decades. More than 4,000 athletes participated in the most recent Paralympic Games, held in London in 2012; few sporting events have seen such a

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rapid evolution in recent years. This rapid growth has also contributed to challenges in understanding the injury risks associated with participation a variety of sports, as well as with the evolution of technical equipment. The last decade has presented an important increase of additional impairment types in new sports and specialities.(Webborn, Uk, & Emery, 2014) In order to provide opportunities for disabled individuals who practice sports, it is necessary to use special devices, such as specialized chairs.(Hettinga et al., 2010)

Disabled people show high rates of chronic disease as well as sedentary lifestyles. Fortunately, access to physical activity and sports opportunities allows for a decrease in the discomfort that a person with a disability may experience. The Paralympic Movement (or International Paralympic Committee) provides an opportunity to transform the stigma surrounding physical disability, and also serves as a catalyst for public health education and program development. (Blauwet & Iezzoni, 2014) In this regard, Paralympic sports aim to promote participation in sports by people with disabilities by controlling the impact of impairment on the outcome of competition.(Tweedy, Beckman, & Connick, 2014)

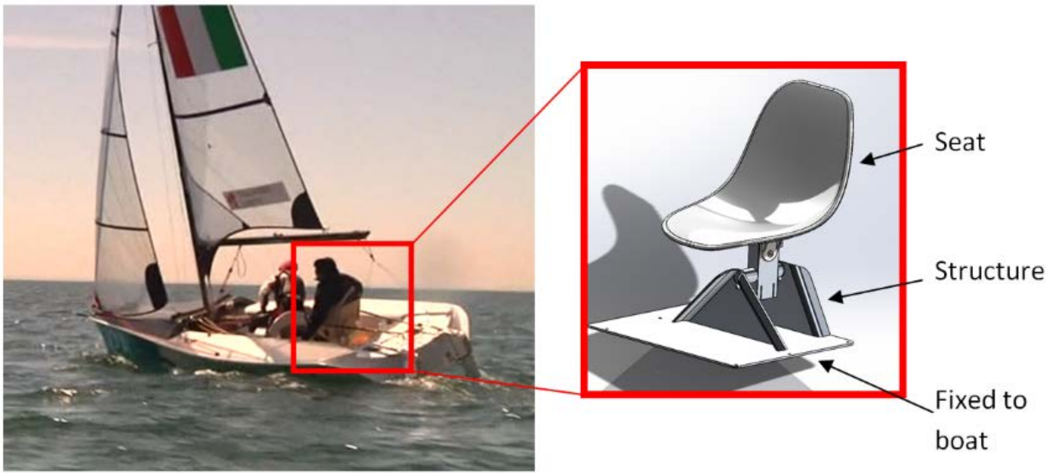
In 1996, sailing was first introduced to the Paralympic Games. The SKUD 18 is a specialized high-performance class of sailing boat used in racing. It is a lead-assisted skiff with a tube-launched asymmetrical and a modern high performance fixed rig; active able-bodied and disabled sailors alike have enjoyed the two-person version since 2006. The debut for the SKUD 18 class was in Qingdao, China during the 2008 Summer Paralympic Games, in which eleven nations competed on the 2-person.(Morton, 2008).

With its 140 kg bulb and 1.7m draft, the 2-person SKUD 18, even with both crew on the centerline, the structure has exceptional stability and is fail-safe.

Further studies led to new developments such as a version of the SKUD 18 that may also be adapted as a three-person boat. In its open configuration, one crew member uses the centerline seat and one uses the trapeze. A wide range of additional equipment can also be added to compensate for any functional disability and to enable the crew to maximize their collective potential.(Hansa Sailing, 2016)

No technical studies have presented any innovation related to this kind of sailing device thus far. For this reason, this study discusses the design of a new swiveling seat located on the sailing boat, to improve upon and provide a comparison to the old seat. The aim of this study is the reduction of the weight of the structure, and increase the precision of the structure's movement. For this reason, a lower weight allows having a lower inertia of the boat and therefore greater reactivity (better handling during the regatta race). Secondly, a better positioning of the seat allows to hence the precision of the centre of gravity in order to compensate the force on the sails. Moreover, the analysis and the introduction of ergonomics solutions optimize the athlete's posture during the regatta race. Maintaining a reasonable price for the structure is also essential for this kind of device. Figure 1 shows the boat with the disabled athlete on board and the current seat under study.

*Figure 1. Disabled athlete on Skud 18 and current seat. Source: Authors.*



Weight reduction of an object can be achieved in various ways; one solution is the adoption of a material with higher structural performance. For example, in the transport sector, the adoption of high-resistant steels or aluminium alloys in place of traditional steels leads to significant weight reductions.(L Solazzi, 2012; Luigi Solazzi, 2010) The use of composite materials with carbon fibers and natural fibers leads to a further significant weight reduction because they present a more powerful Ashby index,(Ashby, 2005) and also because these materials can be designed ad hoc for a specific use.(Collotta et al., 2016; L. Solazzi & Scalmana, 2013)

The first point of development in this research is to change the material and shape of the supports. To further reduce weight, the oversized components in the original seat structure have been identified and changed. Precision in the movement of the swiveling seat is achieved by adopting a new irreversible mechanical actuator, which has been chosen to prevent upsetting the structure's original configuration.

This study was further extended by examining the structure's mechanical stresses using FEM software, with the purpose of verifying analytical elaborations. In conclusion, the new swiveling seat shows a reduction in weight by using a new material (aluminum alloy instead alloy) of 50%, while still maintaining an equivalent safety factor. The optimization of the structure is done by uniformizing as much as possible the stress value on the component. This is possible removing or reducing parts that have less stress. Furthermore, this process happened iteratively to bound the maximum value of stresses in order to have at least the same safety coefficient.

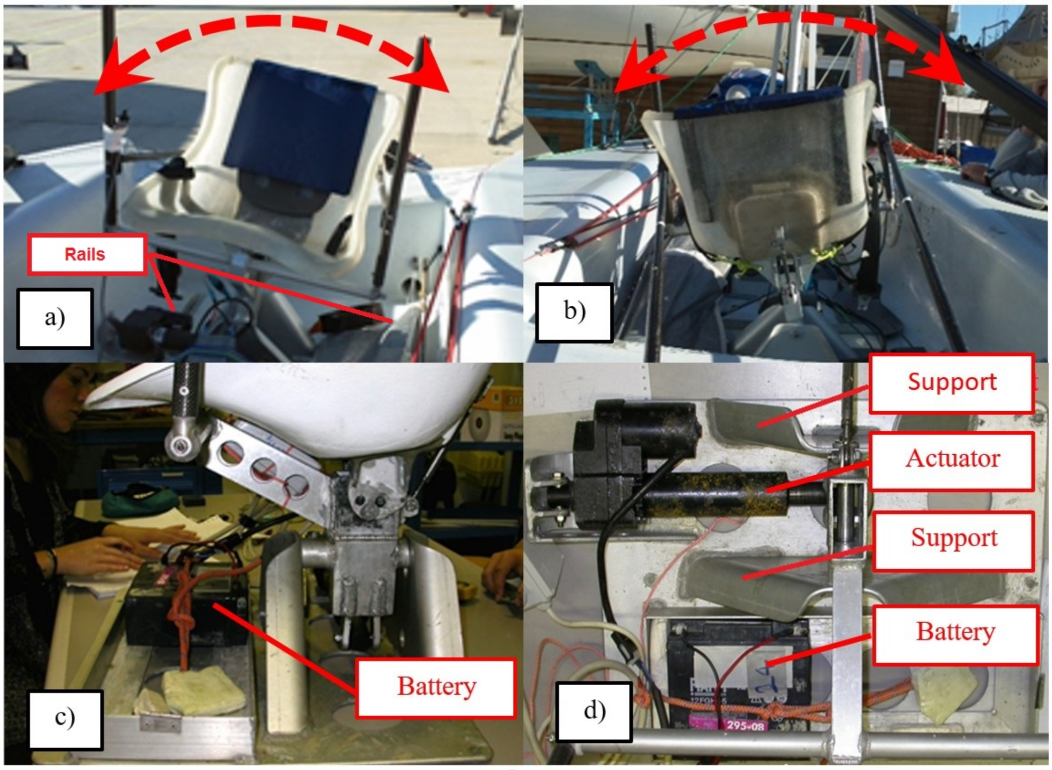
## Methodology

This project is primarily focused on a technical analysis of the seat in order to follow a scientific and rigorous approach. Initially, the original seat was measured and weighted; 3D drawings of all details and a model of the existing seating system were then completed. Following this, loads and constraints were developed, taking into account hypothetical load configurations. During this first analysis, different proposals were introduced in order to solve a variety of technical issues. At this point, new prototypes were identified, studied and analyzed through the information coming from the initial model. A comparison between the two models was performed with the recalculation of safety factors, while part of the initial analysis was focused on the correct precision of the seat movements. Thus new types of actuators have been considered based on the required specifications. Technical drawings of the new swiveling seat were also made to provide a schematic of the final structure.

## Current seating system

Figure 1 and Figure 2 shows the current seat, which has been subject to analysis in this work. The existing seat is fixed to the hull; the helmsman sailor can set their position when the boat is in a stationary position by shifting themselves back and forth along two rails. The sailor can also set the position of the seat by changing the angle settings (lurch and roll angles). Lurch angle (referred to the boat) is allowed by a rear screw (this adjustment takes place when the boat is stationary), while roll angle (referred to the boat) is allowed by an actuator positioned on the base of the seating system; this kind of actuator is also controlled by the athlete during sailing activity.

*Figure 2. Pictures and mechanism of the current seating system: side, front and plan views. Source: Authors.*



The original structure is primarily composed of a bottom plate, with two supports that are welded (which contain the locations of the pin that allows the roll rotation) together above it. The movement of the original seat was made by a linear actuator (Warner K2xG10 - 12v_0.4), which was powered with a direct current. This Warner K2xG10-12v-04 B-Track(L Solazzi, 2012) linear actuator has a 4" stroke and a 10:1 gear ratio for use in rugged duty applications, such as scissor and dump box lifts. This K2x series unit is capable of moving loads of up to 1200 pounds at a rate of 1 inch per second. Moreover, its maximum speed is 38 mm/s, which makes it possible to tread the stoke in 4 s as the athlete requires to be competitive.

The weight of the current structure is an issue of the swiveling seat, which results in bending deformations on the bottom plate. For this reason, a bottom and lighter plate is introduced in order to spread the stress on a wider surface on the hull. Another disadvantage of the seat is related to its reversibility wherein the absence of a power supply the seat is not capable of maintaining its position with an applied load. The reversibility is dictated by the efficiency of transmission. The higher the efficiency of transmission, the greater the possibility that the actuator cannot maintain its position. If the actuator is not irreversible, it cannot maintain its exact position (it may have a low accuracy) and cause a reduction in the performance of the athlete. In addition, the current structure involves play in mechanical connections, which decreases the accuracy of positioning.

### *Preliminary analysis*

Initially, the two parts of the assembly were studied with analytical models. Particularly, the central hollow pin and supports (bigger and smaller).

For both parts, it was important to find loads and define constraints. In particular, the load of the measured seat is $P_s$=29 N(≅3 kg) and the hypothesized load of the human is $P_u$=903 N (≅92 kg).

The load used in the analysis must be calculated as the load of the human added to the load of the seat: both loads are increased by a multiplier, which accounts for dynamic effects:

$$P=(P_s+P_u)\cdot k \quad \text{with} \quad k=1.8$$

k is defined as a constant parameter used to consider a real situation with accelerations generated by the external environment (dynamic effect). It is estimated that the maximum accelerations on the sail may be comparable to the accelerations on the vehicle system. For this reason, the dynamic factor k has been chosen as 1.8.(L Solazzi, 2012)

One of the most stressed parts of the seat is its support. In fact, the section of greatest stress (critical section) parallel to the bottom plate of the seat is the section where the pin is positioned. This is a typical "C" section, with a central linear component that decreases linearly away from the bottom plate. The material of the existing seat is an aluminum alloy (Al 6063-T6).(European Standard Organization, n.d.)

All details about the chemical composition and mechanical properties are reported in Table 1 and Table 2.

***Table 1.*** *Chemical composition of aluminum*

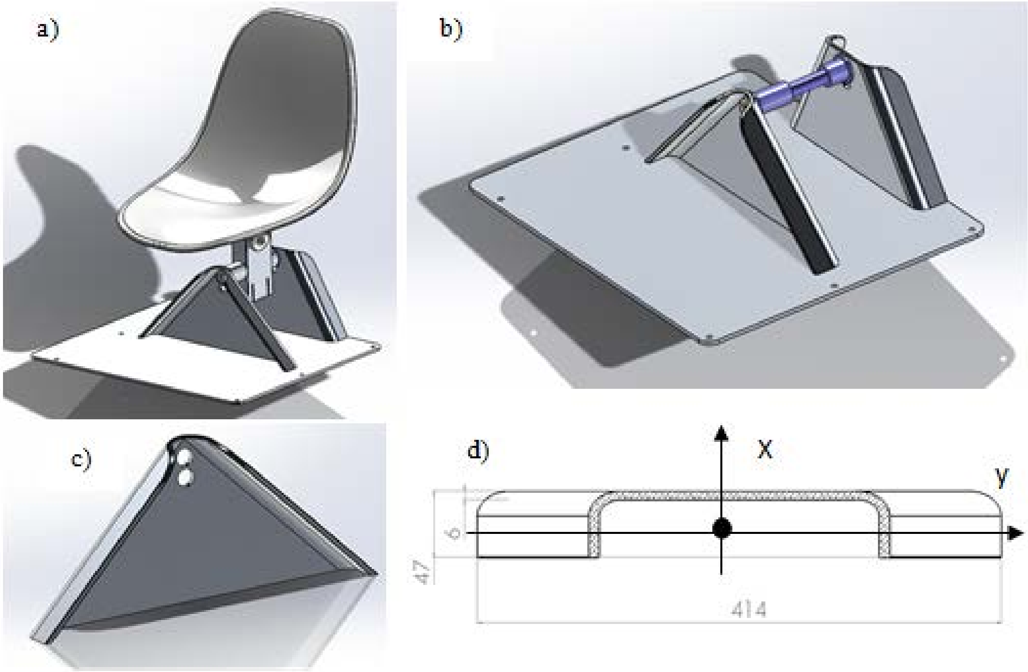
| Si | Fe | Cu | Mn | Mg | Cr | Zn | Ti |
|---|---|---|---|---|---|---|---|
| 0.2-0.6 | <0.35 | <0.1 | >0.1 | 0.45-0.9 | <0.1 | <0.1 | <0.1 |

***Table 2.*** *Mechanical properties of aluminum*

| | | **Ultimate tensile strength σu[MPa]** | **Tensile yield strength σy[MPa]** | **Elongation at break [%]** |
|---|---|---|---|---|
| **Al 6063 T6** | **Thickness <10 mm** | 215 | 170 | 8 |

The solid model of swiveling seat in the original geometrical configuration is reported in Figure 3. Moreover, the strength on the support is calculated with consideration of two different loads: the first is vertical due to the P load (it acts on the pin seat), while the second one is horizontal due to inertial effects.

*Figure 3. 3D model of swiveling seat. (b) 3D model of swiveling seat without chair. (c) 3D model of the bigger support. (d) "C" section of the bigger support. Source: Authors.*



This first analysis shows an initial, technical overview of the system; in which the most critical section has also been outlined. After this initial test, the support safety factors were analyzed and calculated following a standard procedure. In order to obtain a lighter structure, the safety factor has been made more uniform along all the supports; to modify this factor, the geometric configuration was changed (Figure 3 (c)). Another critical element of the structure is the pin that allows the swiveling of the seat. The external diameter of the hollow pin is 20 mm and the internal diameter is 18 mm; this is also made of 39 Ni Cr Mo3 steel. (Ente Nazionale di Normazione, n.d.) The chemical composition and mechanical properties of the hollow pin are reported in Table 3 and Table 4.

*Table 3. Chemical composition of hollow pin steel*

| C | Mn | Si | Cr | Ni | Mo | P | S |
|---|---|---|---|---|---|---|---|
| 0.35-0.43 | 0.5-0.8 | 0.15-0.40 | 0.6-1.00 | 0.7-1.00 | 0.15-0.25 | <0.35 | <0.35 |

*Table 4. Mechanical properties of hollow pin steel*

| | | **Ultimate tensile strength σu[MPa]** | **Tensile yield strength σy[MPa]** | **Elongation at break [%]** |
|---|---|---|---|---|
| **39 Ni Cr MO 3 (hardened and tempered)** | **ϕ>16 mm** | 930-1130 | 735 | 11 |

The ability of this material to resist corrosion is high, and necessary due to is frequent contact with sea water. The effect of corrosion on any component, even in static loading conditions, also significantly decreases the mechanical performance of the component.(L. Solazzi, Scalmana, Gelfi, & La Vecchia, 2012)

The hollow pin is primarily subject to shear strength; furthermore, the previous consideration about the reaction forces is used to provide a further check analysis. The aim of this dimensioning is to consider the worst load situation. In this case, the worst load example exists when all of the P load acts on only one of the supports. The hollow pin is safety dimensioned with a very high safety factor, and for this reason, 39 Ni Cr Mo 3 steel has been used to increase stiffness.(Ente Nazionale di Normazione, n.d.)

## *FEM analysis*

In order to determine the strength and deformation ranges on the structure, a 3D model and FEM (finite element method) of the existing sitting system have been carried out.

FEM analyses are usually used for nonlinear structures and allow the study of a complex and bound geometry that would otherwise be difficult to treat as a simple model. FEM analysis subdivides a large problem into smaller, simpler, parts. This subdivision into finite elements achieves not only an accurate representation of complex geometry, but also an inclusion of dissimilar material properties, an easy representation of the total solution, and captures the local effects.

The structure has been analyzed in configurations with one, two and three loads. In all simulations, some parameters have been defined, such as the kind of analysis (static strength with linear model material), materials of the components (pins: 39 Ni Cr Mo 3; (Ente Nazionale di Normazione, n.d.) central bushings: Nylon 101; other components: Al 6063-T3 (European Standard Organization, n.d.)) and constraints (the bottom plate is fixed while the lower part of the base of the seat is hinged).

An important aspect to consider is the displacement of the center of gravity (CG) of the athlete.

Figure 4 shows the displacement of the center of gravity as a result of the rotation of the seat (maximum rotation $\alpha$= ±25 °). Strengths on the structure are induced by the weight (including dynamic effects) and by the actuator, whose is dependent on the position of the seat. For example, when the seat is upright ($\alpha$ = 0 °), the actuator does not generate any force. Also, the force of the actuator was determined by balancing the rotation around the pin. In particular, it was assumed that the distance of the athlete's center of gravity from the pin is equal to 480 mm (a), while the distance between the actuator point and pin is 90 mm (b).

The analysis is separated into three cases to give values to the different contribution of loads on the distribution and magnitudes of the stresses. Although, each load is distributed and has a value equal to P.

The first load case consists solely of a vertically distributed load, representative of an inertial load. In the second case, there is a vertical and horizontal load. Finally, the third load case consists of a vertical load and two horizontal loads.

*Table 5. Applied forces of the FEM analysis for the current seating system in the studied three different load configurations.*

| Load case | Forces in Z direction [N] | Forces in Y direction [N] | Forces in X direction [N] |
|---|---|---|---|
| **First case** | 1680 | 0 | 0 |
| **Second case** | 1680 | 1680 | 0 |
| **Third case** | 1680 | 1680 | 1680 |

*Figure 4. Representation of load conditions (i) on the three axes (ii) on the two axes (iii) angle of inclination. Source: Authors.*

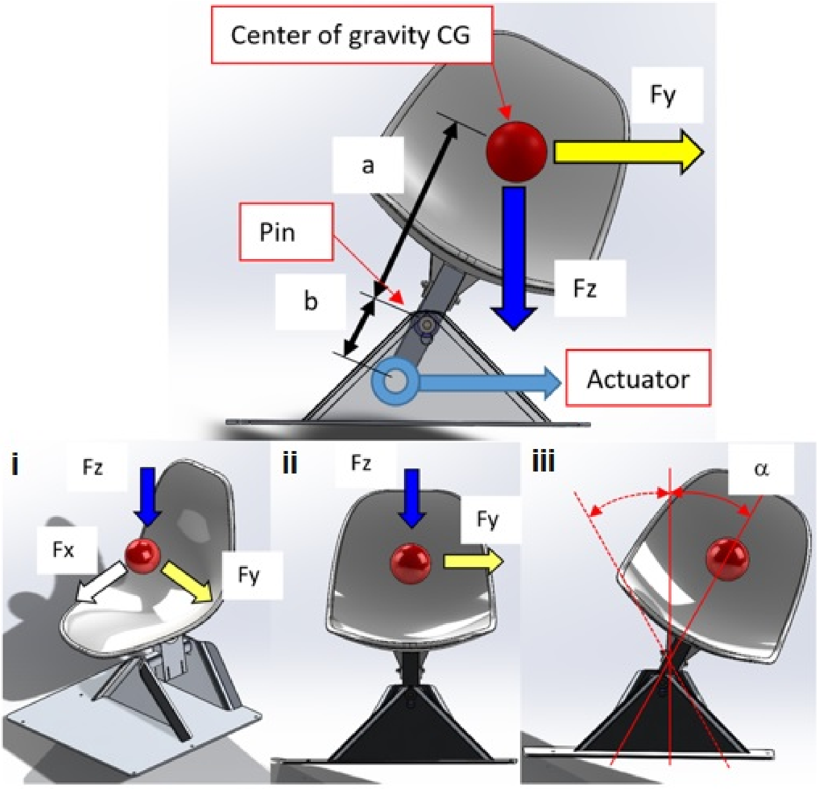


*Figure 5. Results of the FEM analysis of the current structure. (a), (b) displacement and stress of first loading condition (c), (d) displacement and stress of third loading condition. Source: Authors.*

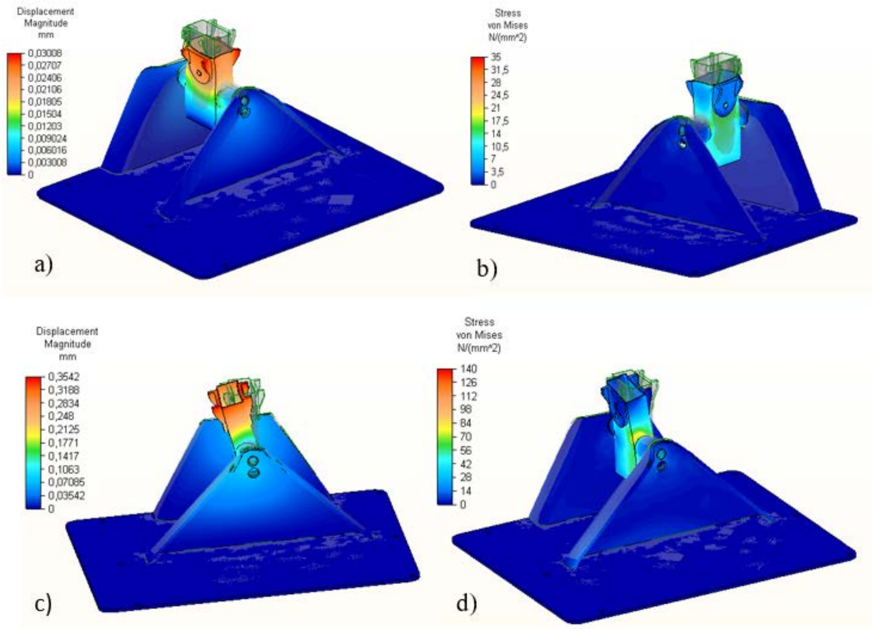


*Table 6. Results of the FEM analysis for the current seating system in the studied three different load configurations.*

| Load case | Maximum stress [MPa] | Maximum displacement [mm] |
|---|---|---|
| First case | **32**.5 | 0.030 |
| Second case | 85 | 0.252 |
| Third case | 145 | 0.354 |

This analysis also shows that supports and the bottom plate are not critical. In fact, stress and displacement values are very low for the first and second load case. In the third load condition, which considers all force components, the stresses are much higher. However, the maximum value of stress is lower than the yield limit of the material.

## Improved seat

In the new structural seat proposal, the extra material has been removed according to the previous analysis, to decrease the weight of the structure. A series of preliminary studies were carried out by adopting composite materials. However, the increased cost made this choice unviable regardless of the significant weight reduction. An aluminum alloy with high mechanical properties compared to the original seat has been used for the structure. Otherwise, the same material has been maintained for the hollow pin. The alloy adopted for the realization of the structure is the aluminum Al 7075 (Ente Nazionale di Normazione, n.d.) which is used in the aeronautical sector; the characteristics are reported in Table 7 and Table 8.

*Table 7. Chemical composition of aluminum*

| Si | Fe | Cu | Mn | Mg | Cr | Zn | Ti |
|---|---|---|---|---|---|---|---|
| 0.4 | 0.5 | 1.2-2.0 | 0.3 | 2.1-2.9 | 0.18-0.28 | 5.1-6.1 | 0.2 |

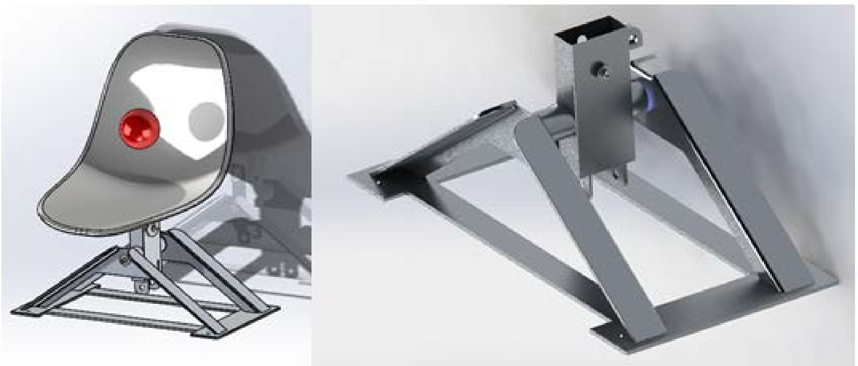
*Table 8. . Mechanical properties of aluminum*

| | | Ultimate tensile strength σu[MPa] | Tensile yield strength σy[MPa] | Elongation at break [%] |
|---|---|---|---|---|
| **Al 7075 T6** | **Thickness <10 mm** | 510 | 430 | 5 |

In the original structure there were two different supports: one large and one small. They were oversized, for this reason the type of material has been maintained, but the shape has been changed (Figure 6). In order to keep the same safety factor of the actual structure, the critical area has remained constant along the vertical direction of the support. A new support shape has been created in order to exhaust the load directly on the drivings.

The original bottom plate has been replaced with four welded plates in order to recover the oversizing of the existing seat. All these modifications are presented in Figure 6 in which the new structural proposal is shown.

*Figure 6. New sitting system. Source: Authors.*



The improvements in this new seat include better load distribution and a reduction in weight; this innovative structure's weight is decreased by about 50% from the original structure. The price of the supports and bottom plates are also estimated at about 150 €, that is lower than the price of original structure. The stress tension is also approximately equal to the current model.

## FEM analysis

The structure has been analyzed with a FEM analysis using the same load conditions as the original structure with one, two and three loads (Figure 7).

*Figure 7. Results of the FEM analysis of the improved model. (a), (b) displacement and stress of first loading condition (c), (d) displacement and stress of third loading condition. Source: Authors.*

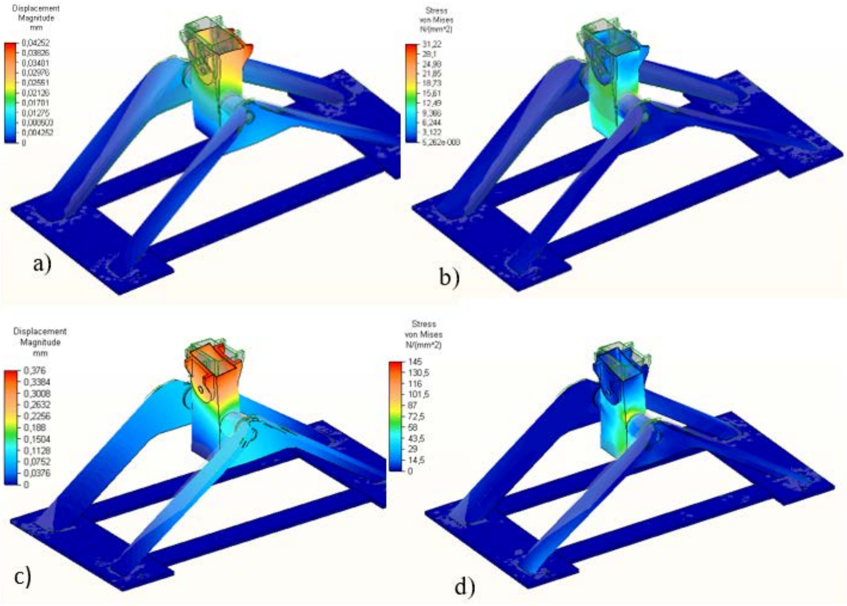


*Table 9. Results of the FEM analysis for the new seating system in the studied three different load configurations.*

| Load case | Maximum stress [MPa] | Maximum displacement [mm] |
|---|---|---|
| First case | 30 | 0.04 |
| Second case | 60 | 0.230 |
| Third case | 140 | 0.370 |

Figure 7 also shows that the areas of highest stress are similar to the previous structure. Moreover, the FEM analysis shows that maximum displacement values are very close to the values of the existing structure.

*Table 10. Safety factors and displacement comparison between the existing seat and new proposals.*

*a) First load case*

|  | Current | Proposal |
|---|---|---|
| η (safety factor) | 11.3 | 14.3 |
| CG Horizontal displacement [mm] |  |  |

*b) Second load case*

|  | Current | Proposal |
|---|---|---|
| η (safety factor) | 4.2 | 6.3 |
| CG Horizontal displacement [mm] | 0.252 | 0.230 |

*c) Third load case*

| | **Current** | **Proposal** |
|---|---|---|
| η (safety factor) | 2.5 | 2.5 |
| CG Horizontal displacement [mm] | 0.354 | 0.370 |

The safety factor is calculated with respect to the improved structure. The hollow pin does not create any safety issues, and it has also been observed that the new proposal is the safest out of all three cases. Compared to the actual structure, the first and in the second load cases present a higher safety factor (η), while the third case η remains the same as in the existing seat. In comparison with the second proposal, η remains the same in the first and in the third cases and higher for the second case. The structure of the first proposal allows for lower distribution of stresses, so that the seat base is relieved by them.

In the second case, the new proposal presents the most rigid; the CG displacement is also lowest of all of the other models. In the third case, the new proposal is more rigid than the second but with a higher level of deformity than the current structure. It may therefore be concluded that the new supports are more deformable (than the actual ones) if they are loaded by a force in the pin axis direction.

## *Movement system*

The required movement of the swiveling seat presents a roll rotation of ± 25° with respect to the vertical axis through the centroid of the seat itself. This angular movement is translated into a linear translation of the actuator piston of 76 mm.

To maintain the dimensional specifications of the current structure, the required force from the actuator is equal to 13140 N. In this case, the sizing is used to choose the optimum drive. The required power for moving the load is 0.2 kW so the power actuator must be higher than the calculated power. The original linear actuator, Warner K2xG10 - 12v_0.4 (Warner linear, 2016),powered by direct current (DC) - is the first movement device, which has been chosen for its speed and compatibility with the required speed. The price is also affordable and presents an average cost of 500€.

It was verified that the power needed to overcome the forces is equal to 0.2 kW, but the actuator chosen must have the necessary parameters to achieve the desired stroke with the speed required, if the size characteristics of the structure are to remain unchanged.

This drive is reversible and movement is more accurate and in the absence of a power supply it will not be able to maintain its position with an applied load. This irreversibility gives more stability to the athlete, (i.e. it avoids additional forces applied to the structure as well as ensures greater precision to the movements).

In addition, the type of engine is also maintained and is powered by direct current (DC) in order to maintain the battery already supplied, and remove the possibility of the requirement for additional components such as a transformer. When selecting the drive, the service of the drive must also be considered, which is characterized by the duty cycle. As required by the actuator operation, this parameter is not restrictive because the movement does not require a continuous service or an immediate reaction to the load.

The possibility of connecting a linear actuator drive without a motor, and with a gear-motor, is evaluated to keep the dimensional characteristics of the structure unchanged, and to introduce the irreversibility properties.

The actuator and related gear-motor chosen are Thomson Electrack FA14 10B65 (Thomson Linear Motion, 2016a) and Thomson AKM24C respectively (Thomson Linear Motion, 2016b.) All adjustments and lubrication are made at a factory level, and it is not required or recommended that further maintenance be completed throughout its duration, as the actuator ensures consistent performance and is reproducible. The component Electrack FA14 10B65 has a flange for mounting of the gear-motor, and is durable and robust. This is optimal because the actuator is used in an open atmosphere in contact with water and salt. The stem is made of stainless steel and has a cover tube of corrosion resistant aluminum.

Furthermore, this actuator allows attaining a maximum speed of 19 mm/s; its speed is compatible with the required speed of 17 mm/s in order to have the stroke time equal 4 s.

This model has been chosen despite being driven ball screw and is reversible because this will be compensated by the gear-motor with a transmission ratio of 1:50. The gear-motor, AKM24C, which drives the actuator, offers the precision and performance required by the most demanding motion control environments and fits perfectly for this elaboration. This actuator is the best option for several reasons, such as its irreversibility, the possibility of maintaining the dimensional features, and the price.

## Conclusion and result application

This research work is focused on the analysis of the structure of a swiveling seating system for the SKUD 18 boat by evaluating different values of tensile strength of materials. In this way, it was possible to study and present a suitable improved proposal for this Paralympic boat seating system. The aim of this work has been to improve the performance and ergonomics of the swiveling seat for athletes using the SKUD 18.

The support section has been changed, and it allows both a reduction of about 50% material weight, as well as better stress distribution. This is possible thanks to a reduction in the base of the seat (the top of the structure), and the safety factor of the whole structure, which has been increased.

The new structure has the load directed downwards on the drivings of the seat so deformation is reduced on the bottom plates. The disadvantage of the current seating system driving is its reversibility, and the driving chosen for the new swiveling seat achieves irreversibility without a change in the price. The actuator, Thomson Electrack FA14 10B65, and relative gear-motor, Thomson

AKM24C, are irreversible and there is a possibility of maintaining the same dimensional features as the previous actuator.

The system can also be developed further, and changes in the structure have been produced without distorting that of the original. In this way, the material used can be changed as well, in order to decrease the total weight, but maintain the same tensile strength.

The driving has been chosen to maintain the same type of engine, and is powered bywith direct current. This is necessary to maintain the battery charge and remove the requirement for additional components, such as a transformer, for the system. In future developments, a new movement concept could be investigated in order to optimize not only the rotation of the system, but also ergonomics. In conclusion, this structure is being built and it will be settled in the SKUD 18 of the Italian national team that will compete at Rio 2016 Paralympic games.

## References

[1] Ashby, M. F. (2005). Materials Selection in Mechanical Design. Design, 624. ISBN 978-0-7506-6168-3. Retrieved from http://www.knovel.com/web/portal/browse/display?_EXT_KNOVEL_DISPLAY_bookid=1472

[2] Blauwet, C. A., & Iezzoni, L. I. (2014). From the Paralympics to Public Health: Increasing Physical Activity Through Legislative and Policy Initiatives. PM&R, 6(8), S4–S10. doi:10.1016/j.pmrj.2014.05.014

[3] Collotta, M., Solazzi, L., Pandini, S., Tomasoni, G., Alberti, M., & Donzella, G. (2016). Design and realization a skiff racing boat hull made of natural fibers reinforced composite. AIP Conference Proceedings, 1736(1). doi:10.1063/1.4949706

[4] Ente Nazionale di Normazione. (n.d.). Reference standard - UNI 7845.

[5] Ente Nazionale di Normazione. (n.d.). Reference standard - UNI 9007/2.

[6] European Standard Organization. (n.d.). Reference standard - EN 755.

[7] Hansa Sailing. (2016). Boats: SKUD 18. Hansa webpage. Retrieved October 15, 2017, from http://hansasailing.com/about-us/

[8] Hettinga, F. J., Valent, L., Groen, W., van Drongelen, S., de Groot, S., & van der Woude, L. H. V. (2010). Hand-Cycling: An Active Form of Wheeled Mobility, Recreation, and Sports. Physical Medicine and Rehabilitation Clinics of North America, 21(1), 127–140. doi: 10.1016/j.pmr.2009.07.010

[9] Morton, K. (2008). Brits gunning for Paralympics sailing glory. Yacht and yachting. Retrieved July 12, 2016, from http://www.yachtsandyachting.com/news/143298/Brits-gunning-for-glory

[10] Solazzi, L. (2010). Design of aluminium boom and arm for an excavator. Journal of Terramechanics, 47(4), 201–207. ISTVS. doi:10.1016/j.jterra.2010.03.002

[11] Solazzi, L. (2012). Applied research for weight reduction of an industrial trailer. FME Transactions, 40(2), 57-62.

[12] Solazzi, L., & Scalmana, R. (2012). New Design Concept for a Lifting Platform Made of Composite Material. Applied Composite Materials, 20(4), 615–626. doi:10.1007/s10443-012-9287-2

[13] Solazzi, L., Scalmana, R., Gelfi, M., & La Vecchia, G. M. (2012). Effect of Different Corrosion Levels on the Mechanical Behavior and Failure of Threaded Elements. Journal of Failure Analysis and Prevention, 12(5), 541–549. doi:10.1007/s11668-012-9593-x

[14] Thomson Linear Motion. (2016a). Electrak Non-Driven Actuator FA14: 54. Retrieved July 12, 2016, from http://www.thomsonlinear.com

[15] Thomson Linear Motion. (2016b). AKM Gearmotor Selection Guide – Standar Line: 10-12. Retrieved July 12, 2016, from http://www.thomsonlinear.com

[16] Tweedy, S. M., Beckman, E. M., & Connick, M. J. (2014). Paralympic Classification: Conceptual Basis, Current Methods, and Research Update. Pm&R, 6(8), S11–S17. American Academy of Physical Medicine and Rehabilitation. doi: 10.1016/j.pmrj.2014.04.013

[17] Warner linear. (2016). P_1581_WL. Retrieved July 12, 2016, from http://www.altraliterature.com

[18] Webborn, N., Uk, B. S. F., & Emery, C. (2014). Paralympic Sports Medicine and Science Descriptive Epidemiology of Paralympic Sports Injuries. Pm&R, 6(8), S18–S22. doi: 10.1016/j.pmrj.2014.06.003