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A Review: Tribological Analysis of Cast Iron by Advanced Coating

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ABSTRACT
In our engineering system, friction, wear and tribology are not phenomena that most peoples are considering on daily basis. Wear (tribological process) occurs when two surfaces are in contact and both/one are moving relative to each other. The cast iron is widely used in industrial sector. It have high rate of friction. To reduce the friction the various types of coating is analyzed as well as with lubrication the rate of wear decreases.

KEYWORDS: *Tribology, Wear, Cast Iron, Coating*

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INRODUCTION
Usually wear is undesirable, because it makes necessary frequent inspection and replacements of parts and also it will lead to deterioration of accuracy of machine parts. It can induce vibrations, fatigue and consequently failure of the parts.

A tribology study reveals that even 15-20% reduction in wear/friction can significantly reduce economic costs in relation to environmental benefits [24].

To increase the Tribological performance of any substrate material the coating is found. The small layer of hard material coating is to be found to reduce the frictional force and wear of the any part of the machine. The cast iron is used due to low price, good machining and good damping capability. But, it has huge friction so, to reduce friction lubricant or coating is necessary to increase the tribological performance of Cast iron. In certain automotive components such as cylindrical liner, arms, sprockets, tool holders, whereas spherical graphite cast iron is utilised in the automotive field such as camshafts, crankshafts and gears,cast iron is used [1].

Carbon is one of the commonest elements throughout the universe. In the nature carbon is found as diamond, graphite and amorphous carbon. The name of DLC was first coined by Aisenberg in 1971. DLC coatings have been widely used in the field of machine components due to their attractive properties including chemical inertness, high hardness, and wear and corrosion resistance [6].

LITERATURE SURVEY:
Some important previous studies and findings on wear analysis, wear resistance properties of various materials, with lubricants, without lubricants, some wear analysis has been done with additives added in lubricants. In the following section, various developments taken place in the area of tribology and following fields is discussed with appropriate reference given.

- On various materials coating is available, by using coating we can increase wear resistance property.
- With dry condition wear analysis has been done.
- With water based and with various types of lubricants are used on coating.
- Some %of additives added in lubricants and wear analysis has been studied.

Majority of the contributions of this research work is related to various types coatings is applied on materials and increases the wear resistance property as well as density, hardness, mechanical, tribological and microstructural study. Major part of the wear analysis has been done without lubricants, so the characteristics of wear induced by the sliding contact piston ring cylinder liner without lubrication. And it is to be analyze a comparative research about the tribological behavior of Al7075, AISI 1020 and AISI 1045 steels during the ball crater abrasion wear test without the presence of lubricants. [1-2].

- In 2017 all materials having less wear rate than without coating as well as friction force acting on contact surface is also less with coating surfaces. For manganese phosphate range of wear rate is 34μ/min to 40μ/min. It is advisable to coating the cam with manganese phosphate. Data obtained from experiment about friction force are very near to wear rate. Here also manganese phosphate is the best material with minimum force of 8.179 N at 900 rpm. For without coating 17.54 N forces measured at 1800 rpm which one is maximum from experiment [3].

- In 2017 a wide range of commercial lubricants including SAE10W30, SAE20W40 and SAE20W50 were used to analyze frictional and wear behaviour. Tests were conducted for constant load at 140 N for 105 min and increment load with the range from 20 N to 140 N for 105 min to evaluate the behaviour of frictional force and wear for cylinder liner and piston ring. Relative amount of wear is directly correlate with the effectiveness of the lubricant due to this wear was measured by weight loss before and after testing. Result shows that viscosity and variation of load plays a vital role to characterize the behaviour of frictional force and wear [23].

- In 2018 the coating is deposition techniques are explained, the various techniques has merits and demerits given in this paper. According to merits and demerits the Physical Vapour Deposition (PVD) technique is best. And we can coat the complex material on any substrate. And also it is possible to coat the dense material with nano thickness on substrate material. Only the deposition process is very slow and for deposition cost requires high means PVD is an expensive technique [24].

- In 2015 it has been found that the coated specimen has improved the properties in improving the diesel engine performance. The results show less deformation and fewer scratches due to wear on the multilayer coated Piston Ring as compared to the uncoated one. The surfaces topography and the structure of the plasma spray coatings is observed on the scanning Electron microscope (SEM) [4].

For various Engineering applications in various fields like automobile, aerospace, marine engineering the material is to be required hardest but less in weight. So, many coatings are available to achieve the greater wear resistance property, following some coatings are discussed have good results.

DLC (Diamond like carbon) coating have a better wear resistance property,

- In 2018 a multitechnical experimental analysis of these solutions in dry and lubricated conditions. With lubricant, steel without treatment suffers carbide removal. PTFE coating prevents it by diminishing the coefficient of friction but are less resistant in highly loaded contact. Nitriding results in higher wear resistance, especially when lubricated. (DLC+WC) coating is the most efficient in dry conditions by minimizing friction coefficient and wear rate [5].

- In 2017 it is studied that diamond-like-carbon (DLC) coating process was applied to 8620 H steel used for camshaft production. Coatings are only applied to cams on the camshaft. DLC coated cam surfaces improved, the amount of wear has been reduced [6].

- In 2010 in a formula one engine valve train parts, the camshaft and rocker arm are subject to severe sliding conditions and constant demands for higher rotating speeds, so it was necessary to increase endurance reliability. Therefore, diamond-like carbon (DLC) coating films that strengthen the surface were developed, the film compositions and hardness balance were optimized, and the coating films were applied. As a result, friction was reduced by a total of approximately 5kW, and endurance reliability was achieved that enables continuous camshaft use in 4-Race events [7].

- In 2018 the surface coated with diamond-like carbon (DLC) significantly reduced both the friction and the wear. The friction of the SS/DLC in water was even lower than the friction of the SS/DLC or SS/SS contact in oil. Furthermore, the wear coefficient of the SS/DLC in water was comparable to the wear coefficient of the SS/SS in oil [8].

- In 2017 DLC deposited onto nitrided grey and nodular cast iron substrates and the low friction of coated GCI samples during the lubricious regime was attributed mainly to the presence of tribolayers covering most part of the wear track. These tribolayers play a major role in reducing the friction coefficient due their highly disordered graphitic structure confirmed via Raman analysis, which have been reported to provide low shear strength. Another effect provided by the formation of these tribolayers is the smoothening of contact region, reducing the severity of the asperities found on coated GCI samples and, thus, contributing to maintain the system in self-lubricating regime for longer periods [9].

- In 2017 the lubricated DLC coatings on polished samples suffered under strong fatigue wear on the same surface. Fatigue wear was found for lubrication with oil as well as for lubrication with water. In contrast DLC coated rough surfaces showed no fatigue wear, also under lubricated condition. By using rough DLC coatings the wear of the counterpart is obviously remarkable increased. If the tribological experiments were done under excessive use of oil (not on a thin oil film), no fatigue wear on the surface could be found as well [10].

- In 2017 The maximum wear rate value for the H-DLC coatings was 14 x 10-8 mm-3 /N m under a normal load of 10 N and 5.5 x 10-8 mm-3 /N m under a normal load of 50 N, following 2160 m of dry sliding. According to the outcomes from the present research, the H-DLC coating could be useful for wide range of industrial applications such as automotive, aircraft and machine components [11].

For increase the Tribological performance the lubricant is used, the following is the some references which has discussed about good performance of lubrication. Poly-alpha-olefin (POA) is used as lubricant (base oil) for the best results which is added in the mechanical parts then, the Tribological performance is increased.

- In 2017 The friction and wear properties of oil-acid (OA) modified Ag/PDA composites as additives in poly-alpha-olefin (PAO) base oil were measured using four-ball tribometer under different loads. The results show that the PAO containing OA modified Ag/PDA nanoparticles (OAMAgPDA) exhibit a better tribological property than pure PAO. The maximum decrease in wear scar diameter (WSD) and friction coefficient are amounted to 40% and 30%, respectively [13].

- In 2017 Tetrahedral amorphous carbon nitride (ta-CNx) is suitable for tribological application due to its excellent mechanical and adhesion properties. The tribological properties are investigated with a ball-on- disk tribo-tester with lubrication of poly alpha-olefin (PAO). In oil ta-CNx presents slightly decreasing friction coefficient and improving wear resistance with the N/C ratio, indicating softer ta-CNx with better wear resistance [14].

- In 2014 NNBO as an additive in PAO shows better anti-wear ability and load-carrying capacity than NN additive in the same base stock, which is because N-containing hetero- cyclic species and borate ester group in NNBO additive have synergistic antiwear effects [15].

- In 2018 the formation of carbon-based tribofilms from poly-alpha-olefin (PAO) base oil molecules on Ti6Al4V (Ti64) samples after thermal oxidization treatment, where PAO enabling base oils to provide not only the fluid but also the solid tribofilm. Lower friction and wear was found for oxidized Ti6Al4V under lubrication by PAO base oil [16].

In the lubricant some additives are added means the hybrid lubricant is used to increase the Tribological properties of material. So, below some references which worked on the additives to get better result in friction & wear.

- In 2004 The layered structure and the rheological properties of anti-wear films, generated in a rolling/sliding contact from lubricants containing zinc dialkyldithiophosphate (ZDTP) and/or molybdenum dialkyldithiocarbamate (MoDTC) additives, have been studied by dynamic nanoindentation experiments coupled with a simple modelling of the stiffness measurements. This low friction coefficient is attributed to the presence of MoS2 planes sliding over each other in a favourable configuration obtained when the pressure is sufficiently high, which is made possible by the presence of ZDTP [17].

- In 2016 During the irradiation of high molecular weight poly(tetrafluoroethylene) (PTFE) in presence of oxygen perfluoroalkyl(peroxy) radicals and functional groups are formed which allow chemical coupling reactions (cc = chemical compatibilized) with oils and plastics. The micropowder resulting from the irradiation of PTFE are used in base oils to improve the tribological properties significantly if oil molecules are covalently linked to primary PTFE particles in the oil dispersion. These oil-PTFE-cc-dispersions show primarily anti-wear (AW) properties [25].

- In 2018 the effect of tappet insert clearance on the tribological and tribochemical performance of the camlobe/follower tribopair when lubricated in a fully-formulated oil containing 1 wt% of Molybdenum Dialkyl Dithiocarbamate (MoDTC). Results show that the chemistry of the tribofilm derived on camlobes and tappet inserts vary as a function of tappet insert clearance and cam profile. Also, regardless of the type of coating, the smaller clearance of tappet inserts exhibited higher friction and wear. Therefore, based on this work, the use of the thicker tappet insert would be inadvisable as this possibly can cause higher fuel consumption and inefficient performance of the intake/exhaust valves of the engine [18].

- In 2018 an automated micropitting test rig was applied to study the effect of slide to roll ratio (SRR) on micropitting behaviour in rolling-sliding contacts lubricated with Zinc Dialkyl Dithiophosphate (ZDDP) containing lubricants [19].

- In 2008 Alkyl amine salts of three representative dialkyl phosphates showed excellent antiwear effectiveness in the low load region (5 kg) being generally equal or superior to the component acid phosphates and greatly superior to tricresyl phosphate. With the alkyl amine phosphates, no pattern of performance vs, molecular structure appeared. The absence of differentiation in wear results with the amine components, especially at 5-kg load, supports the view that the timine salts reported here function as antiwear additives by releasing acid phosphate, the actual antiwear agent, at frictional contacts [12].

- In 2018 Polypropylene and lithium complex thickened (Li-complex) greases were tested both as neat greases and with a 2 wt% addition of ZDDP and/or MoDTC. A combination of ZDDP and MoDTC in the polypropylene grease provided the lowest friction with greater longevity compared to the Li-complex grease with the same additives, independent of sliding speed, contact pressure, temperature or type of sliding: continuous vs. reciprocating. The additive combination of ZDDP and MoDTC provided the best antiwear performance in both greases [20].

- In 2016 the anti-wear performance and action mechanisms of zinc dithiophosphate (ZDDP) have been investigated under various test conditions. after rubbing tests the physical and chemical properties of ZDDP tribofilms have been investigated using surface characterisation methods such as atomic force microscopy (AFM), scanning electron microscopy (SEM), Energy-dispersive X-ray spectroscopy (EDX) and X-ray absorption near-edge structure (XANES) [21].

- In 2015 the wear rates of coatings and AISI 52100 steel balls lubricated with the GMO-containing oil were the lowest in most cases. From these results, it was concluded that the GMO was a compatible FM with the coating and improved tribological characteristics of both sliding surfaces [22].

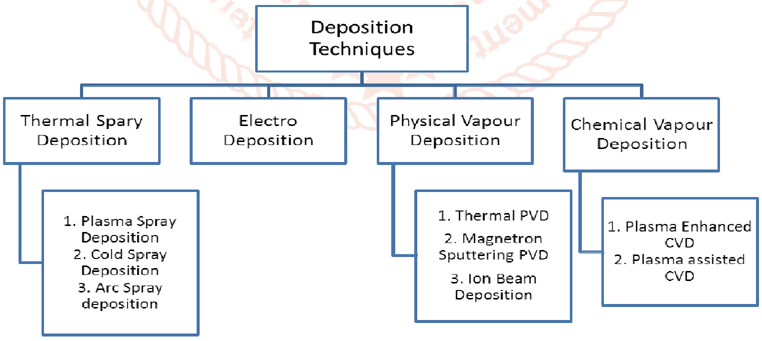
By reviewing the above literature coating on substrate material with lubricant, additives added in lubricant. Tribological terms are dependent on the various parameters.

RESEARCH GAP IDENTIFICATION:

Sr. No.	Substrate	Coating Material	Deposition technique	Condition	Result	Gap
[1] [2] [6] [9]	Cast iron, Al7075, AISI 1020 and AISI 1045 steels, 8620H Steel, GCI and NCI	- - DLC	- - CVD PECVD	Dry Dry	It is found that the material hardness also greatly affects the wear depth, wear volume and wear width. DLC coated cam surfaces improved, the amount of wear as compares to without coating. The low friction of coated GCI samples during the lubricious regime was attributed mainly to the presence of tribolayers covering most part of the wear track	Coating, Lubricant, Additive
[8] [10] [11]	AISI 440C , 52100 stainless steel	DLC coating	CVD, PECVD	Lubricated (Oil & Water)	The lowest coefficient of friction was obtained for the SS/DLC contact in water, taking into consideration all the tested parameters.	Additive in lubricant
[12]	440C *stainless steel*	-	-	Lubricated (Neopentyl Polyol Esters +Amine Phosphates)	The amine phosphates promoted significantly less deterioration of the base ester than did the dialkyl phosphates.	Coating
[13] [14]	High carbon chrome steel	ta-CNx	ion beam assisted filtered arc deposition	Lubricated (poly alpha-olefin+Ag/ polydopamine)	In oil ta-CNx presents slightly decreasing friction coefficient and improving wear resistance.	Cast Iron
[18] [22] [25]	AISI 52100 steel, 100Cr6 metallic surfaces	DLC -	CVD -	Lubricated (SAE-5W20, PAO+MoDTC & GMO, PTFE)	The GMO reduces the friction & wear of the DLC coating. PTFE-cc product provides a very good wear protection, with a rollerwear dimension of 1 mg.	Cast iron Coating

COATING DEPOSITION TECHNIQUE ANALYSIS:

The commonly used deposition techniques are thermal spray deposition, electrode position, physical vapor deposition and chemical vapor deposition which are elaborated below: [24]

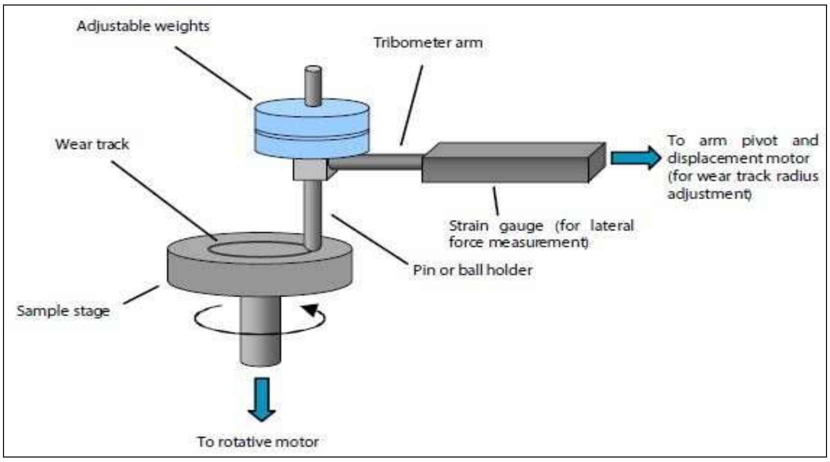


Merits and demerits of Deposition Techniques

Process	Merits	Demerits
Thermal Spray Deposition	(i) Low cost (ii) High deposition rate (iii) Can be widely used for numerous coating material	(i) Residual stress concentration is high (ii) Difficulty in Nano porous coating.
Electro-Deposition	(i) High deposition rate (ii) ability to coat complex materials (iii) Controlled Nano porous coating.	(i) Caustic waste
Physical Vapor Deposition	(i) Can coat complex materials. (ii) Dense coating of Nano scale thickness.	(i) low deposition rate (ii) high initial cost
Chemical Vapor Deposition	(i) Uniform deposition on complex shape (ii) Can coat complex materials.	(i) Restricted to chemical composition and use of volatile gases (ii) Low deposition rate (iii) High initial cost

WEAR RATE CALCULATION:

Pin-on-Disc wear testing is a method of characterizing the coefficient of friction, frictional force, and rate of wear between two materials. During this tribological test, a stationary disc articulates against a rotating pin while under a constant applied load. As shown in below Figure. A pin on disc test consists of a stationary "pin" under an applied load in contact with a rotating disc. The pin can have any shape to simulate a specific contact, but spherical tips are often used to simplify the contact geometry.



Pin-on-Disc Machine

CONCLUSION:

Cast iron has great demand in industrial applications, but in the mechanical linkage or in mechanism the cast iron having high wear rate. So to reduce the wear rate the DLC coating is suitable with lubrication.

REFERENCES:

[1] Muchammad, Imam Syafa, Fuad Hilmy, Mohammad Tauviqirrahman, Jamari, "Wear Analysis of Spherical Graphite Cast Iron Using Pin-on Disc Tribotester" in Journal of Physical Science 29,2018, pp 15–26.

[2] Ernélisson Santos, Janiclay Alencar and Kleber Cruz, "Comparative Analysis of Wear Behavior of Al 7075 Alloy, AISI 1020 and AISI 1045 Carbon Steels", Journal of Materials Science Forum, 930, 2018, pp 411-415.

[3] Gaurav Patel, Kishore N Mistry, Mahesh N Patel, "Experimental Analysis of Cam and Follower of Valve Train System for Prediction of Wear-Rate", International Journal of Advance Research and Innovative Ideas in Education, Vol.-3, Issue-6, 2017.

[4] P. Jayanth, Mr. E. Sangeeth kumar, "Investigation and Analysis of Wear Reduction in Piston Rings through Coating", Journal of Applied Mechanics and Materials, 813-814, 2015, pp 874-879.

[5] G. Schuhler, A. Jourani, S. Bouvier, J.-M. Perrochat, "Efficacy of coatings and thermochemical treatments to improve wear resistance of axial piston pumps", Journal of Tribology International, doi: 10.1016/j.triboint.2018.05.007. 2018.

[6] Tarık GÜN, Bahadır Karaca, Akil MAT, "The Effects of DLC Coating to Camshafts Produced From 8620H Steel", The International Journal of Engineering and Science (IJES), Vol-6, 2017, pp 52-56.

[7] Naoaki ITO, Masaomi YONEHARA, Kazushige YAKUBO, "Development of DLC Coating on Camshaft and Rocker arm", Automobile R&D, Honda R&D Technical Review 2009 pp 260-262.

[8] E. Strmčnik, F. Majdič, M. Kalin, "Water-lubricated behaviour of AISI 440C stainless steel and a DLC coating for an orbital hydraulic motor application", Journal of Tribology International, doi.org/10.1016/j.triboint.2018.10.032, 2018.

[9] Renan Oss Giacomelli, Diego Berti Salvaro, Cristiano Binder, Aloísio Nelmo Klein, José Daniel Biasoli de Mello, "DLC deposited onto nitrided grey and nodular cast iron substrates: An unexpected tribological behaviour", doi. 10.1016/j.triboint.2018.02.009, 2018.

[10] Bernd Rübig, Daniel Heim, Christian Forsich, Christian Dipolt, Thomas Mueller, Andreas Gebeshuber, Roland Kullmer, Reinhard Holecek, Christoph Lugmair, Matthias Krawinkler, Volker Strobl, "Tribological behavior of thick DLC coatings under lubricated conditions", Journal of Surface and Coatings Technology, 314, 2017, pp 13-17.

[11] J. Solis, H. Zhao, C. Wang, J.A. Verduzco, A. S. Bueno, A. Neville, "Tribological performance of an H-DLC coating prepared by PECVD", Applied Surface Science, 383. 2016, pp. 222-232.

[12] M. Hall, Harold Ravner, "Amine Phosphates as Antiwear Additives in Neopentyl Polyol Esters", A S L E Transactions, 16:4, 2008, pp 291-296, DOI:10.1080/05698197308982736.

[13] Zhengfeng Jia, Zhengqi Wang, Chao Liu, Limin Zhao, Junjie Ni, Yuchao Li, Xin Shao, Chao Wangb, "The synthesis and tribological properties of Ag/polydopamine nanocomposites as additives in poly-alpha-olefin", Journal of Tribology International, 114 2017, pp 282–289.

[14] Xiaoxu Liu, Ryo Yamaguchi, Noritsugu Umehara, Xingrui Deng, Hiroyuki Kousaka, Motoyuki Murashima, "Clarification of high wear resistance mechanism of ta-CNx coating under poly alpha-olefin (PAO) lubrication", Journal of Tribology International, 105, 2017, pp 193–200.

[15] Guangbin Yang, Jinfeng Zhang, Shengmao Zhang, Laigui Yu, Pingyu Zhang, Baoli Zhu, "Preparation of triazinederivatives and evaluation of theirtribological

properties as lubricant additives in poly-alphaolefin", Journal of Tribology International, 62, 2013, pp 163–170.

[16] Lei Cao, Jian Liu, Yong Wan, Shuyan Yang, Jianguo Gao, Jibing Pu, "Low-friction carbon-based tribofilm from poly-alpha-olefin oil on thermally oxidized Ti6Al4V", Journal of Surface and Coatings Technology, 337, 2018, pp 471-477.

[17] S. Beca, A. Tonck, J.M. Georges, G.W. Roper, "Synergistic effects of MoDTC and ZDTP on frictional behavior of tribofilms at the nanometer scale", Journal of Tribology Letters, Vol. 17, No. 4, 2004, pp 797-808.

[18] Yasir Al-Jeboori, Shahriar Kosarieh, MacDonald Ofune, Anne Neville, Ardian Morina, "The effect of clearance between tappet insert and camlobe on the tribological and tribochemical performance of cam/follower surfaces", Journal of Tribology International, 2018, doi.org/10.1016/j.triboint.2018.09.021.

[19] Hui Cen, Ardian Morina, Anne Neville, "Effect of slide to roll ratio on the micropitting behaviour in rolling-sliding contacts lubricated with ZDDP-containing lubricants", Journal of Tribology International, 2018, doi: 10.1016/j.triboint.2018.02.038.

[20] Ju Shu , Kathryn Harris, Bulat Munavirov, Rene Westbroek, Johan Leckner, Sergei Glavatskih, "Tribology of polypropylene and Li-complex greases with ZDDP and MoDTC additives", Journal of Tribology International, 118, 2018, pp 189-195.

[21] Yasunori Shimizu, Hugh A. Spikes, "The Influence of Slide–Roll Ratio on ZDDP Tribofilm Formation", Journal of Tribol Lett, DOI 10.1007/s11249-016-0738-z, 2016, 64:19.

[22] Dong-Wook Kim, Kyung-Woong Kim, "Tribological characteristics of Cr/CrN/a-C:H:W/a-C:H coating under boundary lubrication conditions with glycerol mono-oleate

[23] (GMO) and molybdenum dithiocarbamate (MoDTC)", Journal of Wear Vol. 342–343, 2015, pp 107-116.

[24] H.K. Trivedi, D.V. Bhatt, "Effect of Lubricating Oil on Tribological behaviour in Pin on Disc Test Rig", Journal of Tribology in Industry, Vol. 39, No. 1, 2017, pp 90-99.

[25] Ankit Tyagi, R. S. Walia, Qasim Murtaza, Shailesh M. Pandey, Pawan K. Tyagi, Bharat Bajaj, "A critical review of diamond like carbon coating for wear resistance applications", International Journal of Refractory Metals and Hard Materials, 2018, doi:10.1016/j.ijrmhm.2018.09.006. [25] Thorsten Hoffmann, Dieter Lehmann, Martin Anders, Thorsten Schmidt, Thorsten Heinze, Markus Michael, "Additives based on poly(tetrafluoroethylene) for improving wear resistance", Journal of Key Engineering Materials, Vol. 674,2016, pp 195-200.