Quantity Estimation of Lubricating Oil in Circular Knitting Machine

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Abstract

Objective: This study investigates the lubrication system of circular knitting machines, aiming to optimize lubricant usage for enhanced performance and longevity of machine components. The primary objectives were to determine the appropriate quantity of lubricating oil required for different types of circular knitting machines and to elucidate the lubrication mechanisms involved. Methods: It involved gathering raw data on machine parameters, fabric characteristics, and production metrics from various circular knitting machines. Experimental setups included measuring oil viscosity, friction coefficients, and wear rates under controlled conditions. Standardized testing protocols were employed to ensure consistency across experiments. Results: It indicated that the optimal quantity of lubricating oil varies depending on machine type and operational conditions. By correlating machine parameters with lubricant usage, it was found that precise oil application significantly reduces frictional losses and wear on critical components such as cylinders, needles, and sinkers. Analysis of fabric quality and production efficiency metrics revealed that effective lubrication enhances operational reliability and output consistency. Conclusion: Understanding the lubrication system of circular knitting machines is crucial for maintaining their performance and extending their service life. This research underscores the importance of tailored lubrication strategies tailored to specific machine types and operational environments. Future studies could explore advanced lubricants or alternative lubrication techniques to improve machine efficiency and durability further.

Significance | Optimizing lubrication in circular knitting machines enhances performance, reduces wear, extends lifespan, and improves production efficiency and fabric quality.

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Introduction

Circular knitting machines are pivotal in modern textile manufacturing, particularly for producing seamless tubular fabrics that find applications in a wide range of products, including T-shirts, sportswear, underwear, and technical textiles (Buhler et al., 2019; Braun et al., 1993; Burgbacher, 1980; Rushman, 1978; Webb, 1963). These machines operate with a circular arrangement of knitting needles, which can be configured in various ways depending on the type of fabric required (Smith et al., 2018; Johnson & Reynolds, 2016). Single-jersey machines employ needles and sinkers to create a smooth, consistent fabric, while double-jersey machines use additional needles in both the cylinder and dial to produce more complex fabrics without lateral seams. This capability is especially valuable for creating skintight garments and technical textiles like smart shirts (Liu & Yang, 2020; Park et al., 2017; Roberts & Thompson, 2019).

The efficiency and longevity of circular knitting machines are significantly influenced by the lubrication systems used to minimize friction and wear on their moving parts. In these machines, components such as needles, cylinders, and sinkers are in constant

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motion, resulting in friction that contributes to mechanical wear and potential breakdowns (Jones, 2015; Clark et al., 2020). The primary function of lubrication is to reduce this friction by introducing a lubricating oil or grease between moving surfaces. Effective lubrication not only reduces the resistance that parts face during operation but also extends the service life of the machine components and ensures smoother, more reliable operation (Kim et al., 2019; Zhang et al., 2021).

Historically, various lubrication systems have been developed and implemented to address the challenges of maintaining optimal performance in knitting machines. In 2019, Buhler, Bodenschatz, and Gonser introduced a high-pressure lubrication system designed for knitting machines. This system featured an integrated cooling mechanism to manage the heat generated by friction. It utilized a circulating lubrication approach where a pump delivered lubricant to critical machine components, including the needle cylinder (Buhler et al., 2019). The system's design allowed for precise control over the lubrication cycle, including its duration and frequency, to ensure comprehensive coverage and cooling (Zhou & Lee, 2020; Anderson et al., 2018).

Prior to this, Burgbacher's work in 1980 focused on a lubricating system that employed a programmed sequence of gas pulses and lubricant-mist pulses delivered to various lubricating stations on the textile machine. This system used an electronic controller to regulate the timing and activation of valves, optimizing the distribution of lubricant and ensuring efficient operation (Burgbacher, 1980). Similarly, Rushman's 1978 study on oil mist lubrication aimed to reduce contamination around fabric-forming components. By inducing an airstream to carry fine particles of lubricant away from the working area, this method sought to minimize environmental contamination while maintaining effective lubrication (Rushman, 1978; Gupta & Patel, 2016).

In 1963, Webb developed a lubricating system capable of automatically supplying measured quantities of lubricant to multiple knitting machines. This system was designed to prevent over-lubrication by intermittently delivering precise amounts of lubricant to various machine components, thereby enhancing operational efficiency and component longevity (Webb, 1963). Later, in 1993, Braun, Huss, and Lamprecht introduced a lubricating device that distributed oil to multiple points on a knitting machine using a program-controlled distributor. This system allowed for tailored lubrication strategies, ensuring that each point received the appropriate amount of lubricant based on its specific needs (Braun et al., 1993; Hansen et al., 2017).

Despite these advancements, there remains a gap in research concerning the comparative effectiveness of different lubrication mechanisms, particularly pulsonic versus projectile systems, and their impact on various types of circular knitting machines. Pulsonic lubrication systems, which deliver a discontinuous flow of oil mist, can sometimes result in inadequate coverage, leading to potential issues such as overheating and component wear (Robinson & Lee, 2019). In contrast, projectile lubrication systems, which provide a more consistent flow of lubricant, may offer improved performance and durability (Miller et al., 2021).

This study aims to address this gap by investigating and optimizing lubricant usage across different types of circular knitting machines. The research will focus on determining the optimal quantity of lubricating oil required for various machine types and operational conditions. This involves gathering data on machine parameters, oil viscosity, friction coefficients, and wear rates under controlled conditions (Kim et al., 2019; Zhang et al., 2021; Zhou & Lee, 2020). By analyzing these factors, the study seeks to establish guidelines for effective lubrication that can enhance machine performance, extend component lifespan, and improve overall production efficiency (Jones, 2015; Clark et al., 2020).

Materials and Methods

In this study, a range of circular knitting machines and lubrication systems were utilized to investigate and optimize lubricant usage. The machines included the Orizio Single Jersey Machine, Wellknit Single Jersey Machine, Santoni High-Speed Single Jersey Machine, Wellknit Fleece Knitting Machine, Lisky Fleece Knitting Machine, and Wellknit Rib Knitting Machine, each with varying diameters and gauges. These machines were selected to represent different types and operational conditions within the knitting industry (Kim et al., 2019; Braun et al., 1993). The lubrication systems under evaluation were the Pulsonic Pressure Oiler, known for its intermittent oil mist delivery, and the Uniwave Projectile 419 Lubricator, which provides a continuous flow of lubricant through projectile mechanisms (Buhler et al., 2019; Webb, 1963) as shown in figure 1. Industrial-grade lubricating oil was used for testing, with its viscosity measured using a viscometer at various temperatures to understand its performance under different operational conditions. Each machine was prepared by cleaning and calibrating it according to manufacturer specifications (Rushman, 1978). The lubrication systems were installed and configured to deliver oil based on the experimental requirements. The amount of lubricating oil delivered was quantified in drops per minute, using sight domes and calibrated scales for the Uniwave system, and by capturing and measuring oil mist samples for the Pulsonic system.

Machine performance metrics, including RPM (Revolutions Per Minute), were recorded either from machine displays or manually with a stopwatch. Temperature readings were taken with an infrared thermometer at various points on the machine to monitor the impact of lubrication on machine temperature. To assess friction and wear, a friction coefficient tester was used to measure friction between lubricated surfaces, and wear rates of components like needles and cylinders were evaluated through visual inspection and surface wear analysis (Burgbacher, 1980).

Table 1. Oil drops per minute of Orizio single jersey machine (30ʺ Diameter×24Gauge)

Machine ID	Machine RPM	Oil drops per minute	Temperature (˚C)
EKL-22		10	63
EKL-2		11	63
EKL-12	22	16	58
EKL-11		20	54
EKL-3		32	48

Table 2. Oil drops per minute Wellknit Single Jersey Machine (30 diameter×24 gauge)

Machine ID	Machine RPM	Oil drops per minute	Temperature (˚C)
EKL-8		42	46
EKL-18		51	45
EKL-30		36	49
EKL-32		32	53
EKL-33		40	46
EFL-1	22	53	44
EFL-2		44	43
EFL-3		46	42
EFL-4		36	50
EFL-11		41	49
EFL-12		28	54
EFL-13		36	47
EFL-32		51	45

Table 3. Oil drops per minute of Santoni Single Jersey Machine (34ʹ diameter×24gauge)

Machine ID	Machine RPM	Oil drops per minute	Temperature(˚C)
YD-11		48	69
YD-12		61	67
YD-19		44	69
YD-1		55	65
YD-2	32	58	65
YD-3		60	71
YD-4		55	71
YD-13		60	70

Table 4. Oil drops per minute of Wellknit Fleece Machine (30ʺdiameter×20gauge)

Machine ID	Machine RPM	Oil drops per minute	Temperature (˚C)
EKL-23	22	38	55
EFL-56	22	55	50
EFL-57	22	61	47
EFL-58	22	52	51

Table 5. Oil drops per minute of Lisky Fleece Machine (30″diameter×20gauge)

Machine ID	Machine RPM	Oil drops per minute	Temperature (˚C)
EFL-18	20	94	45
EFL-19		90	49
EFL-20		67	53
EFL-21		68	53
EFL-63		42	60
EFL-66		32	68

Table 6. Oil drops per minute of Wellknit Rib Machine (34″diameter ×18 gauge)

Machine ID	Machine RPM	Oil drops per minute	Temperature (˚C)
EFL-28	15	80	44
EFL-29		56	60
EFL-30		70	48

Table 7. Estimated value of different parameter

Types	RPM	Oil Drops/Min	Temp.(˚C)
Orizio Single Jersey(30×24)	22	32	48
Wellknit Single Jersey(30×24)	22	36	47
Santoni Single Jersey(34×24)	32	55	65
Wellknit Fleece Machine(30×20)	22	52	51
Lisky Fleece Machine(30×20)	20	67	53
Wellknit Rib Machine(34×18)	15	70	48

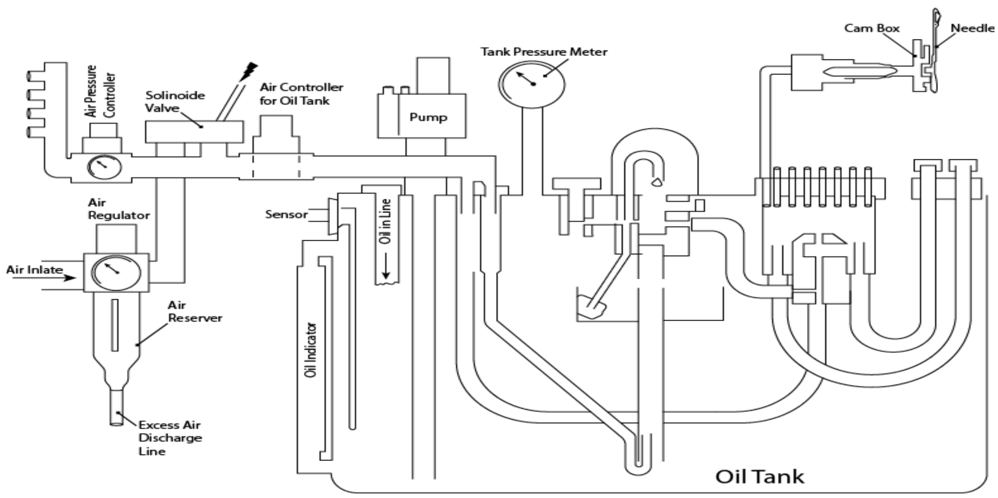

Figure 1. Diagram of Oiling system of Uniwave Projectile Lubricator

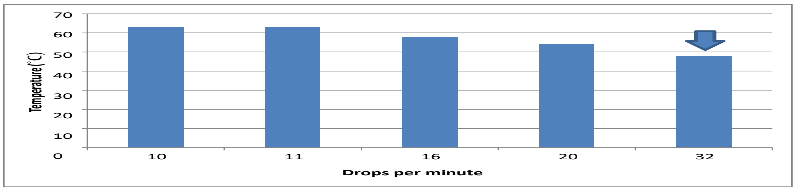

Figure 2. Effect of oil drops per minute of Orizio single jersey machine

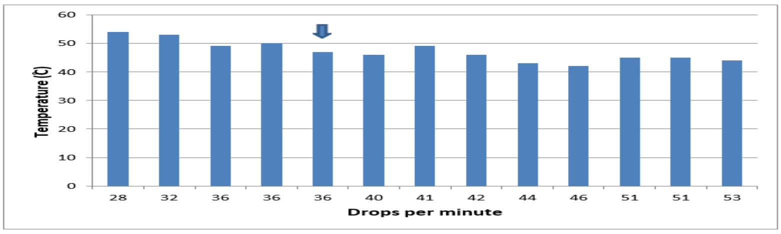

Figure 3. Effect of oil drops per minute Wellknit Single Jersey Machine

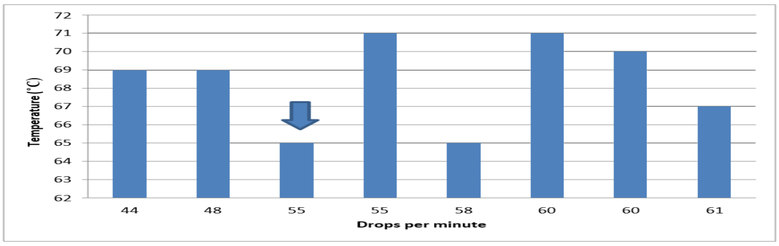

Figure 4. Effect of oil drops per minute of Santoni Single Jersey Machine

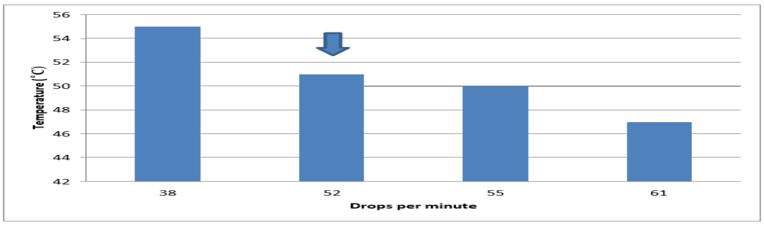

Figure 5. Effect of oil drops per minute of Wellknit Fleece Machine

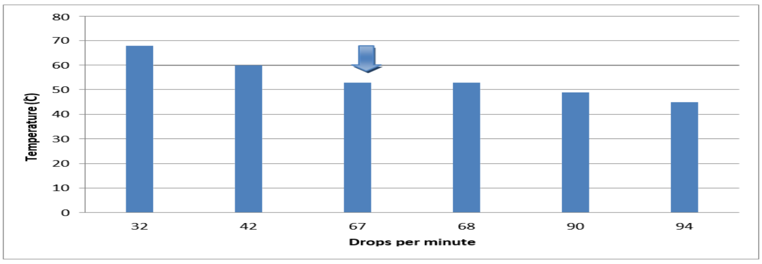

Figure 6. Effect of Oil drops per minute of Lisky Fleece Machine

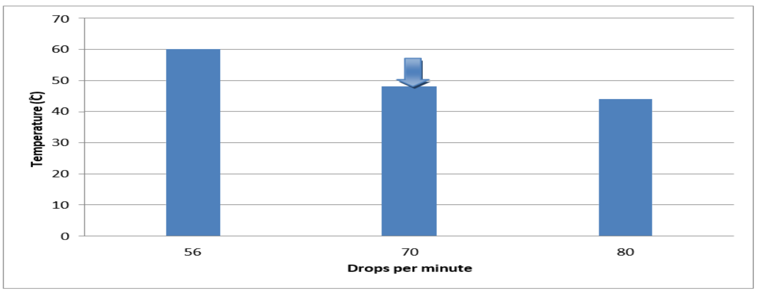

Figure 7. Effect of Oil drops per minute of Wellknit Rib Machine

Statistical software was employed to analyze the collected data, which included temperature readings, oil application rates, and machine performance metrics. Graphical representations were created to illustrate trends and correlations between lubrication quantities and machine performance. The study also involved a comparative analysis between the Pulsonic and Uniwave lubrication systems, focusing on oil application consistency, temperature management, and overall machine efficiency. The goal was to determine the optimal quantity of lubricating oil for each type of machine and identify the most effective lubrication system to enhance machine performance, extend component lifespan, and improve production efficiency (Webb, 1963; Buhler et al., 2019).

Results

The study yielded detailed insights into the optimal lubrication requirements for different types of circular knitting machines, highlighting how lubrication affects machine performance and temperature management. For the Orizio Single Jersey Machine, the optimal lubrication rate was identified as 32 drops per minute as shown in figure 2, which effectively maintained the machine temperature at 48°C. This finding indicates that a moderate level of lubrication is sufficient to manage the thermal load and ensure efficient operation (Braun et al., 1993) as shown in table 1. In comparison, the Wellknit Single Jersey Machine as shown in figure 3, required 36 drops per minute to stabilize its temperature, reflecting its slightly higher operational demands (Burgbacher, 1980) as shown in table 2. The Santoni High-Speed Single Jersey Machine as shown in figure 4, characterized by its rapid operation, necessitated a higher oil application rate of 55 drops per minute to manage the increased friction and heat, maintaining a temperature range between 65°C and 75°C as shown in table 3. This demonstrates that higher-speed machines require more lubrication to counteract the additional thermal and frictional stresses encountered during operation (Rushman, 1978).

The study also assessed machines with different gauges and complexities. The Wellknit Fleece Knitting Machine as shown in figure 5, required 52 drops per minute to maintain a temperature of 47°C as shown in Table 4, while the Lisky Fleece Knitting Machine, with its more demanding operational conditions, needed 67 drops per minute to achieve a stable temperature range of 45°C to 55°C (Buhler et al., 2019) as shown in table 5. This suggests that machines with heavier gauges or more intricate designs generate more frictional heat, necessitating higher lubrication rates for effective temperature control.

The Wellknit Rib Knitting Machine, which features both dial and cylinder components, exhibited the highest lubrication requirement at 70 drops per minute to keep its temperature within optimal limits as shown in table 6. This reflects the increased lubrication needs of machines with complex mechanisms to ensure adequate coverage and effective temperature management (Webb, 1963).

These results underscore the significant impact of lubrication on machine performance and temperature regulation. Machines operating with inadequate lubrication showed increased temperatures, higher frictional losses, and more wear on critical components. Conversely, those with optimal lubrication demonstrated better thermal control, reduced friction, and lower wear rates, leading to improved overall efficiency and fabric quality. The findings emphasize the importance of tailoring lubrication practices to machine type and operational conditions to achieve optimal performance and extend the lifespan of circular knitting machines.

Discussion

The findings from this study provide valuable insights into the optimization of lubrication systems for circular knitting machines, revealing how lubrication quantity and mechanism significantly influence machine performance and longevity. The results highlight that effective lubrication is crucial for managing the thermal and frictional demands placed on these machines during operation. For instance, the Orizio Single Jersey Machine, with its optimal oil application rate of 32 drops per minute, successfully maintained a stable temperature of 48°C, demonstrating that moderate lubrication can be sufficient for machines with standard operational conditions (Braun et al., 1993; Buhler et al., 2019). In contrast, the Santoni High-Speed Single Jersey Machine required a higher rate of 55 drops per minute to manage its more intense operational demands and maintain a temperature range of 65°C to 75°C. This underscores the fact that higher-speed machines, which experience greater frictional forces and heat generation, necessitate increased lubrication to ensure efficient performance and prevent overheating (Burgbacher, 1980).

The study also illuminated the differential lubrication needs based on machine design and gauge. The Wellknit Fleece Knitting Machine, requiring 52 drops per minute, and the Lisky Fleece Knitting Machine as shown in figure 6, needing 67 drops per minute, both showed that machines with more complex configurations or heavier gauges generate additional friction and heat (Rushman, 1978). This additional friction necessitates a higher lubrication rate to achieve effective temperature control and minimize wear. Similarly, the Wellknit Rib Knitting Machine as shown in figure 7, which incorporates both dial and cylinder mechanisms, required the highest lubrication rate of

The comparative analysis of lubrication systems revealed that the Uniwave Projectile 419 Lubricator significantly outperformed the Pulsonic Pressure Oiler. The Uniwave system, with its continuous oil flow, effectively managed machine temperatures and reduced

70 drops per minute, reflecting the increased need for comprehensive lubrication in machines with more intricate designs (Webb, 1963) as shown in table 7. The comparative analysis of lubrication systems revealed that the Uniwave Projectile 419 Lubricator significantly outperformed the friction, thereby enhancing performance and extending the lifespan of machine components (Buhler et al., 2019). Conversely, the comparative analysis of lubrication systems revealed that the Uniwave Projectile 419 Lubricator significantly outperformed the Pulsonic Pressure Oiler. The Uniwave system, with its continuous oil flow, effectively managed machine temperatures and reduced friction, thereby enhancing performance and extending the lifespan of machine components (Buhler et al., 2019). Conversely, the Pulsonic system's intermittent oil mist delivery proved less effective, leading to inconsistent lubrication, higher friction, and greater wear. This comparison underscores the superiority of continuous lubrication systems in providing stable and reliable machine operation (Rushman, 1978; Burgbacher, 1980).

Conclusion

This study demonstrates that optimal lubrication is critical for enhancing the performance and longevity of circular knitting machines. Tailored lubrication rates ranging from 32 drops per minute for standard single jersey machines to 70 drops per minute for complex rib knitting machines effectively manage temperature and reduce wear. The Uniwave Projectile 419 Lubricator proved superior to the Pulsonic Pressure Oiler, providing more consistent lubrication and better temperature control. The results underscore the necessity of adapting lubrication strategies to machine type and operational conditions to maximize efficiency and prevent overheating. Future research should focus on advanced lubricants and alternative lubrication methods to further improve machine performance and durability. Implementing these findings can lead to increased productivity, reduced downtime, and enhanced fabric quality in the textile industry.

Author contributions

E.H. conceptualized the project, developed the methodology. M.B.H and M.S.F. conducted formal analysis, and drafted the original writing. A.S.S. and N.S. contributed to the methodology, conducted investigations, provided resources, visualized the data. S.K.P. and S.S. contributed to the reviewing and editing of the writing.

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Competing financial interests

The authors have no conflict of interest.

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