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STUDY OF A BENCH MILLING MACHINE REFRIGERATION SYSTEM FOR LABORATORY ENVIRONMENT

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Abstract. *Cutting fluid is a feature that can offer benefits for machining, such as increased useful life of the cutting tools, better surface and dimensional qualities, and the ability to machine at higher speeds that reduce working time. The selection of cutting fluid involves, among other factors, the machining process, material to be machined, tools used and maintenance conditions related to the working environment. In order to provide better conditions for the use of an academic mechanical machining laboratory, this paper presents the proposal of a refrigeration system for a drilling / milling machine, in which the application of the cutting fluid has the minimum operator intervention. For this purpose, the foremost cutting fluid varieties were studied in terms of applicability and maintenance, their application techniques and basic concepts for the design of hydraulic reservoirs. The methodology of the study was characterized by an experimental research for application purposes, in which the system was built with the minimum of possible resources. As a result, the system achieved the proposed goal, however, due to resource conditions and adaptation in a machine not designed to receive such a system, some shortcomings were pointed out for future optimizations.*

Keywords: *Cutting fluid, Milling machine, Refrigeration system.*

1. INTRODUCTION

Machining processes consists of a manufacturing system in which the raw material becomes a finished product by material removal. Its study is based on mechanics (friction and deformation), thermodynamics (heat) and properties of materials. In the case of manufacturing systems, any attempt to improve productivity or reduce costs should be considered. In machining at conventional cutting speed or at high speed the use of cutting fluid is an option and when properly chosen and applied it brings a lot of benefits (Iceri *et al*., 2012).

Liquid fluids can be classified as: integral, emulsion, synthetic and semisynthetic in which the ideal choice involves factors such as the type of operation and the material to be machined. More versatile fluids have been produced in recent years, which can be applied in different types of operations, incorporating different dilution rates (Gonçalves *et al*., 2010; Fernandes, 2007).

Cutting fluids are profitable to machining, however, their application and reuse involve costs, such as: tanks, pumps, special machines to pressurize the system and treat the oil and constant replacement of fluid due to the drag in the machined part. The work environment becomes unhealthy due to operator exposure to the chemical components. Complications arise that should be monitored and mapped as: fire risk due to large quantities stored near the machine and end-of-life oil disposal through specialized companies (Dhar *et al*., 2006). To meet the demand and quality of machining, the machine tools are equipped with cooling systems that guarantee the constant application of the cutting fluid. As a competitive form of operation, the machine must present high technical performance with economic efficiency. According to Micaroni (2006), the Makino machine manufacturer states that most of the machining centers marketed come with conventional cooling system.

A conventional cooling system is characterized by the application of low-pressure (or abundance) jet stream, whose flow rate generally ranges from 300 to 4000 ml/min (Lisboa *et al.*, 2013). It need to present elements that store, filter and induce fluid flow. These should be designed for satisfactory operation of the system, avoiding insufficient flow, contamination and flow restriction. The maximum reuse of the cutting fluid is fundamental for factory operations.

Therefore, the objective of this work was to design, manufacture and validate a conventional refrigeration system with only easily accessible inputs in the market for a bench milling machine located in laboratory of a university, developing a system that guarantees the applicability of the constant and adjustable cutting fluid with minimal intervention of the operator and providing improvements in the conditions of use.

The practical classes are performed with application of the cutting fluid with direct intervention by students. Because most of the operators have little or no experience, the risk of accidents during these practices becomes greater. According to Stoeterau (2004), accessibility and arrangement of the various constituents of machine tools should be arranged in such a way that the set-up and control operations are done safely and with the least intervention possible. The oiler handling promotes a variable flow rate that, in tribological terms, changes the area of part/tool contact, presenting abnormal variations of roughness and unreliable results regarding the machining with application of the cutting fluid.

2. EXPERIMENTAL PROCEDURES

In this project was presented an experimental method for application purposes. The theoretical basis and the information obtained in the mechanical environment allowed the construction of a prototype that after its validation, would meet the proposed objective.

The SolidWorks 2013 program was used for 3D modeling of components and refrigeration system assembly. The reservoir modeling, the selection of the filter elements and its location in the system as well as the components construction of the cooling system were based on the industrial hydraulic technology handbook (Hannifin, 1999) and previous works (Fialho, 2004; CIMM, 2010; Renner, 2010).

2.1 The milling machine and its tools

The present work consider a drilling machine/bench milling machine of the brand Manrod, model ZX-40 / PC MR-205. In order to adapt the cooling system, the best reservoir positioning location that minimized the operator's work area was analyzed. The fixation at the lower back of the machine was then suggested, as shown in Fig. 1.

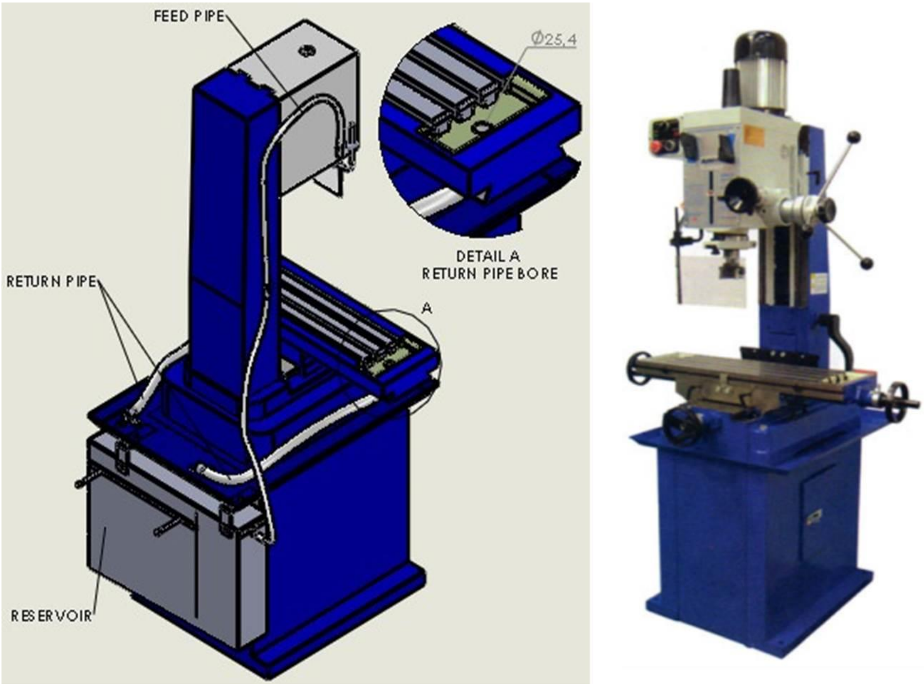

Figure 1. Refrigeration system mounting and Manrod ZX-40/PC MR-205 milling machine 3D model.

2.2 Refrigeration system features

The reservoir modeling followed the maximum possible references, limiting to the resource conditions of the project. It is an 18 liters, non-pressurized tank with drain bolt and a vertical baffle that secures the pump. The bottom has a slope to direct the waste to near the drain. The cap keeps fluid insulated from external medium to reduce potential contamination. When the system is used the- operator must remove it to allow the fluid return that will drain from the return hoses connected to the milling machine table. Figure 2 shows the proposed reservoir.

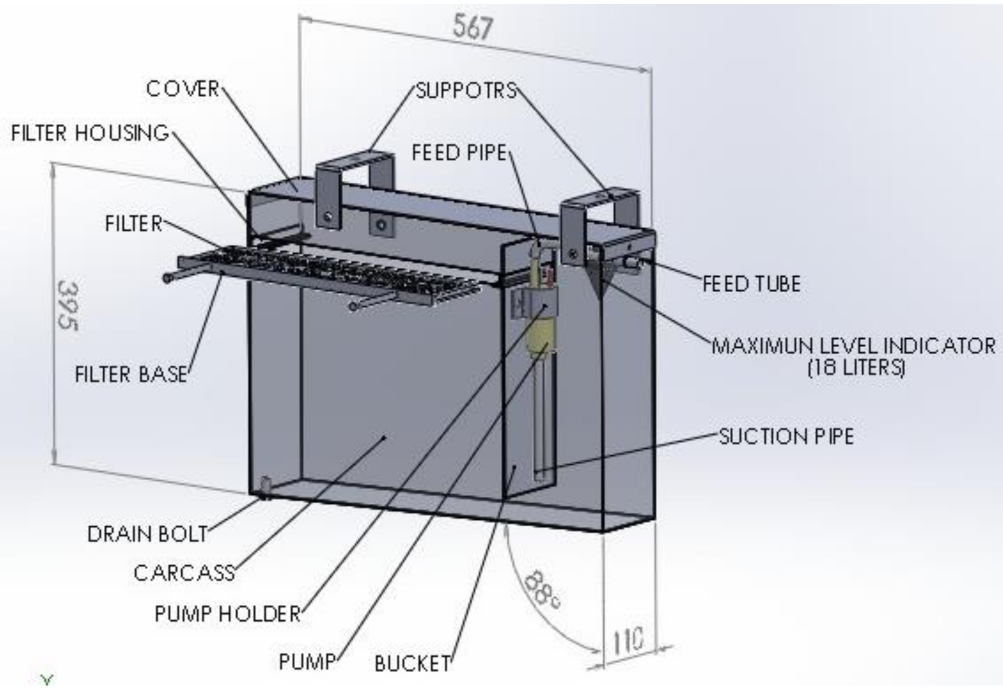

Figure 2. Refrigeration system reservoir

The system filter fixed in the reservoir is a 30 x 14 galvanized mesh (0.30 mm wire diameter and 1.4 mm mesh opening) acting on the fluid return. The filter option on the return line proved to be more appropriate due to the ease of installation, simplicity of construction and maintenance. In addition, the mesh can be reusable, with periodic cleanings. Through the handles the operator can remove and insert a similar filter to the handling of a drawer.

An electric automotive pump was applied (model GM06443268/VCH032, 2.5 kgf/cm^2 and 1.9 l/min). The pump choice was performed by consultations in the Bosch 2014/2015 automotive electric pump catalog. The option of a standard application pump, in addition to meeting project conditions, provided positive points of ease of maintenance / replacement and costs. The system pressure reference value was determined through an application developed in Excel with the following input data: specific mass, dynamic viscosity and fluid flow, system reference point's height, roughness, total length, diameter and accessories of the pipe system. The distance of the reference points and total length of the pipe (suction and settling) were measured in 3D model. The water was taken as the fluid, with a mean flow rate of 1.7 l/min (0.03 l/s), referring to the values presented in the catalog and the pipe diameter of 12.7 mm. As a result the application presented a pressure range of approximately 0.15 kgf/cm², which is satisfactory for those presented in the catalog (1 to 3 kgf/cm²). Thus, according to the pressure criterion, the selected pump would serve the system, characterizing the application of the cutting fluid by the jet method at low pressure. Figure 3 demonstrates the application interface used.

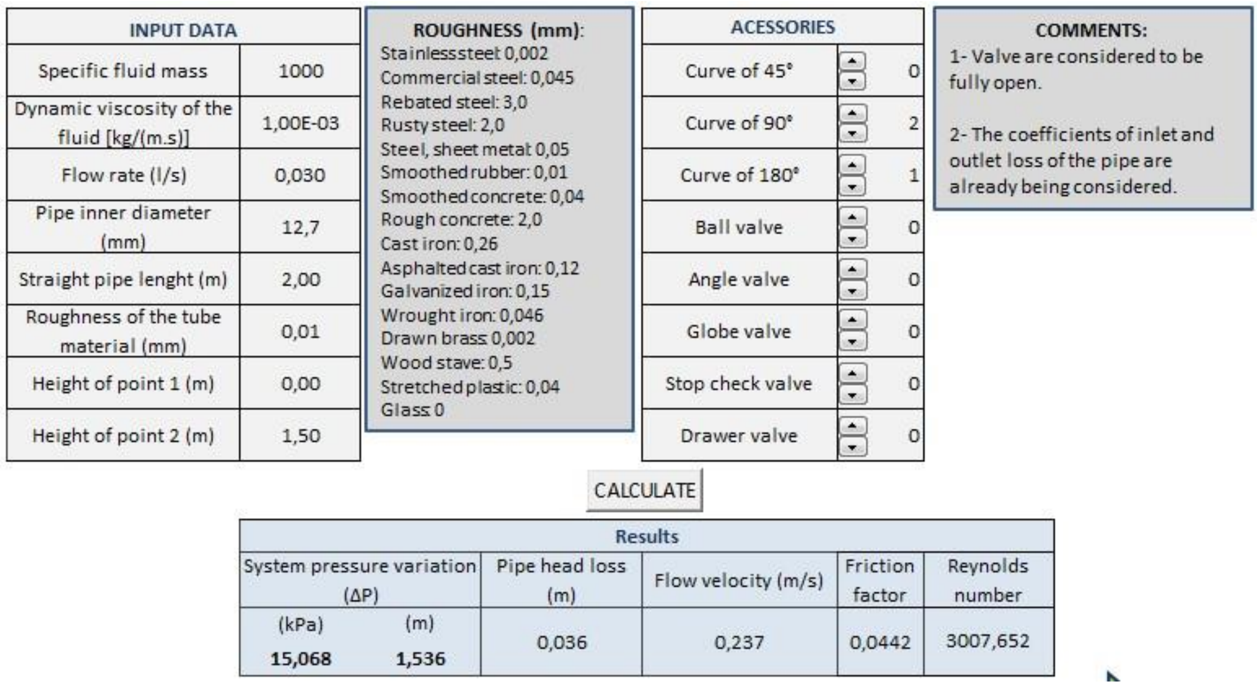

Figure 3. Application interface – System pressure range

An electric transformer of 200 watts, 110/220 to 12 volts was added and a PWM (Pulse Width Modulation) controller to adjust the pump power. The operator can activate the refrigeration system by means of a button independently of the milling machine operation.

The pipe network system consisted of transparent flexible elements that did not interfere with the advances of the table and allow the visualization of the fluid flow. Near the tool holder a flexible pipe of 19.05 mm external thread and 300 mm in length enables fluid projection adjustment. For return, at each end of the table was secured a flexible to conduct the contaminated fluid to the reservoir. The Figure 4 illustrates the simulation of the advance movements of the milling machine with the flexible fixing and the flexible articulation used.

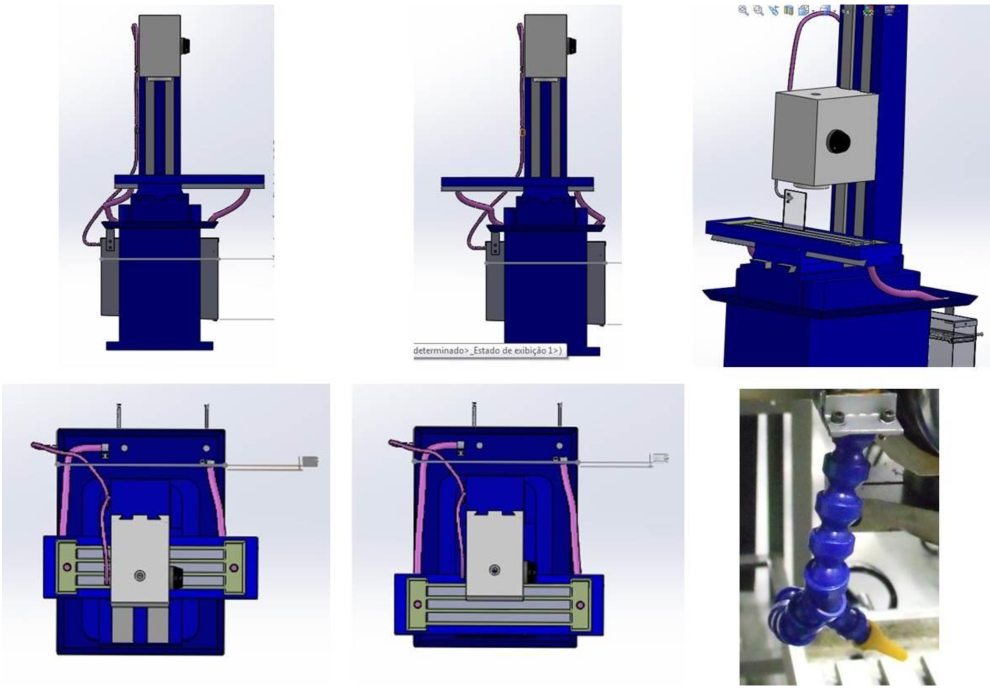

Figure 4. Cooling system and guide pipe

The soluble semisynthetic oil ME-I Quimatic was applied with a ratio of 19 to 1 (water to oil) recommended by the manufacturer for general applications and for all types of metals. The choice of this soluble oil was due to the availability (provided by college), which consequently supported the reduction of the project expenses, besides presenting satisfactory characteristics, according to Tab. 1 (Gonçalves *et al*., 2010).

Table 1. Parallel between cutting fluids.

Features	Synthetic	Semisynthetic	Emulsion	Mineral oil
Heat dissipation	Excellent	Great	Good	Bad
Lubrification	Bad	Good	Great	Excellent
Maintenance	Great	Good	Bad	Excellent
Filterability	Excellent	Great	Good	Bad
Environment	Excellent	Great	Good	Bad
Expenses	Excellent	Great	Good	Bad

2.3 System validation

For the validation of the system two tests were performed: (1) operation and (2) application in machining process, milling an aluminum hub at 520 rpm, cutting depth of 0.5 mm with a planetary cutter of 90 mm of diameter. The main objectives were to verify the presence of leaks and to observe the flow behavior of the spout, recirculation and filter of the system. Through the PWM the pump flow rate was adjusted so that the fluid was not spread excessively, which would result in too much waste and splash in the working environment. In addition, the return flow should be the best possible as the high restriction would cause a rapid emptying of the reservoir, drastically reducing the operating time of the system.

3. RESULTS

3.1 Refrigeration system construction

A guide for the refrigeration system construction was developed to avoid reworking and additional material expenses. Much of this construction was carried out at the academic institution where the machine was located, using the welding and machining laboratories with all its available tools.

The construction of the system was initiated by metal bending, cuts, welding and preparation for the reservoir painting, followed by the construction of the filter and the supports attached of the reservoir to the machine. Figure 5 shows the reservoir mounted on the milling machine.

Figure 5. Coupled reservoir in milling machine

The first changes made in milling machine was the return holes build to table, in which these ones were fixed by interference, how evidenced by Fig. 6.

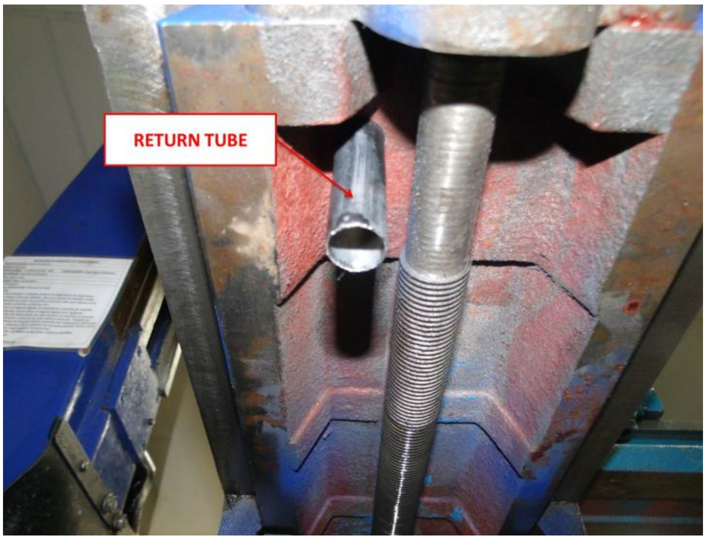

Figure 6. Return pipe fixed under the table

In order to prevent the damaging from longitudinal course over these pipes, a new position limiter (Fig. 7) had to be adapted, resulting in a loss of 150 mm of this length. However, because it is an academic application machine, this loss was not harmful.

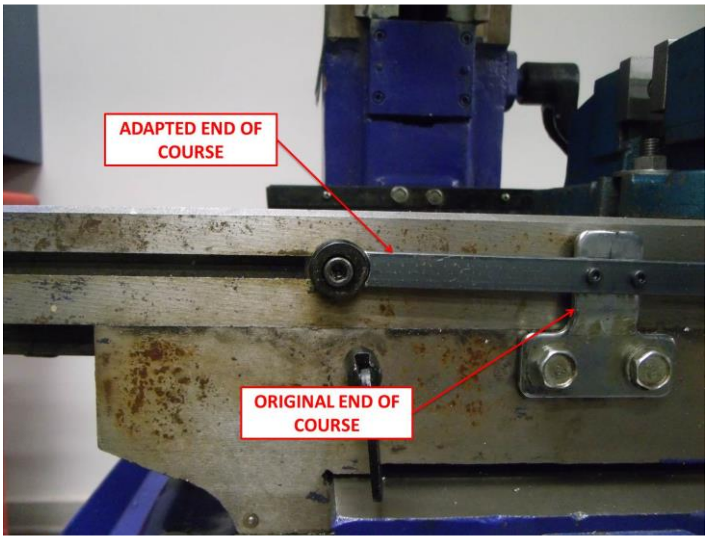

Figure 7. Position limiter applied beside the table

After the final changes the system pipes were installed with flexible transparent crystal rubber in the feed and return lines with 12.7 mm and 15.87 mm of diameter, respectively (Fig. 8).

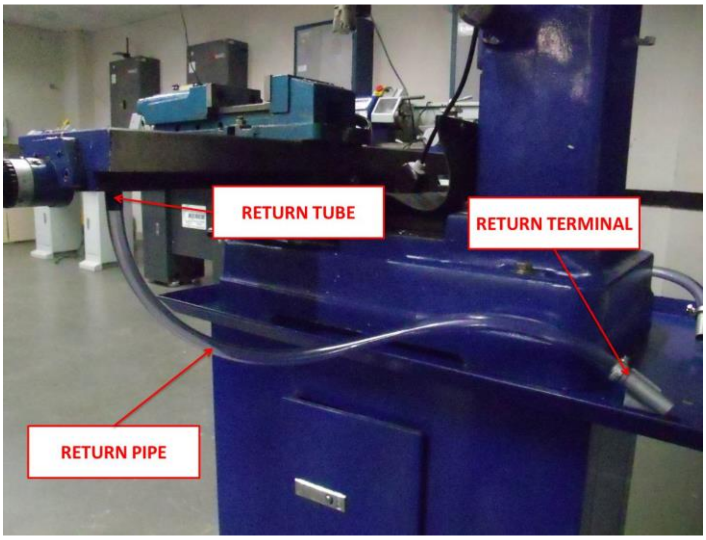

Figure 8. Flexible return pipe located in milling machine

The electric transformer and the pump control system were attached to the electric panel of the machine tool to make the operator access easier (Fig. 9). The control system formed by the PWM, the power switch and the auxiliary 12 volt relay for the communication of the low and high current circuits were inserted in a small box. A 10 amp fuse has been added for system protection.

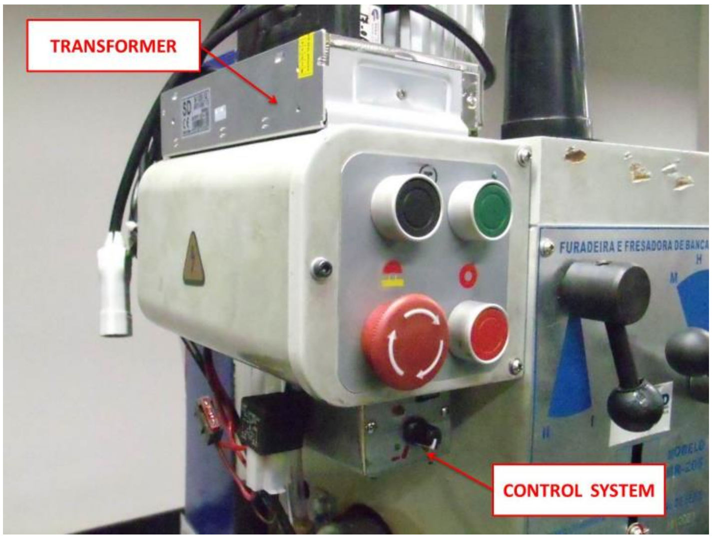

Figure 9. Electric transformer mounting and pump control system

To avoid corrosion and possible contamination, all components in contact with the fluid were coated with Hammerite synthetic enamel sprayed and diluted in the recommended proportion by the manufacturer (75% enamel and 15% of turpentine). After drying, the components were reassembled, completing the installation of the refrigeration system (Fig. 10).

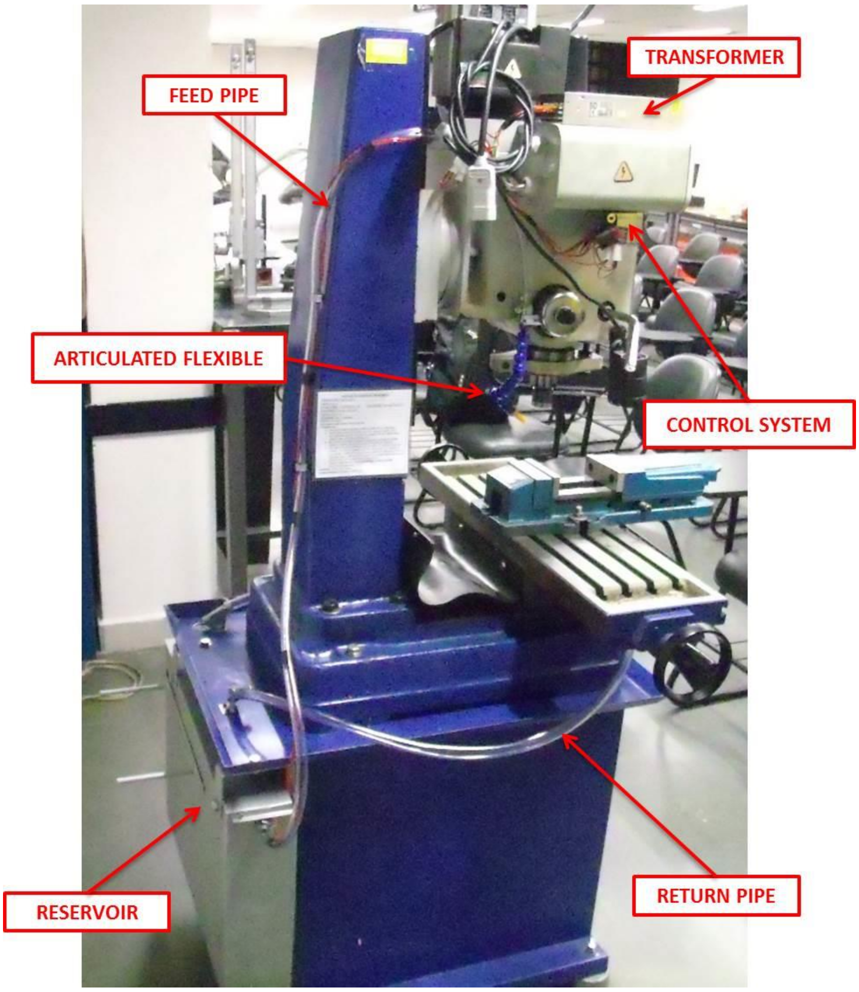

Figure 10. Refrigeration system fixed in machine tool

3.2 Validation test

First a visual inspection was performed only with the cooling system in operation at maximum flow rate. No leaks were detected. It was observed that the absence of flow channels caused the cutting fluid to fill the entire surface of the table before returning to the reservoir. Then, the operator intervention was necessary using a brush to direct the remaining cutting fluid to the return after use of the system. In addition, when the system was disconnected, a quantity of fluid was always stored in the return bends due to the curves present, also requiring the operator intervention.

Then the system was tested in a milling operation by slashing an aluminum hub and moving the table in the longitudinal direction. The PWM potentiometer has been set at 50% of its total stroke to reduce pump flow, achieving a lower cutting fluid dispersion. Figure 11 demonstrates the cooling system operation.

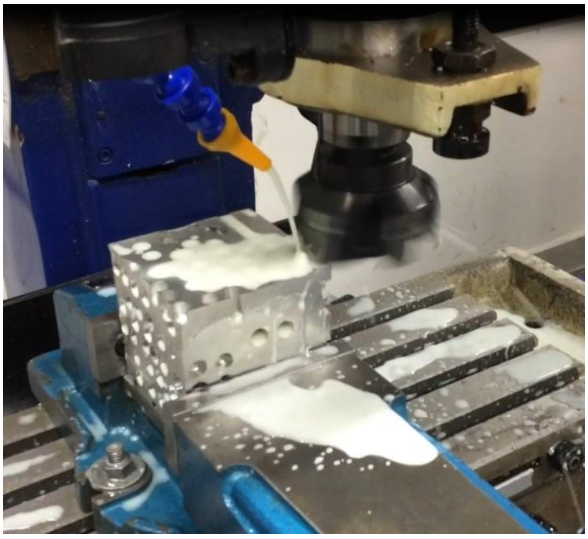

Figure 11. Machining test with cooling system

Commonly some machining chips were thrown out to tabletop, reaching the machine tool platter where it was necessary after machining that the operator moves them to the return holes of the platter. The chips on the machine table flowed easily through the cutting fluid to the return holes, requiring operator intervention only after machining. The system filter played the expected role with respect to chip retention, as shown in Fig. 12.

Figure 12. Machining chips retained by the filter

The tests performed showed positive and negative aspects of the refrigeration system. As for the positives: the location of the reservoir and the feed and return lines did not negatively affect the handling of the machine tool, there were no leaks, the fluid storage in the reservoir was well isolated from the external environment, the electrical system presented easy handling and allowed the flow adjustment and the use of the articulated flexible made the projection of the cutting fluid easier. The negative points were the limitations of system return: first, the diameter used was approximately half of the initially value proposed due to the tool's design limitations, which made it difficult to dispose of the chips and the cutting fluid. However, because they are flexible rubber, even increasing the diameter, there would still be chips stocked due to friction (adhesion). Second, the curves of the flexible, mainly by the storage of cutting fluid that would consequently have more contact with the external environment, causing unpleasant odor with the passage of time. However, with the intervention of the operator handling these flexible, the stored fluid was easily directed to the reservoir.

4. FINAL REMARKS AND FUTURE WORK

This final paper presented the design of a refrigeration system for a machine-tool of an academic laboratory. Through the bibliographic review relevant points were determined to structure the project, such as the cutting fluid selection and its method of application and the basic premises for a reservoir construction. It was essential to use the 3D modeling in the visualization of assembly and construction of the components, making the methodological execution satisfactory. The use of academic labs, accessible and inexpensive components has resulted in a remarkably low investment. Regarding the proposed objective, on a scale of 0 to 100%, the refrigeration system reached 70% of the expected. The application of constant and still adjustable fluid was achieved to reduce waste. The unreached 30% were related to the negative aspects of the return of the cutting fluid that required operator intervention, which is not expected in the project, besides the loss of 150 mm of the longitudinal course of the table. But it is worth mentioning that it would be natural for an additional intervention of the student due to the use of the cutting fluid as the cleaning of the machine tool for example. From this, future studies can be evaluated: increase the diameter of the return pipes, adapt a shaker to maintain the cutting fluid and use the system for a longer period of time for better storage assessment and filtration efficiency for the pump life. It is also suggested to create a standard procedure that contains the main instructions for the correct use of the system, following the safety signaling standard NR 26.

5. ACKNOWLEDGEMENTS

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6. REFERENCES

CIMM, 2010. “Purificação dos fluidos de corte”. 18 Oct. 2016 <http://www.cimm.com.br/portal/noticia/exibir_noticia/6893-purificacao-dos-fluidos-de-corte>.

Dhar, N.R., Kamruzzaman, M. and Ahmed, M., 2006.“Effect of minimum quantity lubrication (MQL) on tool wear and surface roughness in turning AISI-4340 steel”. *Journal of Materials Processing Technology*, Vol. 172.

Fernandes, U.B., 2007. *Análise de métodos de lubri-refrigeração aplicados no processo de retificação cilíndrica interna de mergulho em aços endurecidos*. Universidade Estadual Paulista, Bauru.

Fialho, A.B., 2004. *Automação Hidráulica: Projetos, Dimensionamento e Análise de Circuitos*. Editora Érica, 2nd. edition.

Gonçalves, B.B., Yaginuma, G. and Yamamoto, M.K., 2010. *Óleos de usinagem: tipos, classificação e desempenho.* Universidade Estadual Paulista, Bauru.

Hannifin, P., 1999. *Tecnologia Hidráulica Industrial*. Parker Hannifin Ind. Com. Ltda. Apostila M2001-1 BR.

Iceri, D.M., Sousa, R.M., Destro, R.S., Oikawa, M.H., Bianchi, E.C., Aguiar, P.R. and Fortulan, C.A., 2012. “Comparação entre os métodos de aplicação de fluido de corte convencional e otimizado na retificação plana de cerâmicas”. *Cerâmica 58*, p. 84-89.

Klug, J.L., 2005. *Implantação de um laboratório de controle de contaminação na empresa soprano – unidade equipamentos hidrálicos*. Federal University of Rio Grande do Sul, Porto Alegre.

Lisboa, F.C., Moraes, J.J.B. and Hirashita, M.A., 2013. “Fluidos de corte: uma abordagem geral e novas tendências.” In Proceedings of the 33rd National Meeting of Production and Engineering – ENEGEP2013. Salvador, Brazil.

Micaroni, R., 2006. *Influência do fluido de corte sob pressão no torneamento do aço ABNT 1045*. Universidade Estadual de Campinas, Campinas.

Renner, R., 2010. *Projeto e Construção de uma Unidade de Potência e Condicionamento Hidráulico*. Universidade Regional do Noroeste do Rio Grande do Sul, Panambi.

Stoeterau, R.L., 2004. *Introdução ao projeto de máquina-ferramentas modernas*. Universidade Federal de Santa Catarina, Santa Catarina.

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