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Research paper

Experimental thermal analysis and modelling of single point lathe cutting tools without cooling effect

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Abstract

This study investigated the use of tungsten carbide tool and high speed steel (HSS) tool when machining aluminum and mild steel. The parameters such as feed and speed of rotation were varied in order to observe their effect on machining operation. The experiments were performed without a coolant. FLIR thermo Cam P60 and Infra-Red Camera were used to record the observations. The highest temperature were recorded when feed rate was 2 mm. A comparison of experiments shows that HSS tooling produced high temperatures when machining mild steel. At 625 rev/min HSS failed when cutting mild steel at 2 mm feed rate. It was generally observed that temperatures generated between a tool and work piece is a function of feed rate, speed of rotation and tool material. These observations can aid the selection of a tool before a machining operation.

Keywords: *Tool Selection; Cost Effectiveness; Temperature; Coolant; Work-Setup.*

1. Introduction

Tool selections and application are considered looking at various requirements and cost effectiveness. The life of a tool is imperative in metal cutting since extensive time is lost at whatever point a device is supplanted or reset. Cutting devices free its sharpness as utilization proceeds and their viability diminish after some time. Eventually amid the life expectancy of the instrument, it is important to supplant, record or re-hone and reset the device. Device life is a measure of the time span a device will cut viably. The life of cutting device relies on numerous elements, for example, the small scale structure of the material being cut, metal evacuation rate, the inflexibility of the setup and impacts of cutting liquid. [1] In countries like Botswana, where most or all cutting tools in the industry, domestic use and training institutions are imported, it is important to plan where and when to use a certain grade of tool, in order to minimize cost while maintaining quality. [2] Material removal process may constitute tasks such as selection of which is cost effective in manufacturing sector. The characteristic properties that are used for tool selection include tool melting point, life cycle and material that it is made from. In many manufacturing industries where surface finish of a component in mass production at a long life span is preferred to minimize tool change over time. For this reason an experiment was conducted using cutting tools of different materials to aid the selection of an appropriate tool for cutting a certain material. Dry run cut was used to determine tool life cycle between a high speed steel (HSS) and tungsten carbide. It was discovered that during experiment that for cutting soft material like Aluminum, the HSS tool which is cheaper than Tungsten carbide could be considered. But for hard material like steel, harder tools like Tungsten carbide could be considered, where cooling media is a disadvantage.

2. Experimental setup

The two major effects which accompany a cutting operation are excessive friction and heat. In the interest of tool life and quality of finish, it is necessary to apply a cutting fluid to the operation and the primary functions of such a fluid are to carry away heat and provide lubrication at the point where the chip bears on the tool fact. When considering the use of a fluid in any particular operation the pertinent alternatives to be taken into account are whether to cool or cool and lubricate. There is no doubt that if reasonably efficient lubrication can be maintained, tool life is increased. Generally high cutting speeds require a fluid which is an efficient coolant. Although coolant gives better life cycle to a cutting tool, it could also have the combination of good purpose for application as well as disadvantages.[3] The purposes of coolant may bring good results as: cooling the work-piece tool, reduces load and wear on a tool, reduces machine power consumption and removing chips from surfaces. The limitations of coolant may include; attacking tool chemical, damaging machine slides and sensors, causing corrosion and degreasing a work. During this operation a wooden plate was fixed in front of chuck jaws, in an attempt to prevent the behavior of air flow as shown in Figure 1. [4].

Fig. 1: Prevention of Air Flow from Chuck Jaws.

The essential movement is the fundamental movement gave by a machine tool or physically to cause relative movement between the device and work-piece so the substance of the apparatus approaches the work-piece material. The forces exerted by the tool on the chip are shown in figure 2 below as; Fn: Normal force at the rake face of the tool, Ff: Frictional force at the rake force of the tool, The forces exerted by the work on the chip are; Fc: Compressive force on the shear plane Fs: Shear force on the shear plane.[5] [6] [7] [8].

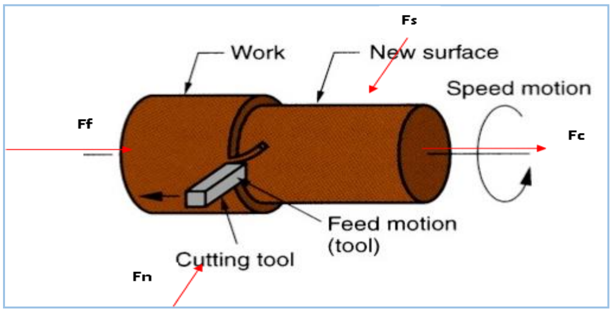

Fig. 2: Forces Acting on A Tool.

3. Analysis of generated data

Figures 3 and 4 below shows the graphs of temperature against time when using tungsten carbide to machine aluminum at various feed rates and at 470 rev/min. The machining process was performed without a coolant. It could be observed that as feed rate increased from 0.5 to 2 mm, the graphs shifted upwards, indicating the increase in temperature. A comparison between Figures 3 and 4 shows that as the speed of rotation increased, the temperature generated between the tool and the work piece increased. Generally, high temperatures make it necessary for the coolant to be used, due to the fact that as temperatures increases the surface finish of the product deteriorates. The other reason is that the performance characteristics of the product deteriorates. A comparison between tungsten carbide and HSS tool (Figures 3-4 and Figures 5-6) shows that generally tungsten carbide tool produces high temperatures. This is clearly shown by a comparison between Figures 3 and 4, when looking at graphs of 0.5 and 1 mm feed rate.

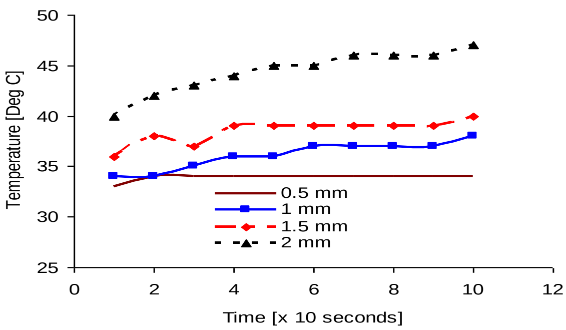

Fig. 3: Temperature Variations for Tungsten Carbide Tool Cutting Aluminum at 470 Rev/Min.

During experiment two types of materials used are aluminum and mild steel of 30 millimeter diameter. After each run of a cut a tool was cooled to room temperature before a different depth of cut is set or tool change. The work rotational speed was also altered, as well as the feed rate. The work piece was not cooled to until the last run is reached in order to examine the accumulation of and transfer of heat. The colors from the shade indicates different temperatures. The lower temperature at the dark point represents a temperature through tool tip. The upper temperature at the brighter area represents a temperature at a tool cutting point. The cutting process began from right hand to the left. These effects are shown in appendix 1.3.

Similar observations as above can be made when comparing Figures 7 and 8, where temperature increased as speed of rotation was increased. The highest temperature were recorded when feed rate was 2 mm. A comparison between Figures 7-8 and Figures 9-10 shows that HSS tooling produced high temperatures when machining mild steel. This was due to the fact that mild is harder than aluminum and its hardness approaches that of HSS. At 625 rev/min HSS failed when cutting mild steel at 2 mm feed rate. This could be avoided by using a coolant, so that high temperatures are reduced.[9]

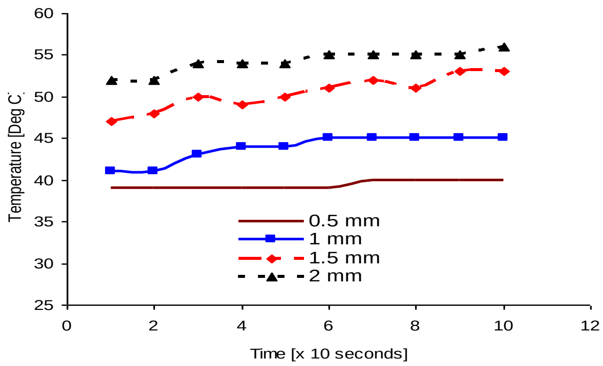

Fig. 4: Temperature Variations for Tungsten Carbide Tool Cutting Aluminum at 625 Rev/Min.

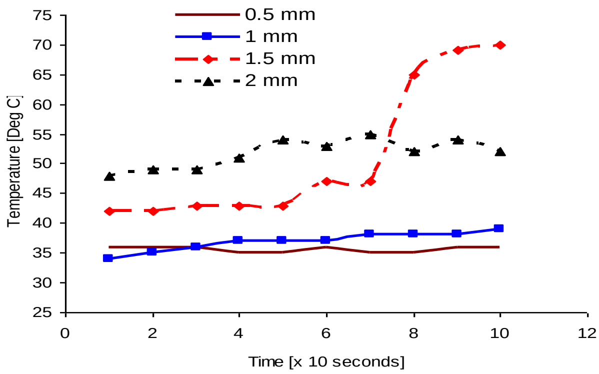

Fig. 5: Temperature Variations for HSS Tool Cutting Aluminum at 470 Rev/Min.

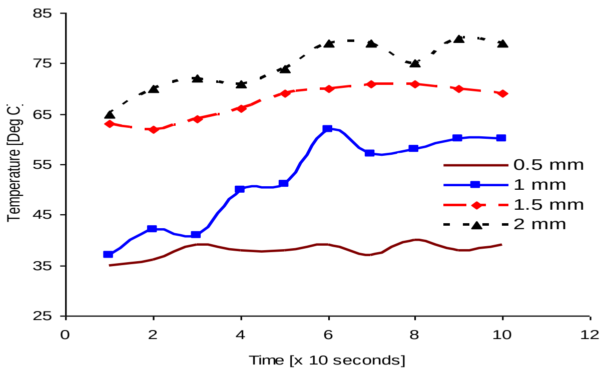

Fig. 6: Temperature Variations for HSS Tool Cutting Aluminum at 625 Rev/Min.

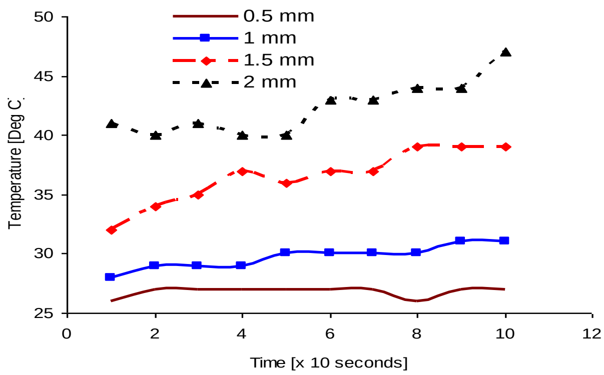

Fig. 7: Temperature Variations for Tungsten Carbide Tool Cutting Mild Steel at 470 Rev/Min.

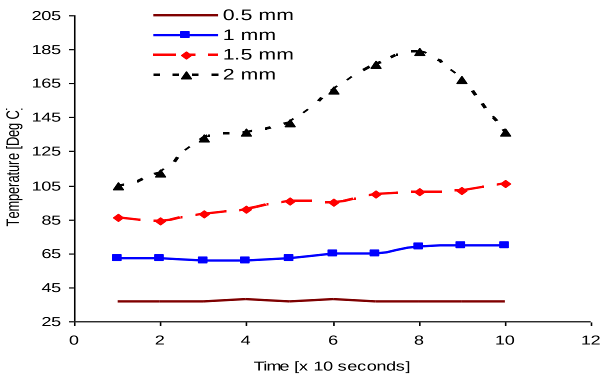

Fig. 8: Temperature Variations for Tungsten Carbide Tool Cutting Mild Steel at 625 Rev/Min.

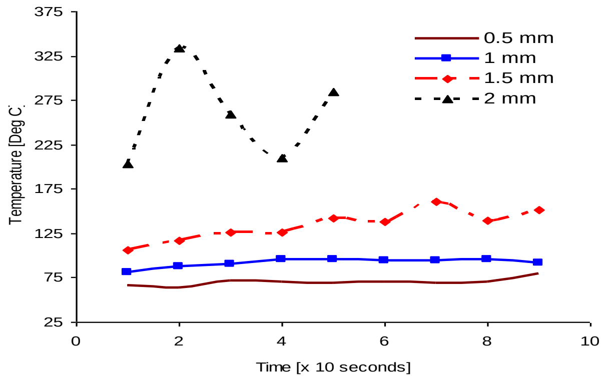

Fig. 9: Temperature Variations for HSS Tool Cutting Mild Steel at 470 Rev/Min.

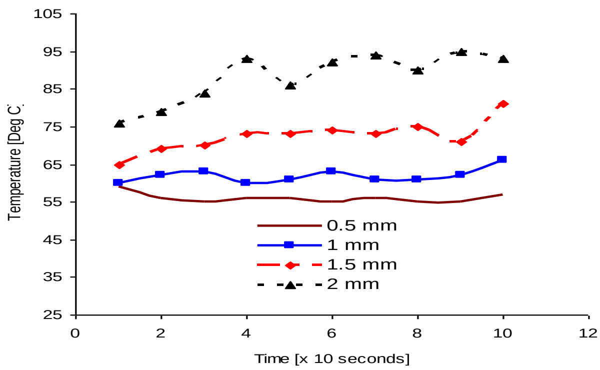

Fig. 10: Temperature Variations for HSS Tool Cutting Mild Steel at 625 Rev/Min.

4. The control of flow of chuck jaw's air along a work-piece

4.1. First set of operation

The direct clamping of a work-piece by a lathe chuck was applied. During machining operation the tool edge reached a point of experiencing temperature drop as a cutting tool approached a chuck face/jaws.

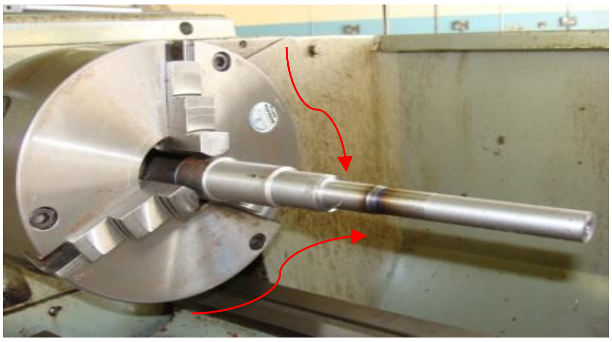

Fig. 11: Traditional/Normal Turning Setup.

As shown in figure 11, the expectation was that, the tool point temperature should keep increasing as a tool is covering more distance along the workplace. The assumption then was there might be air flow, following the chuck jaws steps, hence reaching a point along the work-piece where it acts as a cooling media. The jaws are acting as some fins hence cooling a work-piece at a certain point and causing unexpected cooling action.

4.2. Second setup of operation

During this operation a wooden plate was fixed in front of chuck jaws, in an attempt to prevent the behavior of air flow as shown in Figure 12. During this set up, the action of temperature drop at a certain point along the bar like it happened from the first set up operation did not occur.

Fig. 12: Prevention of Air Flow from Chuck Jaws.

5. Observations from machining operations

Some materials may be machined with relative ease, whilst others can only be cut with difficulty. This difference may be attributed to the "Machinability" of the respective materials.
The most significant variables indicating machinability may refer to:-

a) Tool life: - Time a tool takes before replacement or re-sharpening.
b) Surface finish: - the grade of finish obtained.
c) Tool composition: - materials compound used to make a tool.
d) Heat treatment and Microstructure etc.:- related to structures of materials obtained after heat treating.

Other problems related to tool failure during operations are assumed to be chatter and vibration. The fault may be in-

a) Cutting conditions; when speed is too high, the tool being blunt, having a heavy feed rate and round nose tool.
b) Work condition: over hang in chuck and use of center from tail stock.
c) Design of work; thin work tends to vibrate.

In fig.13 below, the diagrams shows different lengths of turned down diameters. These processes were done by changing speed (revolutions) but keeping the depth of cut, time and set feed rate constant. It is showing that by changing speed the distance covered by tool movement ranges, hence confirming that feed rate is proportional to speed. [5].

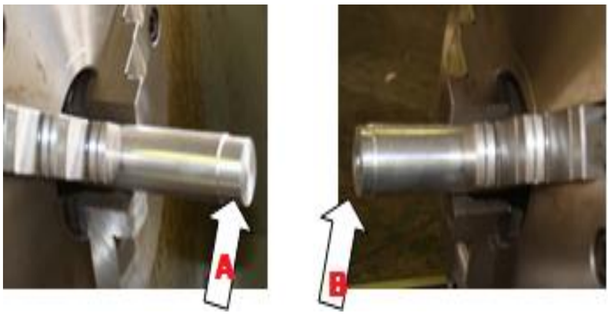

Fig. 13: The Effect of Change of Speed and Feed Result.

From appendix 1.1 and 1.2, in the graphs of temperatures at cutting point, there are peaks of temperatures during the cutting process. This might indicate different structures of crystals of materials which normally caused by error during material processing leaving material ingots with soft and hard portions or due to change of flow of air during experiment since the cooling was left to natural air.

6. Conclusion & recommendations

The experiment was carried out to investigate tool behavior when loaded without lubricant during a tool – material contact. The two major effects which accompany a cutting operation are excessive friction and heat. In the interest of tool life and quality of finish, it is necessary to apply a cutting fluid to the operation and the primary functions of such a fluid are to carry away heat and provide lubrication at the point where the chip bears on the tool fact.

When considering the use of a fluid in any particular operation the pertinent alternatives to be taken into account are whether to cool or cool and lubricate. There is no doubt that if reasonably efficient lubrication can be maintained, tool life is increased. Generally high cutting speeds require a fluid which is an efficient coolant. Although coolant gives better life cycle to a cutting tool, it could also have the combination of good purpose for application as well as disadvantages. The purposes of coolant may bring good results as: cooling the work-piece tool, reduces load and wear on a tool, reduces machine power consumption and removing chips from surfaces. The limitations of coolant may include; attacking tool chemical, damaging machine slides and sensors, causing corrosion and degreasing a work.

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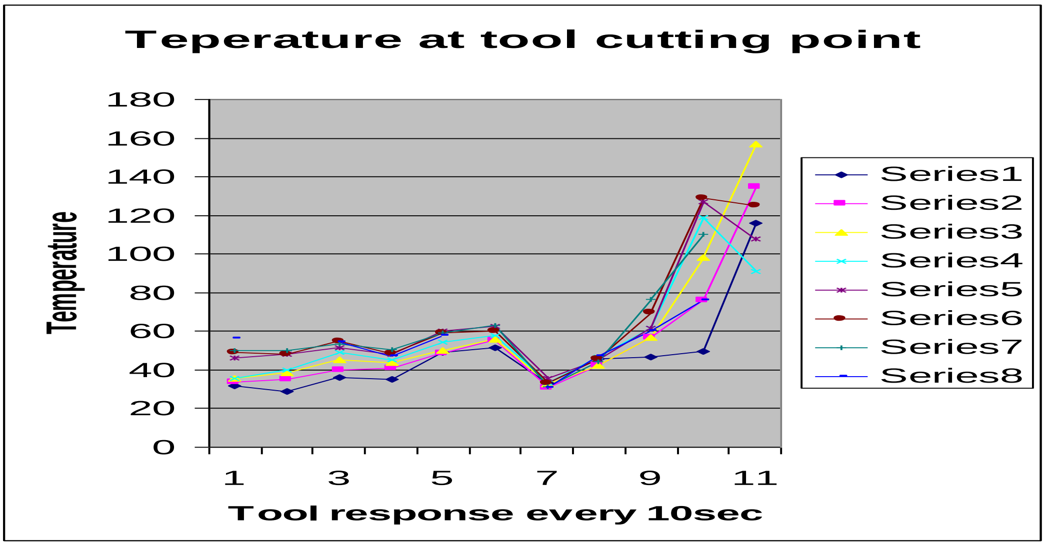
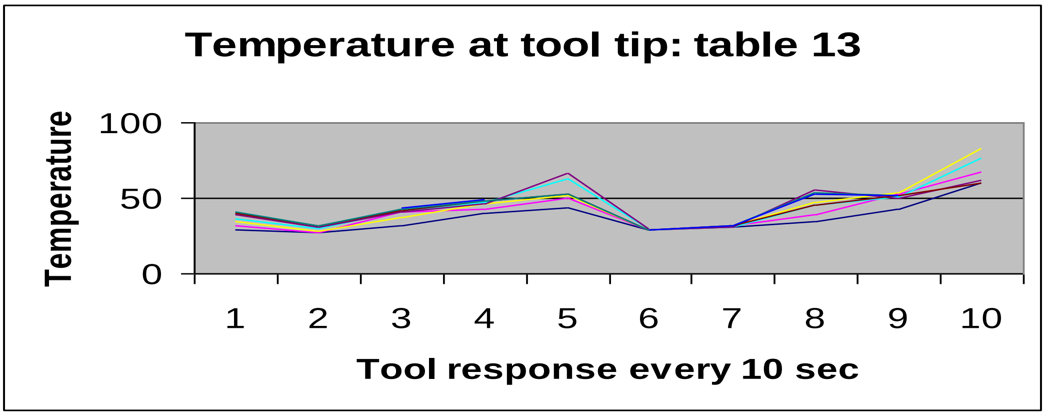
7. Appendix-1.1



Appendix-1.2



Appendix-1.3

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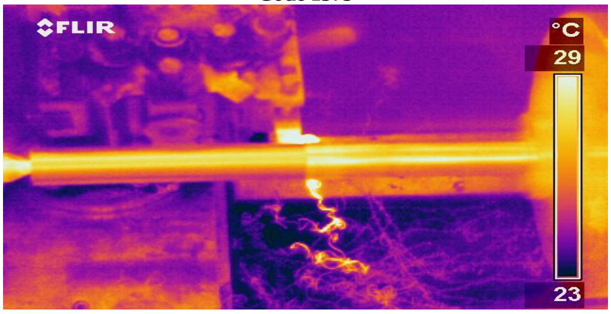

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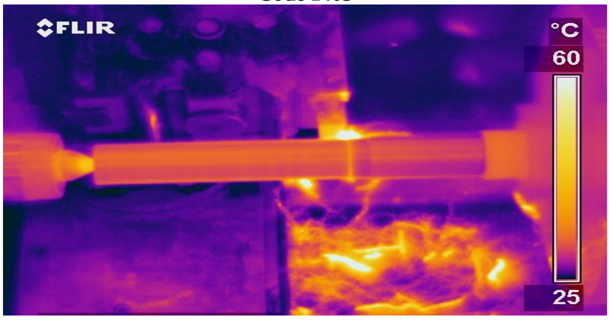

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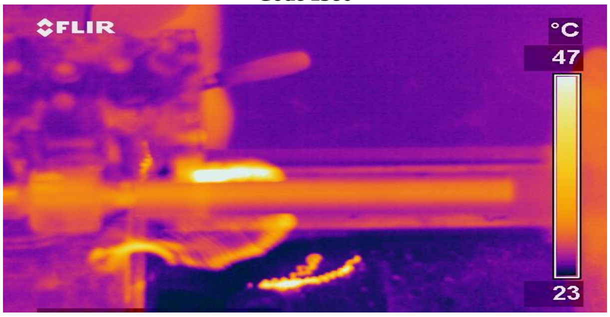

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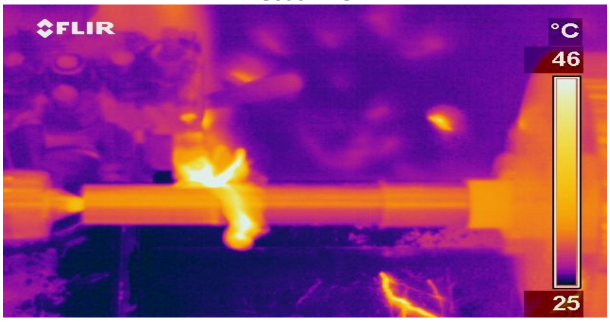

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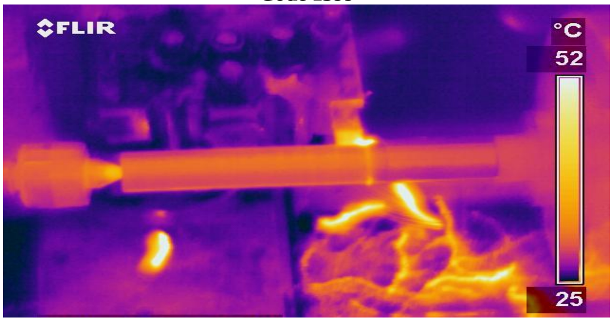

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