USCAR Standards CoK

Right Angle Power Tools: A Summary of the 2018 Research of Dr. Cort

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This document is intended to summarize Dr. Joel Cort's (University of Windsor) 2018 research paper *Final Report for Automotive Partnership Canada: Ergonomics Evaluation of Right Angle Power Tools*. This research was a USCAR project in collaboration with the University of Windsor, Ford, GM, and Stellantis. This summary will discuss three findings that may be used to aid tool selection and rundown strategy for right angle power tools (RAPTs).

The findings include:

- Development of an instrumented measurement device
- Importance of fastening strategy & joint type
- Physical capability limits for a female population

Right angle power tools (RAPTs) are widely used in manufacturing industries. In the automotive industry, researchers estimate up to 70% of operators utilize power tools to complete their tasks (Cort, 2018). Despite the prevalence of these tools, it has been historically difficult to assess the physical demands associated with their operation and to determine human capability limits. This gap led to the 2014-2018 academic research and data collection efforts of Dr. Cort and his colleagues. The objective of the research was to improve worker safety, reduce healthcare costs and increase manufacturing efficiency by reducing work-related musculoskeletal disorders related to RAPT use (Cort, 2018). The research evaluated physical demands associated with Direct Current (DC) based RAPT tightening strategies at various fastener locations, target torques and joint types.

Development of an Instrumented Measurement Device

An instrumented tool, called the RAPT-FH (Right-angled power tool force handle) tool, was developed as part of this research. This measurement device was utilized to assess the physical demands at the hand during RAPT use. With further validation, this tool has potential to be used as a practical measurement device to objectively evaluate the risk and physical demands experienced by an operator for a variety of rundown settings and gun adjustments. This instrumented tool could also assist original equipment manufacturers (OEMs) in comparing the physical demands associated with fastening strategies and across competitive supplier tools.

Importance of Fastening Strategy & Joint Type

This research indicates that fastening strategy and joint type can play a crucial role in the physical demand experienced by an operator as well as an operator's perceived force acceptability limit. These findings provide some key insights that can be used to aid in the selection of RAPTs for reduced ergonomic risk.

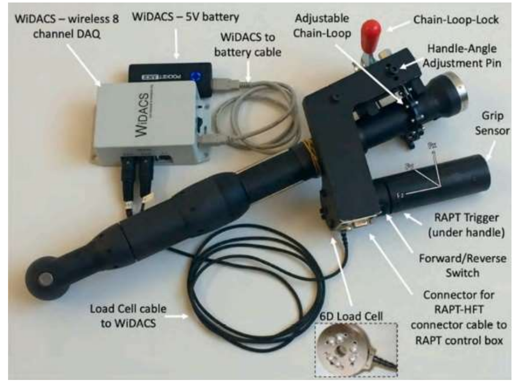


Figure 1. RAPT-FH: Instrumented tool for RAPT hand force measurement

Fastening Strategy

Three main fastening strategies for DC RAPT were studied by Dr. Joel Cort.

- Atlas Copco's Turbo-Tight (TT) model, runs the power tool at maximal speed throughout the tightening phase and decreases the spindle speed almost immediately when the target torque is reached.
- Atlas Copco's quickstep (QS) model, decreases the motor speed in a stairstep manner throughout the tightening phase until a target torque is reached. Once the target torque is reached, the speed of the spindle will be decreased rapidly.
- Stanley Assembly Technologies' automatic tightening control (ATC) model, decreases spindle speed at a constant rate until the target torque is reached, at which point it shuts off rapidly.

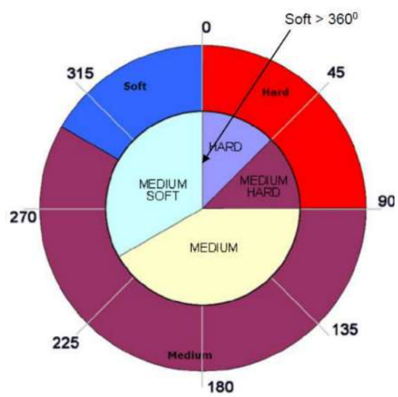
These fastening strategies were used for psychophysical subject analysis. Physical capability limits were identified for these three strategies. The TT model was shown to have the highest acceptable physical capability limits (PCLs). These results are thought to be due to the TT fastening strategy; a rapid torque build-up time and shut-off mechanism. The effects of such a strategy result in an increased inertia of the RAPT or an increased capacity of the tool to resist change in motion (Cort, 2018). This means that at equal target torques, lower torque reaction force would be transmitted to the operator when using TT as compared to the other models. This is believed to be the reason why participants were willing to subjectively accept greater target torque magnitudes when using TT (Cort, 2018).

Fastening strategy has been found to be a key consideration when selecting a RAPT. The fastening strategy utilized in the Turbo-Tight model appears to have many benefits that reduce physical demand during RAPT use and increases an operator's physical capability limit threshold during operation when compared to other models. It is recognized there may be other tooling suppliers using similar fastening strategies that have not been analyzed in this research. The purpose of this document is not to endorse one product over another but rather identify a fastening strategy that has proven to be ergonomically beneficial.

Joint Type

The research indicates that joint type has been shown to have an impact on the physical capability limits operators determined as acceptable. There are several categories of joint type as seen in Figure 2 below. Note: Each OEM may have their own specific internal classification systems.

- A hard joint has been defined as a high torque rate joint where the tightening can "be accomplished in a fraction of a revolution" (ISO, 1994).
- A soft joint has been defined as a low torque rate joint where the tightening "is usually accomplished with several revolutions of the fastener" (ISO, 1994).
- The OEMs have individual specifications for these joint types. They further break them out into hard, medium hard, medium soft and soft joints with corresponding degrees of rotation required to fasten them.
- Figure 2, as seen below, gives an example of the differing hard and soft joint definitions within industry classification systems and research classification systems.



"Joint classification system based on the bolt angular displacement (outer numbers) when target torque is reached. The inner chart represents the industry classification system, while the outer chart shows the modified classification system for research purposes (Radwin et al., 2016)."

Figure 2. Hard and soft joint specifications

Physical Capability Limits (PCLs) for a Female Population

"PCL's are maximum values of a given exposure for which an individual can be exposed to without being subjected to any additional adverse health effects. Physical exposures include but are not limited to, elevated levels of noise, lifting, repetition, and extreme temperatures. In general, PCL's, help to reduce the risk of injury by estimating the upper tolerable exposures for performing specific tasks." (Cort, 2018). Dr. Cort's research identified PCLs for three different fastening strategies using both hard joints and soft joints. These PCLs are calculated from the participants' psychophysical (or perceived ratings) thresholds. Table 1 below outlines in red the PCLs for 75% of the female population. The research does provide evidence that fastening strategy impacts the PCL thresholds that operators consider acceptable.

Physical Capability Limits

Percentile	Strategy	Hard Joint (angle 60 ± 10°) 1/min	3/min	5/min	Soft Joint (angle 450 ± 25°) 1/min	3/min	5/min
90	TT	78.6	73.2	74.3	42.0	40.2	34.8
	QS	44.8	41.9	38.9	35.0	31.3	30.9
	ATC	35.3	37.3	33.3	42.5	37.6	36.8
75	TT	84.4	80.5	80.9	53.2	48.1	44.7
	QS	49.5	47.1	43.5	44.3	40.8	39.0
	ATC	42.1	43.3	39.5	48.7	45.1	43.9
50	TT	90.8	88.6	88.3	65.4	56.7	55.5
	QS	54.6	52.7	48.5	54.5	51.3	47.9
	ATC	49.5	49.9	46.4	55.5	53.4	51.7
25	TT	97.7	97.2	96.2	78.6	65.9	67.2
	QS	60.1	58.8	53.8	65.4	62.5	57.5
	ATC	57.6	57.0	53.8	62.8	62.2	60.1
10	TT	103.5	104.4	102.8	89.5	73.6	76.9
	QS	64.8	63.9	58.3	74.5	71.9	65.4
	ATC	64.2	62.9	59.9	68.9	69.6	67.1

Table 1. Physical Capability Limits (Nm) for RAPT acceptable for a range of the female population percentage. These values represent the magnitude of the torque at the completion of the fastening, known as target torque (Cort, 2018).

Key Observations

- The fastening strategy and joint type impact the PCLs.
- The TT fastening strategy's acceptable PCL is significantly greater than the PCLs identified with either the QS or the ATC models.
- While the PCLs of TT compared to QS and ATC were modest in the soft joint (SJ) conditions, the acceptable PCLs with a hard joint (HJ) were almost double when compared to ATC and QS.
- PCL thresholds are higher on hard joints vs soft joints for TT and QS fastening strategies
- Notably, the ATC tightening strategy did show an increase in PCL threshold for soft joints as opposed to hard joints.
- Fastening strategy and joint type had the greatest influence on impulse and peak force.
- In general, as the frequency of joints fastened per minute increased (1/min to 5/min), the maximum acceptable force decreased.

These observations indicate that an operator is being exposed to less physical demands and risk in the hands and arms when using the TT fastening strategy on a hard joint. Selecting fastening strategy based on the joint specifications could lead to a reduced susceptibility to musculoskeletal disorders. This could result in reduced injuries associated with reaction torque and RAPT at OEM sites. It is important to note that a large majority of the vehicle assembly fastening joints are considered hard or medium hard joints, which makes the identification of a risk reducing fastening strategy for these joints a pivotal find.

Limitations and Future Considerations

While the research has provided a lot of beneficial information, there are a few limitations that may lead to future studies. The research performed on physical capability limits (PCLs) only studied three fastening strategies from two RAPT tooling suppliers. It would be beneficial if PCL studies were performed on additional fastening strategies beyond the scope of the two tooling suppliers used in this research study.

Further research into additional fastening methods may increase the ability to select a RAPT based on joint specifications and ergonomically acceptable PCLs.

Another limitation of the research can be seen in the joint classification system related to hard and soft joints, as seen in Figure 2. The joint classification system defined in the research may vary across the industry. This is a point that is recognized by the researchers and has been identified within the studies. Although a known limitation, this discrepancy of hard vs soft joint classification system may have implications on how OEMs interpret the research during RAPT selection.

While the fastening strategy of the TT model has shown potential benefits, from an ergonomics perspective, the applicability of the technology to meet individual OEM fastening specifications must be proven.

Conclusions

Dr. Cort's research has provided several new insights that may aid in RAPT selection and PCLs. While industry-wide standardization of these limits remains an ongoing topic of discussion, the current research has produced several key findings.

- An instrumented tool was developed as part of this research. This tool may be used by OEMs to assess the physical demands of RAPT operations.
- Research findings indicate that fastening strategy and joint type influence the physical demand and capability limits.
    - The TT model's fastening strategy was shown to have the highest acceptable physical capability limits (PCLs) selected by participants.
    - Fastening strategy and joint type had the greatest influence on impulse and peak force.
    - Fast speed spindle fastening strategies showed reduction in force experienced by the operator at the hand.
- Increased fastener frequency was shown to negatively impact the PCLs deemed acceptable.
- Researchers and OEMs alike should continue to look at additional fastening strategies, not included in this research, that may be available by other tooling suppliers. For additional research, reference (Cort, J, 2021).

List of Figures and Tables

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