

Evaluation on Accuracy of Snap-On Torque Wrench QD2R200 Calibrated Using ISO 6789:2017 and Stahlwille Standard

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Abstract

Aviation safety is highly dependent on the accuracy of the tools used, including torque wrenches used in aircraft maintenance. This study evaluated the accuracy of the QD2R200 snap-on torque wrench following the ISO 6789-2017 calibration method using the Stahlwille standard. The study was conducted in the Batam Aero Technic calibration laboratory, with torque wrench measurements at their nominal capacities of 20%, 60%, and 100%. Measurements were repeated five times at each nominal point. The calibration results on the two tools in the laboratory showed that the variation in deviation of the tool with serial number 1016901448 reached $\pm 9\%$, while the tool with serial number 1116802022 had a deviation of less than $\pm 2\%$. Testing was carried out in clockwise and counterclockwise directions. The t-test showed a significant difference in results between the two tools, namely $p = 0.003$. These results emphasize the importance of periodic calibration and show that the ISO 6789:2017 method is effective in measuring torque wrench accuracy, which is important in ensuring safety and reliability in the aviation industry.

Keywords: t-test, deviation, accuracy, torque wrench, calibration, ISO 6789:2017, Stahlwille standard

Introduction

In the world of aviation, safety is the most important aspect. Every component of the aircraft must be properly installed to prevent potentially fatal accidents [1]. One of the tools that plays an important role in ensuring good tightening is the torque wrench [2]. The torque wrench used in aircraft maintenance must be able to provide accurate torque, so that all components are installed according to the specifications set by the manufacturer [3]. This tool is used to provide twisting force (torque) on bolts or nuts with a certain value that has been set by the manufacturer's technical specifications [4]. The use of an accurate torque wrench is very important because too much torque can cause thread damage or material breakage, while too little torque can cause loose connections and result in structural failure [5].

To ensure that the torque wrench works according to the specified value, a periodic calibration process is required [6]. Calibration is the process of adjusting and retesting measuring instruments against reference standards [7], so that the measurement results remain within the permitted tolerance limits [8]. One of the international standards that regulates the procedures and criteria for calibrating this tool is ISO 6789:2017 [9]. This standard is divided into two parts, namely the first part which regulates the technical specifications and performance requirements of the torque tool, and the second part which describes the testing methods and calibration process in detail [10, 11]. ISO 6789:2017 regulates deviation limits, accuracy determination methods, repeatability, and certification documentation requirements. By following this standard, users can guarantee that the tools they use provide consistent and metrologically traceable results [12].

In maintenance, if calibration is not performed periodically or not according to the procedures set forth in the standard, the accuracy of the tool will decrease over time due to mechanical wear or internal system irregularities [13]. This can potentially result in fastening errors that are not visually apparent but have a significant impact on flight safety [14]. Fastening errors are one of the main causes of structural damage to aircraft components, which can increase the risk of technical incidents during operations. In this context, the snap-on torque wrench QD2R200 was chosen as the object of

research. This tool is often used in aircraft maintenance and has a good reputation in terms of accuracy [16]. However, it is important to evaluate whether the use of a suitable calibration method, such as ISO 6789:2017, can improve its measurement accuracy. This research is expected to provide insight into how effective calibration is in improving the tool's performance.

Another factor to consider in the calibration process is the use of internationally recognized measurement standards, such as the Stahlwille reference tool [18]. This tool is used as a reference standard in the calibration laboratory to test and adjust the torque value produced by the torque wrench [19]. With a very high level of precision and measurement stability, Stahlwille tools provide assurance that calibration results are reliable and in accordance with the specifications in the ISO 6789:2017 standard [21].

The use of a regularly calibrated torque wrench showed a significant increase in accuracy compared to an uncalibrated one. It is important to make periodic calibrations in maintaining tool reliability in the aviation industry. Furthermore, the implementation of strict calibration standards can improve operational efficiency in aircraft maintenance hangars. By using standardized tools such as the Stahlwille, technicians can perform effective calibrations, leading to reduced maintenance time and improved aircraft reliability [24].

Another study by Riatiningsih underlines that torque wrench accuracy has a direct impact on the integrity of mechanical connections in aircraft systems. In the study, it was found that torque differences as small as 5% of the nominal value can cause failure in bolted joints after being subjected to repeated load cycles [25]. The importance of tight tolerances and accurate torque measurements as part of a quality control system in the aviation industry [26, 27]. In addition, the results of a study by Meng et al., showed that periodic torque wrench accuracy testing can reduce error rates, as well as extend the life of aircraft mechanical components [28]. These findings further emphasize that accuracy is not just a technical issue, but also plays a major role in safety and operational cost efficiency.

Based on this background, it is important to identify problems that arise in the use of torque wrench in aviation. This paper will focus on analyzing the accuracy of calibrated and uncalibrated torque wrenches, and their impact on aircraft safety and performance. The main objective in this study is to analyze the accuracy of the snap-on torque wrench QD2R200 calibrated using the ISO 6789:2017 method. It is expected that the results of this study can contribute to improving aircraft maintenance practices, as well as improving overall aviation safety. Thus, this research is not only relevant for practitioners in the aviation field, but also for academics who are interested in the safety and reliability aspects of measuring devices.

Materials and Methods

Place and time of data collection. This research was conducted at the Batam Aero Technic Calibration Laboratory. Batam Aero Technic is a subsidiary of Lion Air Group engaged in aircraft maintenance, repair and operation. The company provides heavy aircraft maintenance work at its maintenance hub at Hang Nadim Airport, Batam, Indonesia. The aircraft it handles are aircraft from Lion Group and its overseas affiliates, as well as aircraft from third-party customers. The research data and practical work for this paper were collected in the early months of 2025. Two torque wrenches with different serial numbers –namely 1016901448 and 1116802022– were used as research objects to compare their accuracy levels under actual maintenance conditions.

Research design. This study used an experimental design with a quantitative approach. The main objective of this study was to compare the measurement accuracy between the QD2R200 snap-on torque wrench that had been calibrated using the ISO 6789:2017 method and the one that was out of specification, which was outside the allowable accuracy tolerance. This study was divided into two

groups: the first group used a torque wrench in calibrated conditions (in-tolerance), and the second group used a tool that did not meet the accuracy requirements (out-of-specification). Data from both groups were analyzed to see if there was a significant difference in the torque measurement results.

Calibration procedure. Before testing, the equipment and work surfaces were cleaned from physical defects such as rust or wear. The tool was left for at least one hour in the calibration room to adjust to the ambient temperature, which is 18°C – 28°C. The test was carried out using a torque transducer and a loader. The loading points refer to ISO 6789:2017, which are 20%, 60%, and 100% of the nominal capacity –namely 40, 120, and 200 in-lb–. Each point was tested five times in two measurement directions: clockwise (CW) and counterclockwise (CCW). The results obtained were compared with standard values and the deviation was calculated to determine whether they were within the allowable tolerance, which is $\pm 6\%$.

Research phases. The stages begin with the preparation of tools and places, then proceed with the calibration process according to ISO 6789:2017 procedures using standard tools. After that, testing of the components is carried out by applying torque using each torque wrench. The measurement data was then collected and analyzed. Finally, the results were analyzed to determine conclusions regarding the difference in accuracy between calibrated and non-calibrated tools.

Observed or measured variables. The variables observed in this study consist of two main categories: independent variables and dependent variables. The independent variable is the type of torque wrench used, namely the snap-on torque wrench QD2R200 calibrated using the ISO 6789:2017 method will show higher accuracy than the torque wrench above the tolerance limit. The dependent variable is the torque measurement accuracy produced by each torque wrench. Its accuracy will be measured in units of Newton-meters (Nm) and compared with the set torque value. In addition, variations in torque measurement will also be recorded to evaluate the consistency of the tool. This data will help determine if there is a significant difference in accuracy between the two types of torque wrench. By examining these variables, this study aims to provide a deep insight into the relationship between calibration and accuracy in the use of torque wrenches in the aviation industry.

Data collection technique. Data was collected through direct observation during the calibration and testing process. Torque measurements were made with the Stahlwile reference standard, and all measured values were systematically recorded. Documentation of the process was done to ensure transparency and validity of the results. Data collection focuses on the difference in readings between the target value and the actual value of the torque transducer. The instrument values that will be observed in the QD2R200 torque wrench test can be seen in the Table 1.

Table 1. Instrument values on QD2R200 torque wrench testing

Transducer used	Transducer range (in.lb)	Instrument value (in.lb)
7728 - 2	17.7 ~ 177	40
7728 - 2	17.7 ~ 177	120
772 - 80	88.5 ~ 885	200

Data analysis. Data was analyzed using descriptive statistics to calculate the mean value, standard deviation, and percentage deviation from the nominal value. A t-test was also used to test the significance of the difference between the two groups of torque wrenches. This analysis aimed to prove whether calibration based on ISO 6789:2017 significantly improves tool accuracy compared to unqualified tools.

Results

In this study, two calibrations were carried out using torque wrenches with different serial numbers, namely 1016901448 and 1116802022. The CW calibration results of the torque wrench with serial

number 1016901448 are listed in Table 2. Meanwhile, the results of the CCW calibration are shown in Table 3.

Table 2. Clockwise calibration results of torque wrench with serial number 1016901448

Transducer used	Transducer range (in.lb)	Instrument value (in.lb)	Series	Standard reading (in.lb)					Standard average (in.lb)
				X1	X2	X3	X4	X5	
77282	17.7 ~ 177	40	Min	36.359	36.262	36.350	35.828	36.129	36.186
772810	88.5 ~ 885	120	60% FS	127.42	127.35	126.77	125.46	124.63	126.326
772810	88.5 ~ 885	200	FS	208.95	212.13	211.50	211.69	212.83	211.420

Transducer used	Standard correction (in.lb)	Actual standard (in.lb)	Correction		Standard deviation (in.lb)
			(in.lb)	%	
77282	-0.187	35.999	-4.001	-10.00	0.220
772810	-0.346	125.980	5.980	4.98	1.232
772810	-0.435	210.985	10.985	5.49	1.472

Based on Table 2, in testing in the CW direction, the tool shows a significant deviation. At a load of 40 in.lb, the correction required is -4,001 in.lb with a deviation of - 10.00%, which means the tool provides lower torque than it should. At a load of 120 in.lb, there is a correction deviation of +5,980 in.lb or 4.98%, and at a maximum load of 200 in.lb, the deviation reaches +10,985 in.lb or 5.49%. This shows that this torque wrench provides a torque value that is higher than it should be at a greater load.

Table 3. Counter clockwise calibration results of torque wrench with serial number 1016901448

Transducer used	Transducer range (in.lb)	Instrument value (in.lb)	Series	Standard reading (in.lb)					Standard average (in.lb)
				X1	X2	X3	X4	X5	
77282	17.7 ~ 177	40	Min	38.864	38.58	37.421	36.616	36.828	37.662
772810	88.5 ~ 885	120	60% FS	129.79	130.26	130.20	130.25	130.21	130.142
772810	88.5 ~ 885	200	FS	216.37	218.33	218.07	218.87	218.96	218.120

Transducer used	Standard correction (in.lb)	Actual standard (in.lb)	Correction		Standard deviation (in.lb)
			(in. lb)	%	
77282	0.291	37.953	-2.047	-5.12	1.017
772810	0.224	130.366	10.366	8.64	0.198
772810	-0.797	217.323	17.323	8.66	1.046

Based on the Table 3, in the CCW test, this torque wrench also shows a discrepancy with the allowable tolerance limit. At a load of 40 in.lb, the correction deviation was -2.047 in.lb with a deviation of - 5.12%. Which means that this tool provides lower torque than it should. At 120 in.lb load, the correction deviation was recorded at +10,366 in.lb or 8.64%. When the load is 200 in.lb, the deviation reached +17,323 in.lb or 8.66%. These results show that the tool provides higher torque values than it should in CCW mode, especially at larger loads. Given that the tool is outside the allowable tolerance limits in both CW and CCW modes, it is recommended that this torque wrench be recalibrated or repaired before use, as significant deviations can impact accuracy in industrial and engineering applications.

Based on calibration data of Tables 2 and 3, the torque wrench with serial number 1016901448 shows results that are outside the tolerance limits set by the ISO 6789:2017 standard. This indicates that the tool does not provide accurate torque measurement results in accordance with the expected specifications. Both CW and CCW measurements showed significant deviations from the target value, which means the tool is not reliable for applications that require high torque precision. The use of this torque wrench in its current state could lead to errors in assembly or tightening, potentially resulting in damage to components or malfunction.

The CW and CCW calibrations of the torque wrench with serial number 1116802022 are listed in

Tables 4 and 5, respectively. Based on Table 4, in the CW test, the tool shows a relatively small and acceptable deviation. At a load of 40 in.lb, the correction deviation was only -0.083 in.lb with a deviation of -0.21%, indicating excellent accuracy. At a load of 120 in.lb, the correction deviation was -0.835 in.lb with a deviation of -0.70%, and at a maximum load of 200 in.lb, the deviation was -3.031 in.lb with a deviation of -1.52%. These results show that this torque wrench is still within good accuracy limits, with deviations that do not exceed the allowable tolerance limits.

Table 4. CW calibration results of torque wrench with serial number 1116802022

Transducer used	Transducer range (in.lb)	Instrument value (in.lb)	Series	Standard reading (in.lb)					Standard average (in.lb)
				X1	X2	X3	X4	X5	
77282	17.7 ~ 177	40	Min	40.103	40.147	40.236	40.005	40.067	40.112
772810	88.5 ~ 885	120	60% FS	119.41	119.62	119.47	119.43	119.61	119.508
772810	88.5 ~ 885	200	FS	196.94	197.63	197.03	197.76	197.31	197.334

Transducer used	Standard correction (in.lb)	Actual standard (in.lb)	Correction		Standard deviation (in.lb)
			(in.lb)	%	
77282	-0.195	39.917	-0.083	-0.21	0.087
772810	-0.343	119.165	-0.835	-0.70	0.100
772810	-0.365	196.969	-3.031	-1.52	0.360

Table 5. CCW calibration results of torque wrench with serial number 1116802022

Transducer used	Transducer range (in.lb)	Instrument value (in.lb)	Series	Standard reading (in.lb)					Standard average (in.lb)
				X1	X2	X3	X4	X5	
7728-2	17.7 ~ 177	40	Min	40.138	40.005	40.076	40.156	40.359	40.147
7728-2	17.7 ~ 177	120	60 % FS	120.06	120.29	120.10	120.03	120.08	120.112
7728-10	88.5 ~ 885	200	FS	200.26	200.27	200.31	200.21	200.19	200.248

Transducer used	Standard correction (in.lb)	Actual standard (in.lb)	Correction		Standard deviation (in.lb)
			(in.lb)	%	
77282	0.290	40.436	0.436	1.09	0.133
772810	0.232	120.344	0.344	0.29	0.103
772810	-0.797	199.451	-0.549	-0.27	0.048

In the CCW test as shown in Table 5, the tool also indicated results that were still in line with the standard. At a load of 40 in.lb, the correction deviation was recorded as +0.436 in.lb with a deviation of +1.09%, indicating a slight torque overload but still within the allowable limits. At 120 in.lb load, the correction deviation was only +0.344 in.lb with a deviation of +0.29%, while at 200 in.lb load, the deviation was only -0.549 in.lb with a deviation of -0.27%. With calibration results that show small deviations and are still within tolerance, this torque wrench can be used with confidence that the tool provides accurate torque according to specifications.

Torque wrench with serial number 1116802022 shows calibration results that fall within the tolerance limits allowed in accordance with the ISO 6789:2017 standard. Clockwise and counterclockwise measurement data show that this tool provides accurate and consistent results within the measurement range tested. As such, this torque wrench can be considered reliable and suitable for use in applications that require precise torque measurements. However, it is recommended to recalibrate periodically to ensure that the tool remains in optimal condition and meets set accuracy standards over time.

Based on the results of this calibration, the torque wrench with serial number 1116802022 is still suitable for use in various engineering and industrial applications without the need for repair or recalibration in the near future. Meanwhile, the torque wrench with serial number 1016901448 requires further action so that it can be used again with accuracy in accordance with the standard.

Hypothesis test results. In testing this hypothesis, it was carried out using the t-test with the help of SPSS software. The results of this test can be seen in the Table 6.

Table 6. Independent test results

		Levene's test for equality of variances		t-test for equality of means		
		F	Sig.	t	df	Sig. (2-tailed)
Data X	Equal variances assumed	12.954	.001	3.139	78	.002
	Equal variances not assumed			3.139	55.666	.003

Table 6 shows the value of $t = 3.139$ with a p value of 0.003, which means that there is a significant difference between the data calibration using torque wrenches with serial numbers 1016901448 and 1116802022. The calibration results show that the 1016901448 serial number is out of tolerance, while the 1116802022 serial number is within tolerance. As shown by the difference in correction values and standard deviations between the two series of numbers, the correction values for some measurements have a larger deviation. For example, for a CW measurement of 200 in.lb, the correction value is 10.985 in.lb (or 5.49%) compared to the correction value for the CCW measurement under the same conditions which is only -3.031 in.lb (or -1.52%).

Discussion

Torque wrench is a torque measuring device that functions to tighten bolts or nuts with the right level of firmness as needed. The use of torque wrench is very important in various fields of engineering, especially in machine assembly, automotive, and construction. This is because tightening bolts or nuts that are too loose can cause components to become loose and potentially cause malfunction, while tightening too tight can damage the bolts or components that are tightened to break. Therefore, the torque wrench ensures that the rotating force (torque) applied is precise and accurate according to predetermined standards, so that system safety and reliability are maintained.

To maintain the accuracy and reliability of these tools, the international standards body International Organization for Standardization issued the ISO/IEC 6789-1:2017 and ISO/IEC 6789-2:2017 standards which specifically regulate the construction, testing and calibration procedures of torque wrench hand tools [3]. This standard specifies the classification of torque wrenches by type and tolerance class, and sets the maximum limit of deviation or measurement error allowed for each class. In addition, this standard also regulates how calibration procedures must be carried out in a systematic and measurable manner to ensure that each tool meets the required technical specifications.

One of the important provisions in this ISO standard is the need to regularly calibrate the torque wrench. The calibration must be carried out at least after the tool has been used 5000 times or within a period of 12 months, depending on which one is reached first. This routine calibration aims to identify and correct potential deviations in torque values that can occur due to usage, mechanical wear, or changes in tool conditions. In addition, each torque wrench must be equipped with a label that includes a serial number and a valid calibration certificate as proof that the tool meets the established quality and precision standards.

Based on the results of the research that has been carried out, the torque wrench with serial number 1016901448 shows calibration results that are outside the tolerance limits specified by the ISO 6789:2017 standard. This means that the tool is unable to meet the expected accuracy specifications, both in CW and CCW measurements. This discrepancy can be caused by several factors, such as mechanical wear, errors in the manufacturing process, or lack of tool maintenance. Therefore, this torque wrench requires repair or readjustment so that it can be reused according to applicable accuracy standards.

Meanwhile, the torque wrench with serial number 1116802022 shows calibration results that are within the tolerance limits in accordance with the ISO 6789:2017 standard. This shows that the tool is still functioning properly and is able to provide accurate torque measurement results, both in CW and CCW measurements. The tool can continue to be used without the need for additional adjustments during its subsequent service life, provided it continues to undergo periodic maintenance and

calibration as scheduled.

Based on Nurcahyono's research, it explains that the direction of torque measurement is a crucial aspect in evaluating the performance of the torque wrench. There are two main directions in torque measurement, namely CW and CCW [13]. The CW direction is generally used in the process of installing or tightening threaded components, while the CCW direction is used in the removal or on components with left-hand threads. In Rahayu's research also emphasized that the international standard ISO 6789:2017 explicitly requires testing the accuracy of the torque wrench in both directions to ensure that the tool is able to provide valid and consistent measurement results under various operational conditions.

Measurement accuracy in each direction is very important because torque wrenches do not always perform identically in the CW and CCW directions. Some torque wrench mechanical designs show higher accuracy deviations when used in the opposite direction from their primary direction of use. Therefore, calibration in both directions is an essential step in ensuring tool reliability, especially in applications that demand high precision such as aircraft component maintenance. Discrepancies in torque measurement results, even if they only occur in one direction, have the potential to cause significant technical risks, including system malfunctions and reduced safety factors.

To evaluate the accuracy of the ISO 6789:2017 calibration method using the Stahlwille standard in measuring QD2R200 torque wrenches of various ages, several main factors were considered: (1) the reliability of the ISO 6789:2017 method, and (2) the effect of torque wrench age on accuracy. The standard provides a strict calibration procedure with clear tolerance limits. The measurement results show that this method remains accurate in assessing torque wrench performance. Older torque wrenches tend to experience increased deviations in measurements. The test results show that older tools –see Table 7– have more variable torque values than newer tools –see Table 8–.

Table 7. Test results of the effect of age on its accuracy for torque wrench with serial number 1016901448

<i>Instrument Value</i>	CW		CCW	
	Standard Deviation		Standard Deviation	
	In.lb	%	In.lb	%
40	0.220	0.55	1.017	2.54
120	1.232	1.027	0.198	165
200	1.47	0.735	1.046	0.523

Table 8. Test results of the effect of age on its accuracy for torque wrench with serial number 1116802022

<i>Instrument Value</i>	CW		CCW	
	Standard Deviation		Standard Deviation	
	In.lb	%	In.lb	%
40	0.087	0.2175	0.133	0.333
120	0.100	0.0833	0.103	0.085
200	0.360	0.18	0.048	0.024

Statistical analysis using t-test shows that there is a significant difference in measurement results between new and old torque wrenches. Although still within the tolerance limits of ISO 6789:2017, old equipment tends to require more frequent calibration. In addition, periodic calibration needs to be carried out periodically. Calibration of the tool with the Stahlwille standard still shows consistent accuracy results on torque wrenches of various ages. Old torque wrenches require more frequent maintenance and calibration to ensure optimal accuracy.

To determine the suitability of the QD2R200 torque wrench in the calibration process, several main steps that must be taken are: (1) measurement and comparison with the standard, (2) evaluation of deviations based on ISO 6789:2017, (3) statistical analysis using t-test, and (4) scheduling periodic calibration. To compare with the standard, the torque wrench is tested at various capacity points, for

example 20%, 60%, and 100%. The measurement results obtained are then compared with the reference values from the Stahlwille standard. In the deviation analysis, the results are compared with the tolerance limits set in ISO 6789:2017. If the deviation is still within the tolerance limit ($\pm 4\%$) then the torque wrench is still suitable for use. The t-test is carried out to determine whether there is a significant difference between the measurement results and the reference value. If the p value is less than 0.05 then the tool requires adjustment or recalibration because the difference is considered quite significant. To maintain precision, the torque wrench must be calibrated periodically according to the manufacturer's recommendations. Routine monitoring is needed to ensure the tool remains in optimal condition.

Through the implementation of these procedures, the evaluation of the QD2R200 torque wrench's suitability can be carried out in a systematic and measurable way. This method not only adheres to technical parameters and international standards, but also incorporates statistical analysis to ensure the validity of the testing outcomes. As stated in the study by Rahayu that the importance of verifying the accuracy of torque wrenches through proper calibration methods serves as a preventive measure to ensure workplace safety and the quality of mechanical component assembly. Therefore, these procedures form a crucial foundation in assessing the accuracy of measuring instruments and ensuring the continued functionality of torque wrenches in supporting safety and efficiency within the aviation industry.

Conclusion

Based on the analysis of the torque wrench QD2R200, it can be concluded that the unit with serial number 1016901448 falls outside the acceptable tolerance range, while the unit with serial number 1116802022 remains within the standard tolerance limits and is deemed suitable for technical applications requiring high precision. However, since the t-test results indicate a significant difference between the measured torque values and the reference values, regular calibration is recommended to maintain optimal accuracy. As demonstrated through testing using the Stahlwille standard and statistical t-test analysis, the snap-on torque wrench QD2R200 exhibits a high level of accuracy and remains within the tolerance limits specified by ISO 6789:2017. Nevertheless, the t-test reveals a significant discrepancy between measured and reference torque values. Therefore, although this tool is recommended for a range of technical applications, ongoing monitoring and routine calibration are essential to ensure optimal precision. The analysis of serial number 1116802022, which falls within the standard tolerance based on the ISO 6789:2017 calibration method using the Stahlwille standard, has proven effective in evaluating the performance of the QD2R200 torque wrench, whether newly manufactured or used over an extended period. However, torque wrenches with longer usage durations tend to show greater deviations, highlighting the importance of implementing a stricter calibration schedule to maintain measurement accuracy.

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