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ON THE BEHAVIOUR OF SETTING-TYPE TORQUE SCREWDRIVERS

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Abstract:
This article describes the behaviour of setting-type torque screwdrivers. In contrast to setting-type torque wrenches, such screwdrivers have multiple setpoints that can be quite different from those of torque wrenches. This fact has a crucial impact on their calibration. The current article focuses on the determination of the setpoints as well as on the statistical behaviour of the data. It further presents initial measurements obtained from various screwdrivers.

Keywords: torque measurement; setting-type torque screwdrivers; torque calibration

1. INTRODUCTION

The international standard ISO 6789:2017, “Assembly tools for screws and nuts — Hand torque tools” [1], contains information on a wide range of different screwdrivers (e.g., with/without scale, with mechanical/electronic torque measurement, and adjustable/fixed). Most calibration laboratories primarily calibrate setting-type torque screwdrivers that are adjustable by means of a mechanical scale. The biggest disadvantage of the ISO standard, however, is that it focuses on torque wrenches. The main difference between a torque wrench and a torque screwdriver (besides the fact that the screwdriver has no lever arm) is the number of setpoints necessary to release the tool at a certain torque setting. Most setting-type screwdrivers often have three or more releases in one full turn (360º). Because this crucial point is not considered in the ISO standard, most calibration laboratories have difficulties applying this standard to setting-type screwdrivers. A calibration procedure for setting-type screwdrivers should therefore focus on the turns of a screwdriver instead of requiring a fixed number of measurements.

2. FUNCTIONALITY OF SETTING-TYPE TORQUE SCREWDRIVERS AND MEASURING SET-UP

The main mechanical parts of a setting-type screwdriver with six setpoints are shown in Figure 1. The setpoints are realised by means of a special ball plate consisting of a ball holder and a cover plate. The cover plate is pressed onto the ball holder by means of a spring. By adjusting the stiffness of the spring, a certain torque can be realised: the stiffer the spring, the greater the torque. In the example pictured here, the screwdriver is released six times over one full turn. Figure 2 shows a picture of the measurement set up. For the measurement of the torque, a calibrated torque transducer with a nominal range of ± 10 N·m was used. The transducer included a conditioning amplifier with one digital and one analogue output channel. Both channels were used for data acquisition. To measure the trace of individual signals as seen, e.g., in Figure 3, the analogue signal was recorded by a 350 MHz oscilloscope with a maximum sampling rate of 6.25 GS/s. For the measurement over a full turn that included all the setpoints of a screwdriver, the digital output was used in addition, with the maximal internal sampling rate set to 10 kHz. The measurements were performed manually. An attempt was made to increase the torque as uniformly as possible during measurement.

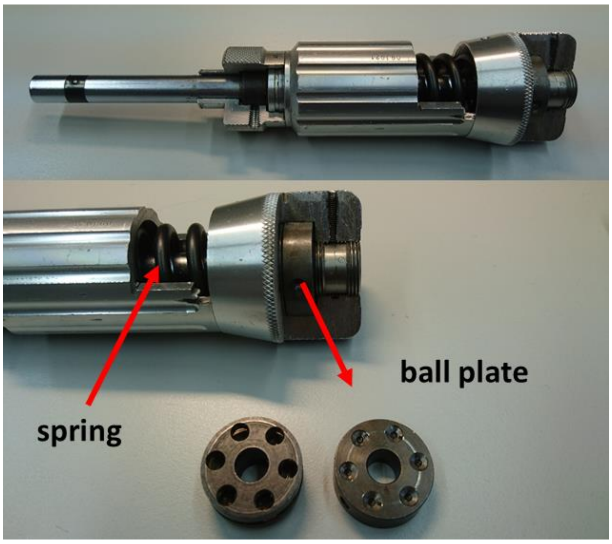

Figure 1: Partial cross-section of a torque screwdriver. The lower part shows the ball plates responsible for the setpoints. The spring used for setting the torque is also indicated

Figure 3 depicts the behaviour of three different setting-type torque screwdrivers. The plot shows the torque measurement as a function of time. The torque value of the determined setpoint is given at the peak maximum. As seen in Figure 3, the shape of the peaks can be quite different depending on which screwdriver is used (especially as concerns their behaviour after release). Often, a sharp decrease in the torque after release is followed by a second peak that can reach about half the nominal torque. For this reason, the full range of behaviour should be measured and not only the release point.

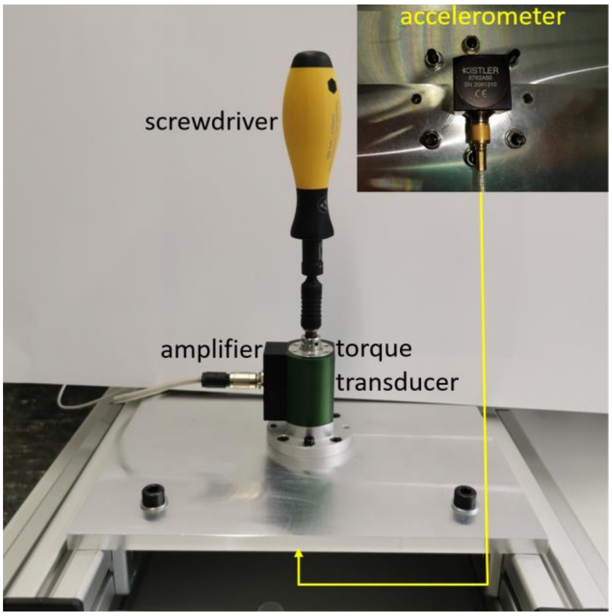

Figure 2: Measuring set-up, with an accelerometer on the underside of the plate, directly below the torque transducer

3. MEASUREMENTS

The signals of different screwdrivers are plotted in Figure 4. The main difference between all these signals is their behaviour after the maximum when the device is mechanically switched off. The fall times can vary greatly, stretching from a few milliseconds to a hundred milliseconds, something which is not necessarily visible in the plots. After switch-off, the signals in all cases have an undershoot, the depth of which can also differ widely. An extreme case is seen in subplot 6, where the undershoot is of the same order of magnitude as the maximum. That means that when using this device, a short pulse with an opposite torque acts on the screw. It is not known whether this causes the screw to loosen in any way. One might suppose that the acting time of this negative pulse is so short that the torque is not realised by the mechanical structure.

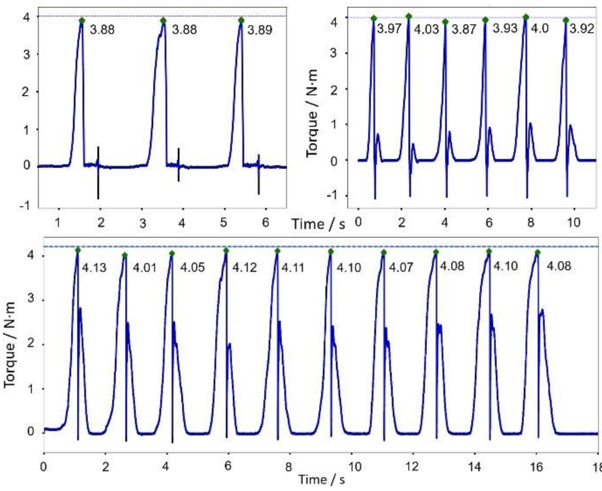

Figure 3: Measurement data of three different screwdrivers. Each data set is obtained from one full turn (360°). The maxima are given in N·m

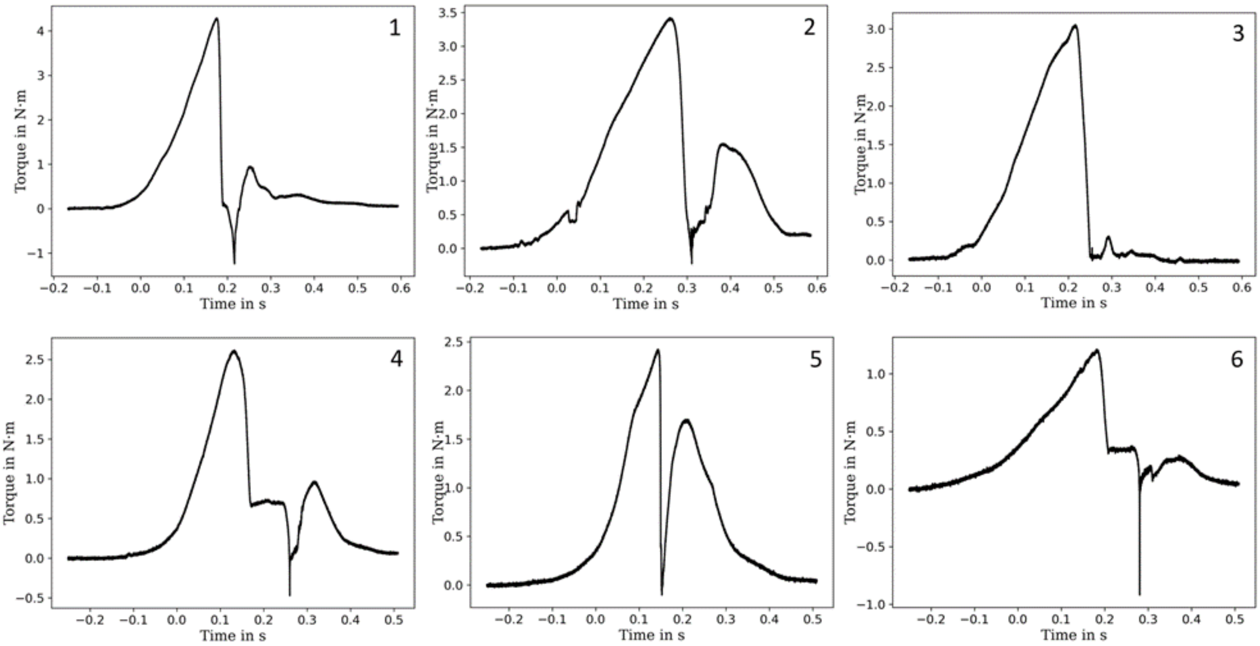

Figure 4: Different signal behaviours of various screwdrivers. Note that the main differences are seen after torque switch-off

After the undershoot one can usually observe a second increase in torque, the level of which may also differ depending on the device. This effect can be seen as a kind of bounce back of the screwdriver. Finally, one can conclude that it takes approximately half a second to reach zero torque. In terms of accurate switch-off behaviour, the performance of the device in subplot 3 is nearly ideal. The point at which the screwdriver is released must be determined from the data. As seen in Figure 5, the data can be filtered to reduce the noise. Two methods are shown. In the first, a Savitzky-Golay filter uses a window of 40 samples and a third-degree polynomial. The second method is a moving average procedure using a window of ten samples.

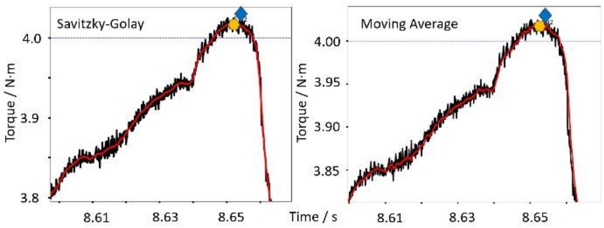

Figure 5: Determination of the peak maximum (the release point of the screwdriver). The data is filtered by means of two methods, one using a Savitzky-Golay filter and the other using a moving average. The maximum point is indicated in blue for the unfiltered data and in yellow for the filtered data

Besides the determination of the release point of the screwdriver, the time it takes to reach this point and the fall time are also important. Figure 6 shows an example of these time intervals for two different screwdrivers.

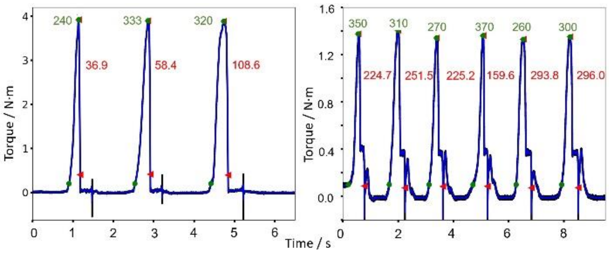

Figure 6: Determination of the rise and fall times shown for two different setting-type screwdrivers. The rise and fall times are given in milliseconds

The rise and fall times are not included in the calibration certificate. However, as seen in Figure 4, they can be useful when characterising the quality of the screwdriver. The right-hand image in Figure 6 indicates a distortion of the falling edge which might indicate that the device needs maintenance.

Another aspect of setting-type torque screwdrivers is the behaviour observed after the device is switched off (see Figure 7). Here one can recognise a mechanical shock, the strength of which is proportional to the set torque. This is illustrated here by an acceleration signal in the direction of the screwdriver that was measured by an accelerometer directly below the torque sensor. The accelerometer was mounted below the mounting plate (see also Figure 2). Note that such a shock could have a very disturbing effect on the mechanical structure to which the screwdriver is applied (an electronic circuit board, for example).

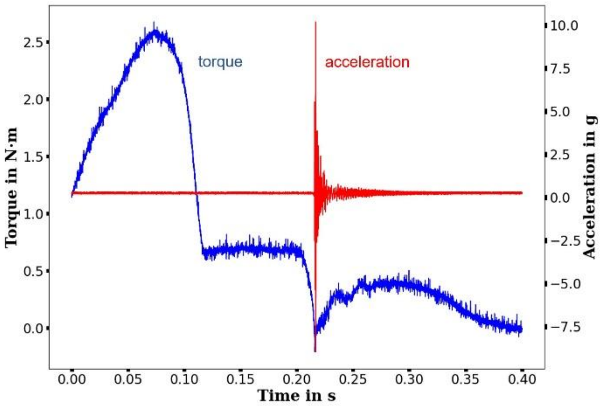

Figure 7: The time-dependent torque signal of a screwdriver in coincidence with the acceleration signal, measured by the acceleration sensor below the torque transducer

Table 1 shows the results of a screwdriver with six setpoints. The device was rotated five times yielding a total of 30 data points. In the table, the data are sorted according to their setpoints, so the run number is identical to the same number of full screwdriver turns. Characteristic parameters (release point [maximum torque], fall time, time to reach maximum and minimum torque) of a setting-type torque screwdriver are shown. The fall time is given in milliseconds, whereas the time to reach maximum torque is indicated in seconds. The run number is equivalent to the number of full turns of the screwdriver.

Figure 8 shows the behaviour of different screwdrivers. The data are grouped according to the specific setpoints. Each setpoint was measured five times, meaning that 30 measurements were made for a screwdriver with six setpoints, and 50 measurements were conducted for a 10-setpoint screwdriver. The error bar of the setpoints is the uncertainty of the mean value obtained from the standard deviation. The solid red line is the overall mean value of the torque, while the dashed line is the related statistical uncertainty. The different measurements show that the behaviour of the screwdrivers is dependent on their individual setpoints. There are cases where one setpoint is quite different from the others, for example in subplots 2 and 5 of Figure 8.

Table 1: Measurement results of a six-setpoint screwdriver

Set point	Run	Max. torque / N·m	Fall time / ms	Time to max. / s	Min. torque / N·m
1	1	4.34	42.62	0.11	-1.15
	2	4.30	40.86	0.16	-1.34
	3	4.29	8.18	0.18	-1.26
	4	4.32	9.15	0.25	-1.29
	5	4.26	10.43	0.17	-1.30
2	1	4.30	11.28	0.16	-1.35
	2	4.34	12.46	0.19	-1.29
	3	4.29	10.50	0.21	-1.32
	4	4.25	11.11	0.18	-1.31
	5	4.24	65.96	0.20	-1.29
3	1	4.31	38.92	0.13	-1.24
	2	4.34	10.48	0.16	-1.27
	3	4.28	50.03	0.16	-1.22
	4	4.28	41.83	0.18	-1.25
	5	4.22	11.72	0.19	-1.37
4	1	4.24	43.90	0.13	-1.21
	2	4.23	40.31	0.15	-1.16
	3	4.21	10,07	0.21	-1.17
	4	4.26	9.22	0.19	-1.29
	5	4.24	8.29	0.20	-1.44
5	1	4.29	45.22	0.15	-1.21
	2	4.24	9.40	0.15	-1.24
	3	4.30	47.66	0.21	-1.25
	4	4.22	9.23	0.20	-1.37
	5	4.19	10.39	0.21	-1.32
6	1	4.23	8.29	0.17	-1.23
	2	4.29	43.98	0.17	-1.28
	3	4.29	50.06	0.22	-1.23
	4	4.20	9.54	0.14	-1.24
	5	4.17	8.58	0.15	-1.21

One question concerning the calibration of such screwdrivers is whether uncertainty contributions due to different adapter positions or to the readjustment of the screwdriver are measurable. The calibration standard ISO 6789:2017 requires that 40 measurements (ten for each position) be done to determine the influence of a square adapter. In addition, 20 measurements are necessary to evaluate repeatability, with readjustment of the device required after every five measurements. Figure 9 shows three different measurement runs for one screwdriver. In Run 1 the screwdriver was simply turned four full rotations with no changes made. In Run 2 the square adapter was turned 90° following one full rotation.

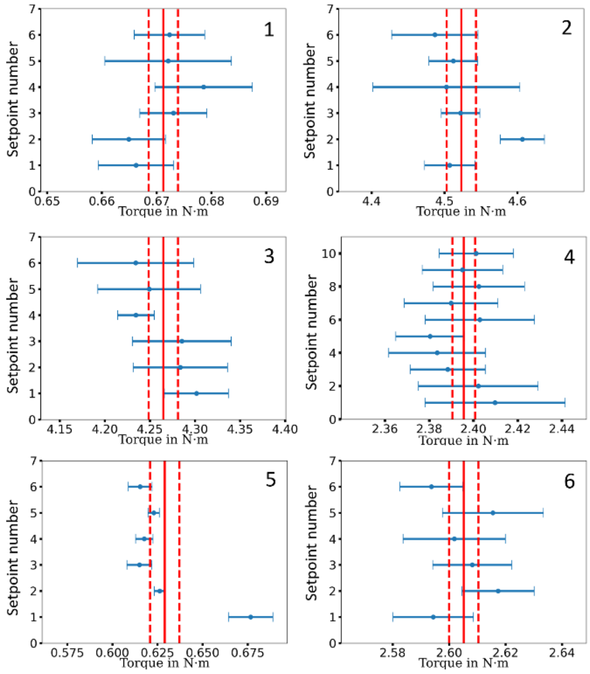

Figure 8: Characteristic behaviour of six different screwdrivers

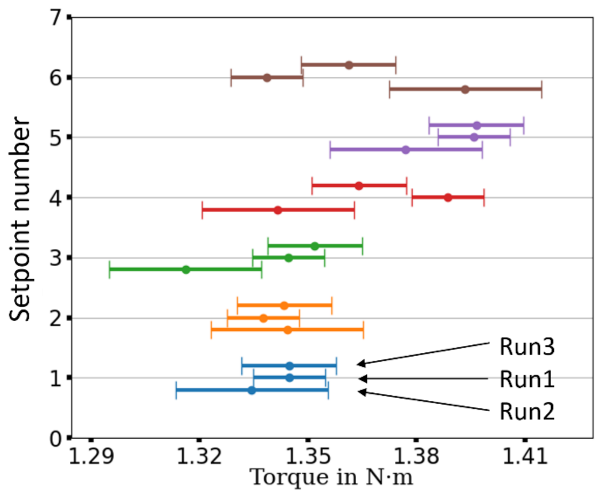

Figure 9: Different measurement runs for one screwdriver

In Run 3 the screwdriver was readjusted after each full turn. Here again, the behaviour depends on the specific setpoint. There are setpoints where the behaviours are quite similar, like setpoints 1 and 2, and others such as 4 and 6 where they are quite different. Table 2 provides the statistical data associated with Figure 8. Comparing the three runs reveals that the maximum mean value, the standard deviation of the mean value, and the span of the maximum are quite similar for each run. One conclusion that could derived from this behaviour is that because of the wide spread of the different setpoints, relatively small effects like the difference of the position of the square adapter or the repeatability cannot be detected through the measurement, at least not in the case described here.

Table 2: Statistical summary for Figure 9. The last row (Avg.) contains the cumulative statistics for all the data collected

	Mean value maximum / (N·m)	**Std. dev. maximum / %**	**Span maximum / %**
Run 1	1.358	1.093	2.093
Run 2	1.351	0.935	2.065
Run 3	1.360	1.102	2.507
Avg.	1.357	1.043	2.222

It should be noted that similar effects were also observed for the other screwdrivers investigated.

4. SUMMARY

In contrast to setting-type torque wrenches, setting-type torque screwdrivers have more than one setpoint. Each setpoint exhibits an individual behaviour that must be considered. Applying a calibration procedure that prescribes a fixed number of measurements (five or ten, for example), such as ISO 6789:2017, does not make much sense in the case of a torque screwdriver. In this case it would be better to apply a certain number of rotations. On the other hand, subtle effects (e.g. the influence of an adapter) cannot be distinguished due to the often relatively wide spread of the setpoints. For a calibration, one should therefore perform several rotations, possibly combining the rotations with a change in the square adapter position and a readjustment of the screwdriver. The main contribution to the uncertainty could, for instance, be derived from the overall span of the setpoint maxima resulting from all rotations.

5. ACKNOWLEDGEMENT

The author would like to thank Siegfried Herbold for his fruitful discussion and for providing different adjustable torque screwdrivers.

6. REFERENCES

[1] ISO 6789 Parts I and II, “Assembly tools for screws and nuts - Hand torque tools”, 2017.