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The development of a snow cleaning system for micro-CMM stylus tips

Xiaobing Feng[1], Simon Lawes[1], Peter K. Kinnell[2]

[1]*The University Of Nottingham*
[2]*Loughborough University*

xiaobing.feng@nottingham.ac.uk

Abstract
Contamination adhered to the surface of a µCMM stylus tip significantly impairs the dimensional accuracy of the CMM systems, potentially causing dimensional errors that are over ten times larger than the uncertainty of a modern µCMM. To reduce such errors, this study investigates removing the surface contamination on µCMM stylus tips using a high velocity flow of CO_2 gas and sublimated particles. This process is known as snow cleaning. Two different types of snow cleaners were evaluated in the study, and a novel multi-nozzle system developed to address the challenges of cleaning occluded features and balancing forces on the stylus. Studies considered cleaning quality, coverage, and force imparted on the stylus tip. Results have shown that a cleaning force close to the rated probing force of the styli can be achieved. Initial results show that the developed cleaning device was able to eliminate the need for stylus rotation and reduce net force, bringing it closer to on-machine cleaning application.

Keywords: snow cleaning system, µCMM, precision cleaning, cleaning force.

1. Introduction

One of the rapidly advancing frontiers in the contact metrology is the reduction of stylus tip size in micro-coordinate measuring machines (µCMMs). Styli with 125 µm tip diameter are commercially available. During probing operation contaminant particles are adhered onto the stylus tip surface and any subsequent measurements that coincide with this contact point will result in a dimensional error as indicated in Figure 1. A particle of a few micrometres in size could cause significant dimensional errors, which are orders of magnitude greater than those reported elsewhere [1, 2]. Therefore, regular cleaning of the stylus tip is critical in maintaining accuracy and extending useful life.

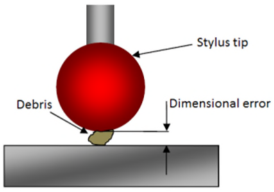

Figure 1. Illustration of the dimensional error of a µCMM caused by surface contamination

This cleaning requirement presents a significant challenge as µCMM styli are fragile by design, rated for very low contact forces (<0.5 mN). In a previous preliminary study [3], several cleaning methods for µCMM styli were evaluated, and snow cleaning was found to be most promising. In section 2, this study looks in detail at the application of two approaches to snow cleaning. Section 3 demonstrates a novel configuration to overcome some of the challenges of applying snow cleaning to µCMM styli. Section 4 concludes the contributions of this study.

2. Evaluation of snow cleaning process

The snow cleaning process removes particles and contamination in the micrometre and sub-micrometre range. It does this by a high velocity gas stream in which solid particles of CO_2 sublimate into 'snow'. On contact with a surface the 'snow' transfers momentum to the contaminants overcoming their adhesion to the surface. This evaluation focuses on two key performances: cleaning capability and risk of damaging the stylus. Two types of snow cleaners with different stream source and nozzle geometry were investigated. Scanning electron microscope (SEM) images of the styli were examined to evaluate their cleaning capabilities. Potential damage to the styli was assessed by measuring the net force exerted on the stylus during cleaning.

2.1. Stylus contamination

Two methods were used to prepare the contaminated styli for subsequent cleaning experiments: The first is the repeated probing of metrological samples. This produces contamination as would be found in normal operation, but the level of contamination can only be effectively visualised under SEM. Secondly the application of developer spray. This contamination is easily removed but provides simple visual feedback on the areas that have not been cleaned by the stream.

2.2. Mixture stream & pure CO_2 stream

The first type of snow cleaner utilises both CO_2 gas and a heated nitrogen gas accelerant. The equipment used in the study was SNOPEN from Cleanlogix. The heated nitrogen gas helps reduce the build-up of CO_2 particles on the stylus tip. The SNOPEN device allows adjustment of gas pressure, and the nozzle geometry produces a divergent stream with a wide field of effect. To better match the low forces required in this study, a low pressure and a long standoff distance of 15 cm were used.

The second type of snow cleaner uses a pure CO_2 stream without the accelerant gas. The equipment used in the study was K1-05 from Applied Surface Technologies, fitted with a special nozzle to reduce the impact on the stylus. The nozzle geometry of the single gas system is more flexible and a non-divergent design was selected. The small orifice and long nozzle produce a non-divergent stream. This can be seen in Figure 2a.

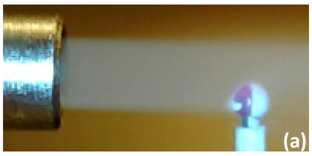
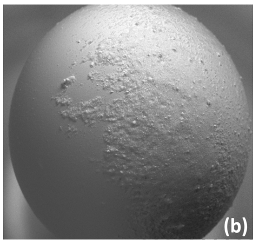

Figure 2. A 1 mm diameter tip (a) being cleaned with a non-divergent CO_2 stream after being contaminated with developer spray, and (b) after one time snow cleaning without stylus rotation.

2.3. Impact force measurement

The fragile nature of the stylus requires the cleaning process to be gentle (typically <0.5 mN). To better understand the risk to the stylus the force exerted on the stylus by the stream was measured during cleaning. For this purpose, a balance was devised, as shown in Figure 3, that measures force on the stylus by means of deflection.

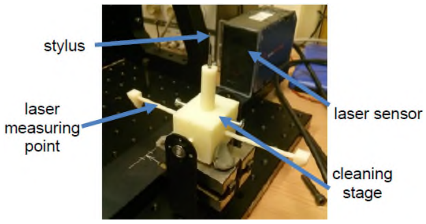

Figure 3. Cleaning stage setup integrated with force measurement sensor.

2.4. Results and discussion

Both the nitrogen accelerated and pure CO_2 systems demonstrated effective cleaning of the contact and developer spray contamination. The only contaminants that were not removed entirely were well adhered metallic compounds compressed onto the surface during contact. The results suggest that these contaminants do respond to higher forces and extended exposure to the stream. While cleaning was effective on the stylus face adjacent to the nozzle, for both systems the occluded back face showed little removal of contaminant, see figures 2a and 2b. The measured impact force on the stylus during snow cleaning is shown in Figure 4. Due to the difference in the stream delivery mechanism and nozzle geometry, the two snow cleaners were tested under different operating conditions in order to produce comparable cleaning performance and exerted force.

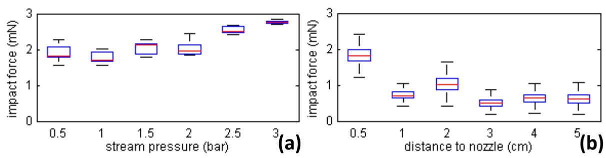

Figure 4. Measured impact force on a 1 mm stylus tip during cleaning (a) with mixture stream; (b) with pure CO_2 stream.

The impact force was found to increase with stream pressure and decrease with standoff distance. The pure CO_2 stream was able to produce an impact force close to the rated probing force of the stylus (0.5 mN), and critically at a much shorter working distance than the accelerated system. It was also noted that prolonged snow cleaning may cause build-up of 'snow' on the stylus tip. This effect limits further cleaning, increases drag, and exerted force. This effect was particularly pronounced on the pure CO_2 system.

While these results were promising there remain a number of technical challenges: force exerted on the stylus remains the limiting factor for effective cleaning; and µCMM instruments do not have a rotational axis that could present all the stylus face to the nozzle. The lower forces, flexible nozzle geometry and shorter working distance of the pure CO_2 system has allowed some of these issues to be addressed.

3. Prototype development

Based on the above findings, a novel snow cleaning device for µCMM styli, as shown in Figure 5, has been developed for on-machine cleaning.

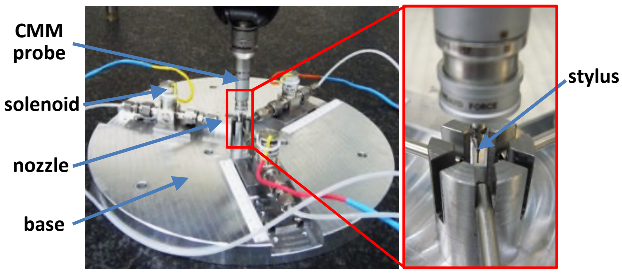

Figure 5. Snow cleaning system developed for on-machine cleaning of µCMM styli.

The system consists of three nozzles oriented at 120° and equidistant, allowing all faces of the stylus to be cleaned without rotation. This capability was demonstrated in Figure 6, where a 1 mm diameter tip was first contaminated with developer spray and then cleaned with the prototype device.

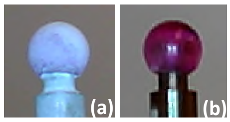

Figure 6. A contaminated stylus tip (a) before and (b) after cleaning with the developed device.

The force applied by each streams acts against that of the others, and net force on the stylus can be minimised while gas pressure is increased. Preliminary results demonstrated a net force at 1 cm standoff distance of 0.11mN down from 0.25 mN. Balance forces allow higher pressures to enhance cleaning efficiency without increasing the risk of damaging the stylus. The rate of build-up of snow was observed to increase however. More systematic tests on the multi-nozzle system will be conducted in the future to better characterise the system. These will include studies with short pulses and assisted heating to attempt to combat the rate of snow build-up.

4. Conclusions

This study investigated the capability of snow cleaning for µCMM styli. Both types of snow cleaners investigated demonstrated effective cleaning of styli. Snow cleaning with a pure CO_2 stream was able to achieve an impact force close to 0.5 mN, and with a working distance compatible with an on-machine cleaning system. Based on these findings a novel nozzle arrangement was developed and demonstrated that cleaning off all faces is possible with just three static nozzles, and can effectively reduce net force on the stylus during cleaning. This could enable a fast, effortless and safe on-machine cleaning operation that will improve measurement performance as well as prolong stylus lifetime.

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