

Study Of Differences Between Motors in Series Compared to Motors in Shunt

Rosli bin A. Rasid^{1*}, Faizul Bin Mohd Noor¹, Roduan Hishambri bin Ismail¹

¹Department of Electrical Engineering, Politeknik Sultan Mizan Zainal Abidin, 23000 Dungun, Terengganu

*Corresponding author E-mail: rosli@psmza.edu.my

Abstract

This study aims to compare series-connected DC motors with shunt-connected DC motors. A DC motor is an electrical machine that converts direct current electrical power into mechanical power. Commonly used DC motors rely on the power generated by the magnetic field of the motor. In this experiment, series DC motors and shunt DC motors are tested in terms of motor speed based on torque values, with varying torque values applied. The current and speed values of both types of motors are recorded and analyzed. The analysis of speed, current in the motor, output power, and motor efficiency compared to the torque of each type of motor can be used to understand and compare these two types of motor connections.

Key Words: *DC motors series, electrical machine*

1.0 Introduction

Almost all types of DC motors incorporate internal mechanisms, either electromechanical or electronic designed to periodically reverse the direction of current flow within the motor components. The speed of a DC motor can be controlled by adjusting the supply voltage or by varying the current strength in the coil. Small DC motors are commonly used in toys, electronic gadgets, and handheld power tools. Universal DC motors, which can operate on both direct and alternating current, are typically found in portable power tools and appliances. Larger DC motors are employed in applications such as electric vehicles, elevators, hoisting machinery, and industrial equipment in steel manufacturing plants. With the advancement of power electronics technology, the use of high-power DC motors has increasingly been replaced by alternating current (AC) motors in many modern applications.

1.1 Research Objectives

This study aims to achieve the following objectives:

- i. To identify and characterize the fundamental design features, operational principles, and typical applications of series and shunt direct current (DC) motors.
- ii. To analyze the performance of both motor types under varying load and speed conditions, with a focus on dynamic response and operational efficiency.
- iii. To compare the energy efficiency of series and shunt DC motors within the context of industrial applications, highlighting their suitability for different operational demands.
- iv. To evaluate the advantages and limitations of each motor type in terms of speed regulation, torque generation, and operational stability.
- v. To recommend appropriate applications for each motor type based on empirical findings and analytical assessments conducted throughout the study.

2.0 Literature Review

Various configurations of direct current (DC) motors—namely shunt, series, compound, and permanent magnet types—are widely utilized across industrial applications. The schematic diagrams representing each motor connection type are illustrated in Figure 1. The selection of motor types is typically guided by mechanical requirements and load characteristics. A shunt motor features armature and field windings connected in parallel, allowing for relatively stable speed under varying loads. In contrast, a series motor has its armature and field windings connected in series, resulting in high starting torque but variable speed depending on the load. The compound motor integrates both series and parallel field connections within its winding

structure, offering a balance between torque and speed stability. Meanwhile, the permanent magnet motor relies solely on armature winding, with the magnetic field provided by permanent magnets rather than electromagnetism [1–2]. These motor types exhibit distinct operational behaviors and are selected based on specific performance criteria such as torque requirements, speed regulation, and energy efficiency.

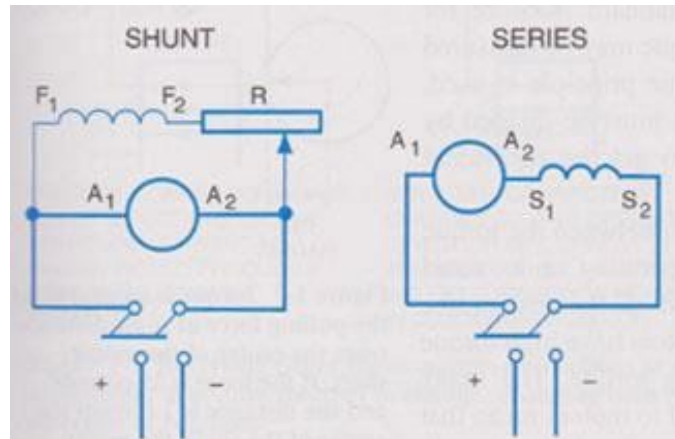


Figure 1: The schematic diagrams: type of direct current motor, namely the shunt and series configurations

Figure 1 illustrates the schematic diagrams corresponding to each type of direct current motor, namely the shunt and series configurations

2.1 Series DC Motor

A series-connected DC motor integrates the armature and field windings in a single series circuit powered by a direct current (DC) voltage source. This configuration gives rise to several nonlinear characteristics, including motor speed, load torque, and armature current behavior. Series DC motors are known for their exceptionally high starting torque, making them ideal for initiating motion in systems with substantial inertia, such as railway locomotives and elevators. The torque-speed characteristics of these motors are particularly advantageous in applications like dredging operations, where the excavating mechanism must move rapidly during digging but slow down significantly when transporting heavy loads [2]. Due to their design, series motors must never be operated without a mechanical load. In no-load conditions, the armature current drops significantly, resulting in a weakened magnetic field. This can lead to a reversal of the electromagnetic field generated by the weakened coil, forcing the armature to accelerate excessively to restore magnetic balance. Such uncontrolled acceleration may exceed the motor's design limits, potentially leading to mechanical failure—a phenomenon commonly referred to as a "runaway condition."

Figure 2 illustrates the equivalent circuit of a series DC motor, where the magnetic field and armature are connected in series.

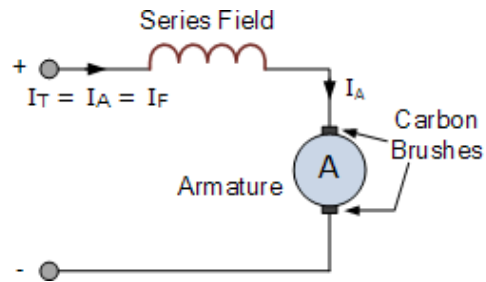


Figure 2: Equivalent circuit of the series-type AT motor

2.2 Shunt DC Motor

Shunt-connected DC motors exhibit a relatively constant rotational speed that is largely independent of load variations. Due to this characteristic, shunt DC motors are widely employed in applications such as elevators, fans, printing machines, and other equipment requiring stable speed control. DC motors are typically rated based on voltage, current, rotational speed, and horsepower output. The number and configuration of armature and field windings significantly influence the motor's operational characteristics. Rotational power at the motor shaft is generated through the interaction between the armature's magnetic field and the field poles, producing torque. Torque is a force measured in Newton-meters (Nm) and is also referred to as moment or moment of force. It represents the tendency of a force to rotate an object about an axis and is considered a vector quantity. While force is perceived as a push or pull, torque is understood as a twisting action applied to an object. Mathematically, torque is defined as the cross product of the lever arm distance and the force causing the rotation [1].

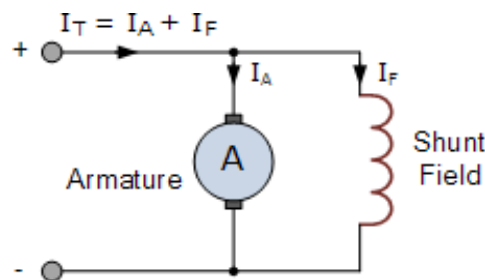


Figure3: Equivalent circuit of the shunt DC motor

Figure 3 illustrates the equivalent circuit of a shunt DC motor, where the magnetic field and armature are connected in parallel.

3.0 Methodology

3.1 Speed Measurement of AT Series Motor

This experiment involved testing an AT series motor rated at 90 Watts, 220V, and 0.53A. The motor circuit configuration is illustrated in Figure 4, which shows the series connection between the armature and the field winding series. Torque was incrementally increased from 0.0% to 1.0% to observe its effect on motor speed. The equipment utilized in this experiment included Three-phase power supply, Control unit servo brake ,4-Q load servo machine, DC multifunctional machine, DC series wound motor connection plate, Ammeter, Voltmeter

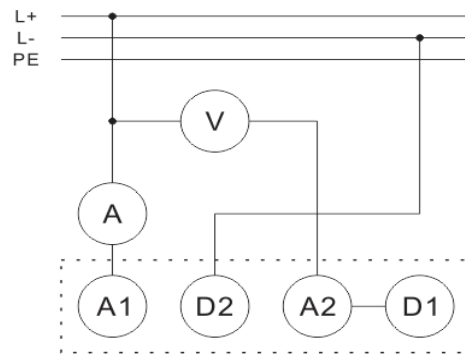


Figure 4: Circuit configuration of the AT series motor connected to a 220V power supply.

The motor was initially powered with a low voltage, which gradually increased until the supply reached 220V. Torque was applied in stages according to Table 1, and corresponding speed readings were recorded.

3.2 Speed Measurement of AT Shunt Motor

A similar procedure was conducted for an AT shunt motor, also rated at 90 Watts, 220V, and 0.53A. The circuit configuration is shown in Figure 5, where the shunt field and armature are connected in parallel. Torque was incrementally increased from 0.0% to 1.0%. The same set of equipment was used as in the previous experiment. The motor started at a low voltage and gradually increased to 220V. Torque was applied in stages as outlined in Table 2, and the resulting speed measurements were documented.

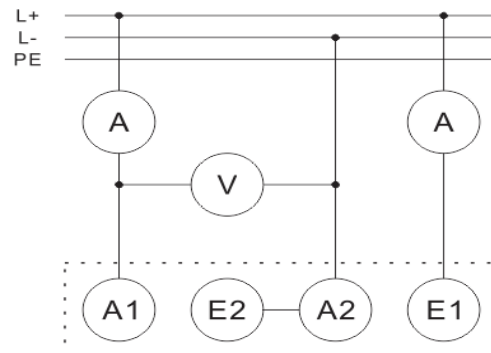


Figure 5: Circuit configuration of the AT shunt motor connected to a 220V power supply

4.0 Findings and Analysis

Table 1: Experimental Results for the AT Series Motor Configuration

													Rated
Pengukuran	Daya Kilas (Torque)	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	0.47
	Arus (I_A)	0.200	0.231	0.346	0.434	0.517	0.697	0.670	0.761	0.832	0.900	0.996	0.572
	Kelajuan (Speed)	4527	3748	2647	2225	1962	1806	1691	1549	1428	1350	1259	1859
P	Kuasa masukan (Input Power)	44.00	50.82	76.12	95.48	113.74	153.34	147.40	167.42	183.04	198.00	219.12	128.00

Kuasa keluaran (Output Power)	0.00	39.25	55.43	69.90	82.18	94.55	106.24	113.54	119.62	127.23	131.83	90.00
Keberkesanan (Efficiency)	0	1.295	1.373	1.366	1.384	1.622	1.387	1.475	1.530	1.556	1.662	0.70

Table 2: Experimental Results for the AT Shunt Motor Configuration

													Rated
Pengukuran	Daya Kilas, % (Torque)	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	0.47
	Arus, I_{A1} (Amp)	0.066	0.171	0.229	0.337	0.445	0.529	0.628	0.723	0.832	0.930	1.032	0.525
	Arus, I_{A2} (Amp)	0.020	0.142	0.142	0.142	0.142	0.141	0.140	0.140	0.140	0.140	0.139	0.145
	Kelajuan, $Speed$ (rpm)	1909	1891	1895	1880	1863	1851	1837	1826	1817	1808	1798	1875
Pengiraan	Jumlah Arus, I_t (Amp)	0.086	0.313	0.371	0.479	0.587	0.670	0.768	0.863	0.972	1.070	1.171	0.67
	Kuasa masukan, $Input\ Power$ (Watt)	18.92	68.86	81.62	105.38	129.14	147.4	168.96	189.86	213.84	235.4	257.62	128.00
	Kuasa keluaran, $Output\ Power$ (Watt)	0.00	19.80	39.69	59.06	78.03	96.91	115.41	133.84	152.21	170.39	188.27	90.00
	Keberkesanan ($Efficiency$)	0.000	0.288	0.486	0.560	0.604	0.657	0.683	0.705	0.712	0.724	0.731	0.700

5.0 Data Analysis

5.1 Data Analysis of Experimental Results for the AT Series Motor

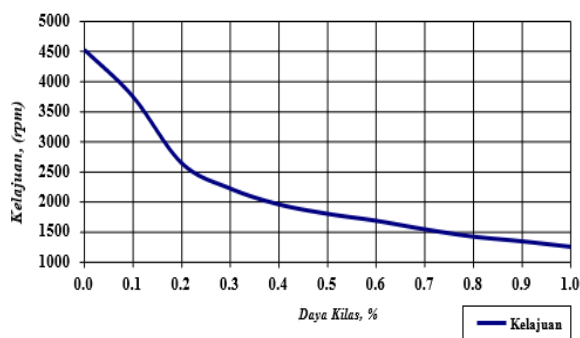


Figure 6: Velocity versus Torque graph illustrating the relationship between rotational speed and applied torque under varying load conditions.

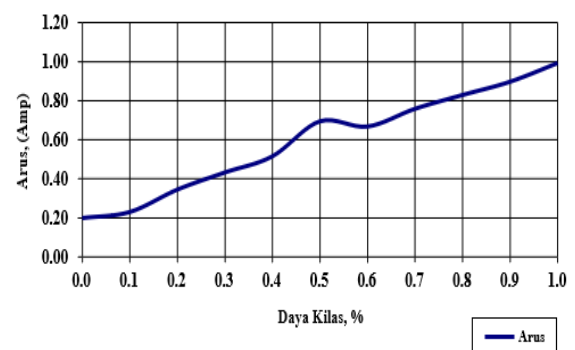


Figure 7: Current versus Torque graph showing the variation in electrical current with respect to applied torque, indicating the motor's load response characteristic.

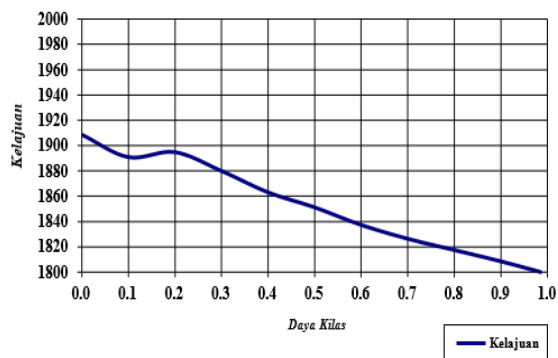


Figure 8: Output power versus torque characteristic curve

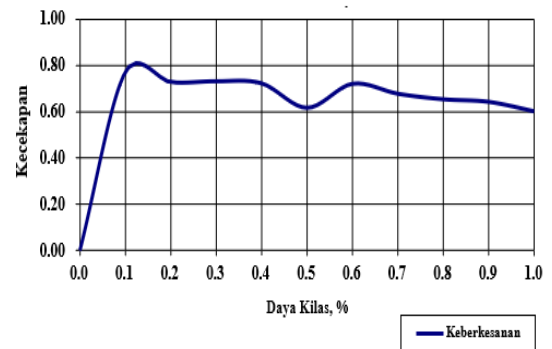


Figure 9: Efficiency versus torque characteristic curve

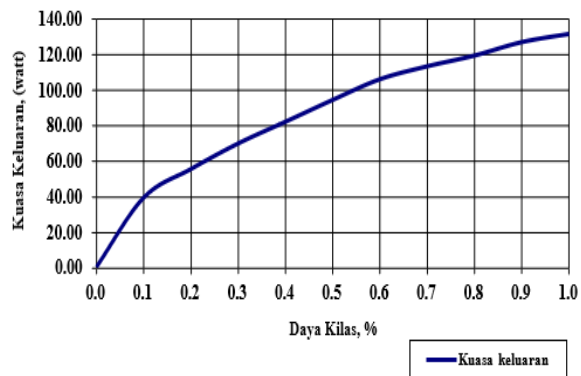


Figure 10: Speed versus torque characteristic curve.

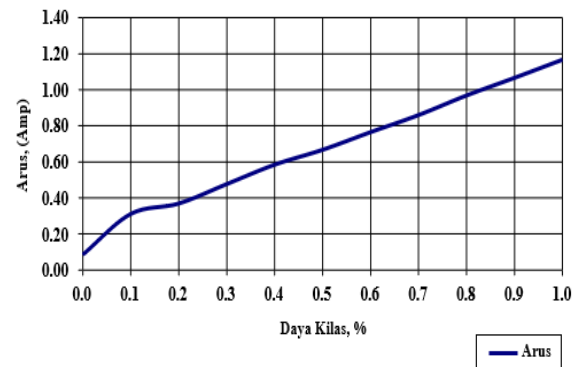


Figure 11: Current versus torque characteristic curve.

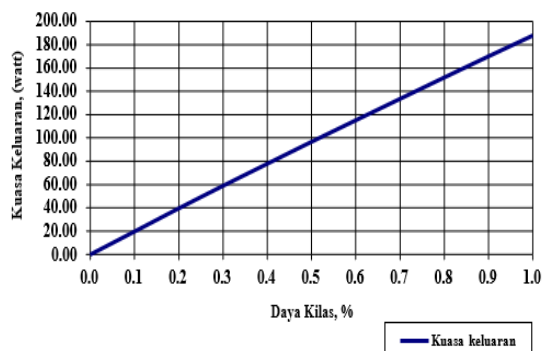


Figure 12: Output power versus torque characteristic curve.

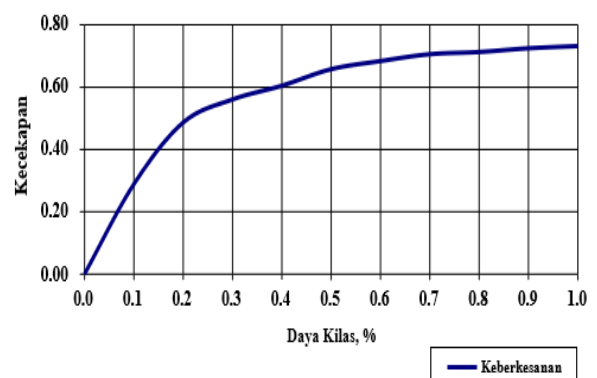


Figure 13: Efficiency versus torque characteristic curve.

6.0 Conclusion

Based on the experimental study conducted, it is evident that the AT series and AT shunt motors exhibit significant differences in terms of design, performance, and application suitability. The AT series motor demonstrated high starting torque, making it ideal for applications requiring substantial traction force, such as locomotives and cranes. In contrast, the AT shunt motor maintained a more stable speed profile, rendering it suitable for applications that demand consistent speed, such as fans and pumps.

From an efficient standpoint, the shunt motor showed greater consistency across varying load conditions, while the series motor performed more efficiently under high-load scenarios. Therefore, the selection of motor types should be guided by specific operational requirements and the characteristics of the intended application. This study provides a deeper understanding of the advantages and limitations of both motor types, thereby supporting more informed decision-making in industrial and technical motor selection.

7.0 Recommendations

To ensure optimal motor selection for industrial applications, it is recommended that motor choice be aligned with the specific operational demands. For instance, the AT series motor is better suited for tasks requiring high starting torque, whereas the AT shunt motor is preferable for operations needing stable speed control.

Furthermore, technical training for technicians and students should be enhanced to improve their understanding of the characteristics and practical applications of both motor types. Future research is encouraged to evaluate motor performance under real-world operating conditions, such as high temperatures, overload scenarios, and voltage fluctuations.

The integration of modern technologies, such as microprocessor-based control systems, should also be explored to improve the efficiency and control of AT series and shunt motors. Additionally, a comparative analysis of operational and maintenance costs between the two motor types is recommended to assist industries in making economically sound decisions.

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