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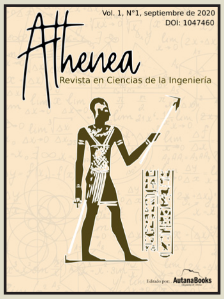
Nuestra Portada:



En nuestra portada se encuentra la imagen del primer ingeniero de la historia, conocido como Imhotep, cuya biografía se remonta al año 1700 a.c. Fue un científico, tanto en las áreas médicas, como en la astronomía. Era considerado por el pueblo egipcio como el dios de la sabiduría. Su mayor obra fue la pirámide escalonada de Saqqara, destacándose entonces como ingeniero y arquitecto [1].

[1]M. Vite, «Quora,» 2020. [En línea]. Available: https://es.quora.com/Qui%C3%A9n-est%C3%A1-considerado-como-el-primer-ingeniero.

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CONTENIDO

EDITORIAL

Las ciencias de la ingeniería son aquellas carreras que han trascendido la historia dándole forma a las nuevas civilizaciones, fomentando nuevos desafíos para el desarrollo industrial y arquitectónico. Así nace la Revista Athenea, como un medio de comunicación y divulgación de las ciencias que componen la ingeniería, de todas las áreas que impulsan las nuevas tecnologías y el desarrollo científico y técnico. Esta revista pretende recoger los aportes científicos de profesionales, investigadores, apasionados de la ingeniería que hacen posible la transformación industrial y tecnológica de los nuevos tiempos.

La Revista Athenea abre sus hojas para plasmar los resultados de investigaciones que como granitos de arena llenan el mar de la ciencia, aportan al desarrollo y al crecimiento industrial, a las mejoras tecnológicas, al porvenir de las nuevas generaciones de profesionales.

Franyelit Suárez

Editora

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Impact on the video game industry during the COVID-19 pandemic

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Abstract: This work presents trends and comparisons that show a change in the consumption and production of video games in times of confinement due to the health emergency. The video game industry has modified its philosophy and adapted its products to the new requirements and trends of consumers who see in this activity a way to appease the psychological and social impact due to quarantine and isolation. There is evidence of a 65% increase in the use of online video games, which has broken a world record. Products that have new aspects and considerations never before proposed by this great industry have been developed and offered, such as thematic games related to the COVID-19 pandemic.

Keywords: Video game, pandemic, online games, confinement.

Impacto en la Industria de los videojuegos durante la pandemia por COVID-19

Resumen: Este trabajo presenta tendencias y comparaciones que evidencian un cambio en el consumo y producción de los videojuegos en tiempos de confinamiento debido a la emergencia sanitaria. La industria de los videojuegos ha modificado su filosofía y ha adaptado sus productos a los nuevos requerimientos y tendencias de los consumidores, quienes ven en esta actividad, una forma de apaciguar el impacto psicológico y social debido a la cuarentena y aislamiento. Se evidencia un incremento del 65% en el uso de videojuegos en línea, la cual ha batido record a nivel mundial. Se han desarrollado y ofertado productos que poseen nuevos aspectos y consideraciones nunca antes propuestos por esta gran industria como los juegos temáticos relacionados con la pandemia por COVID-19.

Palabras Clave: Videojuego, pandemia, juegos en línea, confinamiento.

I.INTRODUCTION

Changes in social, economic and psychological aspects such as isolation, the global market crash and behavioral variations in people, have been imposed unexpectedly during the quarantine period caused by the Covid-19 pandemic worldwide [1]. These changes have been internalized by multiple industries and sectors that have expanded their market niches to improve productivity and economic growth. The video game industry, when linked to the world of entertainment and influenced by these changes, has increased its demand in the last two years and has become a domestic activity within a normal day at home, presenting a record in sales and a predominant positioning in the world market [2].

Even before the pandemic, the growth in demand for video games was evident, therefore, its philosophy of continuous improvement has managed to capture the attention of its consumers through the use of cellular devices, implementing new technologies and through the incorporation of new techniques like non-player characters that allow the implementation of dynamic, credible and strategically unpredictable behaviors, which make the player want to get involved in the game's plot, capturing their attention considerably [3].

The current situation has motivated the video game industry to focus its attention on promoting online games which, from the user's point of view, offers an escape from reality to have fun safely, foster relationships with others people and share experiences, sometimes fostering empathy and creating pro-social themes [4].

The educational system, also affected by social distancing, has seen in video games the opportunity to keep its students safe and at the same time keep them entertained. In recent years, teachers have integrated video games and virtual education as a way of fostering global empathy in children and young people, in other words, interest and curiosity to learn more about other countries and feel identified with their cultures [5] [6], as well as strengthening their skills and technical abilities [7]. Video games as a learning tool highlight the following typical characteristics of a 21st century video gamer: Being the strategist by fulfilling missions, being the creator by making his own game, being the communicator by building relationships and communities, being the hero by overcoming a great adventure, and be the creator of worlds and situations [8] [10]. However, there are video games that provide violent and socially resentful content, which is why it is important that parents accompany them in choosing and controlling the type of video game their allowed to play, especially amongst younglings [11] [12].

The possibility of using online multiplayer video games has become a tool for users of all ages and even in organizations in which these activities are of notable interest within the course of their working hours [13].

The largest number of video game sales worldwide during the quarantine, consist of Grand Theft Auto V, Red Dead Redemption 2, FIFA 20 and in the rpg category, Tomb Rider has emerged. During this time, the increase in users has been substantial in the market due to the quarantine and the notable influence that these video games have had even when they were already well positioned comercially [14] [16].

The quarantine marked a before and after in the video game industry since it has encouraged users from all over the world to learn and enjoy a good video game and, above all, mark a challenge for their designers in order to adapt them to the new user requirements and demands [17] [18].

The advantages of using video games has also been an important factor in the development of new products in the environment of this pandemic. It should therefore be taken into account that play lowers anxiety levels [19], contributes to intelligence, ensuring good judgment in decisión making and the importance of playing in safe spaces and in family ties.

Taking into account that the excessive use of video games could also alter the behavior of children and young people, other studies affirm that the moderate use of video games can be a powerful pedagogical tool to enhance learning not only in traditional content, but also in the formation of social and digital skills, which are key to function in modern society and include: concentration and the ability to multitask[20]. They can also positively affect reaction time, processing speed, and reduce stress levels.

The video game industry has offered new thematic products in its different genres or categories in order to help and inform children, young people and adults of the risks of exposing themselves without protection to the outside environment. For example, in Spain the company Virtual Recall [21] has developed a game called Coronavirus Attack for mobile devices and computers in which players must destroy COVID-19 by means of a ship, positioning it in the adventure and action genre. Another game developed by the company Omnium Lab, called Covid Game, is designed for mobile devices and tablets and encourages children to stay at home and experience multiple situations teaching them to have good hygiene and prevention habits such as washing their hands.

Covid Game is placed in the adventure genre as well [22]. Other games in the educational games category have also been released during the pandemic, such as Immune Attack and Foldit, which help children understand the configuration of molecules and biological processes through 3D puzzles. Within the sports category, games such as esports have been highlighted in favor of avoiding contagion risks [23]. And furthermore, video games are at the forefront of the online battle arena multiplayer genre too with famous titles, such as Leguage of Legends [24], whose generated profits contribute to campaigns to combat COVID-19.

II.DEVELOPING

Impact of the Video Game Industry due to the COVID-19 pandemic.

A.Video game consumer trends

The COVID-19 pandemic produced a total change in the habit and ways of living of people, as well as affecting the way they consume their products and the performance of habits at home. The use of video games has taken an important position within the 20 most important activities that people prefer to carry out during quarantine [25], as presented in Figure 1.

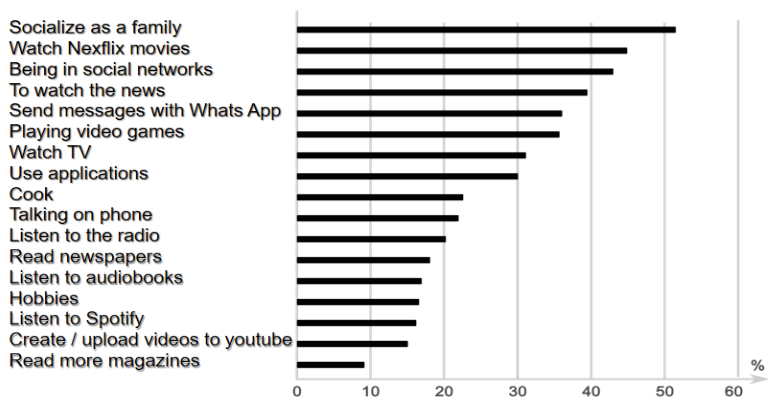

Fig. 1 - Activity usage graph during quarantine [25]

The growing demand in the consumption of video games during quarantine has revealed economic changes to the benefit of this industry showing an increase in the sales within the countries with the highest video game consumers (China 250% in video game sales and Australia 285% in sales of consoles), as well as consoles during the quarantine [26], in short, breaking records sales and impacting the world market on a large scale (figure 2).

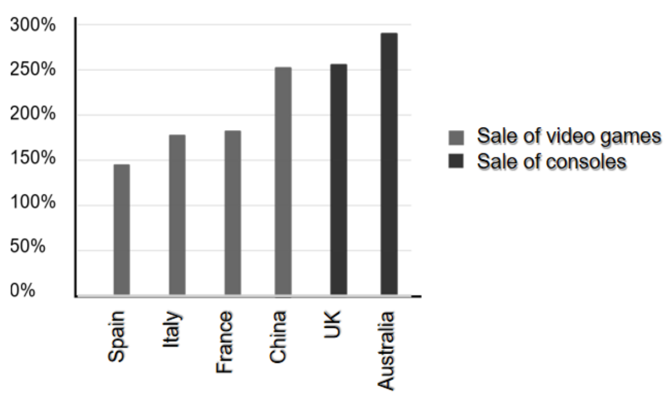

Fig. 2. Graph of video game and console sales in some countries [26]

The rapid growth of the video game industry also entails a degree of uncertainty in investors who, despite benefiting at present, cannot fully anticipate the new changes that will occur when returning to normality after the pandemic.

Young people between the ages of 13 and 24 have doubled their time spent in video games, impacting the big brands. Both the video game industry and other sectors have seen the need to train their employees in the area of social networking as a strategy to maintain investment in the face of new users called hyperconnected users[27].

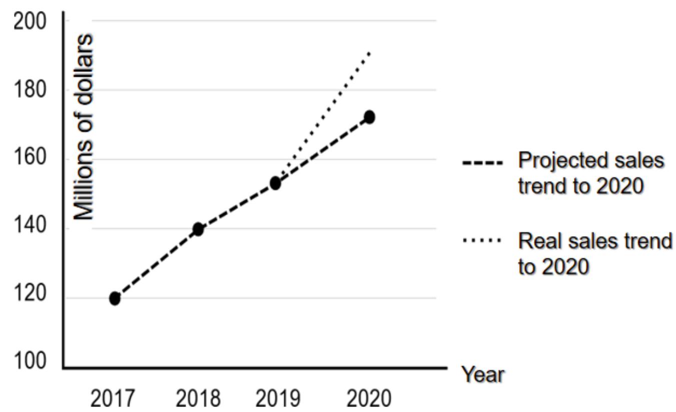

Fig. 3. Real and programmed trend of video game sales in 2020 in Billions of dollars

Figure 3 consists of a graph that shows the increase in real sales, comparing them with the projected sales for the last 3 years up to the first months of 2020 [26] [28], exceeding projected expectations and forecasts by 30% more in gains from 168 to 188.8 billion dollars in video games.

Regarding the games that have been downloaded the most during the pandemic, there are Hunter Assassin, with almost 100 million downloads between Google Play and the App Store, followed by Brain Out (slightly less than 90 million), Johnny Trigger and Woodturning (above out of 75 million) and PUBG Mobile slightly below 75 million downloads [29].

In figure 4, the countries mentioned in this section are highlighted in terms of video game consumption throughout the first two quarters of 2020, as a result of the quarantine and taking into account the number of downloads, evidencing except for China, growth compared to the months after February. It is worth mentioning that China was one of the countries that faster overcame the confinement and returned to its normal activity, which would explain the downloads decrease, for the same months [30].

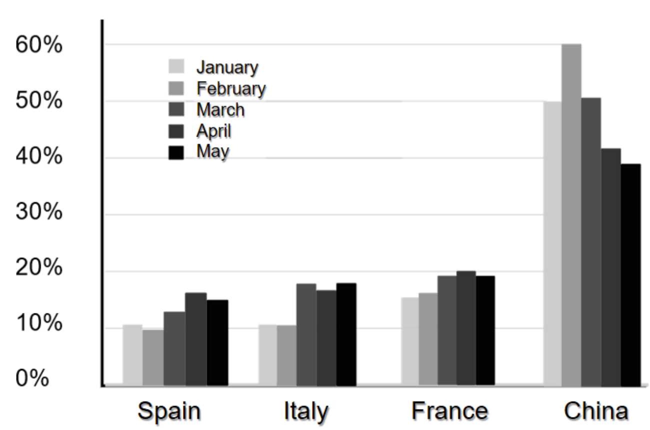

Fig. 4. Video game consumption trends in 2020 in Millions of downloads [30]

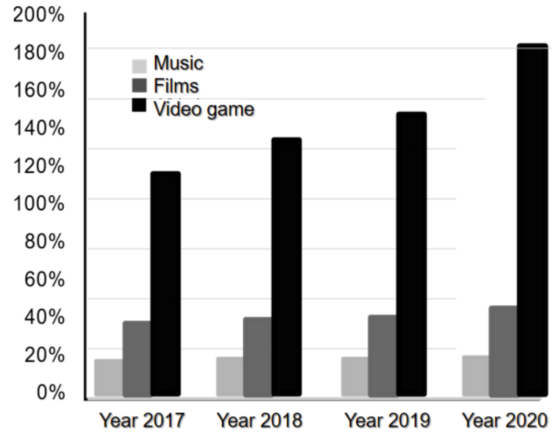

Fig. 5. Comparative graph between user preferences for entertainment in billions of dollars [32]

The notable increase in video games can be justified because, since 2010, video games were not only constituted in the field of entertainment, but also incurred in the educational and cultural field, while films and music still have more representation in the field of entertainment. These considerations enshrine the growth of the profits generated evidenced from 2017 to 2020, even without considering the effect of the COVID-19 pandemic.

At present, the production and design aspects of video games have become crucial, since new products are required as a consequence of the current situation, forcing a change in habits and thus promoting the consumption of online video games.

B.Changes in the video game industry in times of pandemic.

Based on a review of the titles promoted for the year 2020, it can be considered that the video game industry, with respect to the supply of its products, has not been significantly affected [33]. However, the only drawbacks have been face to face events on this subject.

The production regarding the most widely accepted consoles in the world, incorporates developments with improvements in technology and immersive capacity of the player towards the video game. For the use of the PlayStation 5 (PS5) platform, Sony Interactive Entertainment has presented the video game alternatives compatible with the new console, among these titles are new games in the usual categories in Adventure, strategy, sports, action, simulation and role. As a new contribution due to the influence of the situation, the game Plague INC, Envolve, was promoted for PlayStation, which has characteristics of a realistic simulation and strategy game in which the player must survive the extinction of humanity caused by a lethal pandemic [34]. This game was available on the App Store for eight years, but it has been withdrawn from the gaming scenarios for being considered an inappropriate game in times of pandemic, since the game includes material related to viruses in humanity that could be confused with alteration of information on COVID-19 [35].

The video game industry, together with the World Health Organization (WHO), have proposed in a campaign, the use of a video game called PlayApartToghter, whose purpose is to socialize messages and preventive actions promoted by this institution in order to avoid the spread of the Covid-19 [36] [37].

C.Trends in the workplace in the video game industry

The impact of the video game industry during the quarantine has created trends in its users, especially high school youth when choosing a university degree, and it is precisely that video game design has become an official profession today [38], and is catapulted into the most demanded and best paid careers, due to the consumption generated in this last semester. This trend has created certain advantages, such as the convenience of studying online at home, time flexibility, and affordable. Today this profession is being promoted throughout the world through universities [39].

Unlike the rest of the productive sectors where the impact of the pandemic has generated unemployment, in the video game industry, the number of hires has grown and benefited professionals in this area [40]. At present, these professionals are part of a stable and safe profession, not only due to times of pandemic, but also due to the growth of this industry since before the crisis. Figure 6, extracted from [40], presents the demand for experts compared to the professions in the field of multimedia production, where it is evident that video game designers are well positioned with respect to the other disciplines.

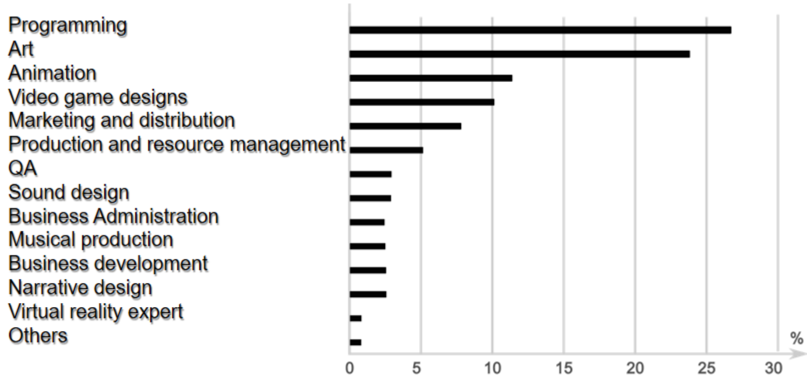

Fig. 6. Job offers in the field of multimedia production by type of profile in 2020 [40]

In addition to this, there are 49% of workers in the video game industry who are not over 30 years old and only 3% are over 45. Of this total of employees, 71% have completed higher education (undergraduate, graduate) and 23 % have completed intermediate studies (diploma, higher vocational training). However, 53% of the companies claim not to have hired a properly competent staff, the reason being the lack of experience within the technique that evolves rapidly [40].

III.METHODOLOGY

For this work, the bibliographic research was considered, taking into account three fundamental aspects that are the trends of the video game consumer, the changes that the video game industry has experienced and the labor aspect that this industry offers.

Regarding consumer trends, an exhaustive search was carried out for preferences, countries with the highest consumption of these products.

To expose the changes that the video game industry has presented, new products have been sought and analyzed, the relevant aspects that benefit the sector, opportunities and decisions regarding the adaptation that has been made to better satisfy the customer.

Finally, statistics have been presented on the job opportunity that video game designers currently have, in addition to the influence that video games have on decisions about related professional careers and their advantages.

IV.RESULTS

16 scientific articles from the years 2019 and 2020 were analyzed, compiled from magazines related to studies of the video game industry, and multidisciplinary sources, in addition, statistics from reports of 20 web pages on the subject under study were considered, in which took into account the collection of those that were strictly relevant to COVID-19.

35.5% [25] (figure 1) of users who prefer video games were evidenced, as part of the time spent working and doing household activities. This figure includes the family, especially the children and young people of the house, evidenced by surveys by the Research & Insights company, which is a social and market research agency.

The massive consumption of video games has positioned China with 250% more sales of video games, this figure has been maintained in the last 3 years, due to its large population and the continuous improvement of technologies [26] (figure 2).

Countries such as Spain experienced a great demand of video game designers and developers who can satisfy the massive consumption that especially has had an exponential growth in the first half of 2020 due to the pandemic. A demand for programmers is evidenced in 27% (figure 7) [40].

The massive sale and download of video games during the quarantine is explained by the confinement of children and young people who have changed their daily activities and certain habits due to the closure of schools and colleges, in addition to outdoor and shared activities, such as sports activities, group games and among others.

An abrupt rise in 2019 was observed in the analysis with an increase in global sales in the video game industry by 20.8 billion dollars, which represents 30% of profits compared to COVID-19.

The impact of the video game industry has caused countries such as China, France, Italy and Spain to predominate video game downloads on mobile devices, increasing by 30% less in China, which shows growth of more than 60 Millions of downloads in the month of February.

V.CONCLUSIONS

The global impact that the COVID-19 pandemic has determined in the world of video games has been clearly evidenced not only in sales figures, but also in changes in learning strategies, marketing and habits in children, youth and adults within their homes that, of course, will unleash social, economic and psychological consequences.

It must be remembered that video games were initially developed in a solitary way, but this evolved and network games became a great attraction for consumers, but in this time of pandemic there was a much more relevant growth, being the development of meetings and collaboration between users are being one of the fields in evolution.

In the labor field, the demand for professionals increases due to this health crisis, as well as the lack of experience and academic training on the part of professionals in the field of programming, as a competition in this new era of video games and new styles of lifetime.

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Innovation, Evolution and History of Technology in Industry

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Abstract: This paper presents a description of the history of the technology used in the industries, its evolution regarding the use of energy and the processes that have innovated it within the industries. It describes the technology that highlighted industrial revolutions from the first to the present, and presents estimates of future trends. The evolution presents changes regarding energy consumption and efficiencies in the use of technologies in the industry. The innovation presents the changes or techniques implemented to obtain greater benefit from the technology and respond in a better way to the market demand. Clear trends are identified in the increased use of technology in industries with respect to their labor and energy consumption.

Keywords: Technologies, industrial revolutions, innovation.

Innovación, Evolución e Historia de la Tecnológica en la Industria

Resumen: Este artículo presenta una descripción de la historia de la tecnología utilizada en las industrias, su evolución en el uso de la energía y los procesos que la han innovado dentro de las industrias. Describe la tecnología que destacó las revoluciones industriales desde la primera hasta el presente y presenta estimaciones de tendencias futuras. La evolución presenta cambios en cuanto al consumo de energía y eficiencias en el uso de tecnologías en la industria. La innovación presenta los cambios o técnicas implementadas para obtener un mayor beneficio de la tecnología y responder de mejor manera a la demanda del mercado. Se identifican tendencias claras en el mayor uso de tecnología en las industrias con respecto a su consumo de mano de obra y energía.

Palabras Clave: Tecnologías, revoluciones industriales, innovación.

I.INTRODUCTION

The term revolution suggests a radical change in the use of technologies and approaches to perceive the world [1], whose consequences affect economic systems and social structures. Throughout history and around the world, three industrial revolutions have been known, which have triggered a fourth revolution and optimizes all the knowledge learned, creating spaces to take gigantic leaps in terms of information technologies (ICT).

As technology evolves, the enormous capacity and potential from which different industrial sectors can benefit becomes more visible, as has been demonstrated in other times, where the main favored were the industries of that time, who changed the production paradigms.

These revolutions occur with shorter intervals [2], producing methodological changes by companies, to make them more competitive and thus occupy all the available technological knowledge to achieve advantages over their competitors, thus generating impulses to new manufacturing eras.

Technologies are developing depending on the needs of the context and the environment, these advances create exponential leaps that in turn generate new stages of production, and for this they are drunk to keep the processes updated and provide greater knowledge to the productive tasks. Creating all this system or optimizing it, causes a higher quality and speed in the manufacture of products, which gives a perfected technological evolution.

The intensive use of different technological tools creates a new philosophy in the industry concerned with optimization and continuous improvement with massive digital media that use the global network to follow trends and thus be updated in terms of production processes [2].

Technological evolution in industries is making great strides, managing to create such a capacity for adaptation, employment and modification that accelerated response to changes in the environment is elementary, through the creation and development of new technologies [3].

Advanced countries owe their economic growth to technological innovation, which strengthens scientific capacities, thus generating innovative processes and products [1] - [4]. These improvement processes create greater technological competencies that favor the industry, granting advantages that must be kept constant, as new and improved instruments are being created every time, which requires permanent industrial updating.

The innovation aims to grant a new benefit to a product or service that is known, being this in any of the creation, production or sales processes, using a new technology at an industrial level, to grant an unpublished product that complies with the consumer and business demands [5].

New and technical improvements in the use of technological tools will grant greater sustainability over time to companies, with success only those that internalize innovation as their ability to meet the changing market demands without losing quality and price, ensuring the future thanks to the potential of technological innovations [5].

II.DEVELOPING

A.History of Technology in Industry

Technology has accompanied the paradigm shift in the history of the industrial revolution, its implications affect multiple areas of society and the world environment.

The first industrial revolution carried out in Great Britain in 1784, was characterized by the growth of the textile industry, in which the use of great inventions such as the steam engine, the telegraph, the railway, the sewing machine, stand out. the light bulb, among others [6]

In the second industrial revolution beginning in 1870, important scientific and technological advances were made. Telegraph and rail networks, gas and water supply and sewerage systems are created, which had previously been concentrated in some cities. In addition, the automobile is created and disseminated by the Ford company, the telephone, the airplane, the phonograph, the cinema, the extraction of oil, dynamite, among other products that changed the vision of the known world are also offered [7].

The third industrial revolution, carried out since 1969, is known as the intelligence revolution and has been characterized by the deployment of advances such as the use of renewable energies, globalization with the use of the internet, transportation of electric vehicles, hybrids, etc. [8].

Finally, the fourth industrial revolution, known as revolution 4.0, mixes cutting-edge production techniques with intelligent systems that integrate with organizations and people [9]. Nanotechnology, virtual reality and augmented reality, robots, 3D and 4D printing are then produced, which are currently prominent.

Along with the industrial revolution, the use of energy has been changing. Before the first industrial revolution, most energy sources came from wood, which was used to light fires in homes, workshops and in the existing manufacturing sector. Other natural sources were also chosen, such as moving water flows to power mills. In the United States, the industrial revolution gained importance at the beginning of the 19th century [10], coal was used in the first instance as fuel for steam engines. The second industrial revolution was characterized (in the mid and late nineteenth century) by the use of oil and gas as the most representative energy sources, which were used in inventions and applications with the use of the internal combustion engine. The automobile and airplanes were propelled by these fuels and later electricity appeared, which as a technical advantage had the capacity for storage and transport in a standardized way, greatly facilitating their consumption.

Fig. 1 shows the most outstanding technological aspects in industrial evolution, which have set a guideline for the social development of nations.

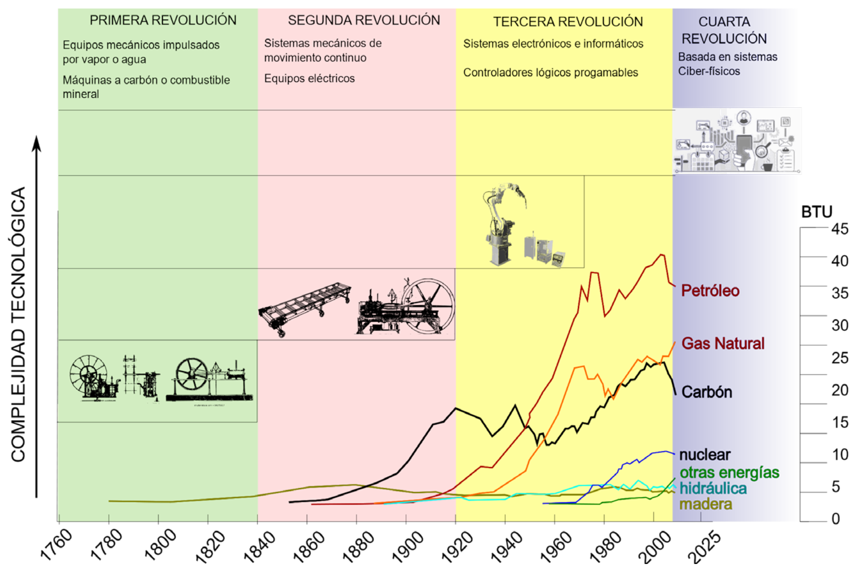

Fig. 1. Technological aspects of the Industry over time.

The technological complexities are an indicator parameter of change, the evolution according to the years and the past revolutions observed in fig. 1. The energy sources and their consumption stand out, and finally a description of the mechanical and / or electromechanical systems used in each stage [11] - [12].

The first industrial revolution, also known as industry 1.0, in the 18th century, was characterized by the use of energy obtained from water, either in steam or by its potential energy. The machines used in these industries generated mechanical work from the expansion of steam or the combustion of fossil minerals.

The second industrial revolution known as industry 2.0, in the nineteenth century, was characterized by the use of energy obtained from oil, either in mechanical systems or in continuous motion. The steam engine is no longer used but the turbine and the combustion engine. The machines used in these industries were of electrical (dc) and hydraulic origin.

The third Industrial Revolution (Industry 3.0), developed in the 20th century, was characterized by the use of energy obtained from hydrogen and renewable energy, whether in electronic and computer systems. In addition, the use of nuclear energy was relevant. The machines used in this period were primarily programmable logic programmers.

The fourth industrial revolution, known as Industry 4.0, occurs in the 21st century and is characterized by the use of energy obtained from alternative sources. In addition, to use much of the energies of the third revolution. The machines used are cyber-physical systems.

Fig. 2 shows a comparison of the source over time, it is observed that for more than a century, the energy consumed that has predominated has been that from coal, its consumption increasing over the years until 1959 [13]. The diversity in the use of new energy sources has been remarked since 1950, the year in which the use of different types of energy, stored in different batteries for use without direct connection to a source becomes important, due between other reasons to the growing need for energy by world economies. Today fossil fuels predominate, accounting for 80-85% of total energy consumption since 1970 [14].

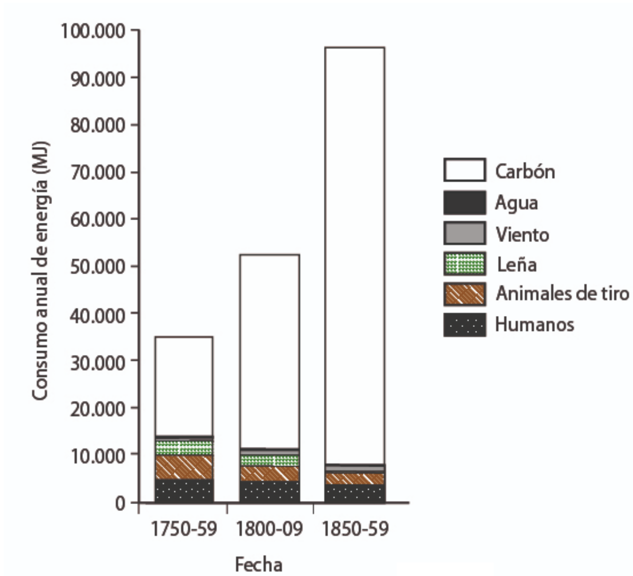

Fig. 2. Annual energy consumption according to its type.

B.Industrial Innovation

The process that generates value and continuous improvement in industries is consolidated through innovation in its technologies. Manufacturing applications have generated sustainable change in three fundamental areas: product, process and management.

This implementation of updated and repowering technologies with ICT achieves better production control through industrial innovation, positively influencing the final quality of both the process and the good or service created, in the same way reducing the associated values, thanks to the technological systems that store, process and deliver information relevant to production. This causes a scenario where conditions are changing profoundly. Technological dominance is becoming more and more essential, not only for growth and prosperity, but even for survival [15].

Industries are increasing and adopting more and more innovative technologies, orienting the emphasis on differentiation, production and commercialization. Adding biotechnology or ICT for this purpose, requiring both skilled labor and restructuring of the same organization. Thus, progress in innovation creates incredible development opportunities for countries that decide to adopt this initiative for their industries, however, in Latin America and the Caribbean this rise is more languid than in other territories (Fig. 3), evidenced in the results of the 2019 global innovation index, prepared each year by the World Intellectual Property Organization (WIPO).

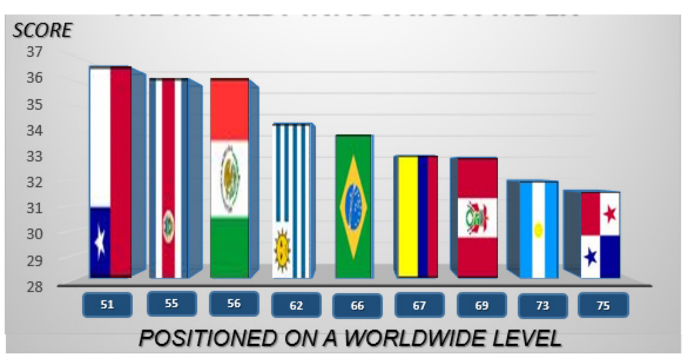

Fig. 3. Most innovative countries in Latin America [16].

Technology allows companies to look beyond the simple offer of products and services, taking an interest in creating deeper and more meaningful relationships with people [17], giving rise to both internal and external demands on companies and positioning the use of technology as an accepted means for the evolution and growth of both industry and people. The innovation of technology is related and allows the development of multiple areas of constant change for every industry (Fig. 4).

Fig. 4. Areas related to and benefited by industrial innovation.

The increasing inclusion of digital technologies is creating an environment that connects the demands of constant and demanding change of the users for an operational efficiency and superior services. Thus, technological innovation is the determining factor for a company to maintain or disappear from the market. Innovation generates the competitive advantages that allow companies to position themselves correctly [18].

Some authors assure that technological innovation is the main source for the development of societies, the promotion of culture and the promotion of the economy of nations [19]. These new development paradigms are the link that makes possible the new trends in education, in the profile of new professionals and in the promotion of new forms of industrial development.

III.METHODOLOGY

A bibliographic review was carried out taking into account the four industrial revolutions, for this, it considered the evaluation in 15 articles that address the most relevant aspects of changes in industrial technology. Statistics on energy consumption have been considered throughout history, as well as descriptions of the use of technologies in each industrial stage. Four books have been reviewed that address aspects to establish the parameters of verification of the types of technologies applied in each historical epoch in the industry, in order to build understandable graphic diagrams that will easily condense the information relevant to industrial technological change, and reflected the importance of innovation in the industry along with its types of classification according to authors.

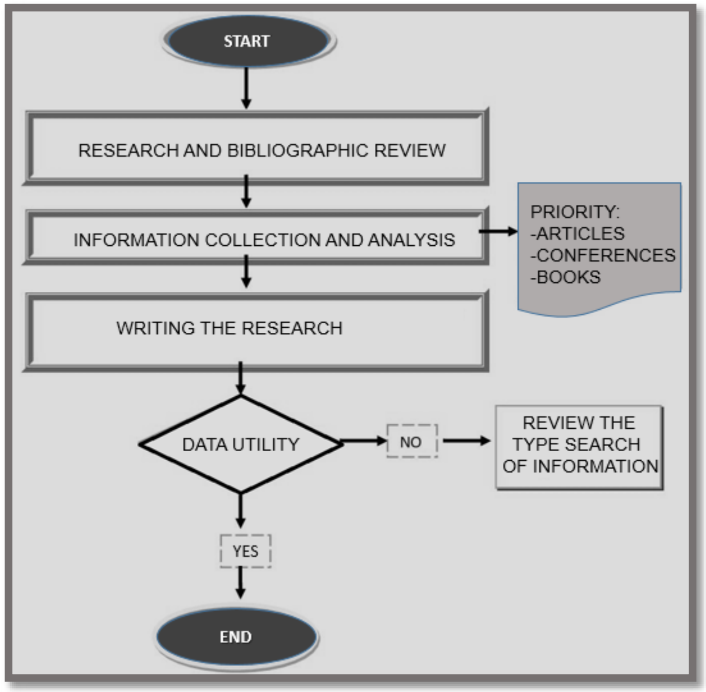

Fig. 5. Investigation model

IV.RESULTS

Once the bibliographic review was carried out, it was evidenced that the greatest technological leap occurred in the third industrial revolution, since in this period a large part of the technologies and energies used in industry 4.0 are discovered, where only part of the knowledge acquired, but which shows great potential with the arrival of artificial intelligence and automated robots, this creates a reduction in the times generated for the leaps from industrial revolution to revolution, as a result of the large amount of technology used.

It was also possible to corroborate that technology is a fundamental part of industrial development at all times, and that it is subject to human aspirations and trends to improve the quality of processes, as well as the impersonation of humans for optimization in the mass production of products.

Another aspect that stands out in industrial evolution is its impact on educational processes, which considerably influence the generation of new professional careers that will be included in the academic curricula of each generation affected by the industrial revolution of its time.

The results show that innovation is fundamental for technological development, and that this in turn is necessary for the creation of new forms of work, new products and markets that focus on social, cultural and human needs.

V.CONCLUSIONS

Technology is undoubtedly one of the forces that allow the development of a country, since the industry faces the challenge of being competitive on a daily basis and is forced to change constantly. Thus, each research and development unit of the companies has the responsibility of optimizing their production models through technological innovation and continuous improvement in all manufacturing phases to become competitive.

Innovation is a key term within industrial processes since it generates new ideas and inventions in the activities for their development and use. Therefore, innovation represents the challenge of production companies, to be sustained over time and transcend with a view to more efficient processes that guarantee the quality of their products.

Ideas become innovations, which then represent new products, services or procedures, create a paradigm shift at a global level when they are massed, founding the so-called industrial revolutions that will guide the new societies of the new times.

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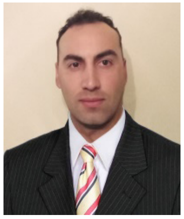
CURRICULUM SUMMARY



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Robotic hand design with linear actuators based on Toronto development

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Abstract: In this work, the design of a robotic hand with 7 degrees of freedom is presented that allows greater flexibility, achieving the usual actions performed by a normal hand. The work consists of a prototype designed with linear actuators and myoelectric sensor, following the mechanism of the University of Toronto for the management of functional phalanges. The design, construction description, components and recommendations for the elaboration of a flexible and useful robotic hand for amputee patients with a residual limb for the socket are presented.

Keywords: Robotic hand, Degree of freedom, Toronto´s Mechanism, lineal actuator.

Diseño de mano robótica con actuadores lineales basados en el desarrollo de Toronto

Resumen: En este trabajo se presenta el diseño de una mano robótica de 7 grados de libertad que permite mayor flexibilidad, logrando las acciones habituales realizadas por una mano normal. El trabajo consta de un prototipo diseñado con actuares lineales y sensor mioeléctrico, siguiendo el mecanismo de la Universidad de Toronto para el manejo de falanges funcionales. Se presenta el diseño, descripción constructiva, componentes y recomendaciones para la elaboración de una mano robótica flexible y útil para pacientes amputados con miembro residual para el encaje.

Palabras Clave: Mano robótica, grado de libertad, Mecanismo de Toronto, actuador lineal.

I.INTRODUCCIÓN

3% of the amputations performed in the United States correspond to upper limbs, involving affectations that affect and limit people's vocational development [1]. Forearm amputations represent a significant number each year around the world. The cost of myoelectric control prosthesis is relatively high and proportional to the number of degrees of freedom [2]. Recent advances have achieved articulated finger configurations [3,4].

In this work we present a design adapted to linear actuators that drive a mechanism design based on the University of Toronto mechanism [5]. And it can be played back using the files found in reference [6]. The proposed prosthesis is presented in Figure 1.

Fig.1. 7DOF hand prosthesis prototype

The Toronto development [5] has been considered because it allows a greater similarity to the human hand, offering three articulated phalanges, including the thumb.

For this design some functional aspects were considered given the experience of previous prototypes [7,8,9]. Given the limited space of the real human hand and in order not to use high-cost and energy-consuming devices, mid-range devices have been used and easily obtained in houses specialized in electronics.

One of the important considerations is an arrangement of the thumb that allows mobility in 2 directions of rotation, achieving abduction and adduction of the thumb. With this it is possible to improve the grip of pieces, placing this finger in a more natural position.

Most prostheses of this type have wide mobility configurations [10]. For this reason, it has been considered to work with a ball joint that allows rotation in 3 axes, as evidenced in works developed [11-14].

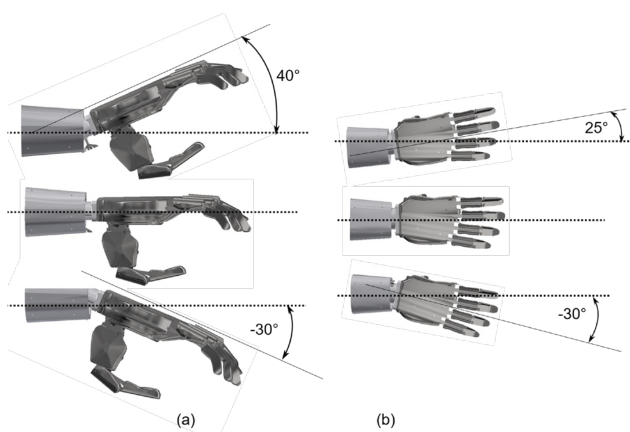

Fig. 2. Degrees of mobility of (a) wrist of the hand, (b) thumb.

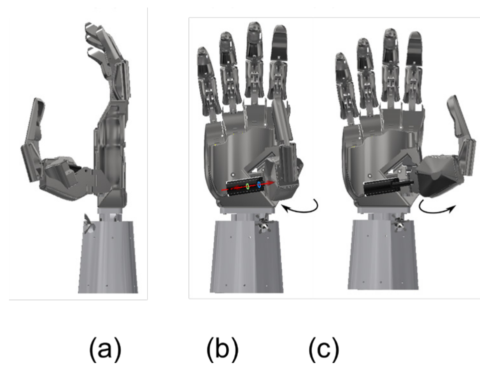

Fig. 3. (a) Lateral view, (b) abduction movement and (c) adduction movement of the thumb.

Figure 4 shows the breakdown of the parts that make up the prototype, it shows the mechanical and electronic elements that make the movement of the hand possible.

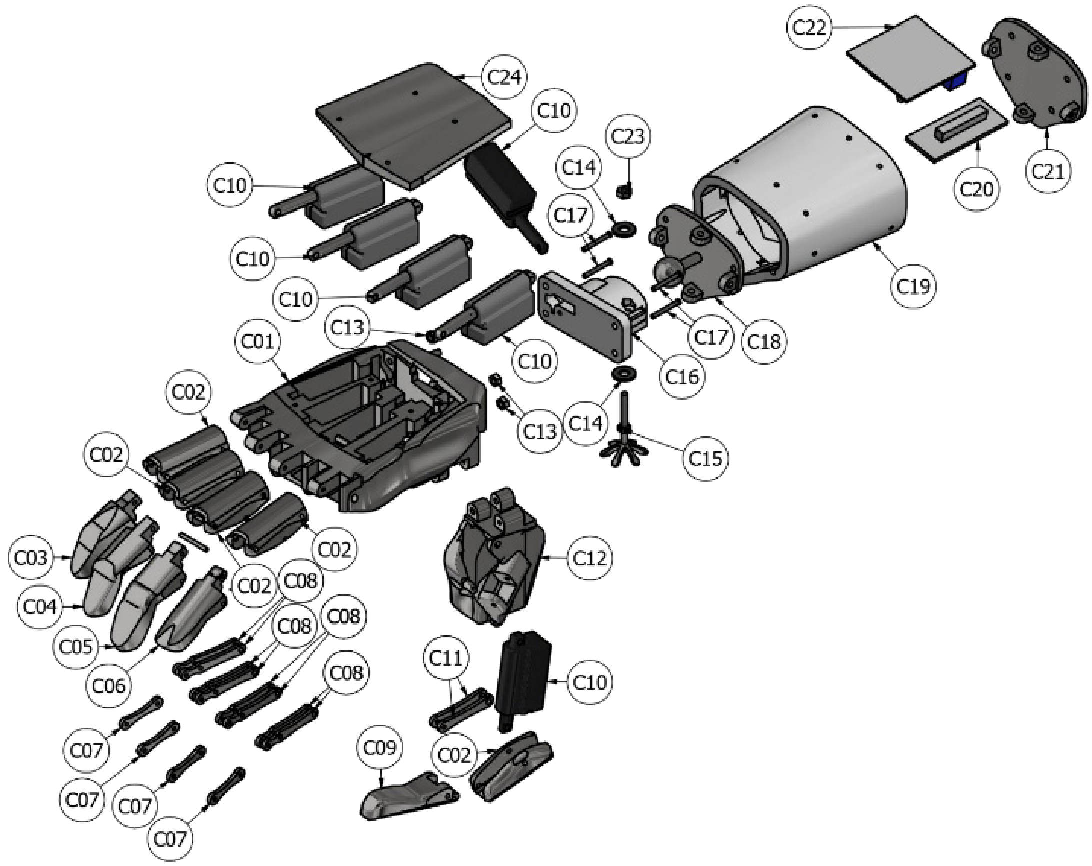

Fig. 4. Assembly diagram of the robotic hand.

II.METHODS AND MATERIALS

A.Methods.

The methods used to obtain the parts for the manufacture of the design can be obtained through the use of some existing technologies in machine shops, machining centers and cutting plotters. These are: (P1) 3D printing, (P2) stainless steel water jet cutting, (P3) stainless steel laser cutting, (P4) stainless steel welding, (P5) bolted joint, (P6) steel turning .

B.Materials

For the pieces to be obtained by P1, poly lactic acid (PLA) will be used, while for the pieces obtained manufactured by P2 and P3, stainless steel with a thickness of 2mm will be used. The mobile ball joint that will be incorporated in the C18 component, machine steel is used and through the P6 process, it is machined generating the appropriate shape. The bolts for the joints shall be stainless steel.

III.ASSEMBLY PROCESS

Element C01 corresponds to the Palm. The C10 servomotors are inserted into the respective cavities being snap secured. The C02 Proximal Phalanges are secured to the C01 body by means of E1 stainless steel shafts of 2 mm diameter and 18 mm long. The Medial Phalanx Littlefinger (C03), Annular (C04), Middle (C05), Index (C06) are coupled to C02 components using E1 stainless steel shafts. The C07 Medial Links join the C03, C04, C05, C06 Medial Phalanges by means of E1, C07 stainless steel shafts also join the C08 Proximal Phalanges with stainless steel shafts of 2mm diameter, length 7mm E2. The C08 Proximal Links are fixed to C02 with E1 stainless steel shafts, in addition they are inserted into the C10 servo motor shafts with 2.6mm diameter stainless steel shafts, 6mm E3 length. The Thumb Medial Phalanx C09 to C02 is attached and the latter to the C12 Thumb Base with E1 shafts, C12 to C01 is fixed with a 2mm diameter stainless steel shaft, 24mm E4 length. The Medial Thumb Link C11 is attached to C09 and C02 with E1 axes. C10 is inserted into the cavity of C12 and fixed with a 3mm diameter stainless steel shaft, 23mm length E5. Attach the C16 Ball Coupling to C01 with the C17 Bolts and C13 Nuts. Attach the C18 Ball Joint to the C19 Forearm Coupling with 4 M3 bolts by 15mm length E6. The Control Board C22 and the Arduino C20 controller are inserted into the cavity of C19 and closed with the C21 Cover Forearm Coupling, this is fastened with 4 E6 bolts. Insert C18 to C16 and tighten with the M3 bolt for 20mm length E7 with the M3 C23 nut. For this bolt the flanges (C14) are used for the M3 bolt. Finally, the Palm Cap C24 is placed on C01, it is secured with 4 M6 bolts by 30mm in length, E8 with their respective nuts.

A.Moving joints

The prototype has fixed parts and moving parts. The moving part corresponds to the Toronto mechanism to transmit the movement to the fingers, stainless steel shafts are fixed between the phalanges and the palm of the hand C01.

B.Piece joints

The C01, constitutes the support of all the mobile mechanisms and internal actuators that propel the fingers. The clearance presented by the internal components conveniently ensures the linear servomotors, while the C22 and C20 electronic control devices are supported in the forearm portion C19. Furthermore, in C19 the socket is coupled to the residual limb (part of the forearm) of the user, whose part is designed in a particular way for each user.

C.Electronic equipment

In previous prototypes, use had been made of MyoWare myoelectric sensors which take the user's myoelectric signal, amplify, filter and rectify said signal and in this way the sensor output signal can be read directly through the analog input ports of the a microcontroller, they are also affordable. The drawback that was had in the tests that was carried out on the prototypes was that the user with time of use begins to present an allergy to the use of the electrode, in addition, these electrodes need to be replaced every time the prosthesis is going to be used, since They lose their rubber adherence to the user's skin. For these drawbacks, a sensor with dry electrodes such as the Myo bracelet is sought.

Fig. 5. MyoWare Sensor

To control the prosthesis, it is done using free software and hardware, such as Arduino, thus reducing licensing costs and there are also libraries for the realization of the interface with the myoelectric bracelet "Myo Armband" with which the signals from the muscles of the prosthesis wearer. The data acquisition bracelet is in charge of carrying out the amplification and filtering stages of the myoelectric signals obtained from the user, as well as their analysis and processing through "machine learning"; thus the interface between the controller and the bracelet serves as a means of communication for sending commands for five types of movements.

The library that allows communication between the bracelet and the controller is MyoBridge, also the Arduino needs a bluetooth module HM-10 or HM-11 that has the CC2541 chip to which a "firmware" must be loaded, with an Arduino, called CCLoader, once the entire configuration process has been carried out in which it is necessary to make extra connections in the bluetooth module, all this is explained in [15] it is necessary to perform all the steps so that the interface on the bracelet and the Arduino controller are set.

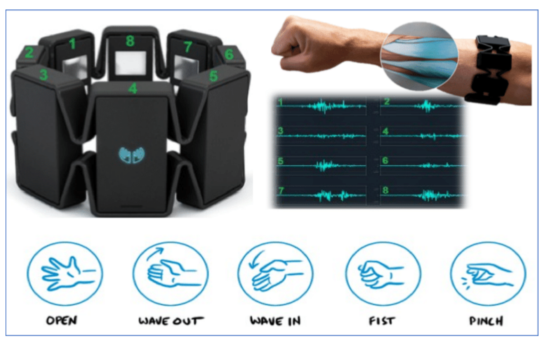

Fig. 6. Myo bracelet with the movements it recognizes in the user.

The Myo bracelet is configured in its Myo Connect application which can be downloaded from its page [16], through this application the Myo bracelet is trained to recognize the five patterns that the user is going to make, once they have been recognized the patterns, the bracelet communicates them through the HM-11 bluetooth module to the Arduino controller in which this data is received through RS232 serial communication and processed for the control of six Actuonix PQ12-R linear servo motors, which are It controls with a PWM signal where the bandwidth for the opening or closing of the servomotors is varied, which in turn move the fingers of the prosthesis.

IV.RESULTS

The proposed design presents constructive feasibility, low cost of both electronic and structural components, due to the use of simple technologies to find in any region or country.

The mobility developed by the 7 degrees of freedom robotic hand has improvements in movement dexterity, improving 5 degrees of freedom prototypes. Given the movements of the thumb, small pieces can be manipulated, especially to hold them.

Fine motor skills and the fine movement of the fingertips allow the holding of fine items such as sheets of paper in conjunction with the thumb.

An improvement in battery life is offered given the use of low consumption devices and the Myo bracelet which is independent from the rest of the electronic devices in the bracelet, this also helps to reduce the workload of the controller and avoid failures due to Processing overhead on both the Myo armband and the Arduino controller.

Separating the processing of myoelectric signals with the control of the movement of the prosthesis is optimal due to the large amount of data and functions that are carried out in pattern recognition; In addition to generating the PWM signal for the control of servo motors, it interferes with the myoelectric signals coming from the user's forearm.

The recognition of movement patterns of the user through its myoelectric signals becomes almost impossible to do when trying to do it using traditional programming logics because there is a great variability of said signals due to various factors, which is why it is necessary to use Non-traditional and even experimental methods such as fuzzy logic and “machine learning” for the processing and recognition of patterns to be effective, as the Myo bracelet does, this in turn requires powerful processors which is difficult to achieve in microcontrollers that also need to perform additional functions, it is important to separate this recognition process from the rest of the functions.

The mass of the prosthesis does not exceed eight hundred grams, being similar to the mass of the lost limb of the user, this factor is important because the use of the device must be continuous and the user must be given the greatest possible comfort.

The movement of the wrist is necessary because the prosthesis must grasp objects in different positions for which it is important that the prosthesis adapts to the natural grip position of a person, otherwise the user must perform movements to accommodate and make the grips in different positions, these with continuous use tire the user causing him to stop using the prosthesis since it is not helpful.

V.CONCLUSIONS

This design proposes a solution adapted to the technology of manufacturing by deposition of molten plastic material, with few components in steel, which must be manufactured in specialized workshops. These features allow this project to be replicated and used by people who lack their hand and who have a residual limb for fitting, as detailed in the figures.

The presented robotic hand presents a sufficient and necessary flexibility for multiple operations of the hand, in addition its configuration improves the grip of small objects providing the performance of fine motor skills by the user.

The elaboration of the parts has been a rigorous process of computer-aided design, limiting the design to the linear actuators used and explained in the development. In this work, the interior space has been optimized, allowing that in subsequent works to design, without inconvenience, covers that have dimensions of a real hand.

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CURRICULUM SUMMARY

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Criteria for the design of an educational robotics platform

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Abstract: This document explains the criteria, considerations and formulations used for the design of the main components of a mobile platform with a robotic arm. This type of robot is one of the most used in the educational field, it facilitates learning and allows the incorporation of control strategies for navigation. Aspects of resistance of materials useful for branches of engineering that lack bases on mechanics are raised.

Keywords: Design; robot; platform; educational.

Criterios para el diseño de una plataforma robótica de carácter educativo

Resumen: El presente documento explica los criterios, consideraciones y formulaciones que se emplean para el diseño de los componentes principales de una plataforma móvil con brazo robótico. Este tipo de diseños es uno de los más usados en el ámbito educativo, facilita el aprendizaje y permite la incorporación de estrategias de control para navegación. Se plantean aspectos de resistencia de materiales útiles para ramas de la ingeniería que carecen de bases sobre mecánica. Como resultados es posible destacar la obtención de las dimensiones de los elementos estructurales del robot como por ejemplo el espesor y la determinación del material más óptimo para un mejor desempeño.

Palabras Clave: Diseño mecánico, plataforma robótica, aplicaciones educativas.

I.INTRODUCTION

Mobile robotic platforms are used at an educational level at multiple levels of university instruction, either to employ electronic techniques or to implement remote or autonomous navigation [1-4]. The field of mobile robotics is in potential development and its study is mandatory for careers related to electrical or electronic engineering. There are multiple works developed on mobile platforms [5-8], however, there are few basic design aspects related to mechanics for mobile robots and that allow adapting existing platforms in specific applications, of different capacities and situations [9].

The design of the structure of a robotic platform must consider manufacturing techniques [10], multiple geometric aspects, as well as resistance of materials [11], mechanical properties of materials and dimensioning of the main components of a mobile robot, of differential type and 4 traction wheels and with a manipulator arm with 5 degrees of freedom. It is important to consider in this design the load limitations that exist due to the geometry and weight of the robot, as well as reach lengths for the manipulation of objects taking into account the stability of the vehicle, in order to avoid possible rocking and loss of contact of the wheels with the ground [12]. In addition to this, the space must be considered to adapt the components in a convenient way and to facilitate the assembly and construction [13].

II.DEVELOPING

Developments in nanoelectronics and mechanics have allowed developments in robotics, the most general case being that of a mobile platform with a manipulator arm that allows an educational understanding of the kinematics, dynamics and control strategies of robots for the industrial field.

Continuous improvement in education models constitutes an essential challenge for teachers in order to apply and relate theory to practice in all disciplines, specifically in careers of a technical nature focused on Engineering students as well as students with engineering fundamentals. limited. Thus, a descriptive and didactic compendium of the construction of a robotic platform has been created, detailing the design of its components necessary for its proper operation in order to simplify and specify its dimensioning and construction more easily.

The study that has been carried out in this work complements the training of electronics and telematics, providing criteria, formulations, comparisons and references to execute multidisciplinary integrative projects.

III.METHODOLOGY

A.Design considerations

The robotic platform [1] with a manipulator arm to be assembled, must first consider a material that supports the distributed loads that the P1 plate must carry. The length L depends largely on the size of the wheels to be used. To determine the diameter D of the wheel, the engine speed [14] must be considered, since a large wheel will make the vehicle move faster, however, it will reduce the effect of the engine torque applied to each wheel [15]. Another consideration is the size of the terrain variations. If the terrain is perfectly flat, a small wheel may be convenient to take advantage of a greater torque from the motor. In practice, this diameter can be associated as a function of the maximum speed required to be achieved and the speed of the motor.

$$\frac{D}{2} = \frac{V}{\omega} \qquad (1)$$

Where, D is the diameter, V is the velocity and ω is the angular velocity.

The speed in (1) linear of a platform [16], works properly with speeds lower than 50 cm / s. The wheelbase is considered sufficient to house the proper motors to move the robotic platform. The width of the wheel tw, is an important parameter in the driving of the mobile robot [17] and should promote good stability to the robot, and due to its weight, the contact area with the ground should be increased. The motor required to move the platform will be a function of the total weight of the robot plus the load and a safety factor, such that the following expression is fulfilled.

$$T = \frac{D}{2} Fr \qquad (2)$$

Where, T is the torque, D is the diameter and Fr is the friction force

$$Fr = k\,\frac{*(qA + pbrazo + ppinza)}{4} \qquad (3)$$

Where, Fr is the friction force, (qA + p arm + p clamp) is the sum of distributed loads applied to the robot wheels. In (2), the torque is presented as a function of the friction force and this, in turn, in (3), as a function of the friction coefficient k and the weight of the complete robot, whose force is considered equally distributed in the 4 wheel drive differential [17].

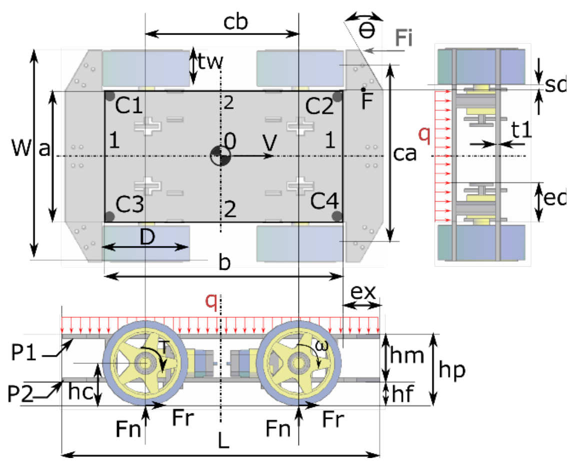

Fig 1. Geometric parameters for the robotic platform design.

Regarding the plates that form the chassis P1 and P2 (Fig. 1), these must carry the load of the rest of the robot that will be distributed appropriately. The greatest load will be supported by plate P1 and the load of robot components and load to be transported in a distributed manner q on the surface of P1 will be considered by applying the distributed load q on plate P1. The P2 plate provides rigidity to the structure of the vehicle chassis and allows fastening for the motors and encoders. The plate P1 will support more load than the plate P2 and its analysis considers the case of a plate supported at its corners C1 - C4. According to [18], the maximum moment will be found along axis 1-1 with its maximum value at point 0.

$$M_2 = \alpha_2 q b^2 \qquad (4)$$

The parameter $\alpha 2$ is obtained from table I, according to reference [18], for which the relationship of the dimensions a and b, (4) must be considered.

TABLE 1. GEOMETRIC PARAMETERS α

a/b	$\alpha_{0(a)}$	$\alpha_{0(a)}$	$\alpha_{0(a)}$	$\alpha_{0(a)}$
1.0	0.0947	0.0947	0.1606	0.1606
0.9	0.0689	0.1016	0.1367	0.1541
0.8	0.0047	0.1078	0.1148	0.1486
0.7	0.0289	0.1132	0.0955	0.1435
0.6	0.0131	0.1178	0.0769	0.1386
0.5	0.0005	0.1214	0.0592	0.1339

If P1 has a larger geometry and with more details than the area delimited with sides a and b, the latter will be suitable for the consideration of resistance since it is the region that will be most loaded and that allows a more realistic determination of resistance behavior. In order to verify the material and the thickness t1 of the plate P1, the bending stress of the plate is evaluated, considering the direction of greater bending through the following expression.

$$\sigma_F = \frac{M_2 y}{I} \qquad (5)$$

Where σ_F is the bending stress to which the plate is subjected, M_2 is the greatest moment with respect to the central section of the plate, that is, M_2, and is the distance from the center of gravity of the cross section towards the critical fiber. I is the inertia of the cross section of the material with respect to its center of gravity and considering that its height will correspond to the thickness of the material t1, (5).

In figure 1, the distance hf should be the minimum enough so that, given the unevenness of the ground or the presence of foreign elements, the mobile robot is not stranded. The height hm will facilitate the incorporation of the 4 DC motors that will move each of the robot's wheels, which will be fixed on the plate P2 and below P1, A safety distance ex is required to avoid elements of considerable size , may collide with the wheels directly. The chamfer where the angle θ is specified, will prevent the robot from being immobile in a corner, allowing it to maneuver in closed spaces without getting stuck in corners of the environment. The minimum distance ex must withstand the impact of the vehicle traveling at its maximum speed [19] and whose moment with respect to point F is carried out by force Fi. Using (5).

A safety distance sd between the plate P1 and the wheels, will allow a better mobility without them getting stuck with P1. Distances greater than 6 mm are recommended. The distance ed, when installing the motors, must not exceed a / 2.

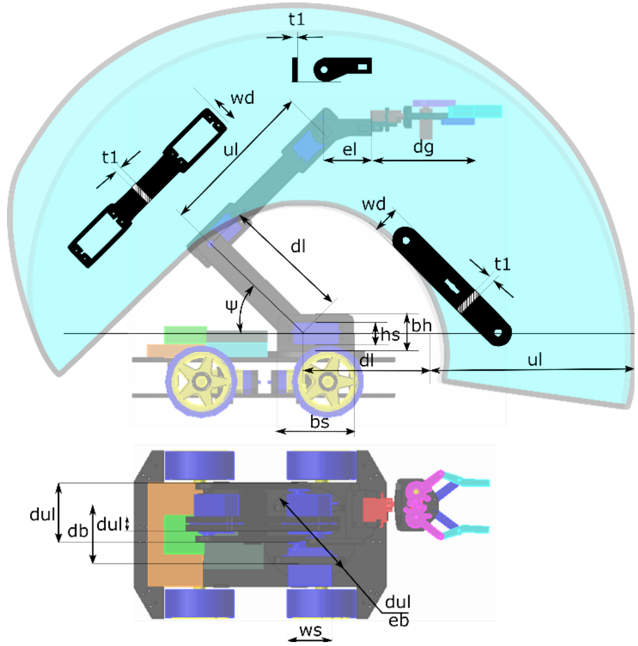

Fig 2. Parameters for the manipulator arm design

Figure 2 presents the dimensional parameters that are taken into account for the design of the manipulator arm, the same ones that consider static loads given that the arm will not exceed the linear speed of 1.2 m / s at the end of the manipulator, avoiding an unnecessarily dynamic analysis. for this efects.

The components of the manipulator arm structure will have thicknesses t1 similar to those of the components P1 and P2.

In figure 2, the height bh and width bs of the servomotor supports at the base of the manipulator arm must consider an opening of dimensions hs and ws depending on the servomotor used. The recommended distance from the hole to the edges can be determined based on the torque of the servomotors. The distance dl and ul should preferably be equal if the intention is to give the manipulator a greater range. The lengths dl, ul, el and dg, should allow the manipulator arm, in the retracted position and described with an angle ψ of 45 °, to locate its center of gravity between the driving wheels to provide better stabilization and reduce the rocking of the vehicle moving with load. To allow displacement with load and arm retracted, the moments generated by the weight of the arm with its components and acting on the platform applying WA at a distance LR, must provide more moment than that provided by the gripper and the load PC sustained with a distance LS, with respect to the CR point of the front wheel, as shown in figure 3.

The securing of elements remotely will transmit a moment that could overturn the platform, therefore, the load to be secured should be considered a function of the estimated weight of the robot. The maximum extension of the manipulator arm is illustrated in figure 3. In it, the load PL corresponds to the load that the gripper will hold, WA is the load generated by the weight of the arm and gripper at a distance RD from the center of rotation and that corresponds to the distance LA minus the radius of the wheel D / 2. The load PL corresponds to the weight of the mobile platform plus the servos that move the elements of the lower link of the manipulator and is located at a distance LD from the center of rotation CR of the front wheel.

$$[(WA*RD)+(PC*LL)]FS=PL*LD \qquad (6)$$

The FS value presents a safety factor to guarantee traction on the wheels in case of movement with load and for the case presented in figure 3. The design presented and composed of three fundamental parts, mobile platform, manipulator arm and gripper, if manufactured from the same material thickness, will present approximate reference weights in percentage values of 82% for the mobile platform with the control components of the whole robot; 12% the weight of the manipulator arm without considering the two lower servos and anchored to the mobile platform; 6% for the chuck with all its servomotors. The payload can be estimated using (7).

$$PC = \frac{W_{plat}LD - W_{arm}RD}{2LL * FSC} \tag{7}$$

The value obtained in PC will correspond to the mass that the robot will be able to lift without affecting the traction of the wheels with the ground, for whose determination an FSC safety factor for the load is considered (7).

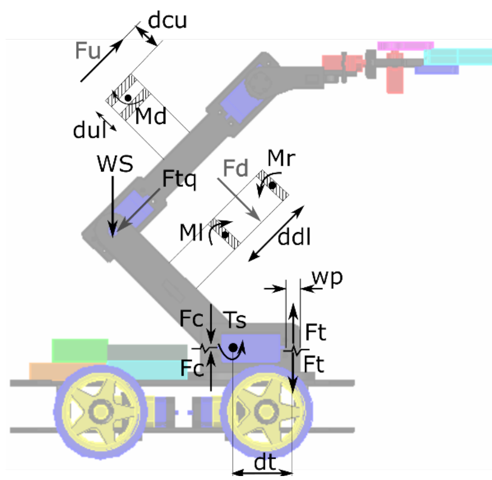

Fig 4. Parameters for the resistance in the structure of the manipulator arm.

In figure 4, One of the critical points in the design is the union of the manipulator arm with the mobile platform and specifically the bases that hold said servomotors. Adequate torques must be chosen to properly and safely move the PC load. The design contemplates a support for two servomotors, used to move the first link of the robot made up of two parallel bars of length dl and separated by a distance ddl. Two servomotors are necessary in the base since it is where greater moment is required. Each of these actuators transmits a moment Ts in the support of the base, generating a traction force Ft on the element and a compression force Fc on the other side. Since the side subjected to compression does not have a length that gives the failure buckling, like a column; the most prone failure in these cases is traction, so this force can be determined by:

$$\frac{\sigma_{tb}}{fst} = \frac{Ts/_{dt}}{t1 * wp} \tag{8}$$

In (8), a section with a minimum area formed by t1 and wp should be chosen that allow σ_tb to be less than the resistance of the material, considering a safety factor fst, recommended equal to or greater than 2. In figure 4, the distance ddl at which the elements of the first link of the robot are separated should be considered such that it provides rigidity to the structure and prevents buckling of both components. Considering the maximum torque load of the servomotors and the weight of the upper link, clamp and load object, a critical load case can be considered in which the force of the weight of the upper elements WS and the force of the torque Ftq, contribute their maximum magnitudes thus applying a force Fd applying moments to the two bars due to the incidence of the centered load and weight of upper elements. The torsion in each element can be analyzed using (9).

$$\frac{\tau}{fstor} = \frac{TL}{G\theta} \qquad (9)$$

In (9), the torque represented by J, represents the shear stress of the material, this considers a safety factor fstor whose value must be greater than or similar to 2, the torque obtained by the force Fd and the distance ddl / 2. The parameter L of (9) represents the length that for the analyzed case will be equal to dl. The value for G corresponds to the value of the transverse modulus of elasticity, a characteristic property of the material used, and ω corresponds to the value of the angular displacement.

A maximum angular displacement ω_max should be considered, such that the stress τ does not exceed the shear strength value of the material. For the case of the upper elements, the load Fu has a lateral displacement a distance dcu, therefore, it transmits a torque with respect to the geometric center of the cross section of the elements of the second link of the robotic arm and of lengths ul. Equation 9 can be used to limit the angle displaced by the effect of the load and the elements of the displaced clamp Fu, which will apply a moment Md forcing the structure to rotate an angle θ, values must be found that confirm that the stress τ is less than the resistance of the material used. Regarding the gripper and given that the load to be transported will be reduced and depending on the weight of the robot, the mechanical requirement is not a relevant aspect for the few grams that will be held in the mechanism.

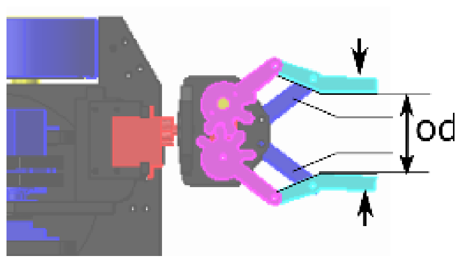

Fig 5. Parallel motion gripper mechanism.

Figure 5 shows a model of a clamping clamp with parallel movement. This movement facilitates the work in structured environments and with multiple geometry frames whose external dimensions are less than the distance or d minus a margin that allows the operation and manipulation of the piece and that in practice can give good benefits.

B.Materials

For the selection of materials, the methodology defined by Michael Ashby [20] is followed, in which the robot is divided into each of its components, and for each of these components the design requirements expressed as functions, restrictions and objectives are defined. . All materials are initially considered candidates for use in components. Restrictions are used to eliminate non-compliant materials, decreasing the number of eligible options; for example, if resistance to corrosion in water is required, materials that do not meet this restriction are initially removed. The component function is used to define a material index that optimizes performance, for this, material selection letters and index selection tables are used, which allow defining a new list of materials that meet the initial restrictions and optimize the index of performance, as an example a reduced table is presented with different indices that consider a design limited by the resistance to minimum mass, according to the function of the product and considering its yield stress σ_f and the density ρ, see table 2.

Table 2. Material selection indexes for design limited by resistance to minimum mass.

Role and restrictions	Index (Maximize)
Tensile element Stiffness and specified length, free section area	σ_f/ρ
Torsionally loaded shaft Load, length, specified shape; free section area	$\sigma_f^{2/3}/\rho$
Beam loaded in bending Load, length, specified shape; free section area	$\sigma_f^{2/3}/\rho$
Compression column Load, length, specified shape; free section area	σ_f/ρ
Flex-loaded flat panel Specified stiffness, length and thickness; free thickness	$\sigma_f^{1/2}/\rho$

To meet the objectives, with the materials that meet the restrictions, they are classified based on the index and the advantages, disadvantages and uses of the material are reviewed in the technical literature, with which the appropriate material is finally chosen.

As an example, the material selection process for plates P1 and P2 is presented below.
Function: Support the loads of the component weights, it works like a flex plate.
Restrictions: Machinable, to screw the components
Free variables: Thickness
Objectives: Minimum weight, in order to optimize the weight of the robot and the duration of the battery
Performance index: which is used for design limited by the resistance to minimum weight for a flexural plate:

$$M = \frac{\sigma_f^{1/2}}{\rho} \qquad (10)$$

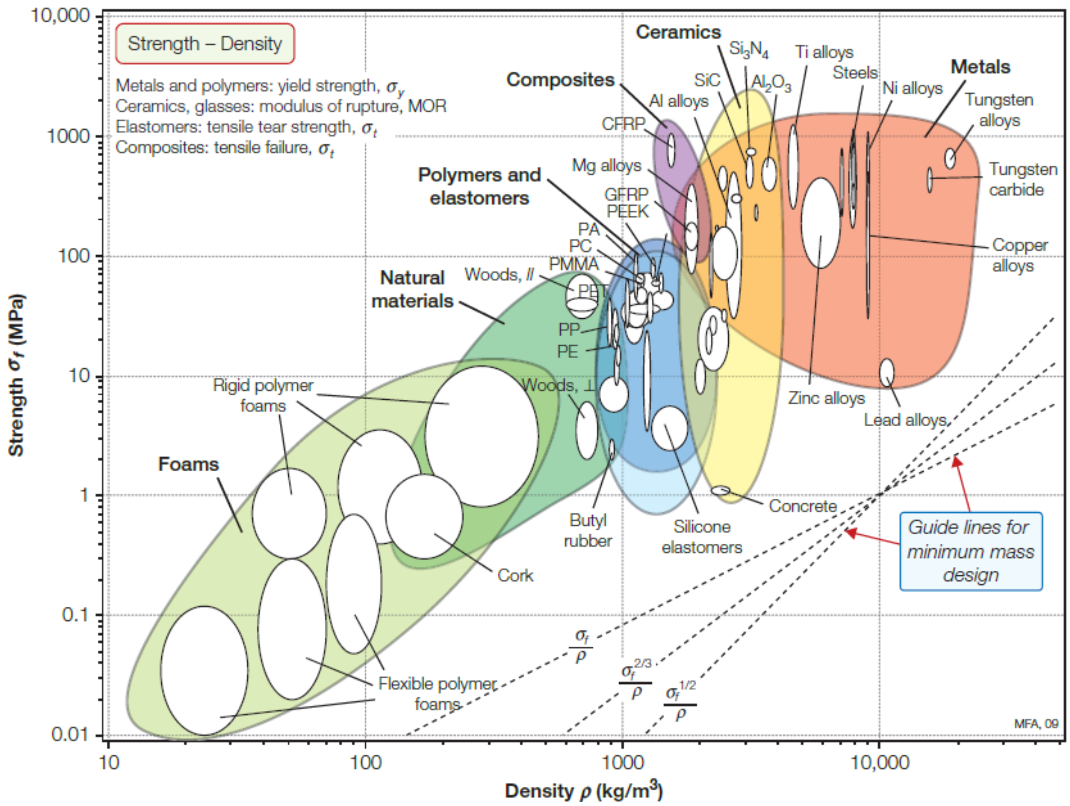

Fig 6. Methodology for selection of materials [20]

Where σ_f is the yield strength or maximum resistance of the material and r is the density of the material. A letter of materials is chosen, which contains in its axes the variables of the performance index, see figure 6. Then the line with the inclination corresponding to the selection index $\frac{\sigma_f^{1/2}}{\rho}$, see line blue in figure. In this case, it is planned to maximize the index, since the platform must have high resistance and low weight, so materials with the value of this high index must be chosen. The line is transported until there are few materials that meet the value of the high index, see selection area in green. Next, a table is made with the materials that are on the line and the material index is calculated and its suitability to the design is critically analyzed, as shown in table III, Where the suitable material was carbon fiber.

Table 3. Final materials after the selection process and selection index.

Material	σ_f (MPa)	ρ (kg/m^3)	$\frac{\sigma_f^{1/2}}{\rho}$ $(\frac{MPa^{1/2}}{kg/m^3})$	Observations
Rigid polymer foam	7.00	200	0.013	Light material, but you could see problems holding the elements
Wood	80.0	7.50	0.011	Suitable material, but could have problems with weather conditions
Carbon fiber reinforced polymer matrix composite	900	1800	0.016	The one with the best strength / density ratio, if price is not important it would be the right material.

More material selection cards and more restrictions can be used, depending on each product function.

IV.RESULTS

The mechanical design of the mobile robot in this document is presented in figure 7. 3 mm thick polymethyl-methacrylate (PMMA) acrylic has been used for the manufacture of the structural parts and the aspects presented in the previous section have been considered to validate and adjust the design, allowing it to be functional and suitable for academic teaching aspects.

The structure designed based on the criteria of resistance of materials and depending on the forces and loads applied allows proper sizing and guarantees the rigidity of the mobile lower part and the manipulator arm.

The designed and assembled platform presents small deflections less than 0.1 mm, ease of assembly for the proposed configuration, speed of manufacturing parts from the selected processes and the feasibility of being dimensioned according to the transport payload q (Figure 1).

The double links that make up the manipulator arm represented in figure 2 have an adequate behavior to torsion and bending, even for the most critical position as long as the payload PC does not overturn the entire robotic platform. Figure 7 represents the result of the verified design that meets all the criteria of the previous sections.

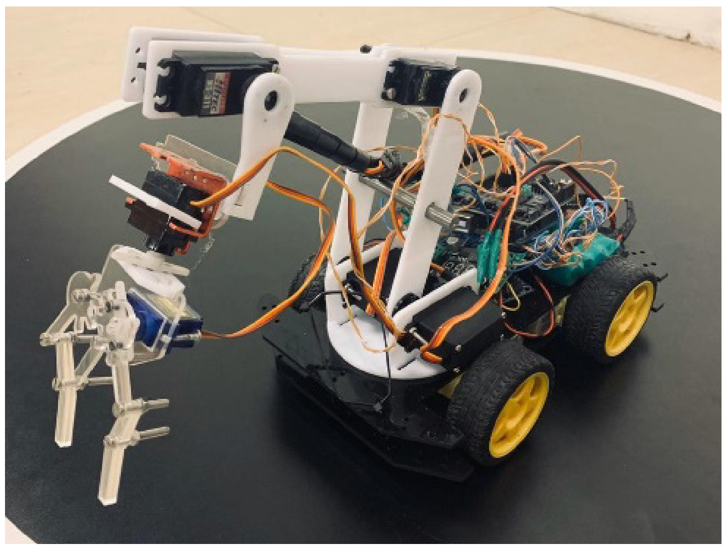

Fig 7. Robotic platform built

V.CONCLUSIONS

The design of an academic robotic platform uses multiple material mechanics criteria, relating parameters and static loads to select dimensions based on their strength as a fundamental parameter for the design. The design aspects presented, allow adapting and proposing designs adapted to multiple load situations and ground conditions, some geometric aspects also consider characteristics of the motors and utility distances for a basic design of the components that support greater loads in the operation of a mobile robotic platform with a manipulator arm. The present work can be proposed as a learning activity at initial levels of electronic engineering in order to acquire fundamentals about mechanics of materials and thus enrich their knowledge by extending it to multiple possibilities. The platform obtained allows the incorporation of control strategies, remote operation and autonomous navigation, it also offers stability in the transfer of cargo, which is a function of the weight and morphology of the robot.

RECOGNITION

We appreciate the participation of students of the Mechatronics engineering career of the International University of Ecuador and those of the Industrial Engineering career of the University of the Americas, who motivated the completion of this document, their doubts have served to create a guide useful, a contribution to

the educational environment of future generations.

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Comparative study on the un test n`5 application on cargoes that emit flammable gases similar to dri c that requires ventilation

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Abstract: This technical note summarizes a technical comparison of common testing procedures, as well as reviewed of the UN Test N` 5, for the assessment of the self-heating properties of cargoes and materials that has shown a clear trend on maritime fire and explosions events, as well as considering of external factors that can combine self-heating and emit flammable gases to conclude in an unlikely event affecting the security of crews and ships. A high understanding of the external factors effect on the cargo materials certainly will help the application of spontaneous reactions management actions (SRMA) on board of ships during the cargo sea passage. The intended comparison is based on laboratory, industry and field observations and data, whereas the among the external factors considered are, moisture content, stockpile procedure and aging, air velocities and moderate pressures internal and externally to the cargo material. The comparison results have shown that the self-heating and the flammable gas emissions has a common pattern when reacting with any oxygen available source, regardless the reactive material chemical composition.

Keywords: Reactive materials, self-heating, self-ignition, Direct reduced iron fines, materials handling, UN test N` 5, maritime safety, spontaneous reactions, risk management. IMSBC Code , IMO

Estudio comparativo de la aplicación de un test n`5 en cargas que emiten gases inflamables similares a dri c que requieren ventilación

Resumen: Estas notas técnicas resumen una comparación técnica de los procedimientos de ensayos comúnmente aceptados, así como una revisión del ensayo UN Test N` 5, para la cuantificación de la tendencia de las propiedades de loa materiales de cargas marítimas riesgosas que puedan causar eventos de incendios y explosiones en buques durante su transporte, considerando además de aquellos factores externos a la carga que cuando se combinan producen auto calentamiento y generación de gases inflamables que conllevan a eventos que afectan tanto la seguridad de las tripulaciones y a los buques de transporte. Por tanto, un elevado nivel de comprensión de los efectos que factores externos involucrados ciertamente ayudara a la aplicación y ejecución de un plan y acciones para el manejo de las reacciones espontaneas (AMRE) a bordo de los buques durante la travesía de dichas cargas, lo cual requiere un nuevo enfoque para las consideraciones de los efectos de dichos factores externos identificados sobre los materiales riesgosos y el umbral para su propensión para autocalentamiento e ignición. La comparación intentada se basa en el análisis de datos disponibles tanto de laboratorio como de observaciones y mediciones de campo en buques y en sitios de almacenamiento, mientras que entre los factores externos se han considerado la humedad de los materiales, procedimientos de almacenamiento, envejecimiento, velocidad de aire alrededor de los materiales, nivel de presiones moderadas tanto internas como externas al material y los métodos de manejo de materiales. Los resultados de la comparación demuestran que los fenómenos de autocalentamiento y de emisión de gases tienen un patrón común cuando los materiales reaccionan con cualquier fuente de oxígeno, independientemente de la composición química de los materiales que reaccionan

Palabras Clave: Materiales reactivos, auto calentamiento, auto ignición, Hierro de reducción directa, manejo de materiales, UN test N` 5, seguridad marítima, combustión espontánea, gerencia de riesgos, Código IMSBC. OMI

I.INTRODUCTION

The ventilation requirements as described in the IMO IMSBC Code are briefly described in Section 3.4.2 clearly specifies that cargoes that may emit flammable gases in sufficient quantities to constitute a fire or explosion hazard should be effectively ventilated as necessary. In Section 3.5.1 of the IMSBC Code also specifies that when cargoes which may emit flammable gases are carried, the cargo spaces shall be provided with mechanical ventilation. Example of cargoes containing metals that emit flammable gases after in contact with water listed in the IMSBC Code are: Aluminum Ferrosilicon Powder forms, Aluminum Smelting By-products or Aluminum Remelting By-products UN 3170, Ferro phosphorus (including briquettes), Ferrosilicon UN 1408, Magnesium powders, Silicon-manganese (low carbon), Zinc Ashes UN 1435, Direct Reduced Iron Fines, pellets and lumps.

These cargoes that require ventilation are listed among others of nonmetallic content such as grains, coal, seed cake etc. In this report are compared the trends of the temperature (`C) increase and the hydrogen gas emissions expressed in lt/kg.h, regardless the type of the glassware test rig used till present but also includes electric grounding of metallic containers and cathodic protection systems on ships. ajo.

II.PROPENSITY OF CARGOES TO SELF-HEATING

The basic reactions for heat generation is the oxidation of the material surface reacting with either air or any other oxygen supply source, which leads in the need for a new approach considering the combined effect of external factors such as air low velocities, impressed DC currents, variable moisture content during stockpiling, moderated low pressure.

Low air velocities and low pressure around the cargoes particles affects the dissipation of newly formed gases reaching the cargo surfaces, such as in the coals gases methane, hydrogen sulphide, carbon monoxide and hydrogen, the two former gases are also common in the case of DRI's, as per the material considered thus depriving the oxygen availability at the particle surfaces whereas high differential pressure will remove the oxidation gases away from the particle surfaces, in either cases the fire risks is less likely to occur. Finally, the threshold point when the required adequate pressure and air flow are appropriate for the self-ignition to occur must be avoided.

A.The stockpiling self-heating mechanism

The self-heating and ignition of coal in stockpiles has been fully studied as show in Fig. 1, from this figure several internal reactive layers are identified in which the heat is different and under such conditions different gas emissions and oxidation reactions occurs, to finally due to its high reactivity enough heat is evolved to ignite the coal.

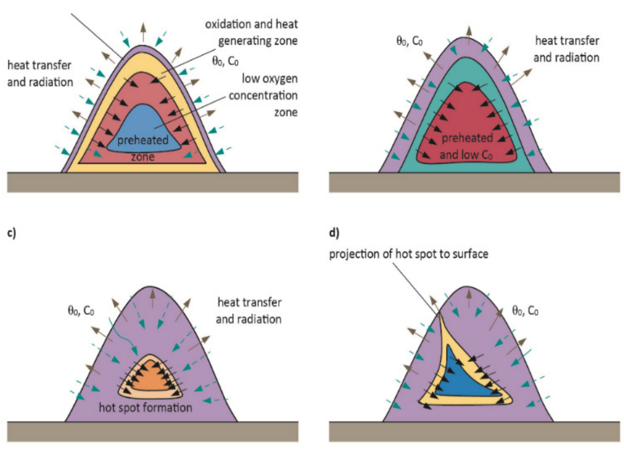

Fig. 1.- Stockpile steps followed for evolving heat and further ignition of coal [2]

A similar mechanism is followed by DRI C Fines stockpiles as show in Fig. 2, showing the temperature measures in a stockpiling yard at the open sky.

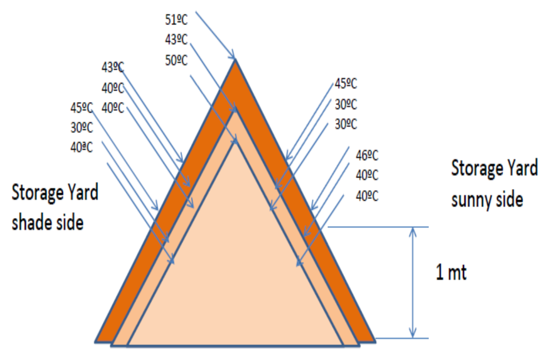

Fig. 2.-Open sky field temperature readings on a DRI C Fines stockpile [15]

In the inner zone of the pile there is an oxygen depletion due to the high bulk density of the of about 3300 kg/m3, the associated low porosity only allows the oxygen source from the moisture content. The heat evolved by the oxidation reactions increases the temperature up to near the 100 degrees centigrade, according to the mechanism show in Fig. 3 [8].

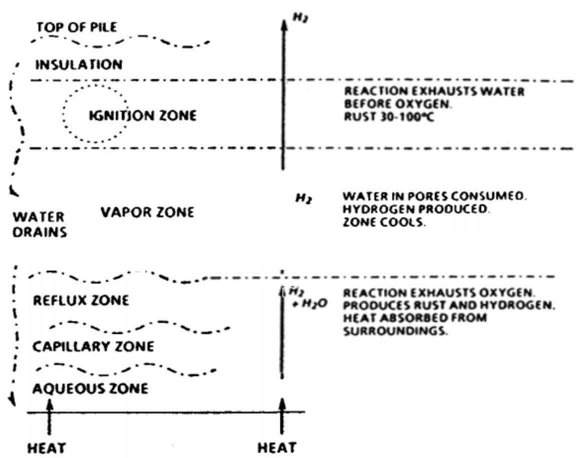

Fig. 3.- DRI C iron rust formation stage [8]

B.The materials handling.

In regard of the assessment of the material handling method effect on the DRI C temperature evolution to take care of the maximum allowed loading temperature, a field measurements program was set. The program did include the conveyor belts length, speed and the material dropping height from the ship loader to the ship holds bottom floor, results are presented in Tabl 1.

Table 1. DRI C Fines temperature in ship holds as a function of material temperature in stockpile yard

	Loading Temp (`C)			
Time min	**40 `C**	**48` C**	**55 `C**	**65 ~C**
1	42,95	50, 95	57,95	67,95
4	45,9	52, 58	59,58	69,58
18	47,53	48, 05	55,05	65,05
22	43	41, 76	48,76	58,76
24	36,71	34, 59	41,59	51,59
35	81,6	79, 48	86,48	96,48

The effect of the materials handling on the temperature increase of the material in the ship holds, could be related with the exposure of fresh reactive surfaces by possible breakage of lumps in for instance coal and DRI in either forms of pellets of briquettes. This effect is schematically show in Fig. 4.

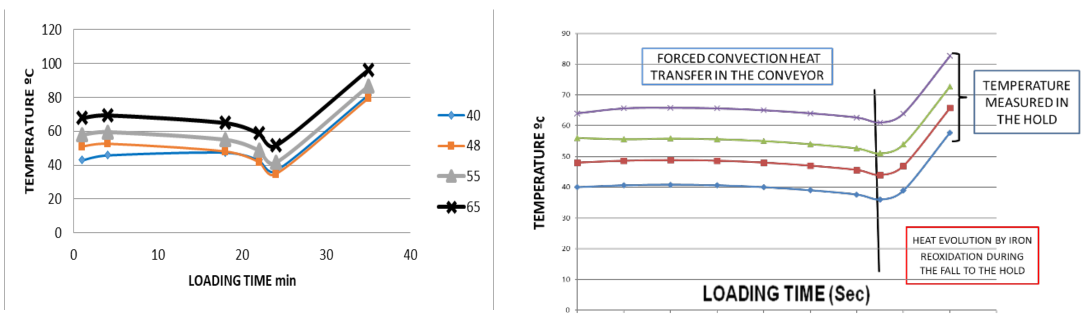

Fig. 4.- Temperature profile of DRI Fines from stockpile to ship hold (Left),Temperature profile of loading DRI Fines at the hold (right)

The shown temperature trend can be related to the air flow over the material surface on the forced convection effect when being conveyed from the yard towards the ship unloading end, whereas the increase of the temperature levels is related to the fine particles reacting surface during the free falling through the air towards the holds bottom. The analysis of the obtained field observations is mathematically expressed by means of a polynomial equation obtained from a minimum square regression from the function in Fig. 5.

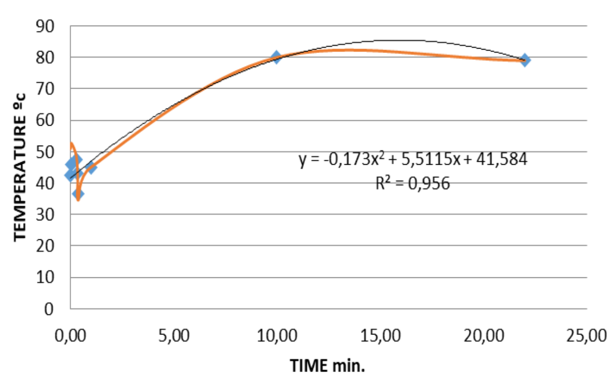

Fig. 5.-Temperature evolution of CRI C Fines during loading from stockpile yard

C.Loading Procedures

For the loading the hazardous materials in Chapter VII of the IMSBC Code it is clearly established loading temperature requirements, as show in Table 2.

Table 2. Suggested loading temperature of selected materials IMSBC Code

Material	Brown Coal	Coal	Pet Coke	DRI C	Seed cake
Loading Temp `C	< 30	< 55	< 70	< 107	< 55

As described earlier, the temperature increase, expressed in `C/min, of the materials is an important issue and its related to variables such as flash point, heat generation and flammable gasses emissions. The R70 test index is associated to coal reactivity described as low reactivity when is less than 99 `C/h and high reactivity is assumed to be less than 0.5 `C/h. In the particular case of coals, the threshold temperature is measures though the R70 adiabatic and non-isothermal heating tests, for the DRI C Fines the value was derived from actual field readings on board of ship cargoes. The results are show in Fig. 6, for low Sulphur, low ash subbituminous coal having high tendency for self-heating (coal A) and a less reactive bituminous coal, whereas in Fig. 7 is show a very low reactive and prone to self-heating of DR C Fines, when comate with coal.

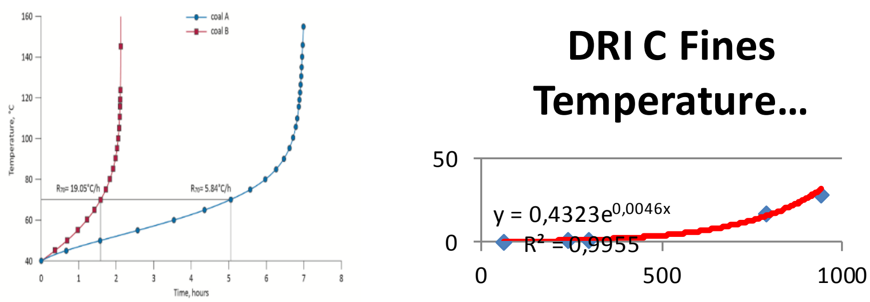

Fig. 6. - R70 values for different coals (left), coal B has higher R70 value meaning less reactive for heating up [2], thermal inertia of DRI C Fines.

Regarding the combined effect of the loading temperature and moisture content on the flammable gas generation in glassware reactor, is clearly show in Fig. 7 and 9.

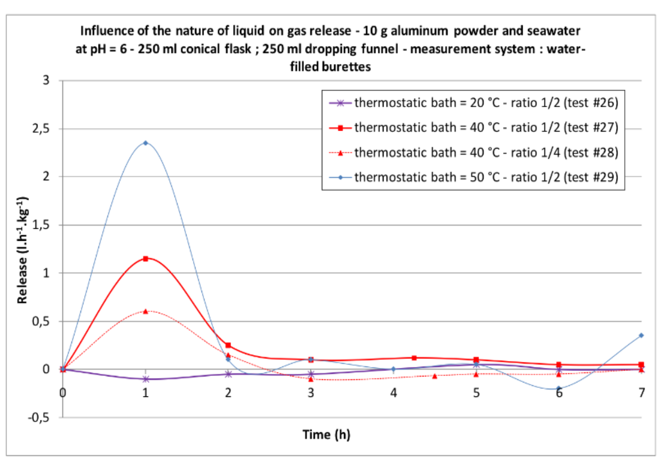

Fig. 7.- Influence of seawater on gas emissions from aluminum powder [3]

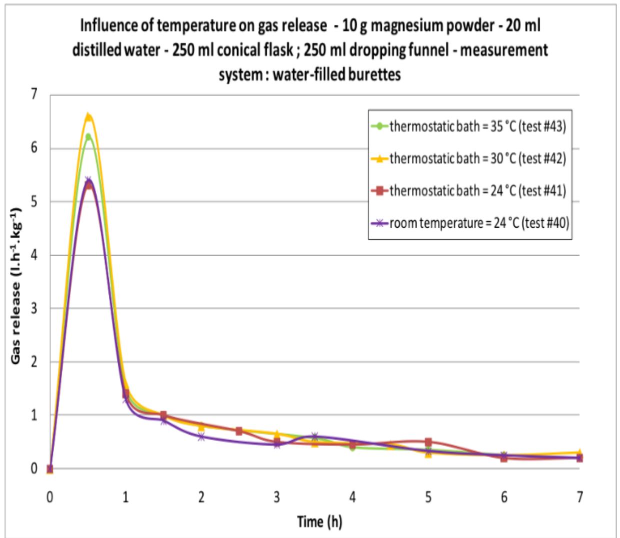

Fig. 8.- Influence of temperature on gas emissions from magnesium powder [3]

D.Moisture type and quality

The moisture content as well as the type it, acting on the material is another important variable for the intended purpose, but quality wise it turns to be close related to its electric conductivity and the corresponding effect via the pH values. This is a general application for the hazardous cargoes when considering the clear effect on temperature increase, heat generation and gas emissions rates especially when DC energy is present, which applies for the galvanic mechanism in batteries design and operation.

The temperature evolution measured in `C/min in the material is a function of the moisture content and it is considered a low rate when the temperature level remains steady and considered high when the rate in the temperature levels initially is high, followed by an steady period because of the moisture evaporation in the range of 80 to 90 `C, when full moisture evaporation is achieved a rapid temperature increase appears until it reaches a runaway overpassing the either the self-heating or ignition threshold for a fire/explosion event. This effect is show in Fig. 9.

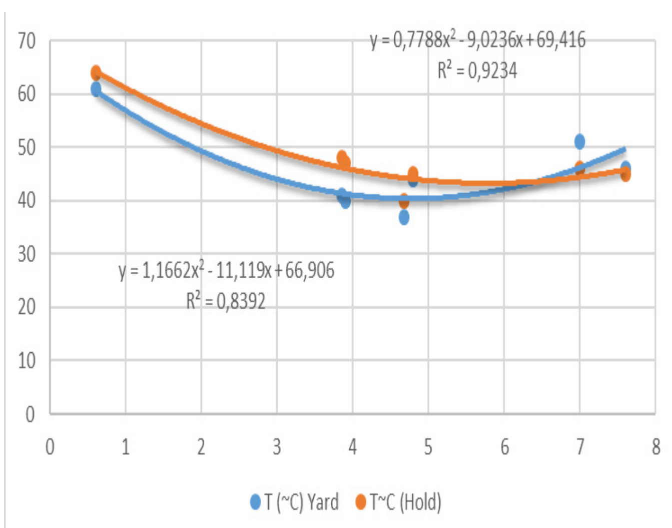

Fig. 9.- Effect of % moisture on DRI Fines temperature variation from yard to ship hold

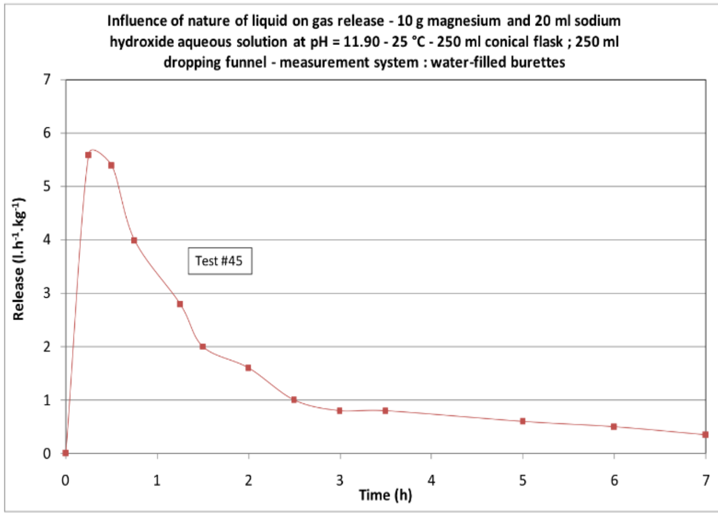

Fig. 10.- Influence of sodium hydroxide (pH 11) on gas emissions from aluminum powder [3]

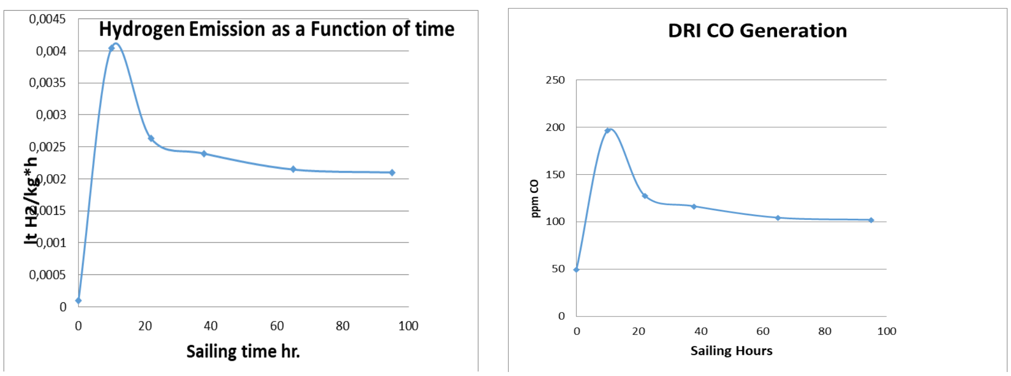

Fig. 11.- DRI C Hydrogen and carbon monoxide gas emissions during the ship sea passage under DC cathodic protection application.

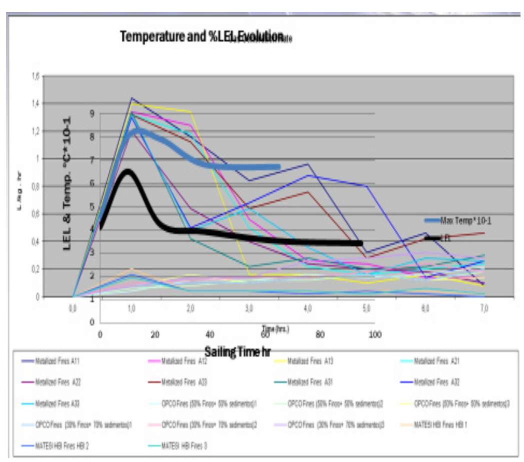

Fig. 12.- Hydrogen emissions and Lower Explosivity Level (LEL) of different DRI C Fines of moisture content betyween 3 and 7 weight percent (upper curves.)

It is worth noticying that the curves shapes in Fig. 7, 8,10, 11 and 12 shows the same pattern, which can de described by the following mathematical function

F. Y = k x exp b e exp (-c x). (1)

Where k, b and c constants values are particular for a particular material, this is expected to be so based on the different energies of activation (Ea), threshold temperature, and electric properties.

E. Direct Current (DC) energy source effect

Electric current can be conducted by and through any material either containing water or wet, including wood, therefore a reasonable aproach to materials properties such as electric conductivity (S m) and resistivity (ohms mt) and establish its relation to the direct curent (DC) energy supply by the cathodic protection systems (CP) used for corrosion prevention of any metallic container. Using this approach it is unavoidable not to consider Ohm's, Faraday laws as well as the Joule/thompson effect on the cathodic container/anodic cargoes. In the former protion of the system is unavoidable the hydrogen gas generation and heat release. Most of the hazardous cargoes listed in the IMSBC Code contains moisture, among which ar grains, wood chips and logs, coal, DRI's, ferrosilicon and metal contsining powders. In Table 3 are show some conductivity and resistivity of selected materials.

Table 3. Resistivity and resistivity values of selected materials

Material	% H2O	Resistivity (Ω-m)
Coal	1-3	0.012-0.032* 10Exp 6
Coke	2.14-1.47	0.20 – 0.50
DRI A	1 max.	0.000588
DRI C	0 -12	0.0005888

When comparing gas emission from DRI C Fines applying the UN Test N` 5 laborarory conditions (glassware testing rig) with 200 kg sample in an steel container (grounded with CP) and a modified UN Test N` 5 using a DC energy source by Impressed Current Cathodic Protection (ICCP), the last two testing procedures shows a substantial difference to those obained in a glassware containers Results are sho in Table 4.

Table 4. Effect of the test container on the results of UN Test N` 5

Test Conditions	Max. Hydrogen Rate lt./kg.hr.	% Variation	LEL Hold 3888 m3 empty space
Inert Gas (IMO/UN) Glassware	**0.00191**	NA	**1.61**
Natural Surface Ventilation (Industry)	**0.00195**	**0,5**	**1.63**
Industry test steel container CP grounded	**0.0040**	**161**	**3,34**
Galvanic ICCP DC energy	**0.0330**	**1680**	**4,48**

Besides the DRI C Fines consideration as a reactive naterial under CP conditions, other iron containing materials such as ferrosilicon, it is worth considering its electric characteristics that turns this material as a highly reactive material to emit hydrogen gas. Very early on the XX Century, it was well known the use of ferrosilicon as a material to mix with sodium hydroxide before water was added for the hydrogen gas generation. The IMO receive an event occurred to the MV AB Bilbao bulk carrier, IMO Number 9130200, reported during 2001, when sailing by the North Sea carrying 3000 metric tons of ferrosilicon. The cause of the accident was holds explosion by the accumulation of hydrogen gas. Although no further comments were found, there is a reasonable doubt that the cargo could be possible either contaminated with other sodium containing chemicals, or got in contact with sea water which also contains sodium and magnesium chlorides. Under those conditions, and the galvanic cell condition between ferrosilicon anodic cargo and the steel floor of the cargo hold, the only requirement to connect the galvanic cell was the presence of the electrolyte, this is the sea water. If this was the case, hydrogen gas was released and under natural ventilation hydrogen accumulation could be a cause for the explosion but even though a source of ignition was needed. In all cases involving DRI C fines and ferroalloys the oxygen depletion for whatever reason due to the accumulation of Hydrogen and carbon monoxide gas, under low air velocity, in either moderate or low pressure and oxygen depletion by actions of water steam and carbon monoxide emissions in the cargo open space environment.

III.MATERIALS REACTIVITY LEVEL AND ACCIDENTS OCCURRENCE

Aiming to obtain a clear relationship between the external factors and the material tendency to accidents and its intrinsic physical and chemical properties, the selected common property is the electric resistivity, in Fig. 13 is show the assumed variable.

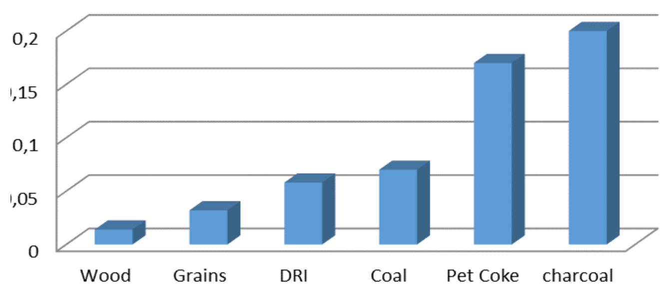

Fig. 13. Cargo materials electric resistivity (ohms cm)

As expected, the materials selected in Fig. 13 also have an especific energy of activation (Ea) expressed in kJ/mol, then the former variable indicates how easy the material could be for reacting under certain available heat generation, of course also depending on the moisture content, therefore it is possible to obtain an empirical and qualitative relationship with the fire and explosions frcuency, as show in Fig. 14.

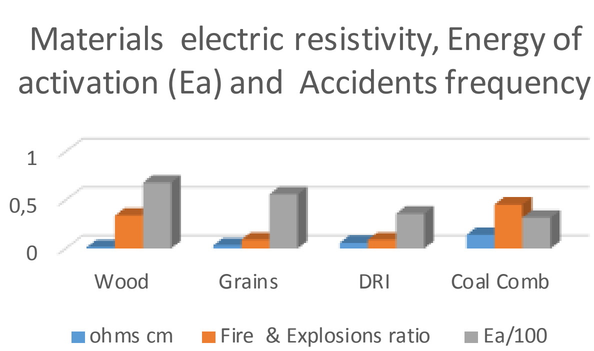

Fig. 14. Materials electric resistivity (ohms cm), energy of activation (Ea, kJ/mol) relationship with the fire and explosions accidents in ships.

Finally, the low fire and explosions index for DRI C Fines compared to coal cargo events can be explained based on the very low Ea value which turns to be a very low reactivity possible related to the moisture content as compared with the coal moisture content, as well as other type and amount and reactivity of the flammable gas emissions in the surrounding air (CH_4 5-15.4%, H_2S 4.5-45 %, CO 29% and H_2 4%), this trend is show in Fig. 15.

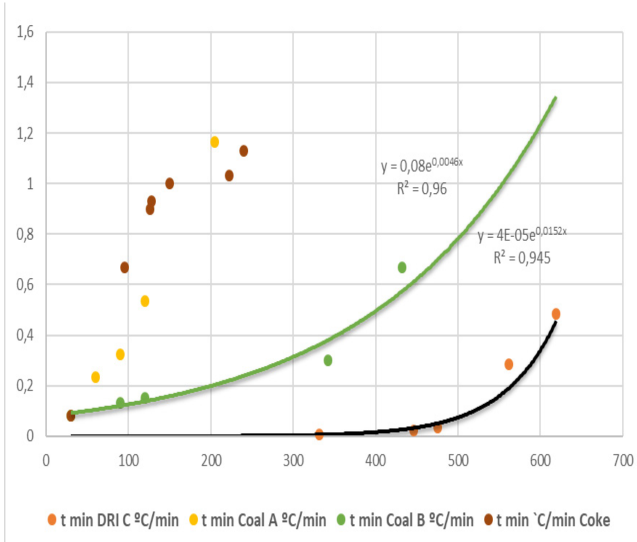

Fig. 16. Temperature variation rate (`C/min) comparison between DRI C Fines (1/100) and high and low reactivity coals and coke (left hand values).

IV.CONCLUSIONS

From the above comparative research, especially when considering the external factors influence on the self-heating and further ignition of the materials, it is possible to derive the following conclusions for further research work.

1.This research has proven he importance of considering the external factors on the reactivity of self-heating cargoes. Among these external factors the most important is considered to be the DC important is the direct current (DC) energy supplied by the cathodic protection systems in either ships or metallic containers. Consequently, the DC factor is recommended to be included in a reviewed and updated UN Test N` 5 for a more representative of the considered studied system and abstention of highly reliable results.

2.Reactive materials such as coal and DRI C Fines, when in stockpiled in yards are safe in open spaces in both extremes of the air circulation, this is in low and extreme air circulation. When the air circulation is low the accumulation of gases on the reactive surface tends to deplete the oxygen concentration reducing the reaction rate, whereas when high the removal of the flammable gases as well as the heat generated by the oxidation reactions

3.The compaction degree of the stockpile, in stockyards and ship holds, to reduce the presence of air is a concept to review to prevent ignition events rather than attempting to increase ventilation or inerting, the former leads to an accumulation of flammable gases.

4.The materials handling systems tends to increase new reactive surfaces when reclaiming fine materials such as DRI C and powders also increases the generation of fines and small particles in lumpy material such as coal.

5.It was found a close relationship between the moisture content in or around the materials, handling methods, energy of activation, liquid type and quality and the overall electric parameters considering the cathodic protection systems and the occurrence of fires and explosions in ship safety events

6.There is a clear trend on the heat, flammable gas evolution reactions when comparing reactions of aluminum, magnesium powder and DRI C Fines. The detected trend follows the mathematical function

$$Y = k\ x \exp b\ e \exp(-c\ x).$$

Where k, b and c constants values are particular for a particulr material, this is expected to be so based on the different energies of activation (Ea), threshold temperature, and electric properties.

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$$H(t)\,|\,\psi(t)\rangle = i\hbar\frac{d}{dt}\,|\,\psi(t)\rangle$$

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