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EDITORIAL

You are holding a special issue of The Journal of Energy, which brings you four chosen papers presented at the 6th International Congress Days of Mechanical Engineers, held under the motto Mechanical technologies – imperative of the future. These papers, primarily from the field of mechanical engineering have a certain interdisciplinary character, along with the projection of new engineering technologies.

Thus, the first paper covers a new approach to testing non-destructive methods, based on the implementation of active infrared thermography and ultrasound tests. Test subjects are composite materials, such as fiberglass and carbon fibres. Namely, due to the non-homogenous structure of the stated materials, they require the use of non-standard methods such as active thermography and ultrasound control. The paper presents the use of both of these methods, which had a synergetic effect and resulted with robust and reliable approach to the analysis of the composite material structure.

The second paper offers an analytical rare approach to transhumanism as a projection of future in the form of a superman or an improved man of the 2050ies. We are witnessing that advanced technologies, with more or less success, are trying to change the way how people, their bodies and brains function and communicate with the environment. The results of the research and relevant scientific sources show that by using new engineering technologies, mental and physical abilities of tomorrow's man are demultiplicated, i.e. improved. In this manner new engineering technologies are solving a series of pressing issues of the Homo sapiens civilization (human blood cultivation, eyesight, effective prosthetic devices…), but each medal has the other side…

Both scientific and professional circles are making ever louder announcements of using carbon-neutral fuel. Despite that, wider application of such fuels is not certain in the near future. The topic of the third paper is on this trail, as it refers to the decarbonization of energy and primary energy sources in the 21st century, and everything is viewed through the focus of changes connected to research and application of hydrocarbon (oil and gas) on the global level, and consequently in the Republic of Croatia.

Following the topic of the third paper is the topic of the fourth paper referring to hydro energy as an effective and efficient way of balancing other forms of electricity generation from renewable energy sources (wind, photovoltaics and biomass etc.). A special emphasis has been put on contemporary and sustainable approach to projecting and designing documentation for the construction of new hydro power plants or revitalization of the existing worn out hydro power plants, which requires the use of new information technologies with 3D projecting and BIM (Building Information Modelling) approach. Along with that, the significance of modelling and engineering tests of turbines in all developmental phases has been highlighted, as well as commercial exploitation, so there are examples of successful revitalized water turbines from Croatia and the world.

Prof. dr. sc. **Marija Šiško Kuliš**
Special editor

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NDT of Composites Based on Active Infrared Thermography and Ultrasound Testing

SUMMARY

Composite materials, such as glass and carbon reinforced ones, are characterized by inhomogeneous structure that requires non destructive testing based on uncommon evaluation methods. The presented approach is based on the active infrared thermography, supported by the A-scan ultrasound testing. The heat wave propagation induced by halogen or xenon bulbs, due to the differences in thermal conductivity, reveals material structure and anomalies. In our previous work we have developed several signal processing and depth evaluation methods, but the real engineering approach requires additional approval testing methods such as the A-scan ultrasound is. The A-scan ultrasound, based on the low frequency probe, enables approval of anomalies located by infrared thermography. The active infrared thermography, as a full field method, enables evaluation of the whole scanned area. The A-scan, as a point-wise method, does not provide the image of whole area of interest. By combining these two methods, robust and reliable approach to analysis of composite structure is enabled.

KEY WORDS

non destructive testing, ultrasound testing, infrared thermography

INTRODUCTION

Non destructive testing (NDT) of polymer composite materials is mostly covered by unconventional methods of evaluation. Polymer composites such as glass reinforced polymers (GRP), or carbon reinforced polymers (CRP) are characterized by an inhomogeneous structure. The low heat conductivity enables methods of testing based on the active infrared thermography (IRT) and halogen lamps as a heat source, contrary to metals where Xenon flesh bulbs are required. As a method that enables better identification of indications reviled by IRT, the A-scan ultrasound testing (UT) is used. When applying UT to polymer composites, particular attention has to be paid on interpretation of readings due to the significant inhomogeneity of composites. The radiographic control, that similar to UT a volumetric method, is not applicable to polymer composites. Production process of composites, e.g. manual laying of resin or vacuum procedure, can cause significant variations in homogeneity. In our previous research we have shown and developed methods for NDT of composites based on the active IRT [1, 2]. In this paper we present procedure of A-scan UT control as a method parallel to IRT with goal to better interpret findings.

The active IRT is a NDT method based on observing heat flow generated by light source. This research is based on halogen lamps and 1kW of heat source. Xenon flash bulbs can be used for polymer composites as well, but according to our experience when using 6 kJ flash excitation, damage of polymer matrix occurred. As mostly the heating period is around 2 minutes, resulting in 120 kJ of introduced heat energy, it will not cause the damage of matrix, as it is the case for the 6 kJ of heat energy introduced during few milliseconds. Due to the short time of energy flow to material, Xenon lamps are causing damage of polymer matrix. When using the active IRT, the simplest approach is to apply halogen light for approximately 2 minutes, and record first moments (seconds) after heat source is turned off. Such image can be enhanced, e.g. by using gradient based approach [4]. Another approach is to apply the sinusoidal heating where sequence of images is processed by the Fast Fourier Transform (FFT) image processing methods. In FFT the time domain (consequent thermal images) is transformed in the amplitude and phase domain, where mostly phase domain is the one that enables better sensitivity to detection of anomalies.

Figure 1. Active IRT, halogen lamp as a heat source applied on GRP specimen and 67 feet sailing yacht

The A-scan ultrasound is a commonly used NDT method, used in control of metallic structures. Typical cases are control of weldments, measurements of thickness (thickness gauging), evaluation of material homogeneity, material inclusions etc. For the case of steel or cast iron, mostly straight and angled probes with frequency between 2 and 10 MHz are used. Bigger material grain size requires probes with lower frequencies, e.g. 2 Hz. The probe size (standard or miniature) is determining focus and intensity of a sound beam. Probes with frequency of 5 MHz and above, are mostly used for thickness gauging because signal for homogeneous materials is strong, sharp and easy to read. Probes with frequency of 1 MHz are rarely used. Their signal is not so narrow and sharp (Figure 2, right). There is no need for such probes when steel is evaluated, except for cases such as the inspection of heat-affected zone (HAZ) in weldments of Duplex steels. The UT probe size is influencing reading capabilities, so standard probe size will enable better penetration and narrow sound beam in comparison to miniature probe. As composites are generally of small thickness, a fiberglass probe delay block is needed to focus the UT beam on the surface of the object. Thus, for the case of a polymer composite material, 1 MHz straight probe with the probe delay is needed as 4 MHz, or 2 MHz probe will not penetrate the material. Figure 2 depicts comparison of 4 and 1 MHz probe applied on the K1 calibration steel block. The 4 MHz is enabling sharper more concentrated signal easier for A-scan reading and evaluation, while 1 MHz signal is wider and such probe will only be used in cases when no penetration can be obtained with the 4 MHz one.

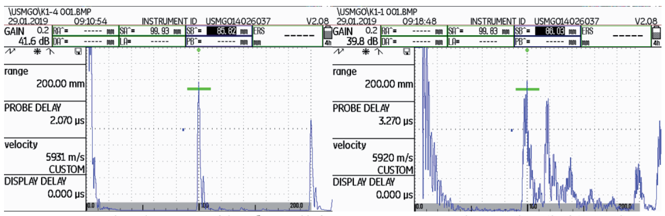

Figure 2. The A-scan of back wall for 4 MHz straight probe (left) and 1 MHz straight probe (right)

The NDT based on active thermography enables detection of composite layers, homogeneities, reinforcements, inclusions, cracks and delamination. Detection of osmotic damage in polymer composites is an extreme case due to the extremely week signal, both for ultrasound and active thermography recognition.

Osmotic damages are common damages of glass polymer vessels caused by humidity migrations from water/sea into air bubbles trapped within resin. Due to the hydrolysis, water reacts with material causing hydrochloric acid, acetic acid or glycol. As inner pressure appearing in foci is increasing, it delaminates material and by osmotic process absorbs more water. Typical damage appears in form of blisters and material delamination (appears like there is no resin in composite). Vacuum curing technologies reduces or eliminates osmosis due to elimination of trapped air bubbles. Epoxy based resins are reducing moisture migrations and osmotic process. Scientific literature in this field is limited, as the phenomena of osmotic damage is not elaborated enough. There are several repair approaches with not so clear long-term stability. Often decades are needed for damage to appear, so all new approaches to eliminate osmotic damage are dubious. Although this problem, as it only matters old vessels, does not seem economically significant, it is a big ecological problem due to reduced recycling possibilityof composite materials. Often old vessels are put on fire or sank. There are initiatives on the EU level where taxes on polymer composite boats should be introduced to encourage market not to buy composite boats in favor of recyclable materials such as aluminum, steel or wood.

2. DETECTION AND EVALUATION OF OSMOTIC DAMAGES

As an example, a sailboat built in 1986 with osmotic damages near surface is inspected and proposed methods, active lock-in IR thermography and A-scan UT, are presented. The combination of these two NDT methods enables proper evaluation of boat's hull. The A-scan UT is giving information about homogeneity of material, thickness of layers and depth of osmotic blisters and delaminations. The UT is a volumetric method that in control of metals is often combined with surface methods such as magnetic particles testing (MT) or penetrant testing (PT). Active IR thermography enables obtaining temperature distribution on the surface of material that is strongly influenced by the heat flow within material, thus enabling the voloumetric control as well. The ultrasound is a reliable confirmation of anomalies located by the IR method. This is similar to humidity evaluation in buildings where moisture gauges are used to prove the moisture.

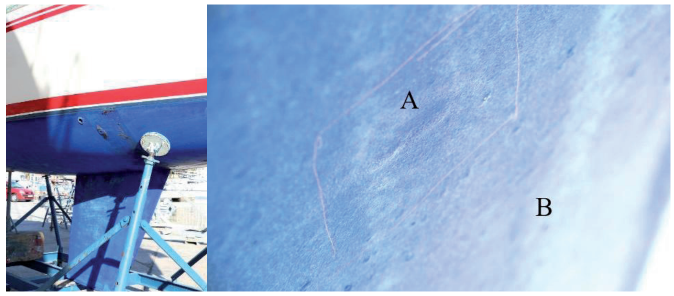

Figure 3. The osmotic damage on a boat hull in form of a blister

Figure 4. Active thermography experimental setup and the UT probe with the probe delay

3. A-SCANS OF EVALUATED ZONES

Figure 5 depicts typical A-scans of glass reinforced polymer boat hull. Peaks are reflections from various layers, such as anti-fouling paint and epoxy primer paint, gelcoat, roving, inner gelcoat. In left image of Figure 5, the loss of signal, i.e. zone without reflections, is a beam trough the blister, after which there are again reflections of layers. The shape of A-scan depends if the vessel was recently docked (presented case), or it is for some time out of water. Conductivity of sound is better for the wet hull, opposite of the case when it is for long period after water. Locating osmotic damage is clearer for the wet hull due to the differences in the impedance between two acoustic media (water and composite). After few weeks out of water blisters will not be visible any more. As soon as a vessel is back to water, the water penetrates the damaged area. In this particular case (Figure 5, left) the damage is 7 mm deep, after which the signal is significantly reduced. Signal peaks at depth of 12 mm are back wall reflections of layers of composite. When compared to steel, such signal has no clear peaks. Measured values (depths) are not exact due to the different sound velocity in comparison with the calibration on the vacuum treated reference block.

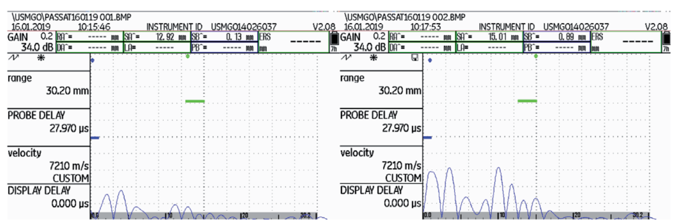

Figure 5. A-scan of osmotic blister (left) and of sane material (right)

4. THE ACTIVE LOCK-IN INFRARED THERMOGRAPHY

The most important condition of infrared (IR) thermography is to provide useful results with enough of temperature difference or thermal contrast between features of interest, e.g. internal flaw – the contrast between the osmotic blister and its surrounding. The active approach is used on materials or systems that do not present significant differences in temperature with respect to their surroundings. For the active approach, the thermophysical properties of the internal defect have to be different from those of the specimen's material. Without this condition, defect detection is impossible. The active thermography, as a NDT method, is based on generating outer heat impulse and acquiring material response during the period of observation. In presented example two halogen lamps (500 W each) and time controller enabling sinusoidal heat flow are used. The method of si-

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gnal processing is based on the sinusoidal fidelity, commonly called the "Lock-in" thermography. The concept of the method is based on the fact that the sinusoidal heat source flow, when travelling through the material, will remain sinusoidal, but with shift in phase and amplitude. Frequency of sinusoidal wave will remain the same. Inhomogeneities in material will reflect and change heat flow, hence reflected sinusoid flow will be different when reflected from surrounding material or feature of interest, e.g. damaged area material. The material heat response, reflected for the reflective thermography and transmitted for the transient thermography, will reach the object surface where it will be recorded by the IR camera. The reflected heat flow will retain same frequency as the heat source, but the phase shift and the amplitude will differ, depending how much heat flow will be damped by inhomogeneities. The amplitude and the phase shift of each image pixel is calculated according to relations:

$$A_{tw}(x,y) = \sqrt{[S_1(x,y) - S_3(x,y)]^2 + [S_2(x,y) - S_4(x,y)]^2} \quad (1)$$

$$\phi_{tw} = arctan\frac{S_1(x,y)-S_3(x,y)}{S_2(x,y)-S_4(x,y)} \quad (2)$$

where points S_i are readings within one period of sinusoid of reflected heat flow [6].

When assembled back to the image, phase shift reveals material inclusion, damage, and other anomalies, where the obtained contrast between sane and damaged material is, when comparing to raw thermograms and amplitudegrams, much better. Phasegrams obtained at higher frequencies are revealing anomalies near the surface. Lowering the frequency, deeper layers of material are evaluated as heat wave penetrates deeper in the structure. As the penetration depth is related to the heat source frequency, the depth of anomaly can be evaluated. Due to the inhomogeneity of composite material, sometimes it is not possible to find exact depth. The A-scan ultrasound is enabling better recognition of the depth. As mentioned before, the ultrasound is affected by the inhomogeneity, but location of the structure back-wall helps to locate the position of anomaly.

The experimental setup (Figure 4) included two controlled 500 W halogen lamps, middle wave cooled InSb FLIR SC 5000 thermal camera, GE Krautkramer USM GO A-scan ultrasonic flaw detector and 1 MHz straight probe with probe delay.

Figure 6 depicts phase shifts (phasegrams) of the zone in figure 3 for different excitation frequencies. Osmotic damages in zones A and B (blisters A and B in Figure 3) are in layers close to the surface. The damage A is shallower from the damage B, where for the excitation frequency of f=0,0083 Hz the damage A is not visible. The depth of the damage A is between excitation frequencies of 0,0083 Hz and 0,0139 Hz. The A-scan located the damage A at the depth of 7 mm. As the damage B is still visible for excitation frequency of 0,0083 Hz, lower excitation frequencies should be used to locate the depth where material is not damaged. Figure 7 depicts the same region after removing antifouling paint and protective epoxy primer.

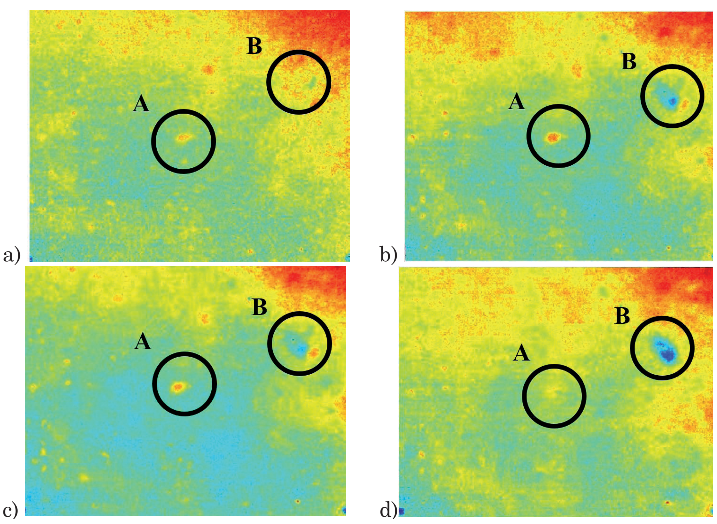

Figure 6. The phase shift images at excitation frequencies of. a) f=0.04167 Hz b) f=0.0208 Hz c) f=0.0139 Hz d) f=0.0083 Hz.

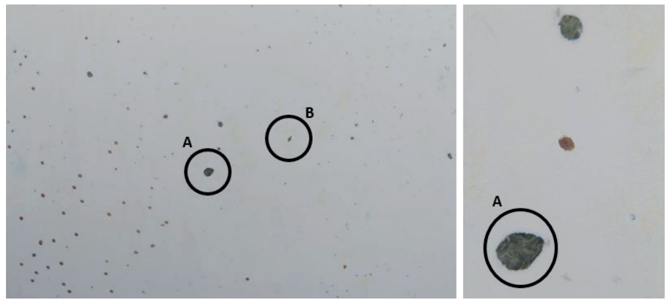

Figure 7. The osmotic damage on the hull surface after grinding the antifouling paint and protective epoxy primer

Figure 8 depicts phase shifts for the location in Figure 4 (left) where smaller blisters have been located. After grinding antifouling paint and epoxy primer, it turned to be that blisters were between gelcoat and epoxy primer so there was no damage of boat hull (Figure 9). Phasegrams show anomalies in zones close to the surface, while for deeper zones they are not visible.

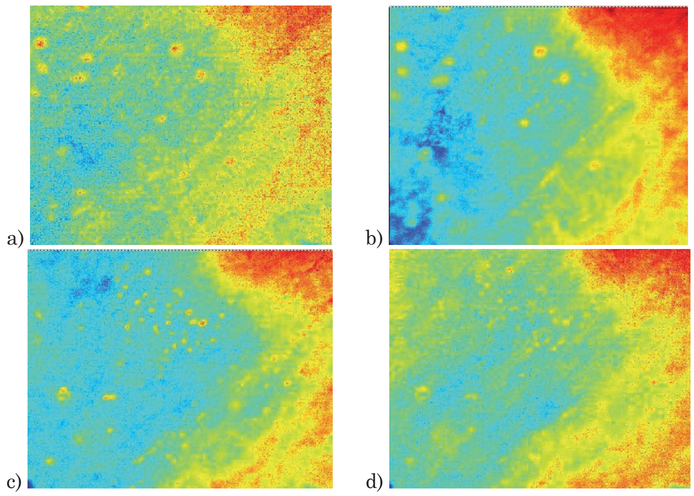

Figure 8. The phase shift images at excitation frequencies of. a) *f*=0.04167 Hz b) *f*=0.0208 Hz c) *f*=0.0139 Hz d) *f*=0.0083 Hz.

Figure 9. The sane hull surface after grinding the antifouling paint and protective epoxy primer

5. CONCLUDING REMARKS

This work is an overview of an infrared approach to NDT. The osmotic damage is used as an extreme example that is characterized by extremely low thermal contrast where simple pulsed thermography, without additional signal processing, will not reveal damage. The A-scan ultrasound is used as additional NDT method with the goal to prove findings and to better locate the depth of detected anomalies. The method is reliable and was already used to find the productions faults of new delivered yacht as a part of reclamation claim.

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Transhumanism — Robotics Interactions

SUMMARY

Thinking wrong that the humanistic ideal has already been realized, transhumanism is promoting the liberation of man by progressive overcoming of his own biological boundaries in order to improve his physical and mental abilities, as well as his life extension. From interaction between biomimetic robotics and transhumanism augmented man was born. But a smart management application is still missing, that one for a future society, in which men and supermen will live together and which would allow technological improvement to everyone and halt the accelerated process of deepening socio-economic inequalities. That's the reason why the transhumanism is often experienced as an opponent and competitor to humanism, same as the new technology development which is often perceived as the goal in itself - as a phenomenon which is not in the service of the real needs of social development. Consequently, It is urgent to move from simple thinking (speculations, preferences and beliefs) to the complex one: proposing hypotheses and solutions, creating relationships and observing interactions, seeking criteria, relying on verified facts and self-correction practices.

KEYWORDS

transhumanism, biomimetic robotics, augmented man, demiurgic power, complex causality

INTRODUCTION

If the researchers want to gather the data from the interaction between biomimetic robotics and transhumanism, they have to leave their Cartesian reductionism: thinking that the world is equal to the sum of its parts, and that the thinking mind (ego cogitans) is separate from the objective world (res extensa). Indeed, until we radically shift our thinking, and our thinking about thinking, humanity will continue to replay 'déjà vu' scenes. It means, we have to approach today's globalized and highly technological world like a whole that can be more and less than the sum of its parts. Then we have to adopt the concept of complexity [1], which is an appropriated transdisciplinary philosophical frame that supports the systemic approach to research and innovation and enables linking and organization in the whole of humanistic, scientific, technological and artistic knowledge.

ORGANIZATION AND RELATION THE ELEMENT - THE WHOLE

The notion of interaction is at the origin of the idea of organization. But the interrelations that produce various random encounters (interactions) can turn into an organization only under certain conditions. This path to transformation can be seen as a natural mutation because it is not due to an "organizing principle" that precedes the organization. It is a question of a change that is born "in and through catastrophe" (in and through disorder) and that defines the organization as "the arrangement of relations between components or individuals, which produces a complex unit or system, endowed with unknown qualities at the level of the components or individuals, which guarantees the constancy of the system" [2] (of the whole). It means: organization binds, transforms, produces and maintains; introduces the "notion of emergence" to designate "unknown qualities" and defines the relationships between the whole and the parts in the following terms:

"The idea of complex unity will take density if we sense that we can not reduce the whole to the parts, neither the parts to the whole, nor to the multiple, nor the multiple to one, but that we must try to think together, in a complementary and antagonistic way, the notions of the whole and its parts, of one and of various." [3]

In other words, in a complex unit, the whole is more than the sum of the parts because of emergences - qualities or properties of a system, which are novel in relation to the qualities or properties of the components considered separately or arranged differently in another type of system. For example: the stability of an atom makes that it differs from the particles which constitute it, as well as specific properties of a human society make that it is impossible to reduce it in a sum of the individuals who compose it, or in the result of their actions. But, the fact that the whole is more than the sum of the parts implies its opposite, so that the whole is also less than the sum of the parts. Indeed, due to organizational constraints, some properties disappear within the system. The organization develops specializations and hierarchies, but in parallel also develop repressions and constraints on the creative potentialities of the elements.

In the relation element-whole of a complex unit, on the one hand we must distinguish the complementarity between parts, and on the other hand the antagonism between parts. The parties have their own identity and participate in identity of the whole. The organization establishes the complementarities between parties that imply the constraints. Consequently, the antagonism stems mainly from these complementarities. Its rooting in the system is deep because the organization incorporates the affinities that create the bonds between the elements, as well as repulsive forces that ensure the essential maintenance of differences between components. [4]

Biomimetic robotics is scrambling to mimic this complex natural agonistic-antagonistic game in the frame of equality that hinges on the humanist ideal of inalienable human dignity or, more and more, on a humanist ideal which calls for transcending the self in order to make room for a universal and generous energy.

HUMANISTIC APPROACH OF BIOMIMETIC ROBOTICS

The humanistic ideal in past century was to liberate human from the predominant struggle to secure material existence in order to dedicate himself to art, science, learning, and creation. Transhumanism starts from the false assumption that the humanistic ideal has already been achieved and goes further. It offers human's liberation by progressively overcoming his own biological limits to improve his physical and mental abilities and extend life expectancy. It is clear that the underlying foundations of transhumanism are distorted. Since the humanistic ideal has never been realized, the accelerated technological progress of the past decades, which theorizes transhumanism, is perceived as an opponent and a competitor to humanism.

Some research structures, such as Versailles Engineering Systems Laboratory, cling to the original humanistic idea while designing different devices which scope of application is mobility in general, and particularly for persons whose mobility is temporarily or permanently restricted, or for robots in order to ensure a balance in human-machine interaction.[5]

Hydoïd [6] is a real-life humanoid robot whose purpose is to contribute to improving the understanding of locomotion, the phenomenon of human motion. Humanoids on a Hydraulic Drive [7] can accomplish full spectrum of heavy and useful tasks, replacing people in environments that require them.

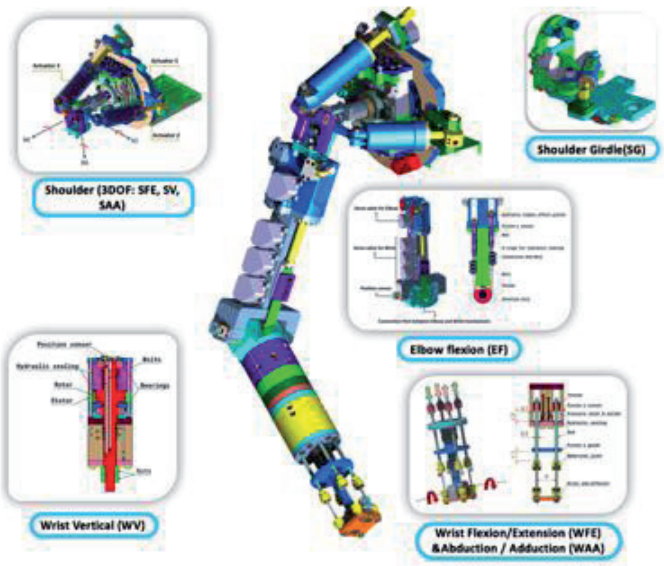


Figure 1 : CAD design HYDROïD (left) and its prototype (right), source of picture LISV, Paris-Saclay.

HOPALALA is an open platform humanoid robot that users can adapt to their own needs. Hopalala is the fruit of joint efforts in developing an open platform of humanoid educational robots that will be used in primary and secondary school education. Its design allows the alternative introduction of different types of sensors (light, temperature, contact, proximity, distance, pressure, navigation / position, acceleration, IMU sensor - Inertial Measuring Unit).

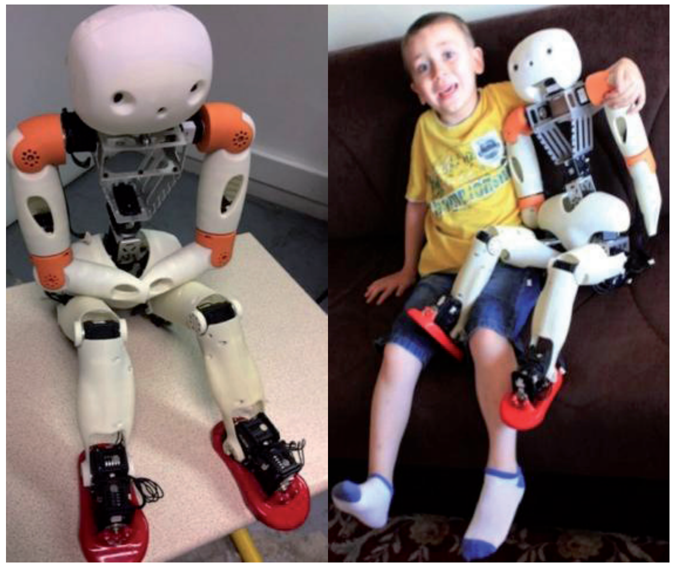


Figure 2 : Robot HOPALALA, source of picture LISV-Paris-Saclay

Project SANDYC: the development of lower extremities for adolescents with spinal cord injury. Problem to resolve: all existing exoskeletons are primarily intended for adults where human body characteristics are set in terms of size and physical properties, which is not the case with adolescents who can still grow. Therefore, in collaboration with SANDYC, in 2014, an industrial project for the development of the lower extremities of the teenagers has been launched, enabling them to move around and around the house.

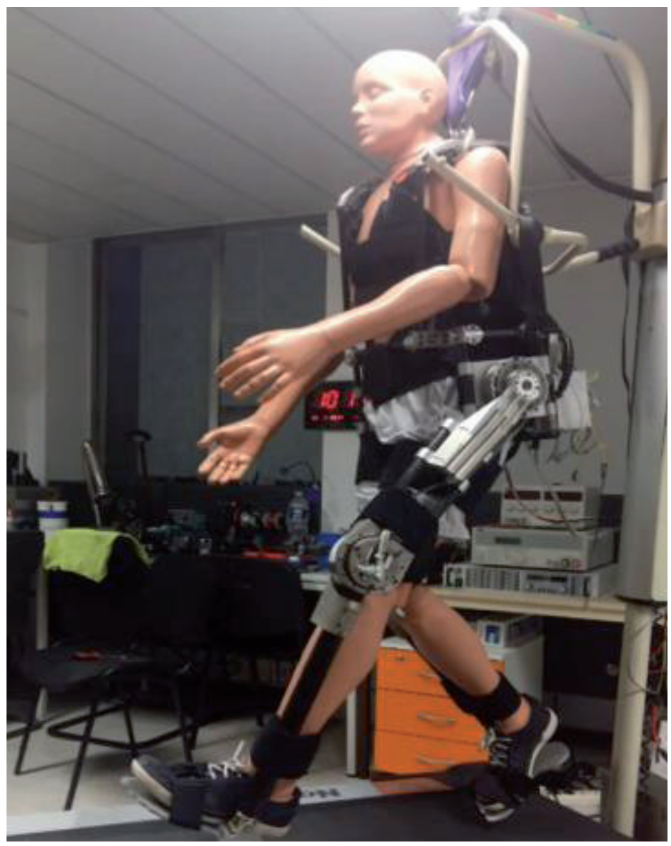


Figure 3 : first prototype of the lower extremities of the exoskeleton, source of picture LISV Paris-Saclay

The ESTA and CEREBRAPTIC projects of the EADS Foundation are related to the study of new interface models from the point of view of linking commands and taking into account physiological signals that allow characterization of user states [8].

Figure 4 : Brain-computer interface, source of picture LISV Paris-Saclay

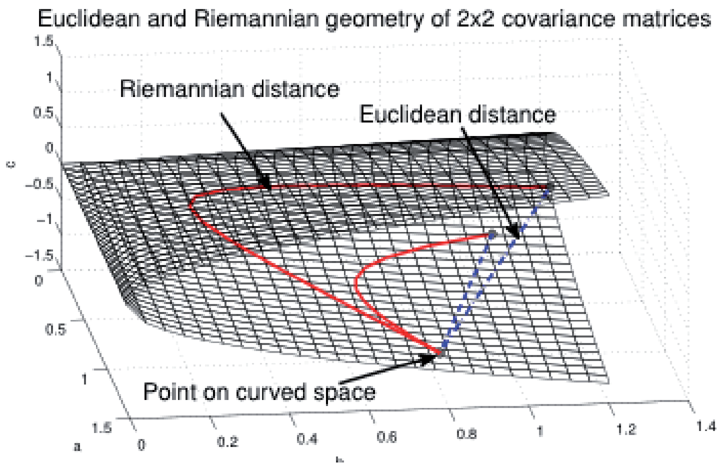
The Virtual Armchair Project (FUI Ile de France with EDF and CEREMH, 2014/2018) was developed as a result of the FUI AccesSim project focused on assessing the virtual reality of urban accessibility. So it's a virtual reality simulator for learning wheelchair mobility [9].

Figure 5 : Platforms Accessim and Becape Eco

Humanistic robotics disregards transhumanistic ideal – Augmented man, but agrees to repair human defects, and thereby accept willy-nilly to play transhumaniste game. Indeed, the way to increase abilities of handicapped persons is often also the way to increase capacities of all persons.

TRANSHUMANISTIC APPROACH OF BIOMIMETIC ROBOTICS

Transhumanistic ideal is augmented man. Transhumanists are convinced that it is necessary to liberate man from his biological vulnerability, to stop the phenomenon of aging, and to improve his abilities, especially those of the brain, which would become more powerful than it is the case today.



They are expecting hypothetical uploading or reconstitution of the complexity of the human brain, as well as transfer to the computer (dematerialization in Cloud or re-implantation in robot) of the most perfect system of interconnected 100 billion cells. With this aim in mind they launched two major projects: the American Human Cognome and the Swiss Blue Brain, in parallel with Singularity University project of Larry Page, a guru of artificial intelligence who enjoys the support of Google and NASA. This University's mission is to train students, entrepreneurs, and governments to recognize the benefits of new technologies, as well as to promote the concept of singularity by which human civilization will experience technological growth of higher order by about 2060. At that time, the developed intelligence would be superior to natural human intelligence, thanks to NBIC (nanotechnology, biotechnology, computing and cognitive science) and the principle of individualism, taken from the philosophy of liberal political thought and the free market economy.

Since liberal transhumanism is directed at an individual, but individuals are not considered as a part of a whole (of society), a new superman is born. Like Elon Musk, who is ready to colonize Mars, and thus inaugurate a new "post-humanist type of man" – superman, more intelligent and then superior to man. The profile of this augmented men, whose intelligence would increase proportionally to his bank account growth, is alarming; as well as a kind of intelligence we can buy, and maybe use against non augmented men with a thin bank account. Therefore, the vision of the future inhabited by the "posthumanist kind of man" reminds us of the fatally unhappy interpretations of Nietzsche's superman of the past, such as Hitler's übermensch, which seeks the extermination of all «undermen» and despises men who do not believe in supermen›s existence. Likewise, because transhumanists did not develop a smart human resource management application that would be able to govern men and supermen and insure technological improvement for everyone, it is not clear how to stop the accelerated process of deepening socio-economic inequalities that followed the last 30 years of work on augmented man. This concern has, of course, increased since Kurzweil predicts that the man himself will become an application capable of repairing his own damaged matter. According to him, man is on the path of mastering «the application of life » and the damaged «human matter» will no longer automatically mean the disappearance of the human spirit with it [10].

INSTEAD OF CONCLUSIONS

Highly technological environment defines augmented man, consequently the development of artificial intelligence that Marvin Lee Minsky defines as the design of computer programs that perform actions that humans are still doing better, because these tasks require high-level mental processes such as: perceptive learning, memory organization and critical reflection. So today's key question is how the augmented man will use the demiurgic power he might possess if his product - artificial intelligence [11] - can really master high-level mental processes that are today a feature of natural intelligence. So it is no coincidence that some opponents of transhumanism, among which the most active historian Francis Fukuyama [12], blame the movement to promote the most abundant form of inequality - the one that will exist between "man" and "superman". For Fukuyama, the possibility of transforming human beings using technology is only a stretch to the limit of technical utopias inherited from Francis Bacon (New Atlantide, 1622). Philosopher Jean-Claude Guillebaud [13] adds that transhumanist militancy is marked by immaturity because it reflects hatred of the human body, its weaknesses, suffering and imperfections. - in short, hatred of all what makes from man a man.

The contemporary world is undoubtedly more complex than transhumanistic ideal - Augmented man with his selfish wish to improve his abilities [14]. Nevertheless, Cynthia Fleury, a philosopher, notes: "We are not only living in the world of machines that have nothing human, but we are also living in the world of people who behave like machines"[15]. People persistently refuse to move from simple thinking (speculations, preferences and beliefs) to the complex one: proposing hypotheses and solutions, creating relationships and observing interactions, seeking criteria, relying on verified facts and self-correction practices. [16] The transition to complex thinking implies a certain effort, which occurs only after systematic acquisition of knowledge, in an adequate environment.

The complex thought is supported by a special form of circular (complex) causality, where there is not only an unbroken chain between effects that affect the causes and causes that affect effects, but there is also the perpetuation of that chain, because the effects themselves produce causes. For example, scientists are at the same time a product and a producer of transhumanism. Transhumanism learned scientists the transhumanist language, by which scientists have become themselves the producers / teachers of that same transhumanist language. The fact that the product is a producer has therefore enabled the inertia of transhumanist culture and the transfer of the transhumanist language from generation to generation of the scientists. Even more, thanks to this principle of recursivity, the generations of scientists can exist. Reproduction is therefore a manifestation of recursivity.

It is clear that it is easier to reach the logic of the machine then to reach complex causality.

However, if transhumanists really want that their thinking become a recognized philosophical concept like humanistic one, then they must abandon the simple causation in which the same causes always produce the same effects, making appear the development of new technologies as the goal in itself, far away from real needs of society. By incorporating the principles of complex thought, especially of recursivity, transhumanism would have reached the stage of the Information Age and became the producer of new norms of humanistic culture.

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Energy Decarbonisation and Primary Energy in the 21st Century

1 Statements expressed in the paper are author's own opinions, they are not binding for the company/institution in which author is employed nor they necessarily coincide with the official company/institution's positions.

SUMMARY

This paper emphasizes the role of primary sources of energy, primarily oil and gas in the future (so-called "energy mix") with the expected trends in the future. The changes expected by the oil and gas sector in the 21st century have been underlined due to energy decarbonisation. There are intense discussions about the oil and gas future due to the effects of climate change and the announcement that oil is in the final phase of exploitation due to the high depletion of fields around the world. How are the big oil companies responding to these challenges and what are the trends of global energy consumption? In the 21st century, it is necessary to take in account all types of energy with the growth of renewable sources. In the meantime, natural gas is imposed as a bridge between fossil and decarbonised energy, and the trends in the gas segment in the world and in the Republic of Croatia will be emphasized as well. In addition, the new Croatian energy strategy must be aligned with changes in the oil and gas sector, as well as exploration and production of hydrocarbons. Carbon-free energy is still a long way, but the low-carbon energy period has begun.

KEYWORDS

primary energy, decarbonisation, oil and gas, hydrocarbon exploration and production

1. INTRODUCTION

What are the most important trends in energy? If you follow mainstream press accounts, there are at least three:

1. The oil and gas industry will soon face radical restrictions as countries respond to climate change;
2. The rapidly growing electrical vehicle market will make oil obsolete;
3. The world is quickly moving toward 100% renewable energy.

All of these supposed trends are part of an overarching narrative that says we are in the midst of an energy transition: the world is moving quickly and inevitably away from "dirty" fossil fuels to "green" solar, wind, and batteries. Regardless of whether the "transition to renewables" narrative is true, the wholesale belief in that narrative poses a threat to oil and gas companies. One major way the industry has responded to this is to talk about the benefits of its work: about how oil and gas power our homes, cars, data centers, and hospitals, and about how the industry creates millions of jobs and billions in tax revenue [1].

All of that is true. But, by itself, it does not counter two core premises:

1. That oil and gas are easily replaceable by solar, wind, and electric vehicles, which means these benefits are not unique to oil and gas but apply to all sources of energy.
2. That oil and gas have catastrophic costs—on our health, our environment, and our climate—which means that even significant economic costs of transitioning to alternatives could be worth it.

Desire of people all over the world is greater development (expecially in India, China and Africa), therefore we should expect that the fossil fuel industry will not cease to exist but that it will be even more developed. In the first quarter of this year, a number of new discoveries of hydrocarbons (reserves) increased by as much as 30% compared to last year (offshore discoveries around Cyprus, Israel, Egypt, etc.) [2]..

2. CHANGES IN OIL AND GAS SECTOR

In September 2015, the United Nations adopted 17 Sustainable Development Goals, addressing the global challenges facing humanity, including poverty, inequality, health, education, energy, climate, the environment, and prosperity. The organization's 2030 Agenda for Sustainable Development is a continuation of its Eight Millennium Development Goals, with, among notable additions, the inclusion of energy access as a separate goal.

Energy is central to many of these goals through its linkage to the economy, education, health, the environment, and water. In 2019, nearly a billion people (more than 13% of the world population) do not have access to electricity, and 3 billion people lack access to clean cooking solutions, even within oil and gas producing/exporting countries.

Sustainable Development Goal no. 7 sets five ambitious objectives to be reached by 2030, including universal access to affordable, reliable, and modern energy services; a significant increase in the share of renewable energy in the global energy mix; and a doubling of the global rate of improvement in energy efficiency. Despite its importance in world energy supply, and its lower environmental footprint compared with coal, the oil and gas

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industry suffers from a poor public image, especially with the younger generation. Given the 2018 Intergovernmental Panel on Climate Change report that raised alarm bells about the consequences of just a small change in average global temperatures, how can the industry support the ambitious agenda of the UN's sustainability goals?

Several organizations including energy agencies, major oil and gas companies, and research and consulting groups have developed energy supply and demand outlooks based on various scenarios. These outlooks (not forecasts) show the potential evolution of energy demand in the future (generally 2040/2050/2060), and the corresponding energy mix.

In these models, energy demand grows between 3% and 44% from now until 2040, while the share of oil and gas in the energy mix varies between 53% today and between 50-58% in 2040. Therefore, oil and, more importantly, natural gas will be important sources in meeting the world's increasing energy demand going forward. Most of the outlooks, however, do not take into account the multiple requirements associated with the UN's sustainable development goals [3].

In 2017, the International Energy Agency (IEA) published an energy outlook that took into account universal access to energy, a reduction of emissions in line with the so-called Paris Agreement regarding climate change, and a major improvement in air quality, which is the cause of millions of premature deaths. In this "sustainable development scenario," which does not require a major increase in energy-related investment compared with the baseline case, it is projected that global energy demand will continue to increase and, that by 2040, the oil and gas share of the global energy mix will still be 50%, representing the major enabler for universal energy access. The major emission-reduction wedges for this energy transition are: energy efficiency, renewables, CO2 capture/utilization/storage, and switching from coal to natural gas.

The oil and gas industry has many opportunities to move public perception of it as being part of the sustainability problem to being part of the solution. The industry has been fueling major economic growth since World War II, enabling access to transportation and electricity to an increasingly larger share of the world's population. Major international and national oil and gas companies are participating actively in an economically and socially acceptable energy transition to the future. Several initiatives are under way, including:

- The majors' shift to natural gas and its role as a major bridge to a low-carbon future. Technological developments such as LNG-Liquified Natural gas, floating storage and regasification units, and floating LNG are contributing to larger access at the country level to natural gas. Additionally, renewables such as solar and wind, which have seen major cost decreases over the past decade and are competing with fossil fuels for power generation, suffer from their intermittency and need to be combined with costeffective energy storage solutions and/or a baseload energy supply such as natural gas.
- The Oil and Gas Climate Initiative, with a $1 billion fund over 10 years to take practical action on climate change and reduce the carbon footprint of energy value chains. The initiative was started by 10 International Oil Companies-IOCs and National Oil Companies-NOCs. Among its initiatives are to monitor and reduce methane leakage and the development of carbon capture and storage projects.
- The Clean Energy Ministerial and Mission Innovation initiatives, which involves public and private organizations (including oil companies) making progress on a range of issues, including sustainability themes as diverse as gender diversity in the energy sector, energy efficiency, and clean hydrogen.
- The Greenhouse Gas Flaring Reduction Partnership, a publicprivate initiative, led by the World Bank, to address the issue of gas flaring, which wastes resources and creates an environmental problem. The partnership disseminates best practices and helps develop country-specific gas flaring reduction programs.
- Carbon capture, utilization, and storage as a single technology, which has the potential to be the largest decarbonisation component in the energy transition. Its application expands beyond capture from natural gas to include power plants as well as industry (steel, cement, aluminium, petrochemicals). Having been a pioneer in carbon capture, and through its subsurface-related technologies, the oil industry can play a major role in making this technology meet the most stringent regulatory requirements.
- Energy efficiency and clean energy in the development and production of hydrocarbons and in the downstream sectors. Technological advances associated with technologies such as digitalization are helping the industry improve its efficiency. Collaboration through industry organizations such as International Petroleum Industry Environmental Conservation Association-IPIECA and International Association of Oil & Gas Producers-IOGP are providing participants the opportunity to benchmark their operational performance. In the refining sector (the most energy-intensive activity of the oil industry), voluntary use of benchmarks such as the Solomon Energy Intensity Index has helped participants improve performance. Novel conversion routes such as crude-to-chemicals provide further potential for efficiency. Other innovation in the upstream sector is the increased use of renewables as an energy source for enhanced recovery (e.g., solar for steam generation).
- Development of renewables and energy storage solutions. Oil companies are investing in novel third-generation biofuels such as algae. They also are providing expertise for offshore wind projects based on experience developing platforms. Reduction in the cost of energy storage and its improved reliability has also been featured in company strategies.
- Several IOCs have created technology venture arms to invest in startups associated with the energy transition.

Changes in the Oil and Gas Sector are permanent regardless of the so called low-carbon strategy as a strategy of primarily developed countries. New gas producers come from unconventional sources as well as those old on the example of Iran. Liquefied Natural Gas (LNG) is coming to Europe after the US government has approved the export. The price of LNG is reduced compared to gas transported by pipeline, which is more concise. Many shipping companies are thinking of using LNG or Gas to Liquid-GTL as fuel for launching marine engines. Further construction of transport pipelines is planned to bring gas to Europe from the Caspian region and Russian gas by pipeline Turk Stream. For many years there have been talk about peak of oil and gas production and reserves disappearance. However, production has grown most thanks to the acquisition of gas from the unconventional layers (shale and tight gas layers).

Change in energy consumption in the world where China's leadership has surrendered to India is shown by Figure 1.

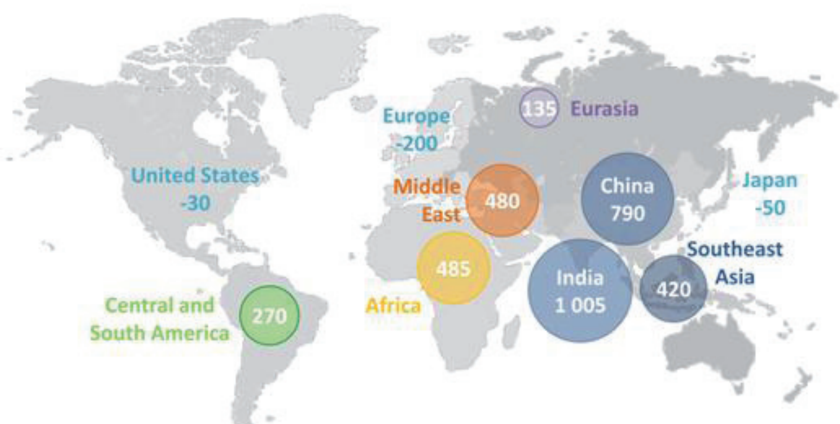

Figure 1. Change in energy demand, 2016-2040 (Mtoe) [4].

The change in the energy consumption structure is given by Figure 2. and new energy capacities by type of production is given by Figure 3.

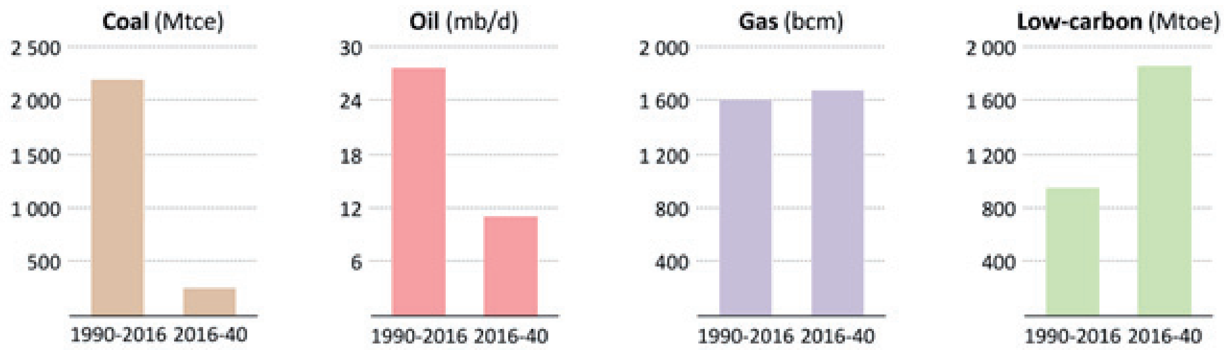

Figure 2. Change in world demand by fuel [4].

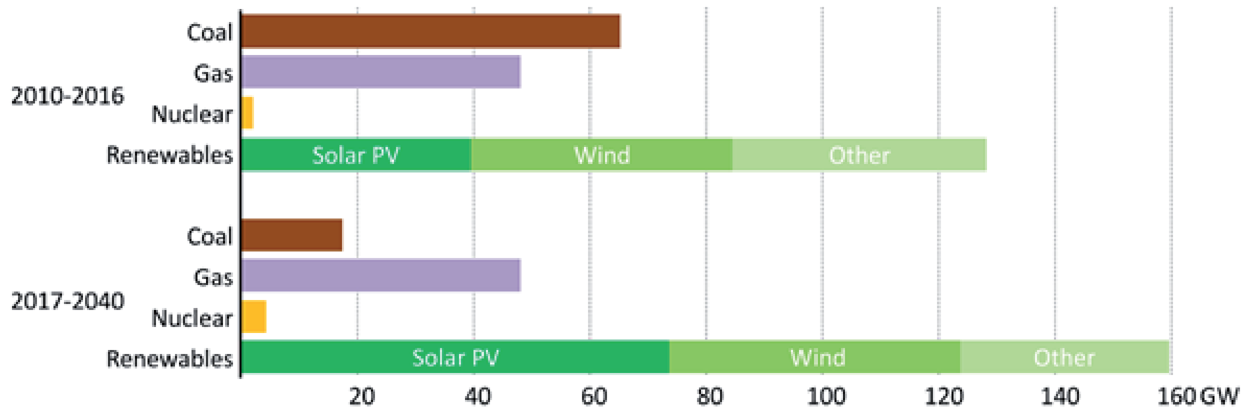

Figure 3. Global average annual net capacity additions by type [4].

Further on, according to forecasts until 2040, despite the increase in the number of electric cars, oil consumption will continue to grow, primarily due to the transport needs and the petrochemical industry (Figure 4.).

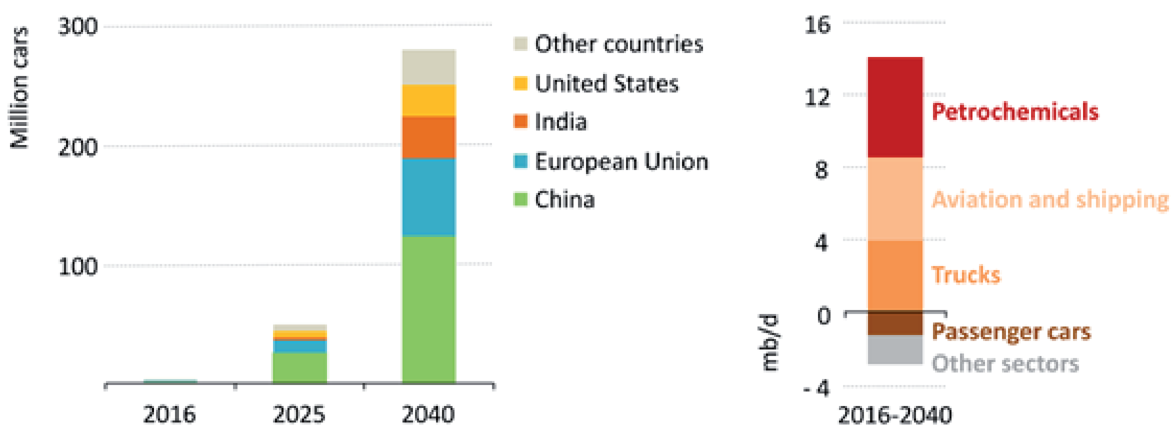

Figure 4. Electric car fleet and change in global oil demand [4].

3. PRIMARY ENERGY IN CROATIA (OIL AND GAS) AND OPPORTUNITY FOR NEW DISCOVERIES

The main guidelines of the Croatian Energy Strategy are the growing, flexible and sustainable energy production. This means:

- Reduce dependence on energy imports by stopping the decline in domestic production;
- Invest in energy production (define the potential of the Republic of Croatia);
- Ensure an adequate energy mix with lower CO2 emissions.
- Invest in existing oil and gas fields as well as new oil and gas exploration (reserve replacement).

There are three areas in the Republic of Croatia that are important for hydrocarbons exploration and production (Figure 5.). These are the Pannonian basin (green area), the Dinarides (red area) and the Adriatic offshore (blue area).

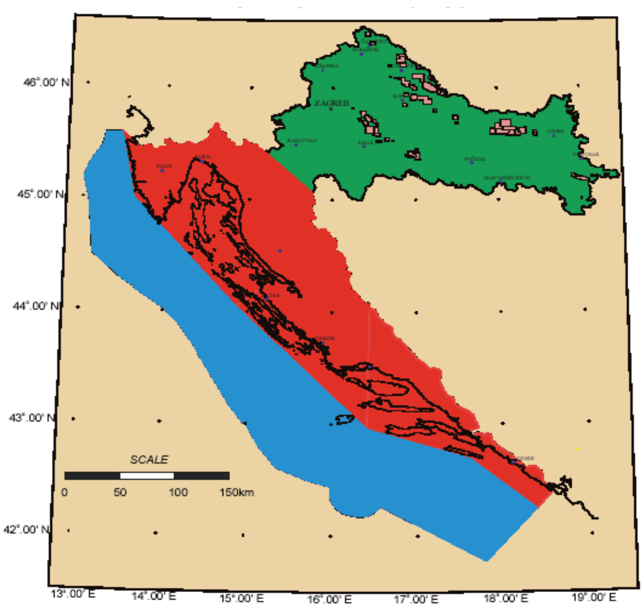

Figure 5. Oil and gas exploration areas in Croatia [5]

The Croatian part of the Pannonian Basin has reached a relatively high degree of exploration. So far most large and medium dimensions fields have been discovered, but there are still a number of »minor« ones. There is a justification for further exploration due to existing infrastructure. The quantity of hydrocarbons produced per volume unit and weight of the source rock, the amount of hydrocarbons derived from the source rock by the generation phases and the amount of hydrocarbon residue held in traps were determined [6]. In the most unfavourable scenario so far 66% of hydrocarbons have been discovered and 33% still exist for discover. In a more favourable scenario, assuming traces of the remaining 10% of the generated hydrocarbons remain, there is a potential scenario that up to now 15% has been detected and there are still 85% of the hydrocarbons to be discovered. The fact is that a small numbers of wells are deeper than 4000 m. Therefore it is necessary to record additional new generation geophysical data. Five exploration areas for which the Government of the Republic of Croatia signed the contracts in 2016 launched new investments in exploration after a long period with a continuous decline in production. In 2018, the Government of the Republic of Croatia announced new bid round for seven new exploration blocks (Figure 6.).

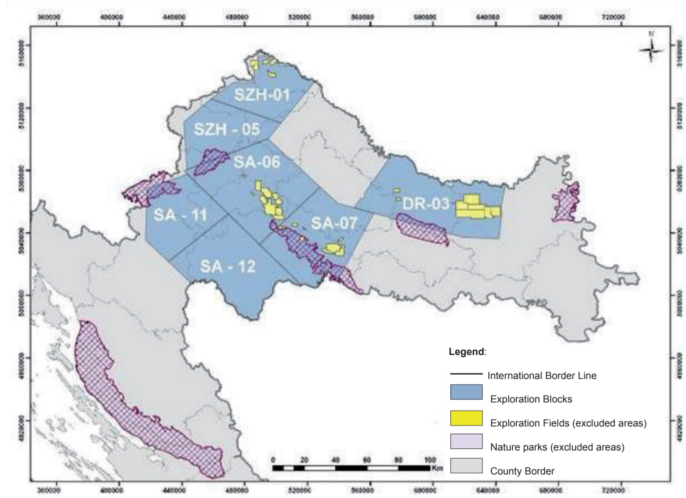

Figure 6. Map of exploration block-Pannonian basin [5]

Regarding Dinarides numerous geological studies, maps and detailed geological profiles were made, gravimetry, magnetometry and seismic (1957/58) were recorded as well. The first exploration well (RK-1) was drilled in 1959 and since then a total of 22 wells has been drilled and 17 wells were located in the coastal area. The poor quality of existing seismic data is a problem in solving complex structures. So, this year, the Government of the Republic of Croatia issued a call for 4 exploration blocks (Figure 7.).

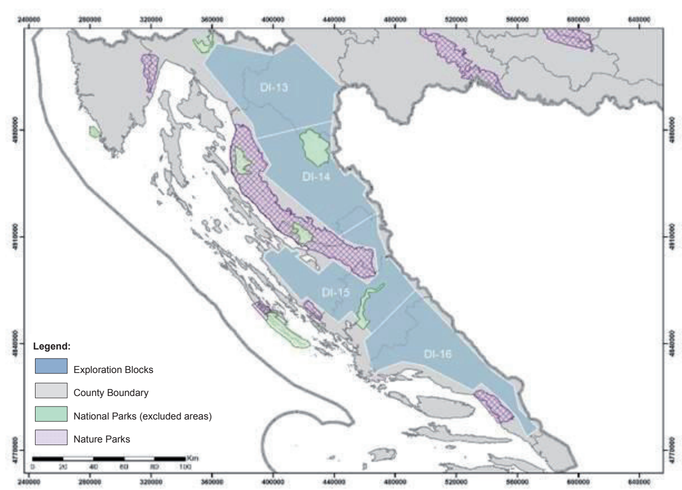

Figure 7. Map of exploration block-Dinaridi [5]

The offshore hydrocarbon potential is not considered in this paper. Gas production from the North Adriatic Sea has been started in 1999. INA PLc. is planning to drill new wells next year.

4. OIL AND GAS PRODUCTION AND RESERVES IN CROATIA

In the period from 1952 to present, 45 oil and 30 gas fields were put in production. More than 100 million tons of oil, 10 million tons of condensate and 80 billion cubic meters of natural gas were produced. Close to 4 500 exploration and development wells were drilled, out of which 1 200 are production oil wells and 200 are gas wells. Oil and condensate production forecast up to 2050 is shown by Figure 8. and Gas production forecast is shown by Figure 9.

Author's opinion of this text is that the current production forecast needs to be changed because it does not show a realistic picture, especially with regard to offshore production.

If there is no additional investment in reserve recovery, and considering the high level depletion of existing production fields, it is to be expected that very soon after 2030 the recoverable amounts of oil will become insufficient for profitable production.

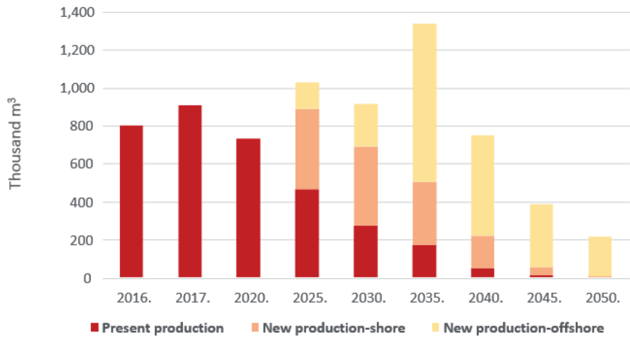

Figure 8. Oil and condensate production forecast to 2050 [7]

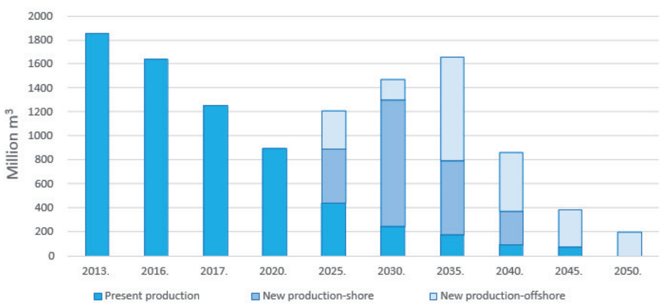

Figure 9. Natural gas production forecast to 2050 [7].

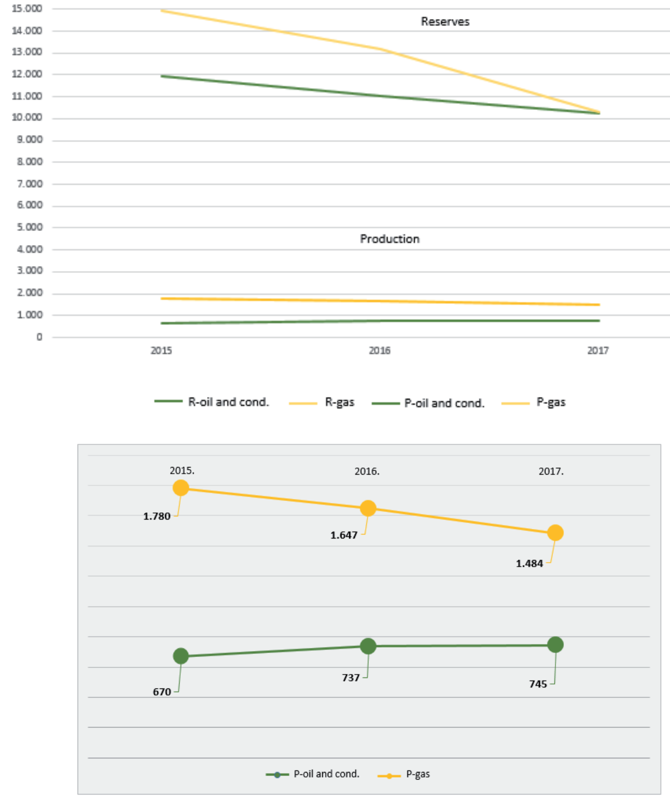

Figure 10. Reserves and production overview: 2015-2017
(oil and condensate - 103 m3 , gas - 106 m3)

The Reserve Replacement Ratio (RRR) ratio is the ratio of added reserves of oil and gas over a period of time and amounts recovered. According to the SPE / WPC definition, inventories represent that amount of oil or gas which is based on the existing technological achievements and profitably to deliver to the market. The negative recovery coefficient means that the reserves decline is greater than the total produced one over a given period of time.

Remaining oil and condensate reserves were 10 million m³ at the end of 2017, while the gas reserves were 13 billion m³ [8].

Rapid gas production and reserves are very concerned and at the moment Croatia for the first time has much imported gas then production from own fields. Further production will not provide enough accumulation of funds for a new exploration.

Figure 10 shows the oil, condensate and gas production and reserves from 2015 to 2017.

Oil and gas stocks reserves be replacement by exploration that could be resulted by discovery, exploration, and hydrocarbons production. This can be realized over a long period and carries geological and technical risk. Reserves can be also increased by expanding of existing fields, implementing new technology and operations to increase oil recovery (Improved Oil Recovery-IOR and/or Enhanced Oil Recovery-EOR). In a shorter period, reserves can be increased by buying new fields in operation.

5. CONCLUSION

In the end, it is necessary to return to the three mentioned trends.

The "transition" narrative with the "expansion" narrative by making the superiority of its product part of every energy discussion. For example:

- Will we impose radical restrictions on fossil fuels, such as a carbon tax high enough to stop people from using oil and gas? Unlikely. Given fossil fuels' enormous superiority, the tax would have to be far higher than those passed already—and which have already led to opposition in places.
- Will electric vehicles make oil obsolete? Unlikely. Given oil's superiority as a source of portable power, even the 2% market share that electric vehicles currently have depends on massive subsidies and mandates. In addition, the majority of oil is not used for personal vehicles, but for even harder-to-replace uses such as shipping and air travel.
- Is the world going 100% renewable? Unlikely. Wind and solar are currently inferior, intermittent sources of electricity and cannot supply reliable power—not without backup from reliable forms of energy such as fossil fuels or cost-prohibitive storage.

Further decline of hydrocarbon reserves and hydrocarbon production in the Republic of Croatia would lead to the disappearing of petroleum engineering and huge increase of energy import. Therefore, it is necessary to slow down hydrocarbons production. The best option is a more intensive exploration activity.

Exploration and production of hydrocarbons has substantial benefits, creates new jobs and stimulates the sustainable development of domestic industry.

Further hydrocarbon exploration and production will provide both a direct and multiplier effect stimulus to all Croatian industries - from shipbuilding to agriculture to transportation.

Increased hydrocarbon exploration and production will also support the establishment of new industries, services and products not yet existing in Croatia and will stimulate new exports of products and services. Ultimately, this will lead to job creation in all sectors.

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Trends in Hydropower

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SUMMARY

With a global focus on reducing carbon dioxide emissions, hydro power has come to the fore as an effective means of balancing other forms of electricity production from renewable sources (wind, photovoltaics and biomass). The role of hydropower in the modern mix of energy has led to favorable climatic conditions for development in the construction of new plants and upgrading with the renovation of existing hydroelectric power plants. Especially reversible hydropower plants with modern equipment with the so-called variable speed technology have a special role, which enables stability in the primary and secondary energy regulation system. A noteworthy trend is the construction of new facilities with low falls with the installation of highly efficient Kaplan and Tubular turbines. The already built projects in the fifth and sixth decades of the previous century, especially in northern Europe, are rapidly revamped and prepared for use in the next 40 to 50 years. Modern and sustainable approach to designing and preparing documentation for the construction of new or renewable power plants requires the use of modern information technology with 3D design and BIM (Building information Modeling) approach. In this way, young generations of engineers and consultants are easier to communicate with each other and reduce the possibility of errors in all phases of project realization. Key to the realization is the contracting of projects, the big dilemma whether to have EPC (Engineering, Procurement, and Construction) contracts (turnkey) a responsibility in one place or to deal with separate lots and engage their employees to control realization in order to minimize risk. Special attention is given to model research and development of turbines with reciprocal tests both on the model and prototype turbines.

KEYWORDS

hydropower, pump storage, BIM, CFD, R&D.

1. HYDROPOWER KEY FACTS

Within many types of renewables technology nowadays, hydropower will undoubtedly play a vital role throughout the world. Hydropower provides around 16.4 % of the electricity throughout the world [1]. Indeed, it is the most important renewable energy source today. In 2017, hydropower development reached 21,9 GW as seen in Figure 1 due to the continued growth. Pure hydropower capacity placed into operation producing 1,267 GW worldwide including 153 GW of pumped hydro of the total installed capacity in the world as seen in Figure 1 and 2.

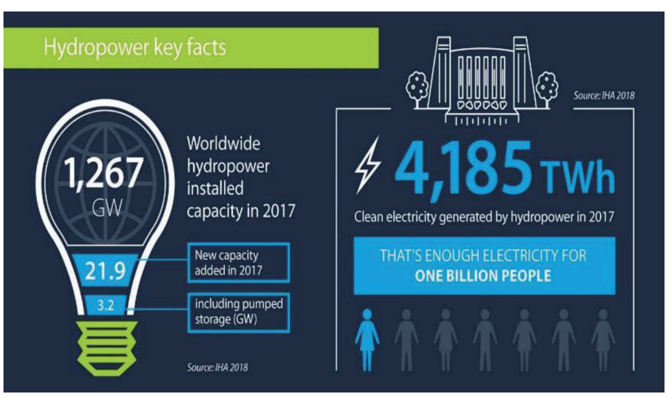

Figure 1. Hydropower key facts [1]

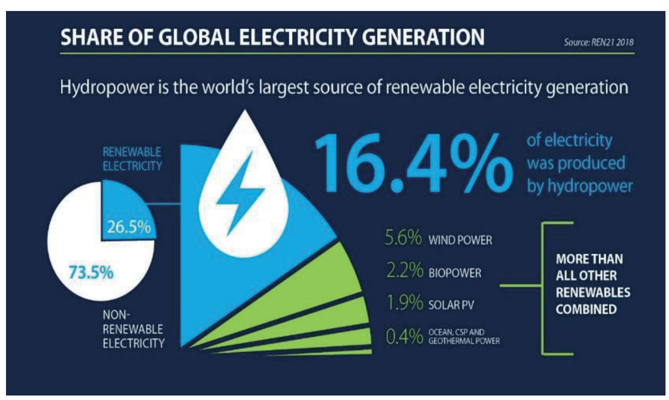

Figure 2. Share of global electricity generation [1]

Currently, many countries in the world have been using hydropower for their electricity supply. Moreover, more than 150 countries are reliant on hydropower to produce their electricity. For instance, Canada, China, Brazil, and the United States are the countries which utilized hydropower generation in a wide range because they have the largest hydropower production capacity as seen in Figure 3.

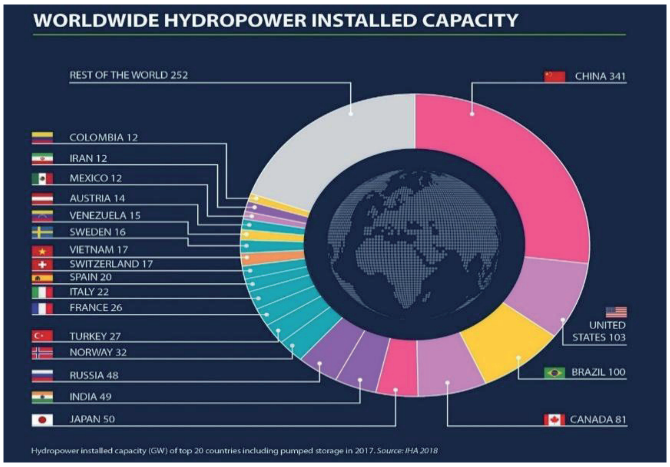

Figure 3. Worldwide hydropower' installed capacity [1]

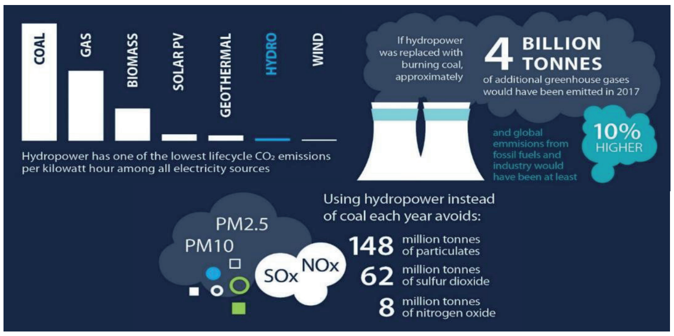

Figure 4. Hydropower versus coal [1]

Hydro energy represents the largest coefficient of energy recovery compared to other traditional and renewable energy sources as seen in Figure 4. The share of the total energy produced during the lifetime of the energy-sharing technology needed to build fuel is the true meaning of the energy return ratio. This is the most important benchmark when considering the efficiency and sustainability of the power plant. Therefore, a higher return ratio is required to achieve better ecological efficiency.

Due to the hydroelectric life span, the plant produces more than 100 times more energy. The extremely long life of hydropower systems and the short energy conversion processes are the reason for obtaining a high energy return ratio. For this reason, the life cycle assessment for hydropower gives a brilliant carbon footprint.

2. CURRENT TRENDS IN HYDROPOWER

2.1. TRADITIONAL HYDROPOWER GENERATING PLANTS

Traditional hydropower units have come a long way since they were introduced in the 19th century. With advances in all technical fields, all aspects of the operation of the hydropower units were greatly improved. Over the past few years by using the Computational Fluid Dynamics (CFD) modeling, especially large steps ahead concerning the efficiency and operating limits of new turbines were made. New runner designs were introduced with very high efficiency. In Fig. 5, some guidelines for model peak efficiencies for different turbine types and specific speeds are presented [3]. These values can lead to efficiencies of 96% in case of prototype Francis turbines.

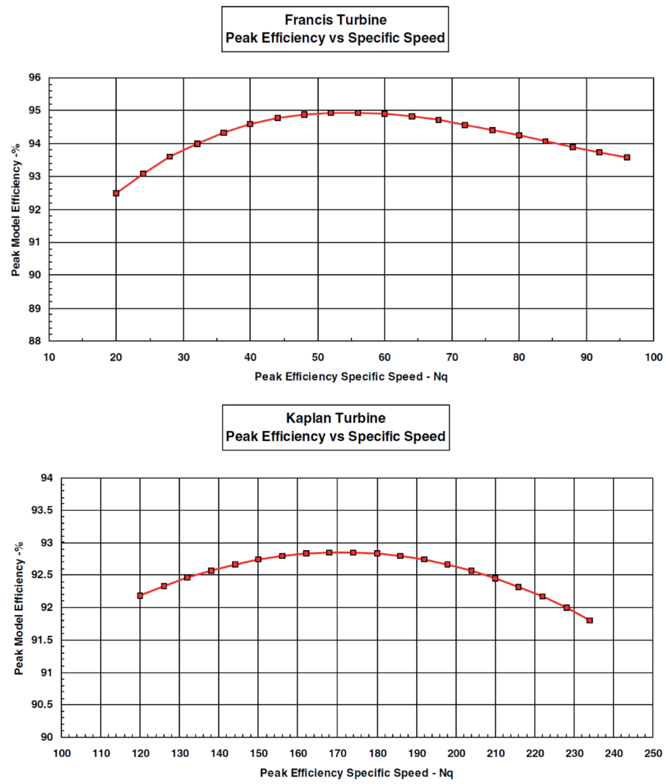

Figure 5. Francis and Kaplan turbines – peak model efficiency versus specific speed [3]

Standard scale-up procedures from model testing to prototype specified in the standard IEC 60193 [7] used for model testing, were complemented with a new standard IEC 62097 [8], which deals with performance conversion procedures from model to prototype in a much more detailed way.

2.2. Modern energy storage plants

Hydropower plays a significant role in reaching Europe's climate and energy target. Notably, hydropower can accomplish the increased development of renewable technologies into the European power grid. The future energy systems in Europe of the wind and solar demands steady capacity and potentiality to stabilize unsteady generation over time varying from hours to several months. The only configuration of hydropower electricity storage that is convenient on a large scale is pumped storage. As a result, pumped storage hydropower provides additional Energy services. A lot of projects of pumped storage under construction such as in Switzerland and Portugal, more than 3,000 MW of new capacity was installed.

2.2.1. Avče pump storage plant

One typical example of modern energy storage plant with high head is project PSPP Avče in Slovenia which generates 426 GWh of electricity per year. The key advantage of this Power Plant is generating of the so-called peak energy from a renewable energy source. PSPP Avce with its advanced technology is one of the first reversible power plant in Europe with such type of variable speed technology in pumping and turbine mode. Due to adaptability to daily needs of consumers this Power Plant is of especially great importance at provision of stable supply of electricity to the Slovenian electric power system.

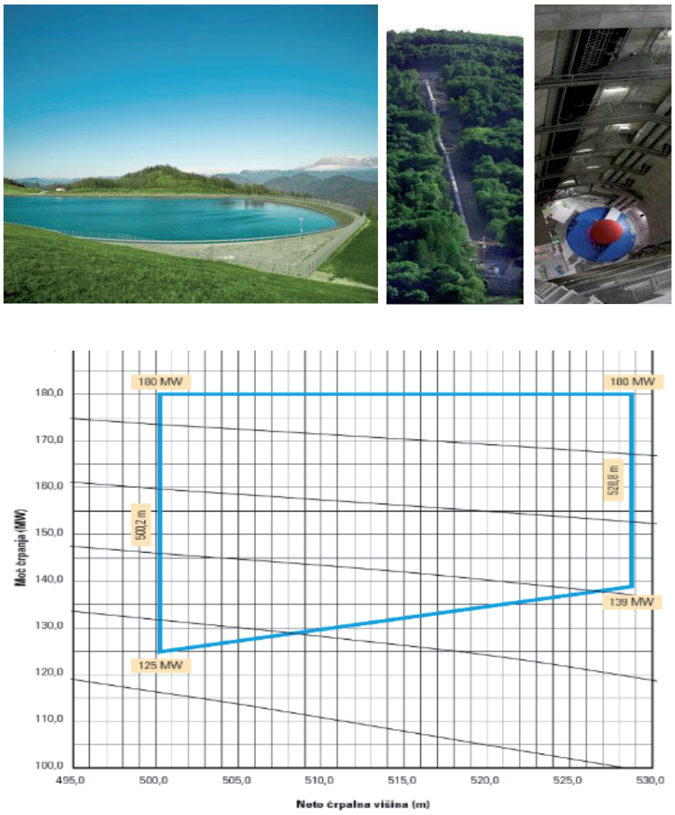

Figure 6. Avče pump storage plant [5]

2.3. CASE STUDY TURBINE REFURBISHMENT – DUBROVNIK HPP, CROATIA

HEP, National power producer is continuously working on refurbishment of units which operates more than 40 years. More than 5 hydro power plants were refurbished by using advanced approach defined by EPRI standard. All of them were very successfully refurbished and modernized and they are ready for continuous operation for next 40 to 50 years with minimum maintenance costs.

In the case of Dubrovnik HPP two turbines were upgraded with peak efficiency more than 95%, with more than 22% bigger power output and by increasing maximum flow more than 11,5 %, as seen in Figure 7.

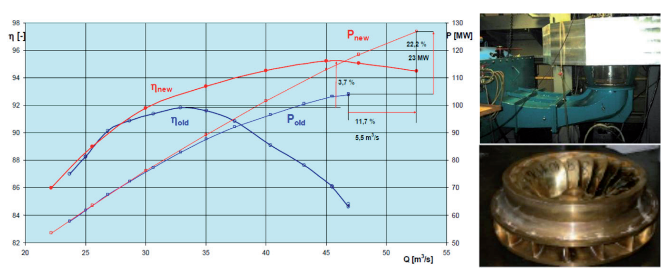

Figure 7. Case study turbine refurbishment – Dubrovnik HPP, Croatia [6]

2.4. CASE STUDY TURBINE REFURBISHMENT – HPP ZAKUČAC, CROATIA

In the case of HPP Zakučac, special approach was implemented by performing so called independent competitive tests by two of biggest turbine manufacturers, Alstom Hydro now GE Hydro and Voith Hydro. The winner of the model tests competition performed in laboratory of Turboinštitut was Voith Hydro. As a result of such approach turbines at units A&B units were upgraded with peak efficiency more than 95,7% with weighted prototype efficiency more than 95%. These are extraordinary results of turbine refurbishment, unique in this part of Europe. Some moments from model tests are given in Figure 8.

Figure 8. Case study turbine refurbishment – Zakučac HPP, Croatia [6]

2.5.MODERN APPROACH TO DIGITAL PROJECT MANAGEMENT - BIM

In a modern and sustainable approach to designing and preparing documentation for the construction of new or renewal of existing power plants, it is necessary to use modern information technology with 3D design and access to Building Information Modeling (BIM). In this way, the younger generations of engineers and consultants communicate with each other and reduces the possibility of errors in all phases of project implementation.

Different BIM levels can be achieved for different types of projects. Each level represents a different set of criteria that show a certain level of »maturity«. BIM levels start with 0 and go to 4D, 5D, and even 6D BIM. The purpose of these levels is to determine how effective, or how much information is shared and managed throughout the process.

Level 0 BIM does not apply to co-operation at all. If you are using 2D CAD and working with drawings and / or digital prints, you can say that you are at level 0.

Using 3D CAD for conceptual work, but 2D for producing production information and other documentation, probably means you are working at level 1 BIM. At this level, CAD standards are managed in accordance with BS 1192: 2007, and electronic data sharing is performed by the common

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data environment (CDE) commonly run by the performer. Many companies are at BIM level 1, which does not involve much collaboration, and each participant publishes and manages their own data.

Level 2 BIM begins with the addition of documentation in a collaborative environment. Level 2 of the BIM became a mandatory requirement in April 2016 on all publicly announced projects in the UK. At Level 2, all team members use 3D CAD models, but sometimes not in the same model. However, the way in which information is exchanged distinguishes it from other levels. The information about the design of the built-in environment is shared through the normal file format. When companies combine this with their own data, they save time, reduce costs and eliminate the need for processing. Because data is shared in this way, CAD software must be able to export to the usual file format, such as IFC (Industry Foundation Class) or COBI (Building Operations Build Information).

BIM level 3 is still collaborative. Instead of each team member working in their own 3D model, level 3 means that everyone is using one, common project model. The model exists in a »central« environment and everyone can access it and change. This is called Open BIM, which means that another layer of protection is added against the conflict, adding value to the project at each stage. The UK Government has even pledged that level 3 of BIM would be a prerequisite for all projects in the coming years.

Because of the clear advantages, it is certain that BIM will remain. It has defined goals that are obviously beneficial for all those who work their way through the levels. Without a doubt, the future of construction will be even more collaborative and digital. As BIM is becoming more and more sophisticated, 4D (add-on time component), 5D (added component costs), and even 6D (maintenance and running of already-built projects), BIM will play a leading role in this construction process. Furthermore, worldwide there is an attempt to reduce waste in construction. Much is attributed to the inefficiency of the supply chain, conflicts and processing. Cooperating in the BIM environment, it all becomes less likely, setting the stage for a better tomorrow.

2.5.1. Smisto hydropower – Norway

Experience from Smisto Hydropower project in Norway shows the possibility of construction of a hydroelectric power plant without 2D drawings – documentation.

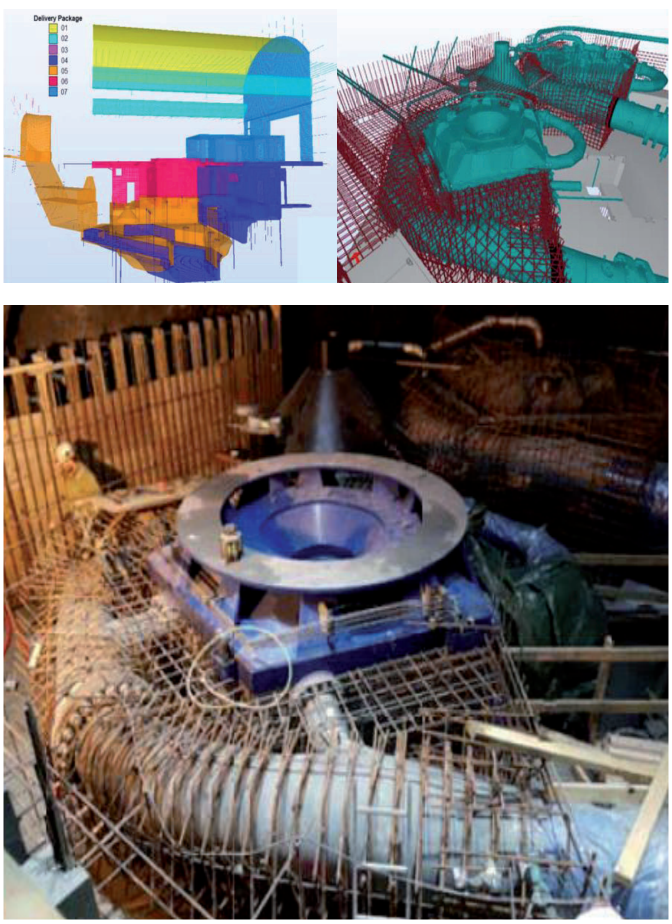

Figure 9. Case study turbine refurbishment, Smisto, Norway [4]

The experience of the Smisto Hydropower (Fig. 9) project shows that the construction of a site without 2D drawings benefits from improved interaction of all parties in the project. By overcoming not only technical challenges, but also challenges with changed working methods, implementation and adoption of a process based on 3D models, it is seen that the project has a better design, mutual understanding between the parties, flexibility and economy compared to the work with conventional 2D documentation.

2.6. CONTRACTING THE HYDROPOWER PROJECTS

Key for successful realization of the hydropower projects is the contracting of projects. The big dilemma is whether to have EPC (Engineering, Procurement, and Construction) contracts (turnkey) a responsibility in one place (single point of responsibility) or to deal with separate lots of the contracts and to engage their employees to control realization in order to minimize risk.

EPC contracts are effective but also sensitive subjects that require high level of consulting and adequate risk management methods. It is the most commonly used contract process for the development of large hydro power projects.

EPC contracting is a chance for projects mainly because of its ability to minimize the duration of a project when is properly managed.

In that sense, the use of FIDIC's (International Federation of Consulting Engineers) so-called "standard package" (e.g. Red, Yellow, Silver, Gold, Green Paper) offers the following advantages:

- internationally recognized,
- provides a standard framework, hence a common language for contractors, employers and engineers,
- determines the general design, supply and quality commitments,
- fair distribution of risk,
- updated practices for dispute resolution mechanisms.

2.7. VT TURBO EXAMPLE OF NEW TURBINE DEVELOPMENT

In 2018 VT Turbo worked extensively on developing a new turbine for a large powerplant with 8 generating units. Powerplant was built in the 1950s and is now in the process of modernization. Modern research and development methods were applied during the development phase. New turbine runner is a 6-blade non-adjustable Kaplan type with fixed blade angle (propeller) having a diameter of 7,2 m (Fig. 10). Rated power of newly developed turbine is 106,15 MW with peak prototype efficiency exceeding 95%.

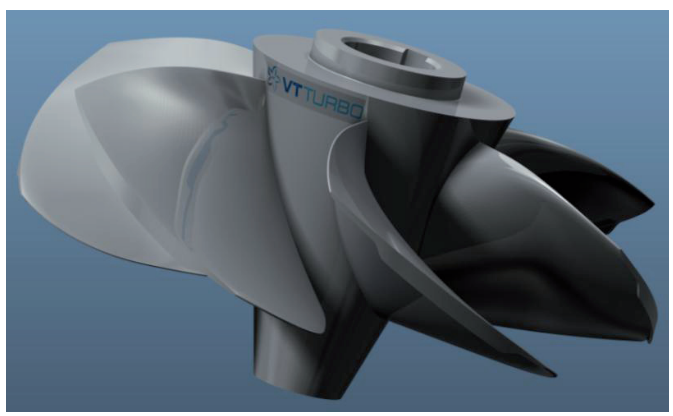

Figure 10. Newly developed runner, D = 7,2 m

During the initial stage of the project a new shape of the runner was proposed, with quite different approach to blade design as the existing ones. Comparison between the two is shown in Fig. 11.

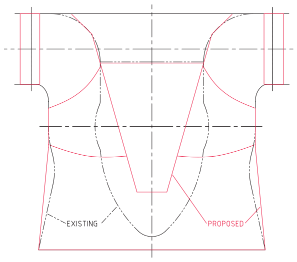

Figure 11. Existing and proposed runner chamber and hub shape

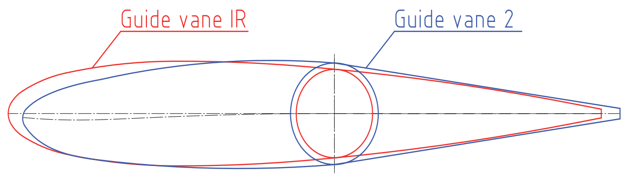

Figure 12. Existing and proposed guide vane shape

When real development began, the first stage was to set the new guide vane shape (Fig. 12). Furthermore, the influence of the wicket gate assembly rotation was examined, and final position was set as pointed in Fig. 13.

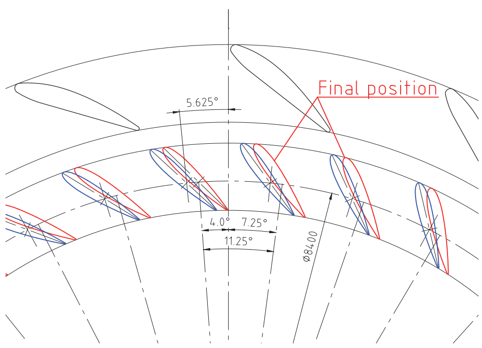

Figure 13. Optimization of guide vanes position

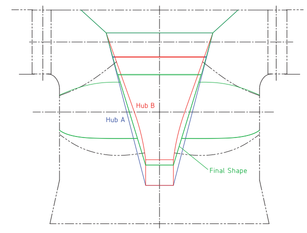

Figure 14. Optimization of runner hub and inner cone

Following the wicket gate optimization, the final shape of the runner hub together with blade profiles were determined as seen in Fig. 13. During this phase numerous variants and combinations were considered and tested with the goal of achieving the best possible outcome according to the specified guaranteed values.

Numerical analysis (CFD) was used extensively during the development phase (Fig. 15, 16) using NUMECA software. HEXPRESS and AutoGrid modules were used for generating hexagonal mesh with excellent mesh metrics and low element count. FINE/Open software was used for solver with k-ω SST turbulence model. Total number of CFD checked designs were 39. For all 39 geometries, efficiency curve for nominal head from low to high discharge was calculated, to ensure optimal curve shape. After confirming the final geometry, additional calculations for multiple heads were done. At the initial development phase, the calculations were done using the steady state approach. Final geometry was then checked by the unsteady analysis with a few revolutions of runner at a very small rotation step. Pressure fluctuations and cavitation phenomena were also analyzed in several operational regimes using the unsteady flow model.

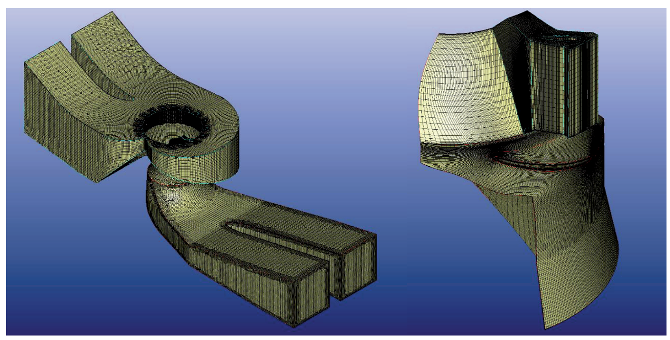

Figure 15. CFD Model – NUMECA, 20 M elements

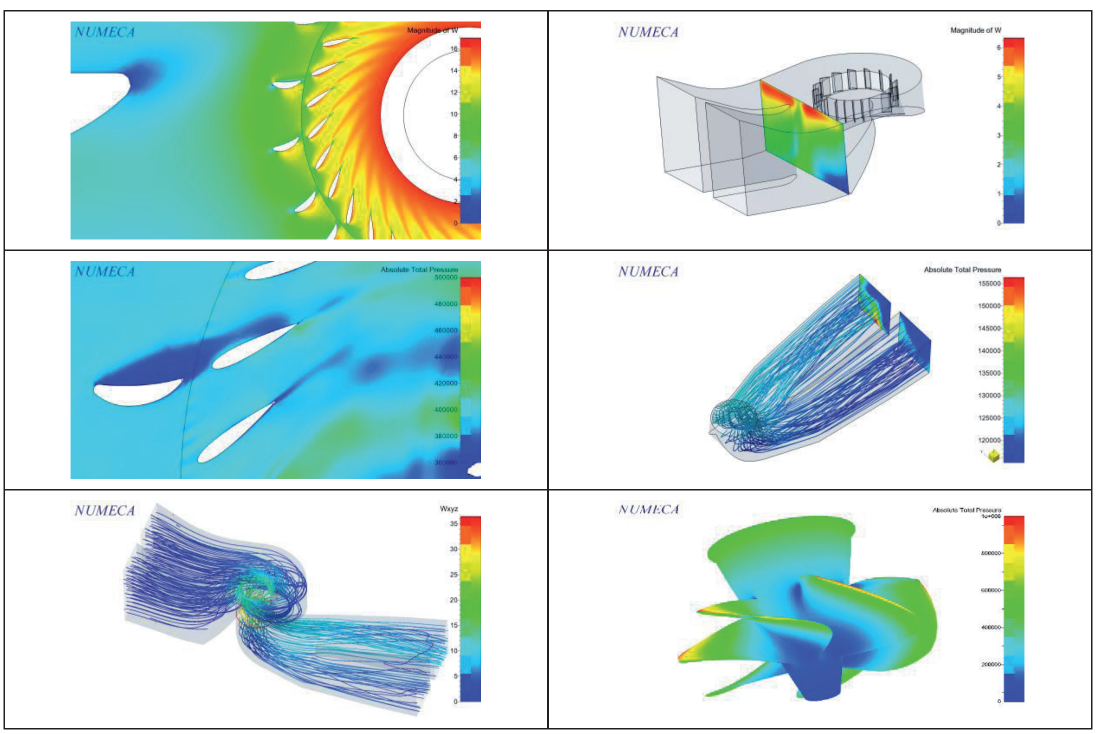

Figure 16. Results of CFD calculation

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Model testing was performed in the hydraulic laboratory of ČKD in Blansko, Czech Republic (Fig. 17) on the new upgraded vertical test rig. Testing was carried out with high accuracy and repeatability, also in compliance with all the requirements, stated in the IEC 60193 standard.

Based on the results of this measurements, the properties of the prototype may therefore be determined quite accurately with appropriate scale-up procedures for all the parameters where the similarity conditions are valid. As shown on Fig. 18, measured efficiency is well above the guarantees. Values have also been confirmed during the acceptance testing.

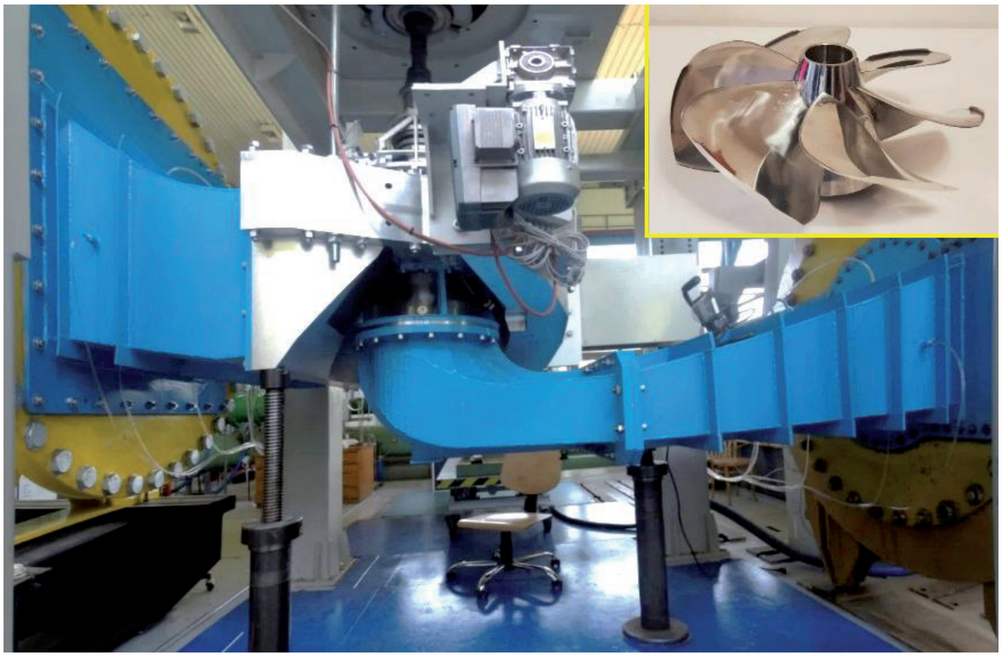

Figure 17. Turbine model installed on the test rig

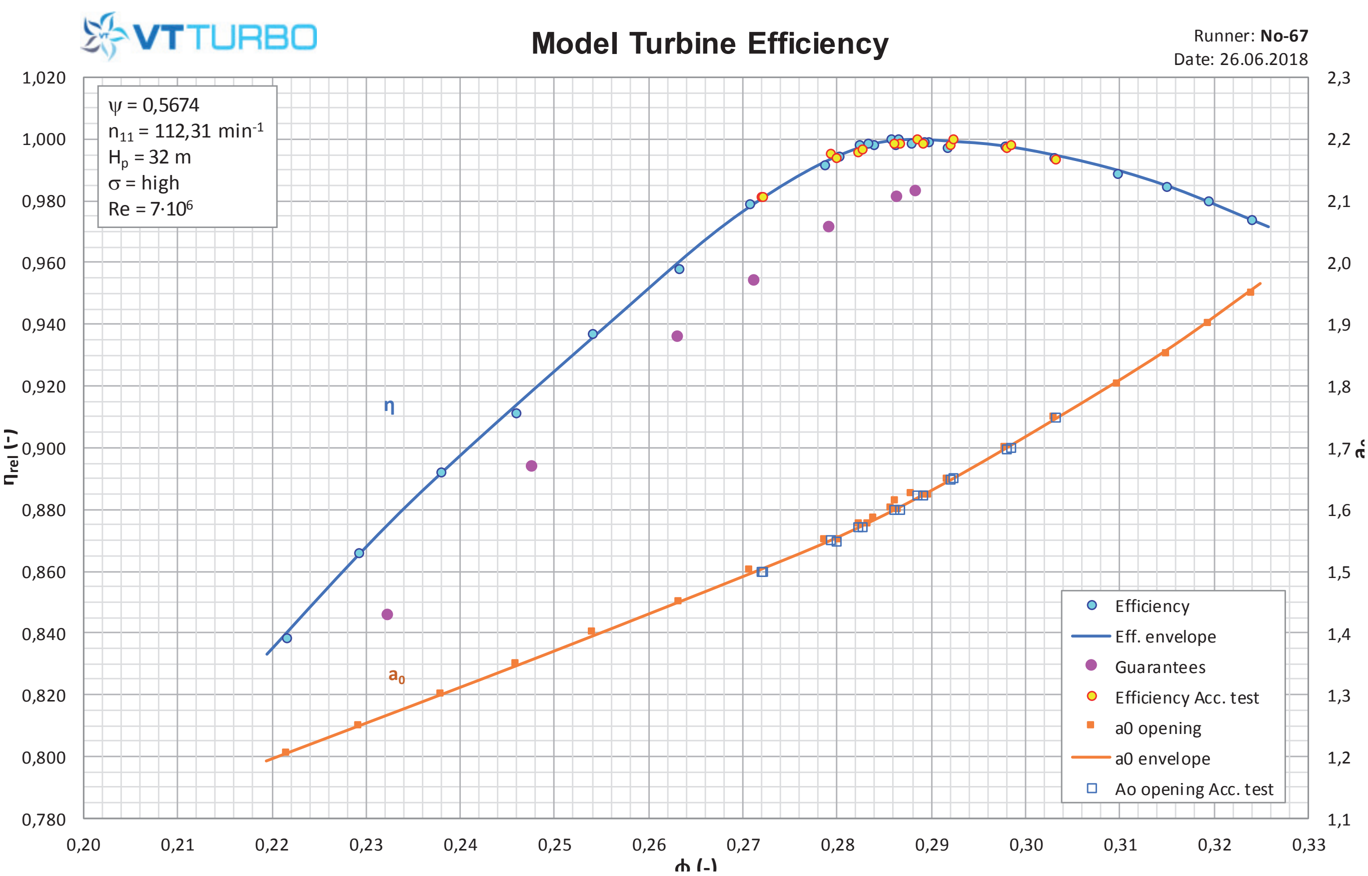

Figure 18. Turbine relative efficiency results from the model testing

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3. CONCLUSION

Hydropower is the most important renewable energy source today.

Recently, the investment is focusing on low head projects, pumped storage projects, refurbishment and modernization projects to boost the lifespan and the efficiency.

Experience from Smisto Hydropower project in Norway and many current projects in Europe shows the possibility of construction of a hydroelectric power plant without 2D drawings – documentation.

EPC contracts by using of FIDIC's so-called "standard package" are the most commonly used contract processes for the development of large hydro power projects.

Advanced tools as CFD simulation, integrated with model testing should be used in order to achieve up to date performances with turbine peak efficiency over 95%, smooth running with acceptable pressure fluctuations and cavitation free operation.

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