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Effects of the use of soybean oil as cutting fluid on the surface finish for turning operations

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EFFECTS OF THE USE OF SOYBEAN OIL AS CUTTING FLUID ON THE SURFACE FINISH FOR TURNING OPERATIONS

An Abstract of a Thesis
Submitted
in Partial Fulfillment
of the Requirements for the Degree
Master of Arts

Carlos Alberto Terán Yengle
University of Northern Iowa
December 2006

ABSTRACT

Concerns about the long term supply of petroleum, the instability of its prices, and growing environmental issues have led to a variety of legislative and public support for the use of agricultural commodities in industrial applications. This study is of importance because of environmental and health hazards concerns, and the possibility of reducing operating costs with the elimination of disposal of used cutting oil that the use of biodegradable oil offers to the metal-cutting operations.

The purpose of this study was to investigate the effect of the use of an experimental soybean-based oil as a cutting fluid on surface finish for turning operations. The work piece material used was carbon steel 1040. The cutting oils used were Valcool (water soluble metalworking fluid) and soybean based oil. The experiment was developed using a lathe machine and 9 TPG VC5 Valenite indexable carbide inserts. The independent variables for this study were cutting speed, feed rate, and depth of cut, which had to be determined before the experiment started. The dependent variable was the surface finish. The experiment consisted of three cuts using one insert. Each cut had different cutting speed and feed rate values. A total of 27 measurements were made. The data obtained was analyzed using F-test, t-test, and ANOVA test from Microsoft Excel. The results of this study showed that there was no difference with the use of soybean oil when compared to the surface finish obtained with the use of Valcool oil.

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Entitled: EFFECTS OF THE USE OF SOYBEAN OIL AS CUTTING FLUID ON THE SURFACE FINISH FOR TURNING OPERATIONS

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CHAPTER 1

INTRODUCTION

The instability of petroleum prices and the deterioration of the environment, by using petroleum-based products, have provided a strong driving force for the development of environmentally friendly alternatives (Howell, 1997). Concerns about the long term supply of petroleum, the instability of its prices, and growing environmental issues have led to a variety of legislative and public support for the use of agricultural commodities in industrial applications. The development of crop-Based products as an alternative to petroleum-based products will enhance rural economies at multiple levels and reduce the negative effects on the environment that are associated with the use, recovery, and disposal of petroleum based products (Howell, 1997). As a result of these concerns, different vegetable oils are being successfully used, instead of petroleum based oils, in various industrial applications such as emulsifiers, lubricants, plasticizers, surfactants, plastics, solvents and resins. Research and development approaches take advantage of the natural properties of these oils. Vegetable oils have outstanding environmental credentials, such as being inherently biodegradable, having low eco-toxicity and low toxicity towards humans, and being derived from renewable resources (Agricultural Research Service, 2005).

Soybean based oil has many actual industrial applications. One of these industrial applications is its use as cutting fluid in the machining process. The United Soybean Board (USB) believes that in order to increase the viability of soybean-based oil, it is necessary to address the performance limitations of the soybean-based oil. USB is supporting research to modify the traits of soybeans through a project called Better Bean

Initiative (BBI). Now, BBI has developed a genetically modified soybean variety that produces high level of oleic acid (United Soybean Board, 2002).

In machining, cutting fluid can be considered an accessory, which is frequently applied in order to increase production rate, improve surface quality, reduce costs and consequently increase profit. This is true in most applications, however, cutting fluid can also cause problems in a few cases, such as machining with ceramic tools (particularly alumina based ceramics), which have inadequate fracture toughness and may not tolerate the application of cutting fluid (Viera, Machado, & Ezugwu, 2001).

Machining operations involve various metal cutting processes that include: turning, drilling, milling, reaming, threading, broaching, grinding, polishing, planning, cutting and shaping. Machining processes use cutting tools of some sort that travel along the surface of work pieces, shearing away the metal ahead of it.

Turning and some drilling processes are done on lathes, which hold and rapidly spin the work piece against the edge of the cutting tool. Drilling machines are intended not only for making holes, but also for reaming (enlarging or finishing) existing holes. While drilling cuts a circular hole, milling can cause unusual or irregular shapes on work pieces. Broaching is a process whereby internal surfaces, such as holes of circular, square or irregular shapes or external surfaces like keyways are finished. A multiple-toothed cutting tool called a broach is used in this process (Schneider, 2001).

Turning is a metal cutting process used to make cylindrical surfaces. Typically the work piece is rotated on a spindle and the tool is fed into it radially, axially or both ways simultaneously to get the required surface. The term turning, in a general sense, refers to the generation of any cylindrical surface with a single point tool. In general, turning is characterized by steady conditions of metal cutting. Except at the beginning and end of the cutting process, the forces of the cutting tool and the tool tip temperature are essentially constant (Schneider, 2001).

The present study compares the surface finish result on a turning process using three different treatments consisting of dry machining, synthetic oil and the use of soybean oil.

Statement of Purpose

The purpose of this study was to investigate the effect of the use of an experimental Soybean-based oil as a cutting fluid on surface finish for turning operations.

Statement of Problem

The problems with this study was predict the quality of surface finish in metal cutting operations when using the soybean-based oil as cutting fluid and the effect that it will have on reducing production costs and consequently increase profit.

Statement of Need

This study is of great importance because of environmental and health hazards concerns, the possibility of reducing operating costs, disposal of used cutting oil that the use of biodegradable oil offers to the metal-cutting operations.

One of the most important actions to protect our environment is through pollution prevention. Pollution prevention involves reducing waste materials generated from all aspects of a production process to the least amount possible, while still accomplishing the production goal. By reducing their generation at the source, lower quantities of wastes will have to be treated in waste treatment plants or disposed of in landfills. One of the forms of reducing this waste generation is to use Soybean Based Oils instead of the Petroleum Based Oils (Cruz, Freidman, & Gerbus, 2004).

In 2002, the Department of Biosystems and Agricultural Engineering of The University of Minnesota included in its annual report a research named "Use of Vegetable Oils in Metalworking Fluids Formulations." (University of Minnesota, 2002) The objective of this research was to formulate vegetable oil-in-water emulsion that performs well as a metalworking fluid and decreases substantially the amount of mist generated during machining. During the description of the project the researchers also presented another problem related to metalworking fluids. In this regard the authors explained that "*The National Institute for Occupational Safety and Health (NIOSH) has estimated that more than 1.2 million people in the United States work with or near metalworking fluids. Metalworking fluids pose potential health hazards for machinists and other workers. NIOSH (1998) has recommended that permissible exposure limits for metalworking fluid mists be lowered from 5 mg/m*^{3} *to 0.5 mg/m*^{3}*. Although metalworking fluid mist concentrations currently rarely tops 5mg/m*^{3}*, significant reductions in mist concentration would be required at many facilities to consistently fall bellow the 0.5 mg/m*^{3} *limit. Thus, finding methods to reduce worker exposures to metalworking fluid mists is an important pursuit."* (University of Minnesota, 2002).

Another good reason is that while cutting oils purchased typically accounts for less than 0.5 percent of the total operating cost, disposal of spent fluid can be very expensive and troublesome, especially with the increasingly tightened environmental regulations, fluid purchases and disposal cost (NCDENR, 2004).

Laboratory tests have shown that heat produced during machining has a definite bearing on tool wear. Reducing cutting tool temperature is important since a small reduction in temperature will greatly extend cutting tool life (University of Minnesota, 2002).

As cutting fluid is applied during machining operations, it removes heat by carrying it away from the cutting tool/work piece interface. This cooling effect prevents tools from exceeding their critical temperature range beyond which the tool softens and wears rapidly. Fluids also lubricate the cutting tool/work-piece interface, minimizing the amount of heat generated by friction. A fluid's cooling and lubrication properties are critical in decreasing tool wear and extending tool life. Cooling and lubrication are also important in achieving the desired size, finish and shape of the work-piece (University of Minnesota, 2002).

Besides the environmental and health concerns it is also good to take into consideration the economical concerns. Spent cutting fluids are generated by metal cutting operations. Since the purchase and disposal of such fluids are increasing the production costs, fluid recycling has become a viable option to minimize costs.

The possibility of using the Soybean-based oil instead of petroleum-based oils is of great importance for environmental health and economic reasons.

First of all, the soybean-based oil is a natural resource produced in a large quantity in the US and is environmentally friendly. In addition, the soybean-based oil is cheaper than the petroleum-based oils, which means cost reduction.

Statement of Hypothesis

Hypothesis one: The null hypothesis 1, H_{01} is that there are no significant differences between types of treatment (dry machining, Valcool oil, and soybean oil) on the dependent variable (surface finish) due to the effects of the use of type of oil. The alternate hypothesis 1, H_{a1} there are significant differences between types of treatment (dry machining, Valcool oil, and soybean oil) on the dependent variable (surface finish) due to the effects of the use of type of oil.

Hypothesis two: The null hypothesis 2, H_{02} is that there are no strong relationships between the independent variables (cutting speed and feed rate) and the dependent variable (surface finish) for turning operations. The alternate hypothesis 2, H_{a2} is that there are strong relationships between independent variables (cutting speed and feed rate) and the dependent variable (surface finish) for turning operations.

Assumptions

The following assumptions are made in pursuit of this study.

1. It is assumed that all the inserts have exactly the same characteristics.
2. It is assumed that the steel to be used for the experiment meets all the guidelines and requirements to be qualified as 1040 Carbon Steel.
3. It is assumed that the measuring equipment is correctly calibrated and will give accurate readings for the data collection.
4. It is assumed that the water used to mix with the Valcool oil is 100% pure.
5. It is assumed that feed rates and cutting speeds are accurate.

Limitations/ Delimitations

The limitations for the development of this study were:

1. This study will be conducted using only 1040 steel for the work pieces during the machining process.
2. The work piece to be produced has the same shape.
3. The type of petroleum-based oil used to compare with the soybean-based oil is the Valcool synthetic oil.
4. The type of soybean-based oil used to compare with the petroleum-based oil is plain soybean oil.
5. The cutting tools used during the experiment are triangle indexable carbide inserts style TPG 322 grade VC5 and all are the same material.
6. The parameter to be measured for each of the methods will be the surface finish value.

CHAPTER 2

LITERATURE REVIEW

Literature on related issues has been reviewed. The review of literature is organized in 3 major headings related to the study. This chapter contains a brief explanation about the classification of cutting oils that are present in the market including their advantages and disadvantages. In addition, this chapter includes an overview of the research performed related to this study, giving a brief explanation of the methods, findings and conclusions of the researchers. Finally, this chapter presents a definition of terms used during the literature review.

Classification of Cutting Oils

The most commonly used metalworking fluids are petroleum-based fluids (including straight oils, soluble oils) and Chemical fluids (including synthetics and semi synthetics)(Iowa Waste Reduction Center, 2003). The most important characteristics of these oils are also explained.

Oil-Based Fluids:

Straight Oils: (100% petroleum oil) so called because they do not contain water, are basically petroleum, mineral, or ag-based oils (Iowa Waste Reduction Center, 2003). They may have additives to improve specific properties (Aronson, 1994). Generally additives are not required for the easiest tasks such as light-duty machining of ferrous or non-ferrous metals (Iowa Waste Reduction Center, 2003).

- Advantages: The major advantage of straight oils is the excellent lubricity or "cushioning" effect they provide between the work piece and cutting tool

(Tuholski, 1993). This is particularly useful for low speed, low clearance operations requiring high quality surface finishes. They provide the longest tool life for a number of applications. Highly compounded straight oils are still preferred for severe cutting operations such as crush grinding, severe broaching and tapping, deep-hole drilling, and for the most difficult to cut metals. Straight oils also offer good rust protection, extended sump life, easy maintenance, and resists rancidity (Iowa Waste Reduction Center, 2003).

- Disadvantages: These oils have poor heat dissipating properties and increase fire risk. They also create a mist of smoke that results in an unsafe work environment for the machine operator. The oily film left on the work piece makes cleaning more difficult, often requiring the use of cleaning solvents (Iowa Waste Reduction Center, 2003).

Soluble Oils: (60-90% petroleum oil) also referred to as emulsions, emulsifiable oils or water-soluble oils. Generally they have 60-90 % petroleum mineral oil, emulsifiers and other additives (Bienkowski, 1993). A concentrate is mixed with water to form the metal working fluid. When mixed, emulsifiers cause the oil to disperse in water forming a stable "oil-in-water" emulsion. Emulsifiers' particles refract light, giving the fluid a milky, opaque appearance (Sluhan, 1994).

- Advantages: Soluble oils offer improved cooling capabilities and good lubrication. Soluble oils also leave a protective oil film on moving components of machine tools and resist emulsification of greases and slide-way oils (Sluhan, 1994). They also provide good rust protection, and are the general-purpose product for light to heavy-duty operations (Iowa Waste Reduction Center, 2003).

- Disadvantages: The presence of water makes soluble oils more susceptible to rust problems, bacterial growth, tramp oil contamination, and evaporation losses, and increased maintenance costs. (Iowa Waste Reduction Center, 2003).

Chemical Fluids:

Synthetics: (0% petroleum oil) synthetic fluids generally consist of chemical lubricants and rust inhibitors dissolved in water. Like soluble oils, synthetics are provided as a concentrate, which are mixed with water to form the metalworking fluid. Due to their higher cooling capacity, synthetic fluids tend to be preferred for high-heat, high-velocity turning operations such as surface grinding (Iowa Waste Reduction Center, 2003).

Synthetic fluids can be classified as: simple synthetic (primarily used for light duty operations), complex synthetics (contain synthetic lubricants and may be used for heavy duty machining operations), emulsifiable synthetics (contain additional compounds to create lubrication properties similar to soluble oils, used during heavy-duty machining operations). The simple and the complex fluids form transparent solutions. However, the appearance of the emulsifiable synthetic fluid ranges from translucent to opaque. (Sluhan, 1994)

- Advantages: Excellent microbial control and resistance to rancidity for long periods of time; non-flammable, nonsmoking and relatively nontoxic; good corrosion control; superior cooling qualities; greater stability when mixed with hard water; reduced misting problems; reduced foaming problems; synthetics are easily separated from the work piece and chips; and they can be used for a variety of machining operations (Iowa Waste Reduction Center, 2003).

- Disadvantages: moderate or high agitation conditions may still cause them to foam or generate fine mists (Aronson, 1994). Ingredients added to enhance the lubricity and wettability of emulsifiable synthetics may increase the tendency of these fluids to emulsify tramp oil, foam, and leave semi-crystalline to gummy residues on machine systems (Bienkowski, 1993). They are easily contaminated by other machine fluids such as lubricating oils and need to be monitored and maintained in order to be used effectively (Iowa Waste Reduction Center, 2003).

Semi-synthetics: (2-30% petroleum oil) also referred as semi-chemical fluids, are essentially a hybrid of soluble oils and synthetics. They contain small dispersion of mineral oil in a water-dilutable concentrate (Aronson, 1994). The remaining portion of a semi-synthetic concentrate consists mainly of emulsifiers and water. The high concentration of emulsifiers tends to keep suspended oil globules small in size, decreasing the amount of light refracted by the fluid (Iowa Waste Reduction Center, 2003).

- Advantages: Good corrosion control, nonflammable, nonsmoking; good microbial control and resistance to rancidity, good cooling and lubrication, good cleaning properties, easy maintenance, and long service life (Iowa Waste Reduction Center, 2003).
- Disadvantages: Water hardness affects stability, may cause misting, foaming and dermatitis, may form residues, easily contaminated by other machine fluids (Iowa Waste Reduction Center, 2003).

Research Involving Bio-Based Metal Working Fluids

Recent research conducted by Clarens A., Zimmerman J., Landis H., Hayes K., and Skerlos S. at the Department of Civil and Environmental Engineering and the Department of Mechanical Engineering from the University of Michigan at Ann Arbor in 2004, titled: "Experimental Comparison of Vegetable and Petroleum Base Oils in Metalworking Fluids Using The Tapping Torque Test" (Clarens, et al., 2004), has shown interesting results. The Metal Working Fluids (MWF) tested in this study were three common bio-based oils available on the market (Canola, Soy, and a synthetic ester) and two common petroleum based oils (a naphthenic and a 50/50 naphthenic/paraffinic blend). The performance of these base stocks were evaluated in tapping operations involving both 1018 and 4140 steel work-pieces. The first results obtained from testing 1018 cold rolled steel using an uncoated hardened steel tool were that *"The bio-based straight oils demonstrated significantly higher tapping torque efficiency relative to the petroleum oils. Both mineral oils had a slightly lower efficiency level relative to the reference (petroleum based, C225) soluble oil (efficiency < 100%). In contrast, the three bio-based oils exhibited a 12-14% increase in efficiency relative to the reference soluble oil. This trend holds, although is much less pronounced, after the vegetable stocks are emulsified into soluble oil and semi-synthetic MWFs"* (Clarens, et al., 2004, p.3). The researchers also conducted the experiment adding secondary additives in order to understand if secondary MWF ingredients might play a major role in affecting the tapping torque efficiencies observed for the base oil-in-water emulsions. In general, MWFs contain a large number of secondary additives that may include couplers, corrosion inhibitors, pH buffers, and others. It does not appear that the presence of these secondary ingredients has a significant impact on the tapping torque efficiency naphthenic-based MWF base emulsion." (Clarens, et al., 2004).

Another research conducted by John Jacob, Mrinal Bhattacharya, Peter C. Raynor in 2004 titled "Emulsion containing vegetable oils for cutting fluid application" the researchers define as objective *"This study also deals with the development of a vegetable-based emulsion that can be used in the metalworking industry to replace partially or completely the commonly used petroleum-based emulsions. Vegetable oils have good lubricating ability and have been used for the formulation of rolling emulsions. However, certain limitations prevent their wide use in lubrication applications. The objective of this study was formulation of vegetable oil emulsions, to replace synthetic esters commonly used as metalworking fluids"* (Jacob, et al., 2004, p. 142). For this study the researchers made different vegetables oil-in-water emulsions. The emulsions were prepared using ionic and non-ionic surfactants. The conditions for an enhanced miscibility for soybean oil or modified soybean oil and water were investigated to prepare emulsions for vegetable oil-based components. The oil modification was achieved using ozonation and sulfurization reactions. The materials used for this study were: Crude soybean oil, modified soybean oil, ozone-modified and sulfur-modified oils, and several emulsifiers: Tween 40 (non-ionic surfactant), Nikkol, Eccoterge 200 (non-ionic fatty acid emulsifier) (Jacob, et al., 2004).

The products were characterized using Fourier transform infrared spectroscopy (FTIR) and nuclear magnetic resonance (NMR). The viscosities of the modified oil were considerably higher than the starting oil. The emulsions were obtained with the aid of three different surface-active agents at room temperature. The stability and efficiency of these emulsions were evaluated. These emulsions also showed good stability and anticorrosion properties. The phase behavior was evaluated using the phase diagrams. It was found that the phase behavior was dependent on the nature and the concentration of surfactant used. The modified soybean oil required comparatively increased amounts of surfactant than the regular oil to obtain a stable emulsion. The researchers determined that *"This study provides information useful for developing modified vegetable oil-water emulsions systems with different surface-active agents. The phase diagrams predict the region where an emulsion can be obtained by mixing the required components. Changes in the FTIR and NMR spectra confirm chain scission at C=C bonds of the fatty acid chains. The viscosity and molecular weights of modified oils increased. All the emulsions tested in this study showed good antirust properties."* (Jacob, et al., 2004, p. 150).

Another research conducted by Walter Belluco and L. De Chiffre titled "Performance evaluation of Vegetable-based oils in drilling austenitic stainless steel" (Belluco & De Chifre, 2004). This research was conducted at the Department of Manufacturing Engineering and Management from the Technical University of Denmark. This work gives a description of the investigations carried out testing the performance of six cutting fluids, five of which were vegetable basestock, in drilling stainless steel AISI 316L taking into account different performance evaluation parameters as tool life, drilling forces, and chip tangling (defined as percentage of machined holes where chip had to be manually removed from the tool before starting a new operation). The work piece dimensions were 300 mm x 200 mm x 35 mm. Three hundred holes per plate were machined, the sequence being randomized to avoid systematic effects due to localized hardness variations. The frequency of measurements was the following: tool life to total failure was measured for each tool, cutting forces and chip formation measured every machining hole, corner flank wear measured every 30 holes; chip tangling was recorded every 30 holes. The fluids were RM (reference oil) commercial general-purpose mineral oil-based; RV commercial general-purpose vegetable oil-based; (A) formulated general-purpose oil blend of rapeseed oil and ester oil; (B) formulated general-purpose oil blend of rapeseed oil, ester oil, and meadow foam oil; (C) formulated mild duty oil blend of rapeseed oil and ester oil; (D) formulated mild-duty oil a blend of rapeseed oil, ester oil, and meadow foam oil. The machine tool was operated for 1 hour, with spindle running at 1000 rpm; cutting fluid was kept recirculating. A new work piece was mounted on a dynamometer and 300 centering holes were machined. A new tool was mounted on the chunk, with 119 mm overhang. The tool was then mounted on the machine and cutting fluid nozzles position was adjusted. Thirty holes were machined at a time, with a randomized position sequence within the place. The cutting cycle was interrupted between holes to clear chip tangling around the drill if necessary. Each measurement of tool wear was carried out after cleaning the built up edge and degreasing the tool with light hydrocarbon solvent. Tools were used to total failure, and each fluid was tested using seven tools. The main result from this work was: all vegetable-based oils produced better results than the mineral reference oil, the best performance being 177% tool life increase and 7% reduction in thrust force with respect to the commercial mineral oil. These results are promising in view of the increased machining performance and lower environmental impact that can be obtained with vegetable-based oils produced from renewable sources (Belluco & De Chifre, 2004).

W. Belluco and L. De Chiffre made another research in the year 2002 at the Department of Manufacturing Engineering from the Technical University of Denmark. The study was titled "Surface integrity and part accuracy in reaming and tapping stainless steel with new vegetable based cutting oils" (Belluco & De Chifre, 2002). This study presents an investigation on the effect of new formulations of vegetable oils on surface integrity and part accuracy in reaming and tapping operations with AISI 316L stainless steel. The analysis of surface integrity involved a study of surface roughness, and surface metallurgy. Roughness was measured using profilometry, whereas the sub-surface was studied with micro hardness testing and optical metallography. In each test, reference and test fluids were evaluated, according to the following sequence: 14 specimens machined with reference fluid; 10 specimens machined with test fluid; and 10 more specimens machined with the reference fluid. The cutting fluids were (A) additivated mineral oil (reference oil), (B) mineral oil without additives (5% lard oil), (C) Mildly additivated vegetable oil, (D) vegetable oil of limnantes Alba without additives, and (E) vegetable oil without additives high erucic content. New tools were used as delivered by the manufacturer, after checking them under the microscope for burrs and imperfections. The hole geometry in reaming was measured on a coordinate measuring machine. Three diameters in each bore were probed, at a distance of 5, 15, and 25 mm from the top face of the cylinder and using a 4-point measurement strategy, yielding a measurement uncertainty of 5 μm. Roughness measurements were carried out with a stylus instrument, on which a skid pick-up with a 5 μm radius tip was used. After roughness testing the samples were milled and mirror polished for micro hardness tests. The conclusions for this study were: cutting fluid was found to have a significant effect on surface integrity and on thickness of the strain hardened layer in the sub-surface. The vegetable oils used in this investigation resulted in comparable or better performance than mineral oils in reaming and tapping. Increases in micro hardness at a distance of 15 μm from the surface were as high as 100% in reaming and 125% in tapping. Surface integrity investigations provided a valid method for qualification of different fluids (Belluco & De Chifre, 2002).

Another research made by Chang-Xue (Jack) Feng in the year 2001 and was titled "An experimental study of the impact of turning parameters on surface roughness." This research was conducted at the Department of Industrial and Manufacturing Engineering from Bradley University in Peoria, IL. The researcher describes his work as "This research applies the fractional factorial experimentation approach to studying the impact of turning parameters on the roughness of turned surfaces. Analysis of variances (ANOVA) is used to examine the impact of turning factors and factor interactions on surface roughness." The screening experiment examined the impact of the following parameters on surface roughness in finish turning: (1) feed; (2) work piece material; (3) cutting tool point angle ($180 - \alpha - \beta$); (4) spindle speed; (5) depth of cut. Chang-Xue explains his experiment by writing "*The first round of regression analysis considers all the five main effects and their ten two-factor interaction terms. Its purpose is to determine which factors and factor interactions are statistically significant in affecting the surface roughness. Based on 95% confidence interval, material, feed, point angle, and speed have statistically significant impact on surface roughness, since their* ρ*-values are smaller than 5%. In addition, the following three two-factor the interactions of AC (Material X Point Angle), AE (Material x Depth of Cut), and CD (Point Angle x Speed)* *produce statistically significant impact on the surface roughness, because their ρ-values are also smaller than 5%"* (Chang-Xue, 2001).

This research presented a factorial experimentation approach to studying the impact of turning parameters on surface roughness. Chang-Xue came to the following conclusions: *"first, the depth of cut does not impact the surface roughness in the studied range, which could be used to improve productivity if it would not worsen the surface microstructure of the material and the dimensional and geometric accuracy. Second, in addition to feeds, nose radius, work material and speeds, the tool point angle has a significant impact on the observed surface roughness. Third, strong interactions were observed among the above turning parameters. Most significant interactions were found between work materials, point angle and speeds. Fourth, a systematic approach was provided to design and analyze the experiments, which is able to reduce the cost and time of experiments and to utilize data obtained to the maximum extend."*(Chan-Xue, 2001)

Another research made by R. F. Avila and A. M. Abrao during 2001 titled "The effect of cutting fluids on the machining of hardened AISI 4340 steel" that was developed at the Department of Mechanical Engineering from the University of Minas Gerais (Brazil) talks about the importance of using the cutting fluids on the machining process. The researchers describe their work as: "*The knowledge over the performance of cutting fluids when applied to different work materials and operations is of crucial importance in order to improve the efficiency of most conventional machining processes. This efficiency can be measured, among other parameters, through cutting tool life and work-piece surface finish. However, the costs associated with the purchase, handling and disposal of cutting fluids are leading to the development of tool materials and coatings which do not* *require their application. In this research the performance of three types of cutting fluids (two emulsions and one synthetic fluid) were compared to dry cutting when continuous turning hardened AISI 4340 steel using mixed alumina inserts. The following parameters were evaluated: tool life, surface finish, tool wear mechanisms, and chips form*" (Avila & Abrao, 2001,p. 21). For this experiment was developed making continuous turning tests were conducted on a CNC lathe (3500 rpm and 5.5kW). Bars of high strength low alloy AISI 4340 steel heat-treated to an average hardness of 49 HRC (Hardness Rockwell C test, used on hard materials) were used as work-piece material. The cutting fluids used were: fluid A (emulsion without mineral oil), fluid B (synthetic), and fluid C (emulsion containing mineral oil). A fluid concentration of 5% was used for the wet cutting tests; the tests were repeated under conditions of dry cutting. The fluids were pumped at a rate of 75 l/min and standard pressure. Flank wear was measured using a toolmaker's microscope equipped with digital micrometers and the work-piece surface finish was monitored after each pass with a Mitutoyo roughness meter to a cut-off of 0.8 mm. The cutting fluids concentration was measured throughout the test programs with a bench refractometer. The test were conducted with varying cutting speed ranging from 50 to 100 m-min for a feed rate of 0.15mm/rev and a depth cut of 2.0 mm (roughing) and also a cutting speed ranging from 200 to 400 m/min for a feed rate of 0.05 mm/rev and depth of cut of 0.5 mm (finishing). The tests were stopped after 60 min if this criterion of average flank-wear of 0.3 mm has not been reached (Avila & Abrao, 2001).

Avila and Abrao conclude from this research that the application of a cutting fluid based on an emulsion without mineral oils result in longer tool life compared to dry cutting. Another conclusions were reducing the cutting fluid concentration from 5 to 3%

resulted in lower tool life particularly at a cutting speed of 300 m/min. Also, when performing finish cutting operations at high cutting speeds, the use of cutting fluid is responsible for reducing the scatter in the surface roughness values. Finally, with regard to chip control, the use of cutting fluids has a positive influence (Avila & Abrao, 2001).

A research by Lou A. T. Honary developed during the year 1996 titled "An investigation of the use of soybean oil in hydraulic systems" state that a report by the National Petroleum Refiners Association (NPRA) indicates that over 909 million gallons of industrial oils were sold by the US oil companies in 1992. Also, an additional 1.3 billion gallons of automotive oils were sold during that year. Economically, disposal of the used oils will be less expensive as the vegetable-based industrial oil could be disposed of safely with minimal expense. Also, prices of petroleum-based industrial lubricants vary based on the application and requirements, and range from $3.00 to $7.00 per gallon. This provides opportunities to add value to some of the vegetable oils typically sold at about $2.00 per gallon. Environmentally too, the used vegetable-based industrial lubricants will be less harmful to the ecosystem, and in certain application they could be helpful to the environment as well. There are other benefits to vegetable oils, such as their being safer for humans when exposed to the oil or its fumes during machining operations. The background information that Honary used is based upon one of the most desired characteristics of most industrial oils is its oxidative stability. The observations the researcher made lead him to conclude that the soybean oil is not adequately stable for use in industrial applications as hydraulic oils. When untreated soybean oil was exposed to the high pressure-temperature conditions of a standard hydraulic test, oxidative stability was particularly a problem when the base oil was not fresh and had not been stored properly. The open reservoir, turbulence, and pressure-generated heat caused the oil to oxidize and increase in viscosity, thus losing performance properties.

Honary concludes from this study that vegetable oils show potential in substituting for some of the industrial lubricants. The advantages of such a substitution will be the environmental benefits, the renewability of the oils, and the relative safety of human exposure to the oils and their fumes. Economically, the vegetable oils will be competitive only in areas where stiff regulations require expensive clean up and disposal. There are many vegetable oils suitable for industrial uses. The purpose of this project was to investigate the performance of soybean oil in hydraulic systems. The limitations of untreated soybean oil, for industrial use, may be more enhanced than some of the other vegetable oils, such as rapeseed and high oleic sunflower oil. The findings indicated that the industrial performance of soybean oil could be improved by chemical modification, through the use of property enhancers (additives) (Honary, 1996).

Definition of Terms

A list of terms that might aid in understanding the review of literature is presented.

Chemical Stability: The liquid's ability to resist oxidation and deterioration for long periods. It is also defined as the tendency of a substance or mixture to resist chemical change (Noria Co., 2006).

Emulsifier: Additive that promotes the formation of a stable mixture, or emulsion, of oil and water. Common emulsifiers are: metallic soaps, certain animal and vegetable oils, and various polar compounds (Noria Co. 2006).

Flash Point: The lowest temperature at which application of a flame to the test chamber a tester cause vapors of the sample in the chamber to ignite. The test can be applied to base fluids being considered for use in an oil mud or a synthetic mud or to any flammable liquid to determine at what temperature an explosion hazard exist (Shlumberger Limited, 2004).

Lubricity: A term used to describe the ability of a lubricant to reduce friction between rubbing surfaces. There are no generally accepted test methods available to evaluate this property. Lubricity is important mostly in conditions of boundary lubrication and probably represents some relationship to the ability of the oil to wet the bearing surfaces and to resist being rubbed off. Lubricity has no known direct relationship to oil viscosity (Shlumberger Limited, 2004).

Miscibility: The ability or tendency of one liquid to mix or blend uniformly with another. Alcohol is miscible in water; gasoline and water are immiscible (U.S. Environmental Protection Agency, 2006).

Mist: Liquid particles measuring 40 to 500 micrometers are formed by condensation of vapor. By comparison, fog particles are smaller than 40 micrometers (U.S. Environmental Protection Agency, 2006).

PH Test: A drilling-fluid test to measure pH of mud and mud filtrates, usually performed according to API specifications. The pH test uses a pH meter equipped with a glass-membrane measuring electrode and reference electrode, which read from 0 to 14. The preferred pH meter automatically compensates for temperature (Shlumberger Limited, 2004).

Pour Point: The lowest temperature at which a liquid remains pourable (meaning still behaves as a fluid). In oils, the pour point is generally increased by high paraffin content. The pour point of liquid is an important consideration for arctic drilling operations (Shlumberger Limited, 2004).

Rancidity: is the decomposition of fats and other lipids by oxidation. Rancid foods and oils develop highly reactive chemicals, which produce unpleasant and obnoxious odors and flavors, and destroy nutrients in food. Under some conditions, rancidity, and the destruction of vitamins, occurs very quickly (Integrated Publishing Co., 2005).

Viscosity: A property of fluids and slurries that indicates their resistance to flow, defined as the ratio of shear stress to shear rate (Shlumberger Limited, 2004).

Viscosity Index: the viscosity index (V.I.) of oil is a number that indicates the effect of temperature changes on the viscosity of the oil. A low V.I. signifies a relatively large change of viscosity with changes of temperature. On the Other Hand, a high V.I. signifies relatively little change in viscosity over a wide temperature range (Integrated Publishing Co., 2005).

Wettability: The preference of a solid to contact one liquid or gas, known as the wetting phase, rather than another. The wetting phase will tend to spread on the solid surface and a porous solid will tend to imbibe the wetting phase, in both cases displacing the non-wetting phase (Shlumberger Limited, 2004).

CHAPTER 3

METHODS AND MATERIALS

Research Design

The research approach will use an experimental quantitative method. Three set of data will be collected: dry machining, using the petroleum based cutting fluid, and the soybean based cutting fluid; making a total of twenty seven measurements (nine each set of data). The parameter to be measured for each of the methods will be the surface finish value.

Materials

The materials necessary for the experiment are:

1. A piece of 1040 Carbon steel of 6" diameter and 30" length,
2. Ten TPG VC5 Valenite Indexable Carbide Inserts,
3. 5 gallons of experimental soybean based oil,
4. One five-gallon pail (19 liters) VALCOOL VNT 800, Water Soluble Metalworking Fluid Concentrate (Petroleum Based),
5. One Taylor Hobson Precision, Surtronic 25 Surface Texture Measurement Instrument,
6. A South Western Industries, Inc. Lathe machine model Track TRL1440P, with a control module Proto TRACK LX2,
7. One PT-795 Valenite Refractometer (hand held instrument to measure actual mix concentration),
8. A box of pH Test strips to measure fluids.

The experimental soybean based oil was developed at the University of Northern Iowa-National Ag Based Lubricants Center. The composition of the experimental soybean oil according to information obtained from the Environmental Scientist Patrick Johnston was: Soybean oil (vegetable oil) used as base oil, as additives it contains: Polysiloxane polyoxyalkylene polymer (antifoam), Triazine (preservative), 3-Iodopropynylbutylcarbonate (preservative), Amine salts (emulsifiers), Phosphate ester (Extreme pressure/emulsifier), Polymeric esters (Corrosion inhibitor/extreme pressure), Glycerol monooleate (Coupler), and Amides (Corrosion inhibitor/reserve alkalinity),

The Experiment

The first step for the research was to determine the cutting conditions that were used during the experiment. The parameters to determine were depth of cut, feed rate, and cutting speeds.

Cutting Conditions

The first step was to select the depth of cut. The general parameter for turning given in the Metalworking Handbook on page 999, as a footnote on the Table 1: Cutting Feeds and Speeds for Turning Plain Carbon and Alloy Steels, is depth of cut of 0.1 inch (Adams, 1976); reason why the depth of cut will be set up at 0.1 inch.

The second step was to select the feed rate. For this The Metalworking Handbook of Adams, published in 1976, on page 1003 table 4b gives for Plain Carbon Steel 1040 an optimum value of 0.017 in/rev and an average value of 0.008 in/rev. as for these two values The Metalworking Handbook on page 992 explains *"The optimum feed/speed data are approximate values of feed and speed that achieve minimum-cost machining by combining a high productivity rate with low tooling cost at a fixed tool life. The average* *feed data are expected to achieve approximately the same tool life and tooling costs, but productivity is usually lower, so machining costs are higher*" (Adams, 1976, p. 992).

It is well known that the surface finish and tool life are affected by the feed rate, chip thickness, and cutting speed; variations of these values could improve the surface finish and reduce or extend the tool life as well (Adams, 1976). Therefore, in this experiment it was necessary to have different values at least three in order to see some changes; these values have to be around the values given by the tables in the Metalworking Handbook. The values chosen for this experiment were 0.01 in/rev, 0.015 in/rev, and 0.02 in/rev.

The third step was to determine the cutting speed. The Metalworking Handbook on its page 1003 table 4b, gives for Medium Carbon Steel 1040 and a coated carbide cutting tool a range of cutting speed between 410 and 590, as for the feed rate. The experiment needed different values for the cutting speed and the values chosen were within this parameter. Based on this, the values used as test values were 400 fpm, 500 fpm, and 600 fpm. From these values it was possible to find the speed in RPM based on the diameter of the work piece by applying the following formula:

$$V = \frac{N\pi D}{12}$$

Where:

N= the test value of the cutting speed in RPM

D= the diameter of the work piece

π= 3.1416

After all these values were calculated the following table was developed:

		Available		Available		Available
Cutting Speed, fpm	400		500		600	
RPM (for D=5”)	305.6	310	381.9	420	458.4	510
RPM (for D=4.5”)	339.5	310	424.4	420	509.3	510
RPM (for D=4”)	381.9	420	477.5	510	573.0	620
RPM (for D=3.5”)	436.5	420	545.7	510	654.8	620
RPM (for D=3”)	509.3	510	636.6	620	763.9	825
RPM (for D=2.5”)	611.2	620	763.9	825	916.7	825
Feed Rate, in/rev	0.02		0.015		0.01	
Feed Rate, in/min (N=310)	6.2	6	4.7	4	3.1	3
Feed Rate, in/min (N=420)	8.4	8	6.3	6	4.2	4
Feed Rate, in/min (N=510)	10.2	10	7.7	8	5.1	6

Table #1: Data calculations for the experiments

The experiment consisted of:

Depth of cut = 0.1 inch

It had 3 speeds values, 3 Feed Rate values, and 3 fluids.

Data Description

All information requested on this study represents a group of continuous data. The data obtained from the surface texture measurement instrument was collected in three groups, one for dry machining, one for the Valcool cutting fluid and one for the soybean based cutting fluid. Each group was divided into three sub-groups, one for each cutting speed (one for 310 rpm, one for 420 rpm, and one for 510 rpm). Three sets of data (surface finish) were collected from each sub-group and one for each value of the feed rate.

As a result, there were two types of variables on this study the independent and the dependent variables.

The independent variables were:

1. Work piece Diameter,
2. Depth of cut,
3. Feed rate,
4. Cutting speed.

The dependent variable value collected from this experiment was:

1. The surface finish.

Data Collection

After the initial parameters for the cutting conditions were obtained, the next step was to prepare the work piece, in order to have a cylindrical shape with a constant diameter and also divide the metal piece into three parts by making two deep cuts. Once the work piece was prepared, and the metal piece was located on the lathe machine centered, the first cutting was located, centered, and set up on the lathe machine (the depth of cut, the cutting speed, and feed rate are entered) to start cutting.

After the first cut, the value of surface finish for the 0.1 inch depth of cut was really high that the surface texture measurement instrument could not record. The decision of changing the 0.1 inch value to the 0.05 inch was made and with that 0.05 inch the experiment was conducted.

The first data collected was using dry machining. The cutting experience used the three divisions of the work piece. While maintaining the same cutting speed (310 rpm), and using three different feed rate values (6 in/min, 4 in/min, 3 in/min), one for each division, the variable measured was the surface finish for each different feed rate used.

After the first three feed rate values were used, the next step was to change the cutting tool and the cutting speed to the next value (420 rpm). This part also had three different feed rates (8 in/min, 6 in/min, 4 in/min) one for each division on the work piece. From these, three sets of data (Surface Finish) were collected as well. For the last cutting speed value (510 rpm), a new cutting tool was needed, and three different feed rate as well (10 in/min, 8 in/min, 6 in/min), one for each division. Also from this part three sets of data (surface finish) were measured.

The experiment was repeated using the Valcool cutting fluid and the Soybean oil, and new sets of data was collected. At the end, the total of experiments were twenty-seven and each of them had the measured variable chip thickness. The data collected from the experiment was analyzed using Microsoft Excel. The statistical procedure used to analyze the data for this study will be (1) F-test, (2) Inferential bivariate statistics (ANOVA), (3) t-test, and finally (4) regression to the surface finish results of the soybean oil treatment.

CHAPTER IV

DATA ANALYSIS

The data captured from the experiment belonged to three groups or treatments applied during the experiment machining using no fluid or dry, using Valcool, and using the Soybean oil.

Experimental Data

The data collected during the experiment was recorded in the following table.

Experiment	Oil	Tool	Work Piece diameter (in)	Depth of cut (in)	Feed Rate (in/min)	Cutting Speed (rpm)	Surface Finish (µm)
1	Dry	10	4.8	0.05	6	310	8.52
2	Dry	10		0.05	4	310	4.38
3	Dry	10		0.05	3	310	2.22
4	Dry	9		0.05	8	420	11.24
5	Dry	9		0.05	6	420	4.86
6	Dry	9		0.05	4	420	2.06
7	Dry	8		0.05	10	510	8.2
8	Dry	8		0.05	8	510	11.32
9	Dry	8		0.05	6	510	9.78
10	Valcool	7	4.6	0.05	6	310	12.2
11	Valcool	7		0.05	4	310	3.8
12	Valcool	7		0.05	3	310	2.36
13	Valcool	6		0.05	8	420	7.28
14	Valcool	6		0.05	6	420	5.62
15	Valcool	6		0.05	4	420	2.42
16	Valcool	5		0.05	10	510	9.36
17	Valcool	5		0.05	8	510	6.5
18	Valcool	5		0.05	6	510	6.48
19	Soybean	4	4.5	0.05	6	310	8.3
20	Soybean	4		0.05	4	310	3.74
21	Soybean	4		0.05	3	310	3.28
22	Soybean	3		0.05	8	420	10.34
23	Soybean	3		0.05	6	420	4.6
24	Soybean	3		0.05	4	420	2.62
25	Soybean	2		0.05	10	510	8.64
26	Soybean	2		0.05	8	510	6.44
27	Soybean	2		0.05	6	510	3.18

Table #2: Data obtained during the experiment

Data Analysis

The table #2 was divided into three tables one for each group or treatment as shown in the following tables:

Experiment	Oil	Tool	Work Piece diameter (in)	Depth of cut (in)	Feed Rate (in/min)	Cutting speed (rpm)	Surface Finish (µm)
1	Dry	10	4.8	0.05	6	310	8.52
2	Dry	10	4.8	0.05	4	310	4.38
3	Dry	10	4.8	0.05	3	310	2.22
4	Dry	9	4.8	0.05	8	420	11.24
5	Dry	9	4.8	0.05	6	420	4.86
6	Dry	9	4.8	0.05	4	420	2.06
7	Dry	8	4.8	0.05	10	510	8.2
8	Dry	8	4.8	0.05	8	510	11.32
9	Dry	8	4.8	0.05	6	510	9.78

Table #3: Data obtained from Dry machining treatment of the experiment

Experiment	Oil	Tool	Work Piece diameter (in)	Depth of cut (in)	Feed Rate (in/min)	Cutting speed (rpm)	Surface Finish (µm)
10	Valcool	7	4.6	0.05	6	310	12.2
11	Valcool	7	4.6	0.05	4	310	3.8
12	Valcool	7	4.6	0.05	3	310	2.36
13	Valcool	6	4.6	0.05	8	420	7.28
14	Valcool	6	4.6	0.05	6	420	5.62
15	Valcool	6	4.6	0.05	4	420	2.42
16	Valcool	5	4.6	0.05	10	510	9.36
17	Valcool	5	4.6	0.05	8	510	6.5
18	Valcool	5	4.6	0.05	6	510	6.48

Table #4: Data obtained from the use of Valcool treatment of the experiment

Experiment	Oil	Tool	Work Piece diameter (in)	Depth of cut (in)	Feed Rate (in/min)	Cutting speed (rpm)	Surface Finish (μm)
19	Soybean	4	4.5	0.05	6	310	8.3
20	Soybean	4	4.5	0.05	4	310	3.74
21	Soybean	4	4.5	0.05	3	310	3.28
22	Soybean	3	4.5	0.05	8	420	10.34
23	Soybean	3	4.5	0.05	6	420	4.6
24	Soybean	3	4.5	0.05	4	420	2.62
25	Soybean	2	4.5	0.05	10	510	8.64
26	Soybean	2	4.5	0.05	8	510	6.44
27	Soybean	2	4.5	0.05	6	510	3.18

Table #5: Data obtained from the use of Soybean oil treatment of the experiment

In order to conduct the analysis of the data collected, first an analysis to check for equal or unequal variances of the groups was made. The way that it was done for this experiment was by applying the F-test two-sample for variances type of data analysis using Microsoft Excel software and comparing two groups or treatments at a time. The results of this data analysis are shown in table #6, 7, and 8:

	Variable: Valcool	Variable: Soybean
Mean	6.224444444	5.682222222
Variance	10.30567778	8.027844444
Observations	9	9
df	8	8
F	1.283741588	
P(F<=f) one-tail	0.36618629	
F Critical one-tail	3.438103136	

Table #6: F-test two sample for analysis of variances (Valcool vs. Soybean)

As it is shown in table # 6, the F value of the sample is less than the F critical therefore it is assumed that Valcool and soybean samples have equal variances.

	Variable: Dry	Variable: Soybean
Mean	6.953333333	5.682222222
Variance	13.3494	8.027844444
Observations	9	9
df	8	8
F	1.662887229	
P(F<=f) one-tail	0.243981157	
F Critical one-tail	3.438103136	

Table #7: F-test two sample for analysis of variances (Dry vs. Soybean)

As it is shown in table # 7, the F critical is greater than the F value of the sample therefore it is assumed that Dry and soybean samples have equal variances

	Variable Dry	Variable Valcool
Mean	6.953333333	6.224444444
Variance	13.3494	10.30567778
Observations	9	9
df	8	8
F	1.295344206	
P(F<=f) one-tail	0.361573074	
F Critical one-tail	3.438103136	

Table #8: F-test two sample for analysis of variances (Dry vs. Valcool)

As it is shown in table # 8, the F critical is greater than the F value of the sample therefore it is assumed that Dry and Valcool samples have equal variances. After all these F test were applied it was possible to assume that all the samples have equal variances.

Since the purpose of the research was to demonstrate that there was not statistically difference between the results of surface finish and the sample had more than two different groups or treatments, a one-way ANOVA test for the surface finish of the three groups or treatments was needed.

Dry	Valcool	Soybean
8.52	12.2	8.3
4.38	3.8	3.74
2.22	2.36	3.28
11.24	7.28	10.34
4.86	5.62	4.6
2.06	2.42	2.62
8.2	9.36	8.64
11.32	6.5	6.44
9.78	6.48	3.18

Table #9: Values of surface finish obtained from the experiment

ANOVA Single factor: SUMMARY 95%

Groups	*Count*	*Sum*	*Average*	*Variance*
Dry	9	62.58	6.953	13.349
Valcool	9	56.02	6.224	10.306
Soybean	9	51.14	5.682	8.028

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F critical*
Between Groups	7.323	2	3.662	0.347	0.710	3.403
Within Groups	253.463	24	10.561			
Total	260.786	26				

Table #10: Results from the one-way ANOVA applied to the three groups of surface finish obtained from the experiment at 95%

ANOVA Single Factor: SUMMARY 99%

Groups	*Count*	*Sum*	*Average*	*Variance*
Dry	9	62.58	6.953	13.349
Valcool	9	56.02	6.224	10.306
Soybean	9	51.14	5.682	8.028

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F critical*
Between Groups	7.323	2	3.662	0.347	0.710	5.614
Within Groups	253.463	24	10.561			
Total	260.786	26				

Table #11: Results from the one-way ANOVA applied to the three groups of surface finish obtained from the experiment at 99%.

From the ANOVA analysis performed at 95% and 99% the F-values were far below than both F-critical values. Therefore we do not have enough statically significant evidence to support that the means of the results of the surface finish are different. In addition, the P value of 0.71 suggests that this analysis may not be statistically significant and also that there is not enough evidence to infer that at least two of the means may be different. For that reason, a comparison of the surface finish values obtained from the use of Valcool and Soybean oil with a t-test for two means in order to determine if the means of these two groups are equal was done.

t-Test: Two-Sample Assuming Equal Variances

	Valcool	*Soybean*
Mean	6.224	5.682
Variance	10.306	8.028
Observations	9	9
Pooled Variance	9.167	
Hypothesized Mean Difference	0.000	
Df	16.000	
t stat	0.380	
P(T<=t) one-tail	0.355	
t Critical one-tail	1.746	
P(T<=t) two-tail	0.709	
t Critical two-tail	2.120	

Table #12: Results of the t-test analysis applied to the groups Valcool and Soybean oil.

The t value (t stat) would need to exceed the t critical two-tail in order for the difference between the means to be significant. From table #11, the t value (t stat) calculated is 0.380 and compared with the t critical two tail, which is 2.120, is lower than the one needed to reject the null hypothesis, which implies that the mean between soybean and Valcool are not statistically different. In other words, the use of soybean or Valcool oil would have similar effects on the surface finish.

After the t-test, the results of it suggest that there is enough evidence to conclude that the means are not statistically different. A regression analysis would be applied to the surface finish data obtained from the soybean oil treatment.

Summary Output

	Coefs	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	5.964	1.753	3.403	0.014	1.675	10.253	1.675	10.253
X Variable (F. R.)	1.646	0.220	7.496	0.000	1.109	2.184	1.109	2.184
X Variable (C. S.)	-0.025	0.006	-4.372	0.005	-0.039	-0.011	-0.039	-0.011

Table #13: Regression statistics analysis for the soybean oil.

Since the t-value of the variables are greater than the one obtained from appendix B (t-table) that is 2.306, it is possible to say that the t values for the coefficient (Coefs), feed rate (FR), and cutting speed (CS) implies that the two variables are significant to the outcome. Cutting speed (CS) has an inverse relationship in the model. Trying to find out how the variation of these two factors could affect the surface finish. A new arrangement of the data was done in order to have one of the independent variables with a constant value, obtaining the following tables:

Experiment	Oil	Tool	Work Piece diameter (in)	Depth of cut (in)	Feed Rate (in/min)	Cutting speed (rpm)	Surface Finish (µm)
3	**Dry**	10	4.8	0.05	3	310	2.22
12	**Valcool**	7	4.6	0.05	3	310	2.36
21	**Soybean**	4	4.5	0.05	3	310	3.28
2	**Dry**	10	4.8	0.05	4	310	4.38
11	**Valcool**	7	4.6	0.05	4	310	3.8
20	**Soybean**	4	4.5	0.05	4	310	3.74
1	**Dry**	10	4.8	0.05	6	310	8.52
10	**Valcool**	7	4.6	0.05	6	310	12.2
19	**Soybean**	4	4.5	0.05	6	310	8.3

Table#14: Experimental data for constant Cutting Speed of 310 rpm.

Experiment	Oil	Tool	Work Piece diameter (in)	Depth of cut (in)	Feed Rate (in/min)	Cutting speed (rpm)	Surface Finish (µm)
6	**Dry**	9	4.8	0.05	4	420	2.06
15	**Valcool**	6	4.6	0.05	4	420	2.42
24	**Soybean**	3	4.5	0.05	4	420	2.62
5	**Dry**	9	4.8	0.05	6	420	4.86
14	**Valcool**	6	4.6	0.05	6	420	5.62
23	**Soybean**	3	4.5	0.05	6	420	4.6
4	**Dry**	9	4.8	0.05	8	420	11.24
13	**Valcool**	6	4.6	0.05	8	420	7.28
22	**Soybean**	3	4.5	0.05	8	420	10.34

Table#15: Experimental data for constant Cutting Speed of 420 rpm.

Experiment	Oil	Tool	Work Piece diameter (in)	Depth of cut (in)	Feed Rate (in/min)	Cutting speed (rpm)	Surface Finish (µm)
27	**Soybean**	2	4.5	0.05	6	510	3.18
18	**Valcool**	5	4.6	0.05	6	510	6.48
9	**Dry**	8	4.8	0.05	6	510	9.78
26	**Soybean**	2	4.5	0.05	8	510	6.44
17	**Valcool**	5	4.6	0.05	8	510	6.5
8	**Dry**	8	4.8	0.05	8	510	11.32
25	**Soybean**	2	4.5	0.05	10	510	8.64
16	**Valcool**	5	4.6	0.05	10	510	9.36
7	**Dry**	8	4.8	0.05	10	510	8.2

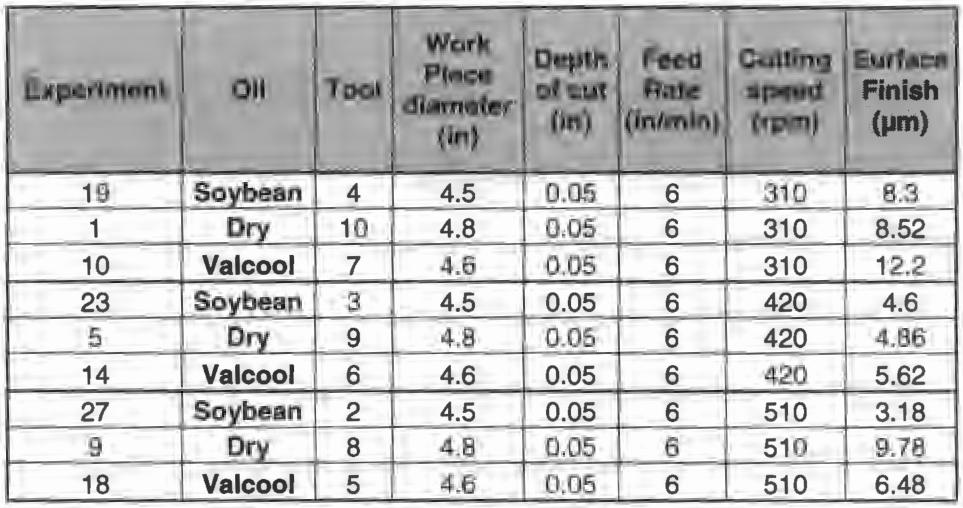
Table#16: Experimental data for constant Cutting Speed of 510 rpm.

Experiment	Oil	Tool	Work Piece diameter (in)	Depth of cut (in)	Feed Rate (in/min)	Cutting speed (rpm)	Surface Finish (µm)
3	**Dry**	10	4.8	0.05	3	310	2.22
12	**Valcool**	7	4.6	0.05	3	310	2.36
21	**Soybean**	4	4.5	0.05	3	310	3.28

Table#17: Experimental data for constant Feed Rate of 3 in/min

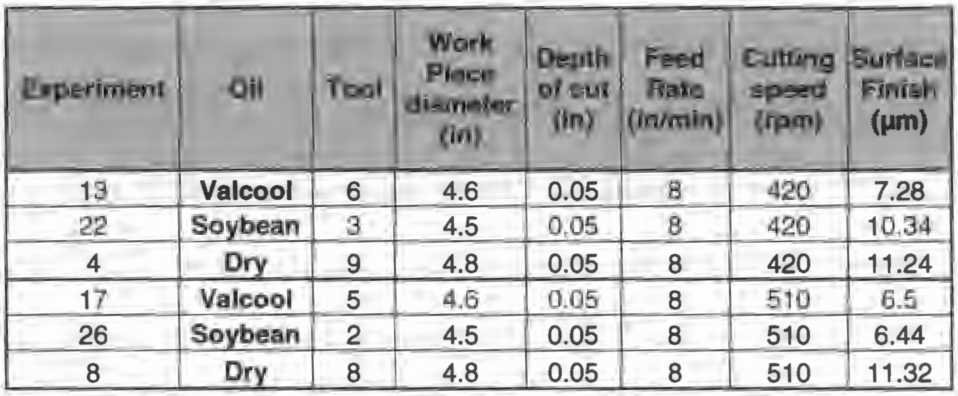
Experiment	Oil	Tool	Work Piece diameter (in)	Depth of cut (in)	Feed Rate (in/min)	Cutting speed (rpm)	Surface Finish (µm)
20	**Soybean**	4	4.5	0.05	4	310	3.74
11	**Valcool**	7	4.6	0.05	4	310	3.8
2	**Dry**	10	4.8	0.05	4	310	4.38
24	**Soybean**	3	4.5	0.05	4	420	2.62
15	**Valcool**	6	4.6	0.05	4	420	2.42
6	**Dry**	9	4.8	0.05	4	420	2.06

Table#18: Experimental data for constant Feed Rate of 4 in/min



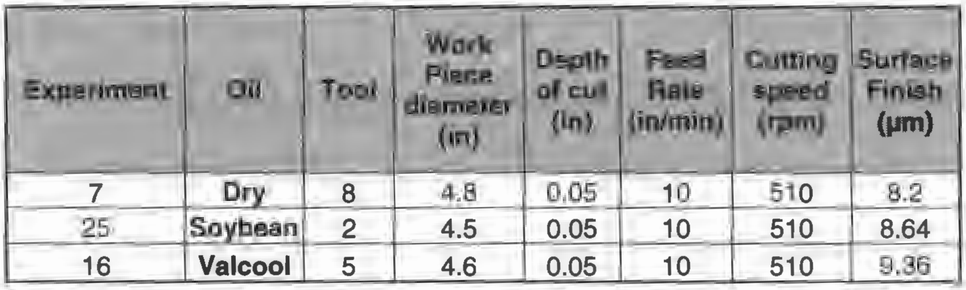
Experiment	Oil	Tool	Work Piece diameter (in)	Depth of cut (in)	Feed Rate (in/min)	Cutting speed (rpm)	Surface Finish (µm)
19	**Soybean**	4	4.5	0.05	6	310	8.3
1	**Dry**	10	4.8	0.05	6	310	8.52
10	**Valcool**	7	4.6	0.05	6	310	12.2
23	**Soybean**	3	4.5	0.05	6	420	4.6
5	**Dry**	9	4.8	0.05	6	420	4.86
14	**Valcool**	6	4.6	0.05	6	420	5.62
27	**Soybean**	2	4.5	0.05	6	510	3.18
9	**Dry**	8	4.8	0.05	6	510	9.78
18	**Valcool**	5	4.6	0.05	6	510	6.48

Table#19: Experimental data for constant Feed Rate of 6 in/min



Experiment	Oil	Tool	Work Piece diameter (in)	Depth of cut (in)	Feed Rate (in/min)	Cutting speed (rpm)	Surface Finish (µm)
13	**Valcool**	6	4.6	0.05	8	420	7.28
22	**Soybean**	3	4.5	0.05	8	420	10.34
4	**Dry**	9	4.8	0.05	8	420	11.24
17	**Valcool**	5	4.6	0.05	8	510	6.5
26	**Soybean**	2	4.5	0.05	8	510	6.44
8	**Dry**	8	4.8	0.05	8	510	11.32

Table#20: Experimental data for constant Feed Rate of 8 in/min



Experiment	Oil	Tool	Work Piece diameter (in)	Depth of cut (in)	Feed Rate (in/min)	Cutting speed (rpm)	Surface Finish (µm)
7	**Dry**	8	4.8	0.05	10	510	8.2
25	**Soybean**	2	4.5	0.05	10	510	8.64
16	**Valcool**	5	4.6	0.05	10	510	9.36

Table#21: Experimental data for constant Feed Rate of 10 in/min

CHAPTER V

DISCUSSION, CONCLUSIONS, AND RECOMENDATIONS

Discussion

At the beginning of the fourth chapter the data analysis started by applying the F test to the surface finish results to determine if there is a case of equal means. From the results shown in tables #6, 7, and 8 the f values are not greater than the f critical. Therefore it is possible to assume that the model has equal variances. After obtaining this result, an ANOVA test was applied in order to know that the three groups or treatments have an equal mean. The ANOVA was performed at 95% and 99% of confidence. The results obtained after the analysis shown in table #10, there is not enough statically evidence to support that the means of the results of the surface finish are different. In addition, the P value of 0.71 suggests that this analysis may not be statistically significant.

For that reason, a comparison of the surface finish values obtained from the use of Valcool and Soybean oil using a t-student test for two means in order to determine if the means of these two groups are equal. The results of the t-test showed in table #11 show that none of the statistical calculated t-values are greater than the t-critical. It suggests that there is not enough evidence to reject the null hypothesis. From the regression analysis to the surface finish showed in table #12 of the soybean oil treatment the results shown that the feed rate (FR) and cutting speed (CS) variables are statistically significant to the surface finish. And also that cutting speed has an inverse relationship to the model. Another approach could be the analysis of the histograms obtained from arranging the data into tables that consider one of these two factors (feed rate and cutting speed) constant.

From tables # 13 through 20, the data is grouped by making one of the two independent variables (feed rate and cutting speed) constant. Histograms were obtained out of these tables (Appendix C). These figures show the influence that these two variables have in the surface finish. The graphics show something interesting. With cutting speed constant at 310 rpm (table #13, figure #1), it shows that the best performance for the soybean oil is at the feed rate of 3 in/min. Then, at 420 rpm (table #14, figure #2), the best performance for soybean oil is for a feed rate of 4 in/min. And finally for 510 rpm (table #15, figure #3), the best performance is shown at 6 in/min and 8 in/min. also it is possible to observe that the soybean oil treatment has a better performance than the dry turning in almost in all of the figures.

When the feed rate is constant at 3 in/min (table #16, figure #4), the cutting sped is also constant for this figure, it shows that the best performance is for the dry turning. Then, with feed rate at 4 in/min (table #17, figure #5) the best performance of the soybean oil is at the cutting speed of 310 rpm. Then, at a feed rate of 6 in/min (table #18, figure #6) soybean oil has the best performance at 310 rpm, 420 rpm, and 510 rpm. With the feed rate at 8 in/min (table #19, figure #7) the best performance for soybean oil is at 510 rpm. And finally, at 10 in/min (table #20, figure #8) the soybean oil is better than the dry turning. From this analysis it is possible to observe that the performance of the cutting fluid varies when the factor such cutting speed and feed rate vary.

Conclusions

The results of this study show that there is not enough evidence to reject the null hypothesis one H_{01}, that say: “there are no significant differences between types of treatment (dry machining, Valcool oil, and soybean oil) on the dependent variable (surface finish) due to the effects of the use of type of oil”. Consequently the results suggest that the use of Soybean oil would not have a different effect in the surface finish than the use of Valcool oil, the conclusion draw from this is that: Soybean oil could be used as a substitute for Valcool oil in turning operations. The advantages of such a substitution will be that it would be possible to help our environment because of the renewability of vegetable oils and the relative safety of human exposure to the oils and their fumes. Another conclusion would be there is not enough evidence to reject the null hypothesis 2, H_{02} that say: “there are no strong relationships between the independent variables (cutting speed and feed rate) and the dependent variable (surface finish) for turning operations. This result suggests that cutting speed and feed rate have a significant impact on the surface finish results.

Recommendations

It is possible to recommend for further research:

1. A replication of the experiment should be done collecting a bigger sample in order to obtain more accurate results.
2. Also the effects on the surface finish of another variable that should be studied is the chip thickness.
3. A further research in order to investigate how the use of these types of oils will affect the cutting tool life.

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APPENDIX A

F tables

F Table for alpha=0.05

df2/df1	1	2	3	4	5	6	7	8	9	10	12	15	INF
1	161.4476	199.5000	215.7073	224.5832	230.1619	233.9860	236.7684	238.8827	240.5433	241.8817	243.9060	245.9499	254.3144
2	18.5128	19.0000	19.1643	19.2468	19.2964	19.3295	19.3532	19.3710	19.3848	19.3959	19.4125	19.4291	19.4957
3	10.1280	9.5521	9.2766	9.1172	9.0135	8.9406	8.8867	8.8452	8.8123	8.7855	8.7446	8.7029	8.5264
4	7.7086	6.9443	6.5914	6.3882	6.2561	6.1631	6.0942	6.0410	5.9988	5.9644	5.9117	5.8578	5.6281
5	6.6079	5.7861	5.4095	5.1922	5.0503	4.9503	4.8759	4.8183	4.7725	4.7351	4.6777	4.6188	4.3650
6	5.9874	5.1433	4.7571	4.5337	4.3874	4.2839	4.2067	4.1468	4.0990	4.0600	3.9999	3.9381	3.6689
7	5.5914	4.7374	4.3468	4.1203	3.9715	3.8660	3.7870	3.7257	3.6767	3.6365	3.5747	3.5107	3.2298
8	5.3177	4.4590	4.0662	3.8379	3.6875	3.5806	3.5005	3.4381	3.3881	3.3472	3.2839	3.2184	2.9276
9	5.1174	4.2565	3.8625	3.6331	3.4817	3.3738	3.2927	3.2296	3.1789	3.1373	3.0729	3.0061	2.7067
10	4.9646	4.1028	3.7083	3.4780	3.3258	3.2172	3.1355	3.0717	3.0204	2.9782	2.9130	2.8450	2.5379
11	4.8443	3.9823	3.5874	3.3567	3.2039	3.0946	3.0123	2.9480	2.8962	2.8536	2.7876	2.7186	2.4045
12	4.7472	3.8853	3.4903	3.2592	3.1059	2.9961	2.9134	2.8486	2.7964	2.7534	2.6866	2.6169	2.2962
13	4.6672	3.8056	3.4105	3.1791	3.0254	2.9153	2.8321	2.7669	2.7144	2.6710	2.6037	2.5331	2.2064
14	4.6001	3.7389	3.3439	3.1122	2.9582	2.8477	2.7642	2.6987	2.6458	2.6022	2.5342	2.4630	2.1307
15	4.5431	3.6823	3.2874	3.0556	2.9013	2.7905	2.7066	2.6408	2.5876	2.5437	2.4753	2.4034	2.0658
16	4.4940	3.6337	3.2389	3.0069	2.8524	2.7413	2.6572	2.5911	2.5377	2.4935	2.4247	2.3522	2.0096
17	4.4513	3.5915	3.1968	2.9647	2.8100	2.6987	2.6143	2.5480	2.4943	2.4499	2.3807	2.3077	1.9604

F Table for alpha=0.01

df2/df1	1	2	3	4	5	6	7	8	9	10	12	15	INF
1	39.86346	49.50000	53.59324	55.83296	57.24008	58.20442	58.90595	59.43898	59.85759	60.19498	60.70521	61.22034	63.32812
2	8.52632	9.00000	9.16179	9.24342	9.29263	9.32553	9.34908	9.36677	9.38054	9.39157	9.40813	9.42471	9.49122
3	5.53832	5.46238	5.39077	5.34264	5.30916	5.28473	5.26619	5.25167	5.24000	5.23041	5.21562	5.20031	5.13370
4	4.54477	4.32456	4.19086	4.10725	4.05058	4.00975	3.97897	3.95494	3.93567	3.91988	3.89553	3.87036	3.76073
5	4.06042	3.77972	3.61948	3.52020	3.45298	3.40451	3.36790	3.33928	3.31628	3.29740	3.26824	3.23801	3.10500
6	3.77595	3.46330	3.28876	3.18076	3.10751	3.05455	3.01446	2.98304	2.95774	2.93693	2.90472	2.87122	2.72216
7	3.58943	3.25744	3.07407	2.96053	2.88334	2.82739	2.78493	2.75158	2.72468	2.70251	2.66811	2.63223	2.47079
8	3.45792	3.11312	2.92380	2.80643	2.72645	2.66833	2.62413	2.58935	2.56124	2.53804	2.50196	2.46422	2.29257
9	3.36030	3.00645	2.81286	2.69268	2.61061	2.55086	2.50531	2.46941	2.44034	2.41632	2.37888	2.33962	2.15923
10	3.28502	2.92447	2.72767	2.60534	2.52164	2.46058	2.41397	2.37715	2.34731	2.32260	2.28405	2.24351	2.05542
11	3.22520	2.85951	2.66023	2.53619	2.45118	2.38907	2.34157	2.30400	2.27350	2.24823	2.20873	2.16709	1.97211
12	3.17655	2.80680	2.60552	2.48010	2.39402	2.33102	2.28278	2.24457	2.21352	2.18776	2.14744	2.10485	1.90361
13	3.13621	2.76317	2.56027	2.43371	2.34672	2.28298	2.23410	2.19535	2.16382	2.13763	2.09659	2.05316	1.84620
14	3.10221	2.72647	2.52222	2.39469	2.30694	2.24256	2.19313	2.15390	2.12195	2.09540	2.05371	2.00953	1.79728
15	3.07319	2.69517	2.48979	2.36143	2.27302	2.20808	2.15818	2.11853	2.08621	2.05932	2.01707	1.97222	1.75505
16	3.04811	2.66817	2.46181	2.33274	2.24376	2.17833	2.12800	2.08798	2.05533	2.02815	1.98539	1.93992	1.71817
17	3.02623	2.64464	2.43743	2.30775	2.21825	2.15239	2.10169	2.06134	2.02839	2.00094	1.95772	1.91169	1.68564
20	2.97465	2.58925	2.38009	2.24893	2.15823	2.09132	2.03970	1.99853	1.96485	1.93674	1.89236	1.84494	1.60738

APPENDIX B

T values

Table of Critical Values for T

	0.2	**0.1**	**0.05**	**0.01**	**0.005**	**0.001**
2	1.89	2.92	4.30	9.92	14.09	31.60
3	1.64	2.35	3.18	5.84	7.45	12.92
4	1.53	2.13	2.78	4.60	5.60	8.61
5	1.48	2.02	2.57	4.03	4.77	6.87
6	1.44	1.94	2.45	3.71	4.32	5.96
7	1.41	1.89	2.36	3.50	4.03	5.41
8	1.40	1.86	2.31	3.36	3.83	5.04
9	1.38	1.83	2.26	3.25	3.69	4.78
10	1.37	1.81	2.23	3.17	3.58	4.59
11	1.36	1.80	2.20	3.11	3.50	4.44
12	1.36	1.78	2.18	3.05	3.43	4.32
13	1.35	1.77	2.16	3.01	3.37	4.22
14	1.35	1.76	2.14	2.98	3.33	4.14
15	1.34	1.75	2.13	2.95	3.29	4.07
16	1.34	1.75	2.12	2.92	3.25	4.01
17	1.33	1.74	2.11	2.90	3.22	3.97
18	1.33	1.73	2.10	2.88	3.20	3.92
19	1.33	1.73	2.09	2.86	3.17	3.88
20	1.33	1.72	2.09	2.85	3.15	3.85
21	1.32	1.72	2.08	2.83	3.14	3.82
22	1.32	1.72	2.07	2.82	3.12	3.79
23	1.32	1.71	2.07	2.81	3.10	3.77
24	1.32	1.71	2.06	2.80	3.09	3.75

APPENDIX C

Figures

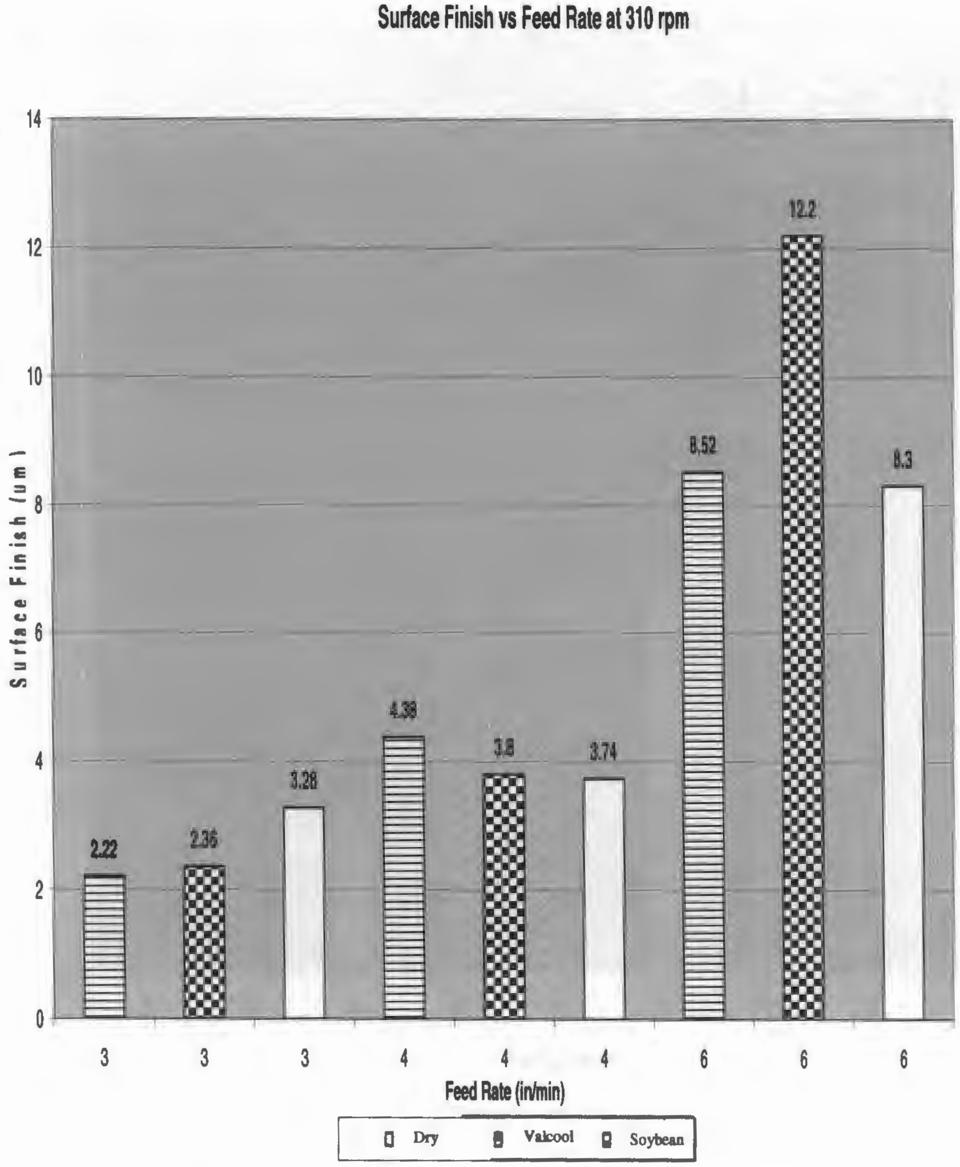

Figure #1: Surface Finish vs. Feed Rate at 310 rpm

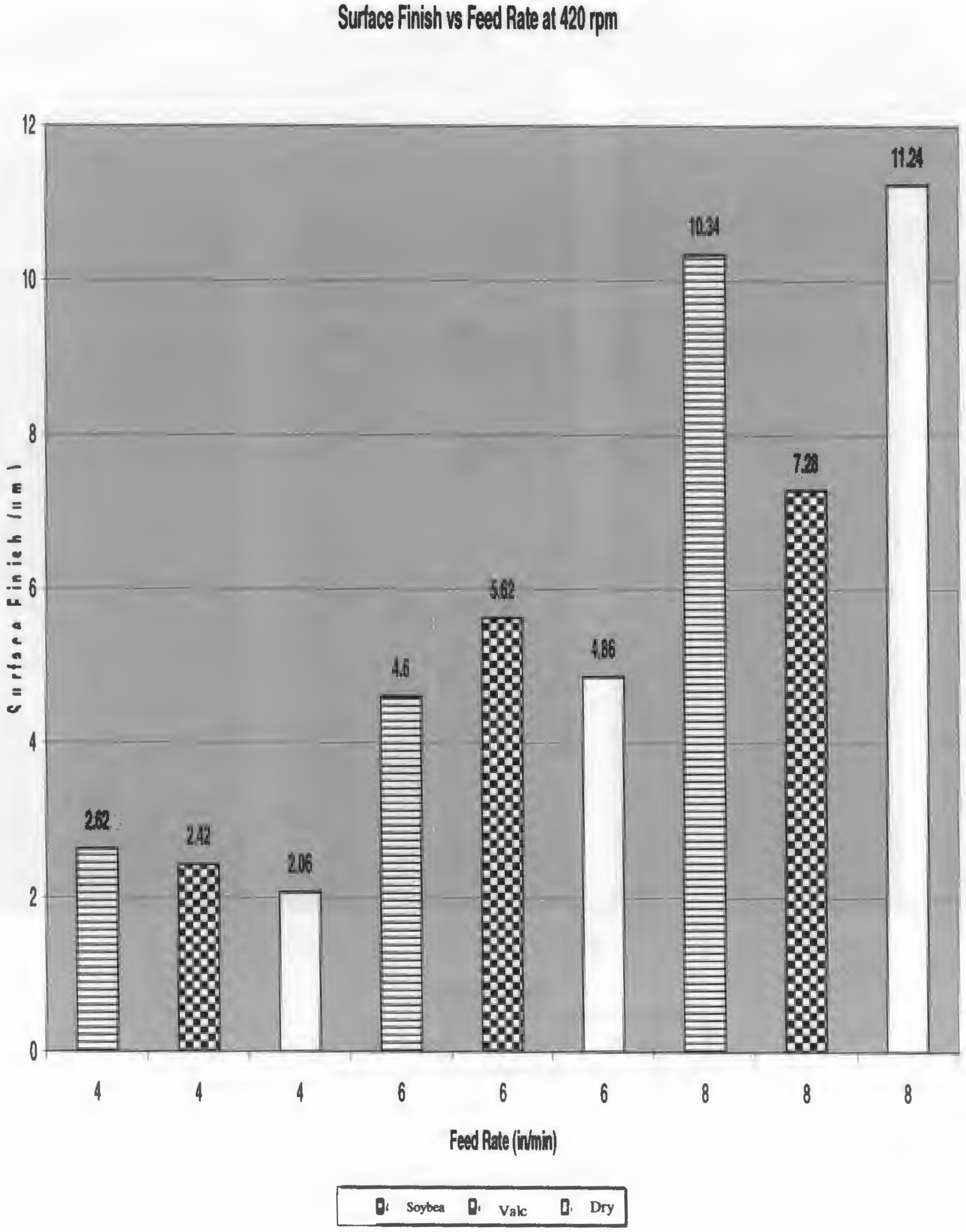

Figure #2: Surface Finish vs. Feed Rate at 420 rpm

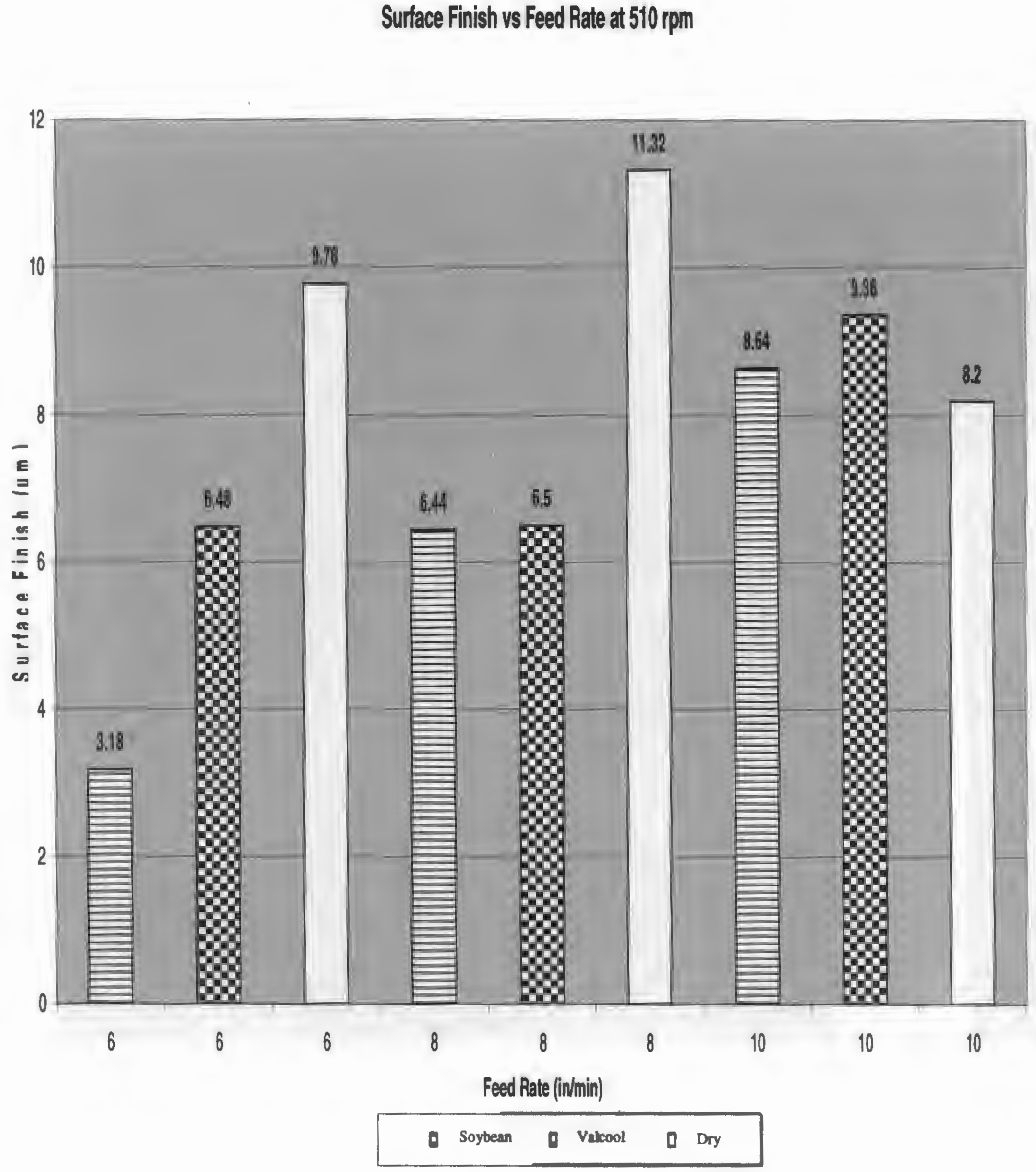

Figure #3: Surface Finish vs. Feed Rate at 510 rpm

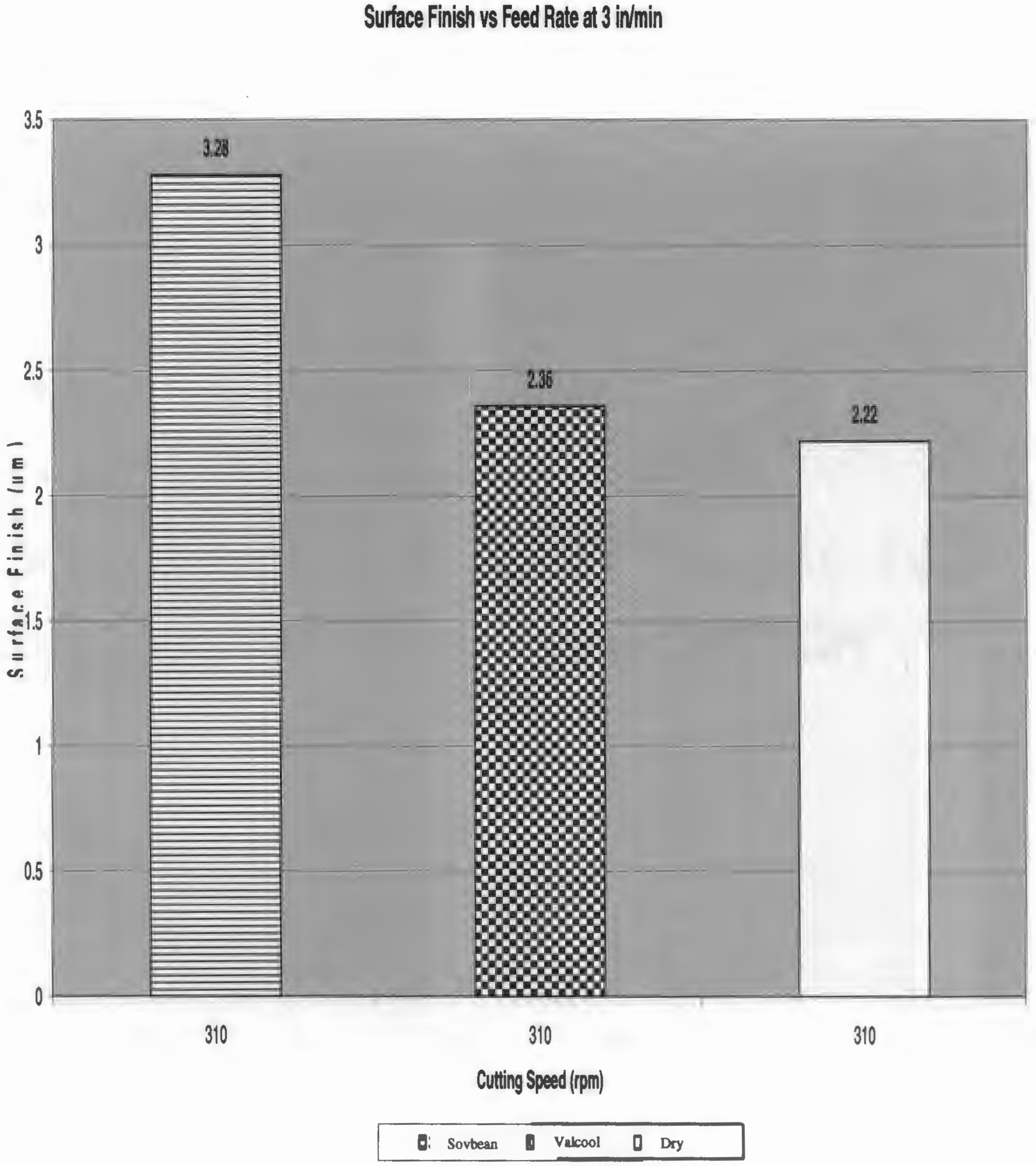

Figure #4: Surface Finish vs. Cutting Speed at 3 in/min

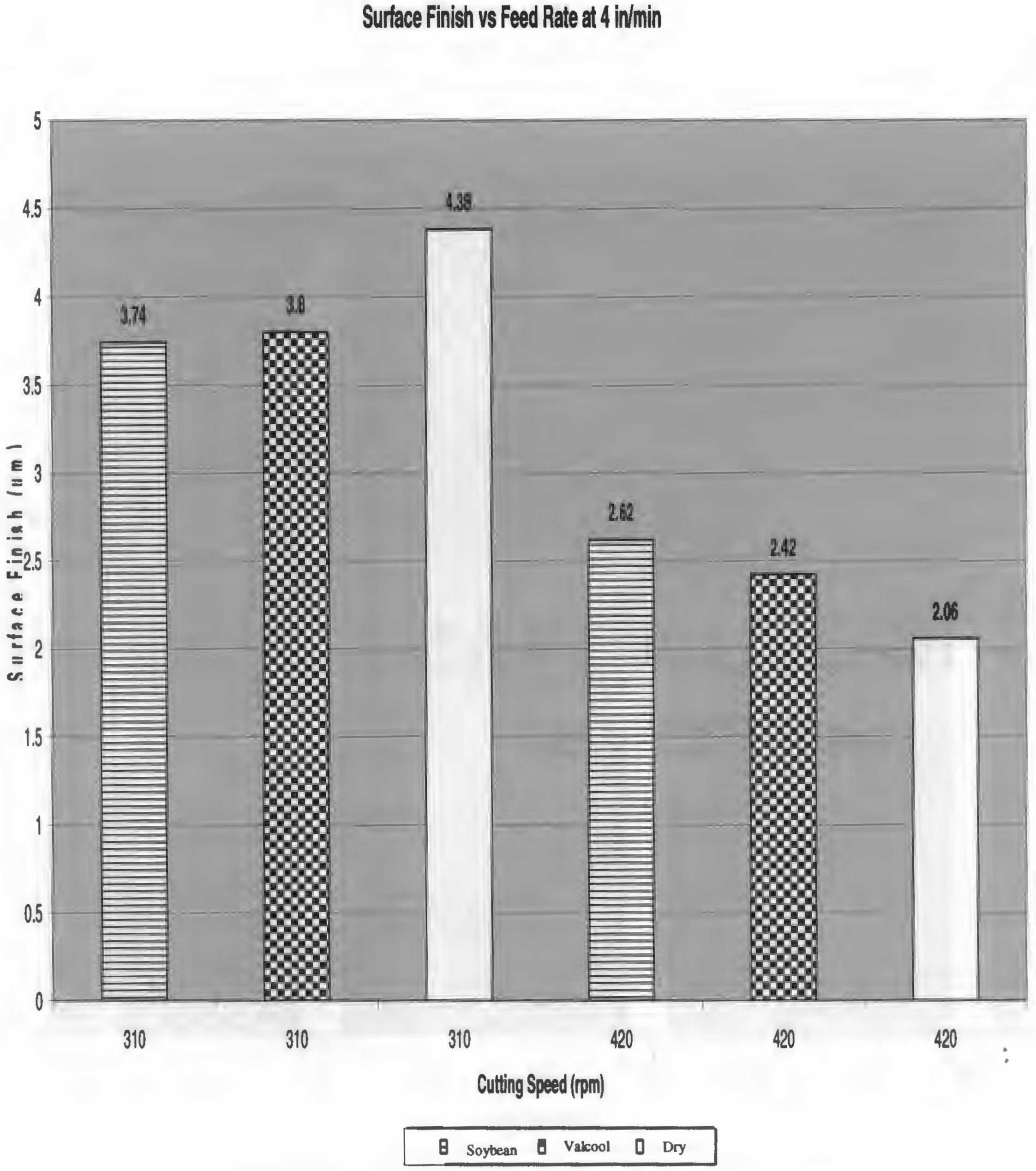

Figure #5: Surface Finish vs. Cutting Speed at 4 in/min

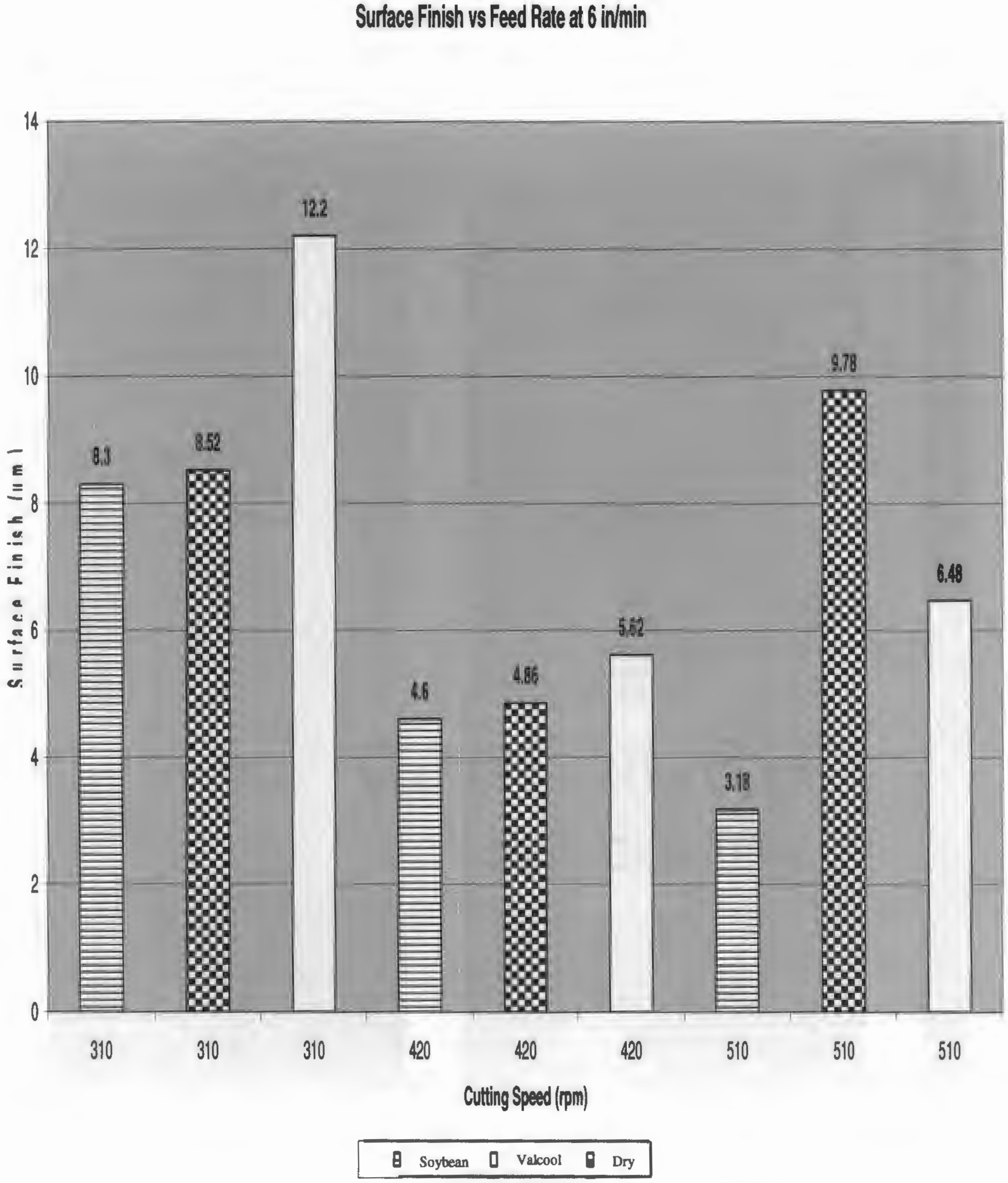

Figure #6: Surface Finish vs. Cutting Speed at 6 in/min

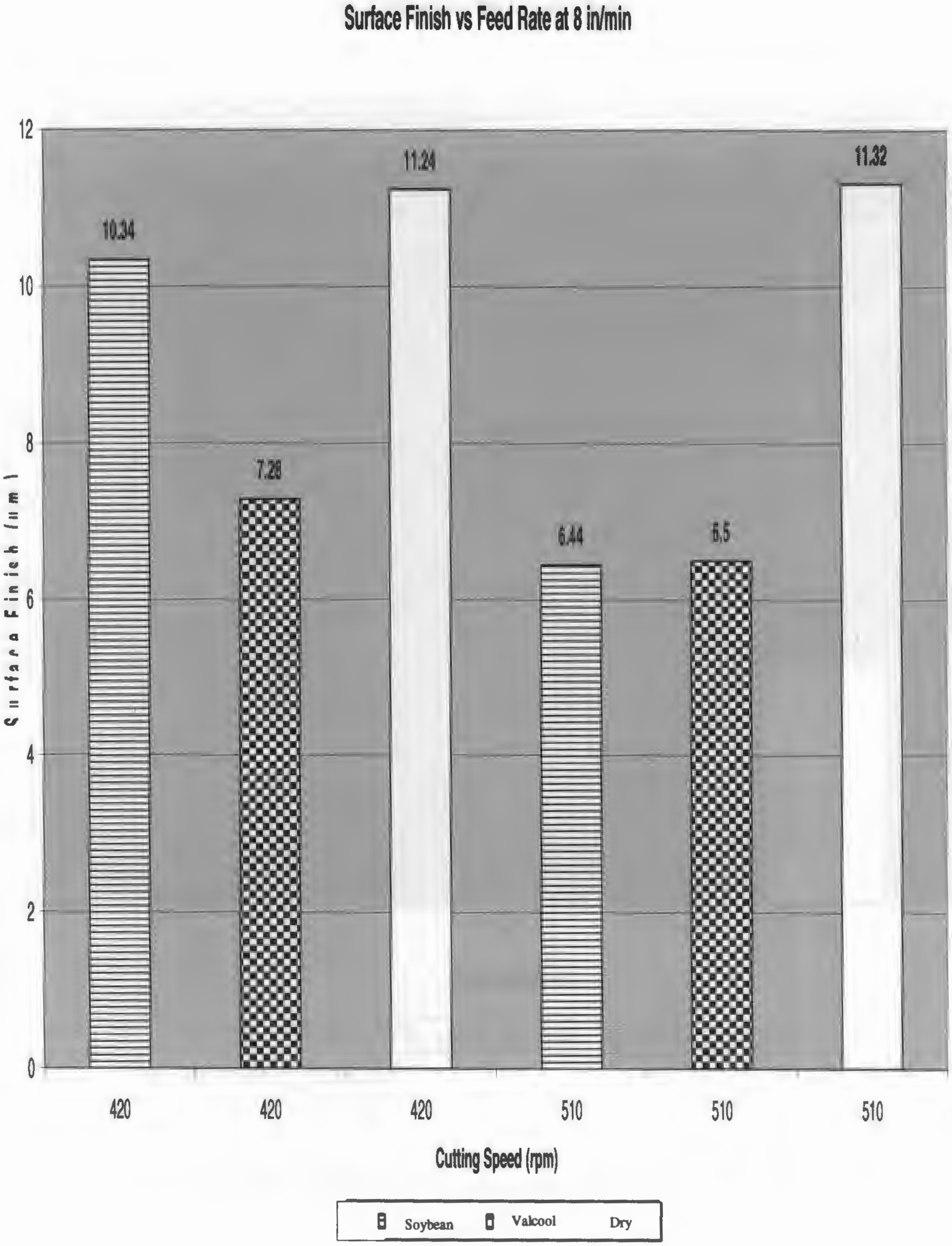

Figure #7: Surface Finish vs. Cutting Speed at 8 in/min

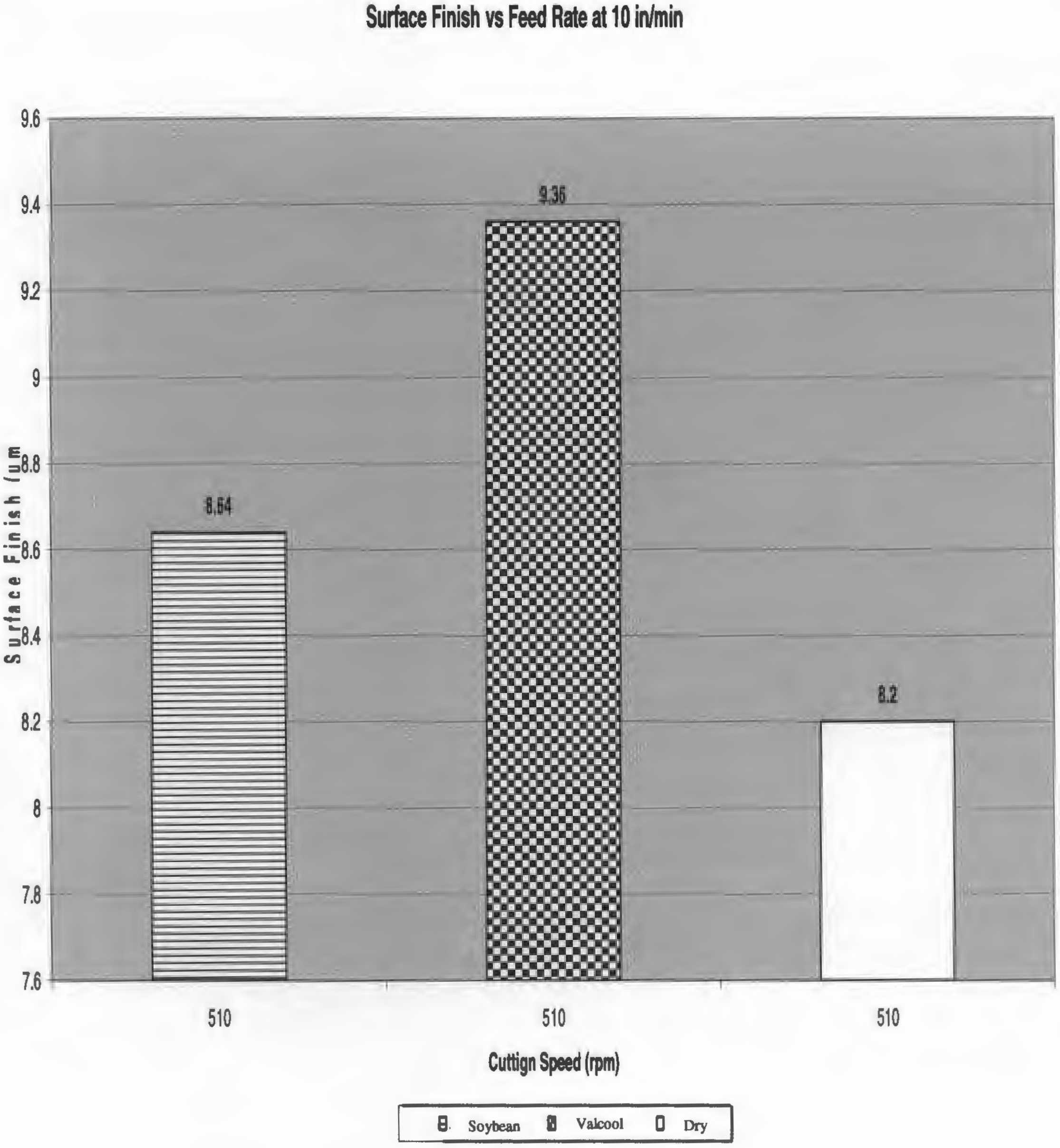

Figure #8: Surface Finish vs. Cutting Speed at 10 in/min