

BULETINUL INSTITUTULUI POLITEHNIC DIN IAȘI
Publicat de
Universitatea Tehnică „Gheorghe Asachi” din Iași
Volumul 72 (76), Numărul 2, 2026
Secția
CONSTRUCȚII DE MAȘINI
DOI: 10.2478/bipcm-2026-0015

A COMPREHENSIVE REVIEW OF BEARING CURRENT PHENOMENA IN ELECTRIC VEHICLE DRIVE SYSTEMS

BY

**RADU-DUMITRU ABURLĂCIȚEI*, MARCELIN BENCHEA,
LIVIU ANDRUȘCĂ and ADRIAN-CRISTIAN BUJOR**

“Gheorghe Asachi” Technical University of Iași, Faculty of Mechanics,
43 Prof. D. Mangeron Blvd., 700050, Iași, Romania

Received: May 27, 2026

Accepted for publication: June 11, 2026

Abstract. The increasing adoption of electric vehicles (EVs) has brought renewed attention to the reliability and durability of drivetrain components, particularly electric motor bearings. Bearing currents induced by high-frequency voltage potentials from inverter-fed motors have become a significant source of premature bearing failure in electric powertrains. Rolling bearings represent essential elements in electric machines, having a direct influence on their efficiency, operational stability, and lifespan. The rapid expansion of pulse width modulation (PWM) inverter-based drive systems has introduced new electrical stress factors within motors, among which bearing currents have become a critical concern. These parasitic currents can pass through the bearing contacts, causing surface deterioration such as pitting and fluting. Over time, this degradation accelerates wear, diminishes the operational lifetime of the motor, and may ultimately lead to unexpected system failure. Current research on bearing current-related degradation primarily focuses on three main aspects: the physical mechanisms responsible for current generation, the key influencing parameters governing these phenomena, and the development of equivalent circuit models to

*Corresponding author; *e-mail*: radu-dumitru.aburlacitei@student.tuiasi.ro

© 2026 Radu-Dumitru Aburlăciței et al.

This is an open access article licensed under the Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License (CC BY-NC-ND 4.0).

describe current paths through the motor system. This paper presents a comprehensive analysis of the electrical currents passing through bearings used in electric vehicles. The mechanisms of current generation, including common-mode voltage, capacitive coupling, and electromagnetic induction, are examined in depth. Furthermore, the effects of various operating conditions such as motor speed, load, inverter switching frequency, and temperature on the amplitude and frequency of bearing currents are evaluated. The resulting electrical and thermal stresses that accelerate bearing degradation are discussed based on both experimental results and simulation models. Current mitigation strategies, including the use of insulated bearings, grounding techniques, and advanced inverter control methods, are assessed in terms of their effectiveness and limitations. Finally, the paper outlines future research directions aimed at developing integrated design and diagnostic approaches to predict, monitor, and minimize bearing current effects, thereby enhancing the reliability and lifespan of electric vehicle drivetrains.

Keywords: Bearing currents, Electric vehicle powertrains, Inverter-fed motors, Bearing degradation mechanisms, Electroerosion.

1. Introduction

Rolling bearings are essential components in electric machines, directly influencing their efficiency, operational stability, and service life. The rapid proliferation of pulse-width modulation (PWM) inverter-fed drive systems has introduced new electrical stresses in motors, among which bearing currents have emerged as a major concern. These parasitic currents can flow through the bearing contacts, causing surface damage such as pitting and fluting. Over time, this degradation accelerates wear, shortens the motor's operational lifetime, and may lead to unexpected system failures (Son *et al.*, 2022).

Similar degradation phenomena have been reported in wind energy systems (Peng *et al.*, 2023), where shaft-induced voltages generate bearing currents that trigger electrical surface damage, including pitting and fatigue-related defects. Such electrical discharges are more likely to occur when the lubricating film thickness is reduced, allowing current to flow through the rolling contact interfaces. The severity of the resulting damage depends strongly on both the lubrication regime and the magnitude of the electrical excitation—factors that are equally relevant in electric vehicle (EV) traction motors (Bleger *et al.*, 2024).

Current research on bearing current-induced degradation primarily focuses on three main aspects: the physical mechanisms of current generation, the key parameters influencing these phenomena, and the development of equivalent circuit models to describe current paths through the motor system (Erdman *et al.*, 1996; Chen *et al.*, 1996). Significant attention has also been devoted to evaluating the impact of electrical currents on bearing performance and long-term reliability.

Existing studies indicate that the severity of electrically induced bearing damage is strongly influenced by several operational and material factors, including rotational speed, mechanical load, lubricant composition, and the presence and quality of insulation layers. These parameters affect both the formation and magnitude of bearing currents, as well as the progression of surface degradation (Muetze *et al.*, 2011; Schuster *et al.*, 2018).

Despite these advances, bearing failure under electrical stress remains a complex and actively researched topic. The detailed mechanisms governing damage initiation and propagation under combined electrical, mechanical, and thermal stresses are not yet fully understood, and further research is needed to clarify these processes (Touzin *et al.*, 2010; Ma *et al.*, 2022).

In this context, a comprehensive and structured review of bearing current phenomena in inverter-fed electric machines is necessary to consolidate existing knowledge and identify current research gaps. The present paper aims to examine, at a general level, the mechanisms of bearing current generation, the key influencing parameters, and the associated damage processes reported in the literature. By critically analyzing existing theoretical models and experimental findings, this study seeks to clarify the interaction between electrical excitation and bearing degradation, with particular emphasis on electric vehicle applications. The insights provided are intended to serve as a foundation for future experimental investigations and the development of improved diagnostic and mitigation strategies.

2. Effects of electrical currents on bearing integrity

Bearing currents can arise under various operating conditions, each affecting the bearing differently. Under full-film lubrication, the rolling elements, raceways, and lubricant collectively form a capacitive path that allows a small current to flow from the motor shaft to the housing in the presence of high-frequency common-mode voltages. When direct metal-to-metal contact occurs between the rollers and raceways, the bearing acts as a resistive element; the current is then confined to the microscopic contact points, generating localized heating that can melt the surface material and cause adhesion between components. Additionally, when an oil film is present, the voltage across the bearing can build up until it exceeds the dielectric strength of the lubricant, resulting in electrical discharges. Variations in the roller-to-raceway separation can also trigger similar discharges due to the intensified electric field between the bearing rings. These phenomena contribute to accelerated bearing degradation, initially manifesting as surface pitting, then progressing to frosting and fluting, and ultimately compromising lubricant performance.

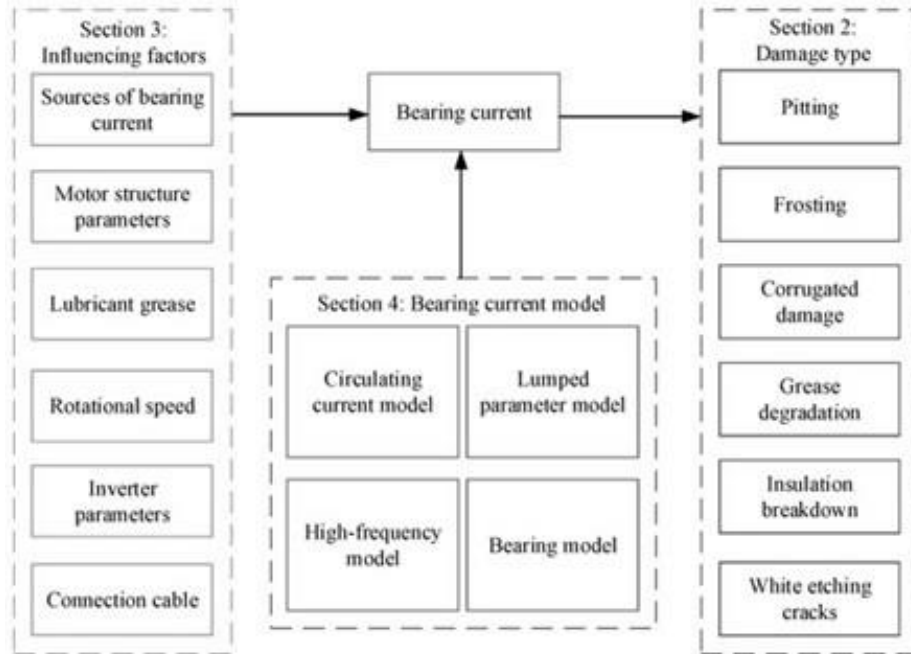


Fig. 1 – Conceptual framework of bearing current generation and associated degradation mechanisms (Ma *et al.*, 2022).

2.1. Impact of bearing currents on lubricant integrity and surface damage

Bearing currents can occur in various operating conditions, each affecting the bearing differently. Under full-film lubrication, the rolling elements, raceways, and lubricant collectively form a capacitive path, allowing a small current to flow from the motor shaft to the housing in the presence of high-frequency common-mode voltages. When the induced shaft voltage exceeds the dielectric strength of the lubricant film, electrical discharges occur across the microscopic gaps between rollers and raceways. As the current passes through these gaps, localized heating occurs, accelerating the degradation of the grease and reducing its insulating properties. The polarization of lubricant molecules further lowers the dielectric strength, making it easier for subsequent currents to penetrate the oil film. In addition, material detached from the roller and raceway surfaces can contaminate the grease, thereby impairing its performance and increasing friction within the bearing (Muetze *et al.*, 2006). When rollers and raceways make direct metal-to-metal contact, the bearing acts as a resistive element, concentrating current in tiny contact areas and generating heat that can damage surfaces and promote adhesion (Noguchi *et al.*, 2010). All these phenomena capacitive currents, oil film breakdown, localized discharges, and contact heating contribute to accelerated bearing wear, surface pitting, fluting,

and reduced service life. Consequently, motor bearing greases must be formulated to withstand both mechanical wear and electrical stress to maintain effective lubrication and prolong bearing durability.

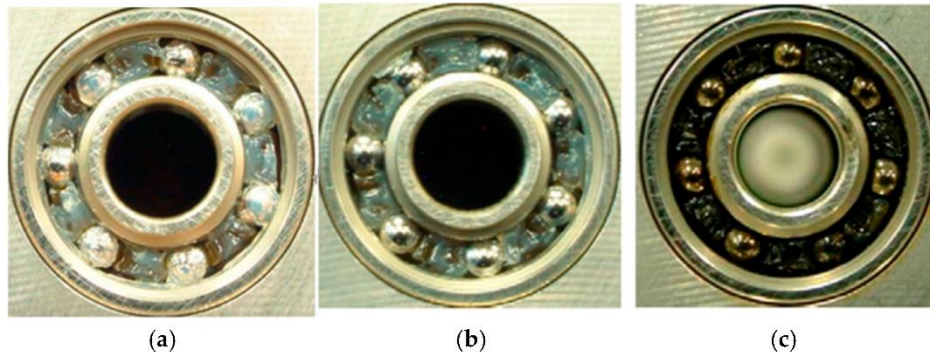


Fig. 2 – Changes in bearing grease after 500 h of operation at different voltages (Noguchi *et al.*, 2010).

The analysis of bearing surfaces subjected to different voltage levels reveals a clear correlation between the applied electrical potential and the severity of electrically induced degradation. Macroscopic and microscopic observations (on the order of hundreds of micrometers) allow the identification of successive stages in the evolution of surface damage.

In the initial condition, the surface exhibits a relatively uniform topography, characterized by fine machining marks and the absence of significant structural defects. This morphology indicates controlled roughness and good surface integrity. Likewise, the sample analyzed at 0 V shows no noticeable deviations from the original state, confirming that the subsequent damage is primarily driven by electrical effects rather than mechanical or tribological factors.

At an applied voltage of 10 V, the first signs of electroerosive degradation become evident, manifested as localized melting areas and the formation of small, irregularly distributed micro-pits. These features are associated with intermittent electrical discharges that penetrate the lubricant film, generating localized high temperatures and leading to microstructural modifications through rapid melting and solidification.

Increasing the voltage to 12 V results in the development of circumferential undulations on the raceway surface, appearing as relatively regular bands. This morphology indicates the onset of the fluting phenomenon, which is characteristic of bearings affected by electrical currents. At the microscopic level, a thermally affected layer becomes visible, formed by repeated cycles of melting and solidification, which contributes to a significant increase in surface roughness.

At 13 V, the degradation becomes more pronounced in both depth and spatial distribution. The surface exhibits a severely altered texture, with larger craters and a porous morphology typical of rapid solidification. This stage reflects an increase in the energy of electrical discharges and an acceleration of the electroerosion mechanisms.

In the case of 14 V, a well-defined periodic pattern emerges, consisting of parallel and uniformly spaced grooves, commonly referred to as a “washboard” pattern in the literature. This morphology suggests a stable discharge regime, likely synchronized with the relative motion of the bearing components, leading to systematic surface degradation.

At the highest tested voltage of 15 V, severe damage is observed, characterized by extensive melted regions, coalescence of craters, and significant material removal. The surface becomes highly irregular, with pronounced roughness and loss of structural continuity. These features indicate a regime of continuous electroerosion, in which the integrity of the bearing surface is critically compromised.

The observed degradation mechanism is governed by electrical discharges occurring through the breakdown of the lubricant film, leading to localized melting followed by rapid solidification. The progression of damage follows a consistent pattern, evolving from isolated micro-pitting to periodic surface structures and ultimately to extensive material deterioration. These findings highlight the strong dependence of bearing surface integrity on the magnitude of the applied voltage (Ye *et al.*, 2025).

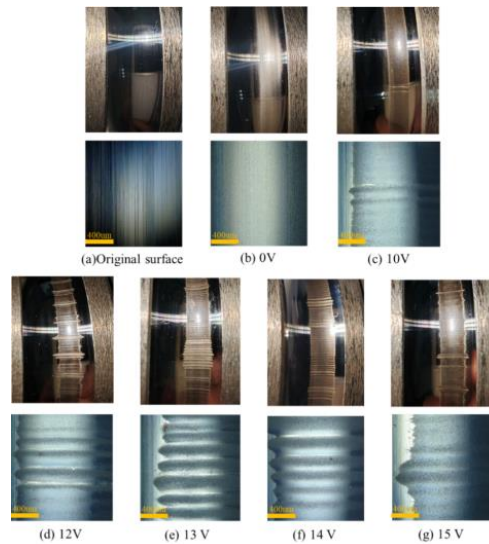


Fig. 3 – Progressive surface degradation of bearing due to electrical discharge at different voltages (Ye *et al.*, 2025).

2.2. Electrical failures of bearings

In complex electrical operating environments, degradation phenomena can affect all contact and sliding interfaces within mechanical systems, with rolling element bearings being particularly susceptible due to their operating conditions and contact mechanics. As such, bearings constitute a representative system for the investigation of electrically induced failure mechanisms. Conventional failure modes in bearings are typically associated with rolling contact fatigue (spalling), fretting wear, smearing, skidding, abrasive wear, corrosion, crack initiation and propagation, as well as true and false brinelling, all of which are governed by mechanical loading and tribological interactions (Bonnett, 1992).

However, the presence of shaft voltages and parasitic bearing currents introduces additional degradation mechanisms that are fundamentally different in origin and manifestation. These electrically induced failure modes are primarily governed by discharge phenomena occurring across the lubricant film, leading to localized thermal effects, material melting, and subsequent rapid solidification. From a mechanistic perspective, such failures can be broadly classified into two categories: (i) morphological surface damage, characterized by features such as micro-craters, fluting patterns, and material removal, which represent the cumulative effects of electrical discharges, and (ii) alterations of the lubrication regime, involving changes in film thickness, dielectric breakdown behavior, and lubricant degradation, reflecting the dynamic interaction between electrical, thermal, and tribological processes.

Morphological deterioration caused by shaft voltages and bearing currents can be classified into five primary types: frosting, fluting, pitting, spark tracks, and localized welding, each reflecting distinct surface damage mechanisms within the bearing.

Frosting arises from low-intensity electrical discharges. Its satin-like appearance makes it difficult to detect with the naked eye. At the microscopic level, the surface exhibits a sand-blasted texture composed of numerous small craters, each representing a localized melting event induced by an EDM current. Moreover, the increased surface-area-to-volume ratio of a frosted bearing race accelerates chemical corrosion.

Pitting is a surface degradation phenomenon that appears as small, localized depressions or cavities on the bearing race, typically resulting from repeated electrical discharges, high contact stresses, or fatigue. The initiation of pits often occurs beneath the surface, where microstructural imperfections or inclusions concentrate stress, eventually forming micro-cracks that propagate outward. As these microscopic cavities develop, they gradually enlarge and may merge, creating more pronounced surface irregularities. Each pit constitutes a localized area of material removal and can be associated with melting or plastic deformation at the contact points, depending on the intensity and frequency of

the applied mechanical loads or electrical activity. The accumulation of multiple pits increases surface roughness and modifies the contact pattern, leading to uneven load distribution and higher localized stresses that promote further wear. Microscopically, pitted surfaces exhibit a complex topography with sharp edges and micro-craters, which can trap debris and influence lubricant behavior. Additionally, the irregular surface geometry resulting from pitting increases the effective surface area, making the bearing more susceptible to chemical reactions, such as corrosion, and affecting the interaction with lubricants.

Fluting is a surface defect characterized by the formation of periodic, wave-like grooves along the bearing race, typically caused by the passage of electrical currents combined with rolling contact fatigue. These grooves develop as repeated micro-arcing or localized electrical discharges remove small amounts of material from the surface, producing a characteristic ripple pattern. Microscopically, fluted surfaces display alternating ridges and depressions, with each groove representing a zone of localized melting or plastic deformation. The pattern often follows the rolling path of the bearing elements, reflecting the areas of highest electrical or mechanical stress. As the grooves deepen, they alter the load distribution across the bearing, leading to concentrated stresses at the peaks of the ridges and increased friction. The presence of fluting can also influence lubricant flow, creating regions of stagnation or turbulence that exacerbate wear and promote chemical reactions, such as oxidation or corrosion, on the affected surface. Over time, the repeated formation and expansion of these grooves compromise the uniformity of contact and contribute to progressive surface roughening, making the bearing more vulnerable to additional forms of electrical or mechanical damage.

Spark tracks appear as narrow, linear markings on the bearing surface, resulting from concentrated electrical discharges between the rolling elements and the race. These discharges produce localized melting and small depressions along the current path. Microscopically, spark tracks are visible as fine grooves or etched lines, which increase surface roughness and can disrupt the uniform distribution of loads. The altered surface topography may also affect lubricant flow, creating areas prone to accelerated wear or corrosion.

Localized welding occurs when localized overheating causes metal from the rolling elements and bearing race to fuse temporarily, forming small welded spots on the surface. These areas exhibit material buildup and irregularities that increase roughness and disturb load distribution. Microscopically, welded spots show evidence of melting and rapid solidification, which can promote subsequent mechanical wear and accelerate surface degradation.

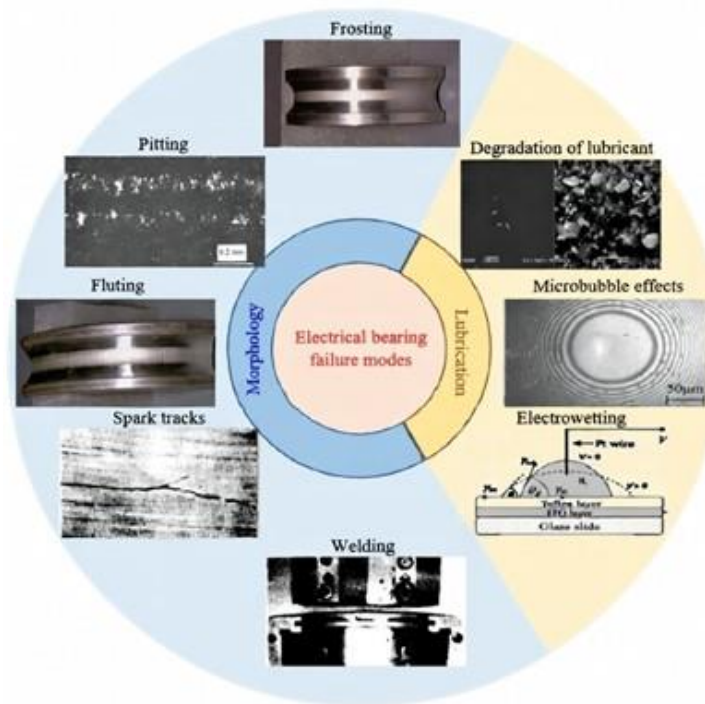


Fig. 4 – Common electrical failure modes in rolling element bearings (He *et al.*, 2020).

3. Origins of electrical bearing failures: generation of shaft voltages and bearing currents

3.1. Electrical bearing failures: sources and mechanisms of shaft voltages and bearing currents

In electric motors, electrical failures, notably those involving electric discharge machining (EDM) triggered by electromagnetic and electrostatic phenomena, are inherent and unavoidable. A clear understanding of shaft voltages, which represent the fundamental source of these failures, is therefore essential. Shaft voltages can be classified into three primary categories according to their origin: magnetic flux asymmetry, electrostatic effects, and inverter-induced voltages.

3.2. Asymmetry of magnetic flux

Magnetic asymmetry originates from any deviation in the spatial distribution of the magnetic poles or from shaft misalignment occurring during design, manufacturing, or installation. The most common sources include

asymmetrical stator windings, rotor eccentricities, casting imperfections, non-uniform magnetic permeability of the core, and unbalanced voltage signals supplied by the inverter.

As a consequence, unlike the balanced condition of a symmetrically operating motor, the rotating shaft continuously cuts through an unbalanced magnetic field and thereby induces a shaft voltage. The resulting voltage and current waveforms exhibit a sinusoidal shape and low-frequency character (Hadden *et al.*, 2016).

3.3. Effects of electrostatics

Triboelectrification arises whenever dissimilar materials come into contact or slide against one another, particularly on dielectric surfaces, where electric charges tend to separate, accumulate, and persist for extended periods. In modern electric vehicles, the drive toward lightweight design has led to the widespread use of composite and polymeric dielectric materials, including carbon-fiber-reinforced plastics for structural body parts, thermally conductive insulating polymers in cooling systems, and rubber sealing rings. Within these components, triboelectrification produces pronounced charge separation across the interfaces, resulting in substantial electrostatic charge accumulation. When the resulting electrostatic field exceeds the dielectric breakdown strength of either air or the lubricant film, the stored charges are suddenly released as discharge currents. This mechanism leads to the formation of electric discharge machining (EDM) currents.

3.4. Inverter-induced voltage

Modern electric vehicles rely extensively on pulse-width modulation (PWM) inverters equipped with high-speed switching devices such as metal-oxide-semiconductor field-effect transistors (MOSFETs) and insulated-gate bipolar transistors (IGBTs) to achieve precise variable-speed control of the electric motor. The rapid switching action of these inverters generates a high-frequency common-mode voltage (CMV), defined as the voltage difference between the motor neutral point and the grounded stator frame.

In a typical three-phase adjustable-speed drive, the CMV corresponds to one-third of the vector sum of the three phase voltages. When the inverter produces a perfectly symmetrical sinusoidal output, the common-mode voltage remains at zero. In practice, however, the inverter approximates the sine wave with a series of discrete pulses; the resulting asymmetrical pulse train creates a stepped common-mode voltage waveform. Even in delta-connected motors that lack a physical neutral point, the unbalanced inverter output still produces common-mode effects.

Shaft voltages are subsequently induced through both capacitive and magnetic coupling during the abrupt transitions of this stepped waveform. Although higher switching frequencies make the common-mode voltage more closely resemble a sinusoidal shape and improve overall drive efficiency, they simultaneously increase the rate of voltage change (dv/dt). This steep dv/dt introduces significant high-frequency harmonic distortion into the system, generating shaft voltages of elevated amplitude and frequency. Such high-frequency shaft voltages are particularly problematic because they can propagate through multiple interfaces, even those that are nominally insulated (Chen and Lipo, 1998; Plazenet *et al.*, 2018).

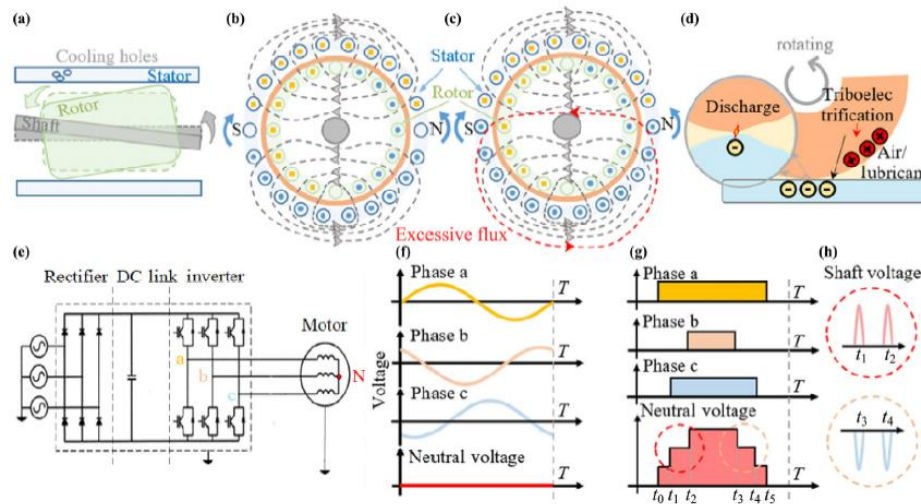


Fig. 5 – Generation mechanisms of shaft voltages. (a–c) Magnetic flux asymmetry: (a) asymmetries of stator, rotor, and shaft during relative motion; (b) normally working induction motor; (c) working condition with unbalanced flux; (d) electrostatic effects: discharge induced by triboelectrification. (e–f) Inverter-induced voltages: (e) Circuit configuration of an induction motor driven by a typical adjustable speed drive which contains a three-phase inverter (Kempski, 2001).

4. Conclusions

This comprehensive review demonstrates that bearing currents remain a critical reliability challenge in electric vehicle drivetrains. These currents arise primarily from high-frequency common-mode voltages generated by PWM inverters. The analysis confirms that shaft voltages originate from three fundamental mechanisms—magnetic flux asymmetry, triboelectrification, and inverter-induced capacitive/magnetic coupling—which give rise to circulating and non-circulating currents that exceed the dielectric strength of the lubricant

film. These currents induce electric discharge machining (EDM) phenomena, resulting in progressive surface degradation (frosting, pitting, fluting, spark tracks, and localized welding) and simultaneous lubricant deterioration through polarization, oxidation, and microbubble formation.

Experimental and modelling evidence consistently shows that current amplitude and frequency are strongly modulated by operating parameters such as rotational speed, load, inverter switching frequency, and temperature, with discharge energy directly governing the transition from isolated micro-pitting to macroscopic fluting and eventual bearing failure. While mitigation strategies—including insulated or hybrid ceramic bearings, conductive greases, shaft grounding rings, CMV filters, and advanced PWM techniques—offer partial protection, each presents inherent limitations regarding cost, thermal performance, or long-term effectiveness under real-world EV duty cycles.

Future research must therefore focus on integrated multi-physics modelling that couples electromagnetic, tribological, and thermal phenomena, alongside the development of real-time diagnostic sensors and adaptive inverter control algorithms. Only through such holistic approaches can the premature electrical failure of bearings be reliably predicted and mitigated, thereby extending drivetrain service life and supporting the broader electrification of mobility.

REFERENCES

- Bleger A., Leighton M., Morris N., *Automotive E-Motor Bearing Electrical Discharge Phenomena: An Experimental and Numerical Investigation*, Tribol. Int. 2024.
- Bonnett A.H., *Cause and analysis of bearing failures in electrical motors*. In *Proceedings of 1992 Record of Conference Papers Industry Applications Society 39th Annual Petroleum and Chemical Industry Conference*, San Antonio, TX, USA, 1992, 87–95.
- Chen S., Lipo T.A., Fitzgerald D., *Modeling of motor bearing currents in PWM inverter drives*. IEEE Trans. Ind. Appl. 1996.
- Chen S.T., Lipo T.A., *Circulating type motor bearing current in inverter drives*, IEEE Ind Appl Mag 4(1): 32–38 (1998).
- Erdman J.M., Kerkman R.J., Schlegel D.W., Skibinski G.L., *Effect of PWM inverters on AC motor bearing currents and shaft voltages*, IEEE Trans. Ind. Appl. 1996.
- Fang T., Han X., Niu F., Zhang G., Wang Y., Li S., *Research on the topology of bearing current conduction path for PMSM in electric vehicles considering parasitic inductance*, IEEE Transactions on Power Electronics, 41(2), 2148–2159 (2025), <https://doi.org/10.1109/tpel.2025.3618954>.
- Hadden T., Jiang J.W., Bilgin B., Yang Y.Y., Sathyan A., Dadkhah H., Emadi A., *A review of shaft voltages and bearing currents in EV and HEV motors*, In *Proceedings of IECON 2016 - 42nd Annual Conference of the IEEE Industrial Electronics Society*, Florence, Italy, 2016: 1578–1583.

- He F., Xie G., Luo J., *Electrical bearing failures in electric vehicles*, Friction 8(1), 4–28 (2020).
- Kempski A., *Capacitively coupled discharging currents in bearings of induction motor fed from PWM (pulsewidth modulation) inverters*, J Electrostat 51–52: 416–423 (2001).
- Ma Jiaojiao, Xue Yujian, Han Qingkai, Li Xuejun, Yu Changxin, *Motor bearing damage induced by bearing current: A review*, Machines 2022.
- Muetze A., Binder A., Vogel H., Hering J., *What can bearings bear?* IEEE Ind. Appl. Mag. 2006, 12, 57–64.
- Muetze A., Tamminen J., Ahola J., *Influence of Motor Operating Parameters on Discharge Bearing Current Activity*, IEEE Trans. Ind. Appl. 2011.
- Noguchi S., Kakinuma S.-n., Kanada T., *Measurement of Direct Current Voltage Causing Electrical Pitting*, J. Adv. Mech. Des. Syst. Manuf. 2010, 4, 1084–1094.
- Peng H., Zhang H., Fan Y., Shangguan L., Yang Y., *A Review of Research on Wind Turbine Bearings' Failure Analysis and Fault Diagnosis*, Lubricants 2023.
- Plazenet T., Boileau T., Caironi C., Nahid-Mobarakeh B., *A comprehensive study on shaft voltages and bearing currents in rotating machines*, IEEE Trans Ind Appl 54(4): 3749–3759 (2018).
- Schuster M., Springer J., Binder A., *Comparison of a 1.1 kW-induction machine and a 1.5 kW-PMSM regarding common-mode bearing currents*, In Proceedings of the 2018 International Symposium on Power Electronics, Electrical Drives, Automation and Motion (SPEEDAM), Amalfi, Italy, 20–22 June 2018; pp. 1–6.
- Son D.W., Zhang T., Lee G., *Study on Electrical Pitting Prevention Device of a Rotating Shaft Using Automatic Control Potential Balancing*, Materials 2022.
- Touzin M., Goeuriot D., Guerret-Piécourt C., Juvé D., Fitting H.J., *Alumina based ceramics for high-voltage insulation*, J. Eur. Ceram. Soc. 2010, 30, 805–817.
- Ye Hai, Yin Jun, Wang Xiaobo, Lou Wenjing, Liang Peng, Liu Haichao, *Electrical fluting damage of rolling element bearings: Influences of AC electrical parameters and operating conditions*, Tribology International 2025.

O ANALIZĂ DETALIATĂ A FENOMENELOR DE CURENȚI DIN RULMENȚI ÎN SISTEMELE DE PROPULSIE ALE VEHICULELOR ELECTRICE

(Rezumat)

Adopția tot mai accentuată a vehiculelor electrice (VE) a adus în atenție fiabilitatea și durabilitatea componentelor sistemului de propulsie, în special a rulmenților motoarelor electrice. Curenții prin rulmenți, induși de potențialele de tensiune de înaltă frecvență generate de motoarele alimentate prin invertoare, au devenit o cauză majoră de defectare prematură a rulmenților în sistemele de propulsie electrice. Rulmenții cu elemente de rostogolire reprezintă componente esențiale ale mașinilor electrice, influențând direct eficiența, stabilitatea în funcționare și durata lor de viață. Extinderea rapidă a sistemelor de acționare bazate pe invertoare cu modulare în lățime de impuls (PWM) a introdus noi factori de stres electric în cadrul motoarelor, printre care curenții prin rulmenți reprezintă o preocupare critică. Acești curenți paraziți pot circula prin

zonele de contact ale rulmenților, provocând deteriorarea suprafețelor prin efecte de pitting și fluting. În timp, această degradare accelerează uzura, reduce durata de viață operațională a motorului și poate conduce la defectarea neașteptată a sistemului.

Cercetările actuale privind degradarea cauzată de curenții prin rulmenți se concentrează în principal asupra a trei aspecte majore: mecanismele fizice responsabile de generarea curenților, parametrii esențiali care guvernează aceste fenomene și dezvoltarea modelelor de circuit echivalent pentru descrierea căilor de circulație a curenților prin sistemul motorului.

Prezenta lucrare oferă o analiză exhaustivă a curenților electrici care traversează rulmenții utilizați în vehiculele electrice. Mecanismele de generare a curenților, incluzând tensiunea de mod comun, cuplajul capacitiv și inducția electromagnetică, sunt examinate în detaliu. De asemenea, sunt evaluate efectele diferitelor condiții de funcționare — precum viteza motorului, sarcina, frecvența de comutație a invertorului și temperatura — asupra amplitudinii și frecvenței curenților prin rulmenți. Stresurile electrice și termice rezultante care accelerează degradarea rulmenților sunt discutate pe baza rezultatelor experimentale și a modelelor de simulare. Strategiile actuale de atenuare, inclusiv utilizarea rulmenților izolați, tehnici de împământare și metode avansate de control al invertorului, sunt evaluate în ceea ce privește eficacitatea și limitările acestora. În final, lucrarea evidențiază direcțiile de cercetare viitoare orientate spre dezvoltarea unor abordări integrate de design și diagnosticare pentru a prevedea, monitoriza și minimiza efectele curenților prin rulmenți, contribuind astfel la creșterea fiabilității și duratei de viață a trenurilor de propulsie ale vehiculelor electrice.