DESIGN OF MAGNETIC COOLANT SEPARATOR FOR MACHINING TO FERROUS METAL

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In
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By

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CANDIDATE'S DECLARATION

I hereby declare that the work which is being presented in this project report entitled, "**DESIGN OF MAGNETIC COOLANT SEPARATOR FOR MACHINING TO FERROUS METAL**" submitted as major project towards the fulfillment of the requirements for the award of the degree of Master of Engineering in Production Engineering, Delhi university, is an authentic record of my own work carried out under the supervision of **Sri R. C. Singh Sr. Lect., & Sri Rajiv Chaudhary Sr. Lect,** Mechanical Engineering Department, at Delhi College of Engineering, Delhi.

The matter embodied in this dissertation report has not been submitted by me for the award of any other degree.

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CERTIFICATE

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ABSTRACT

Now a day's use of coolants in industry has become dominant because of high production demands. Coolants not only help in speeding up the production but also provide many advantages in the metal working operation. As the consumption of coolants is very high a system is badly in need, so as to recirculate the used coolant. Also the amount of hazardous waste generated by industrial plants has become an increasingly costly problem for the manufactures and an additional stress on the environment.

Since the purchase and disposal of the spent cutting fluids is becoming increasingly expensive, fluid recycling is a viable option for minimizing the cost. Separation of metallic chips from the coolants by using magnetic coolant separation has proven a good management and maintenance of the cutting fluid. By removing the metallic chips, the coolant life is greatly extended, increases the machining quality and reduces downtime.

Magnetic coolant filters uses the principle of magnetic separation to purify the used coolant. So the contaminates should be in the form of ferromagnetic materials like cast iron. The design of this magnetic coolant separation have the capability of purifying 10 liters per minute of coolant with the size of the contaminants ranging from 1µm to 30µm.The filter will be helpful in saving the production cost as the cost associated with the propose design is well justified by the cost savings in production.

LIST OF FIGURES

CHAPTER-1

CHAPTER-2

LIST OF TABLES

LIST OF SYMBOLS

SYMBOL	DESCRIPTION
ALPHAPETS	
b	Width of tray(mm)
c	Center distance between rollers(mm)
d_i	Inner diameter of rollers(mm)
d_o	Outer diameter of rollers(mm)
f_s	Height of the tray(N/mm^2)
h	Height of tray(mm)
h_1	Lower height of frame(mm)
h_2	Total height of frame(mm)
l	Length of tray(mm)
r_i	Inner radius of rollers(mm)
r_o	Outer radius of rollers(mm)
t	Thickness of conveyor belt(mm)
v	Volume of chip in tray(mm^3)
A	Area of the fluid in contact (mm^2)
L	Length of shaft (mm)
M	Mass of chip in tray (kg)
N_g	Speed of gear (rpm)
N_p	Speed of pinion (rpm)
V	Speed of conveyor belt (mm/sec)
W	Mass of the roller (kg)

GRREK LETTERS

μ	Coefficient of friction
θ	Angle of inclination of tray(degree)
ρ	Density(kg/mm^2)
σ_g	Yield stress of gear(N/mm^2)
σ_p	Yield stress of pinion(N/mm^2)

CONTENTS

CHAPTER-1

INTRODUCTION

1.1 REQUIREMENT IN MODERN METAL WORKING OPERATIONS.

The amount of hazardous waste generated by industrial plants has become an increasingly costly problem for manufactures and an additional stress on the environment. One solution to the problem of this waste generated from the various metal working operations is to reduce or eliminate the waste at its source.

In the metal working operations with the development of newer tool material and higher cutting speeds during machining, the use of cutting fluids positively improves the tool life and the work finish by cooling and lubricating mechanism. Once the fluid is used various impurities get mixed into the machining fluid which impacts a lot on the environment and the machining operations. Like the disposal and purchase of the cutting fluids becomes expensive. Fluid recycling is a viable option for minimizing and reuse of the coolant.

Once the cutting fluid is used various impurities get mixed into the machining fluid which impairs its properties. So these impurities are required to be removed from the coolant thus it can be reused. Since the impurities in the coolant degrades the heat transfer and lubrication properties of the machining fluid and that may cause excessive tool and machine wear as well as bacterial growth in fluid baths which produces corrosive sulphuric acid. The bad smell, rust stained poor quality parts and premature tool wear. Renewal of affected coolant is linked with the high costs because of labor, purchase and disposal fees and machine down time.

Therefore to reduce the down time and requirement of large amount of cutting fluid such a device is required which will continuously filter the coolant with fast rate. For the purpose different systems and process are used for cleaning of cooling lubricants. Choice of suitable process depends largely on the parameters of the filtration demand. Therefore no general technology is available which fulfills all demands. So the solution to above problem is to design coolant filters which are required in the modern metal working factory environment in order to recycle metal cutting fluids.

1.2 RECYCLING OF CUTTING FLUIDS.

Despite all efforts to extend fluid life, fluid quality will eventually reach a point where routine maintenance is no longer effective. At this stage, the fluid either needs to be recycled for contaminant separation or disposed. Fluid should be recycled well before it becomes significantly degraded since fluids with excessive bacterial counts or tramp oil concentrations cannot be restored. Recycling means the coolant has to be cleaned and be ready for using again. The conventional gravity separation methods takes too much time to separate metallic chip from the coolant which is not desired because it increases downtime of machining or may require large amount of cutting fluid. Now a days due to advancement in technology new and effective magnets has been developed. These have improved the collection of fine particles of ferromagnetic and paramagnetic dirt. In addition to collecting particles resulting from machining and grinding, these separators collect harmful contaminants such as rust, chips, and fine iron that result from continually eroding pipelines, chutes, bins, and process equipment. Properly cleaning and filtering coolant will lead to longer lasting machine tools, reduced production time and lower coolant disposal costs. In addition, removing metal chips dramatically reduces expensive damage to machine tools while it increases productivity. The right method of magnetic particle filtration will make an impact on any metalworking facility.

1.3 RECYCLING EQUIPMENT.

A wide variety of recycling equipment is available for contaminant removal and most recycling equipment is generally easy to operate and maintain. The choice of recycling equipment will depend on the needs, objectives and financial resources of the shop. The table below illustrates contaminant removal capabilities for various types of equipment used in fluid recycling

EQUIPMENT	CONTAMINANT REMOVED
Skimmers	Tramp Oil
Settling Tanks	Particulates
Magnetic Separators	Particulates
Hydro cyclones	Particulates
Centrifuges	Tramp Oil, Particulates, Bacteria
Filtration Equipment	Particulates
Flotation	Tramp Oil, Particulates
Coalescers	Tramp Oil, Particulates

Table1: fluid recycling contaminant removal equipment.

1.3.1 SEPARATION EQUIPMENT.

Separation equipment includes settling tanks, magnetic separators, hydro cyclones and centrifuges. The primary function of this equipment is particulate removal. Settling tanks and centrifuges may also be used to remove tramp oil. They are discussed as follows.

A) SETTLING TANKS.

This system allows heavy particles to settle to the bottom of a tank while allowing tramp oil and the particles to float to the surface. Settling tanks can be equipped with skimmers to remove the floating oil and light particulates. Chip and other particles, which settle to the bottom, are removed using baskets or automatic chip conveyors. Applications of such type are in Machining & Grinding, Rolling & Drawing Fluids, Stamping operations and Die-casting operations

B) HYDRO CYCLONES

It works on the principle of vortex, according to which density difference between the fluids and contaminants cause the separation. The dirty coolant from the tank is pumped through a high pressure pump into the hydro cyclone which is a cone like vessel made out of steel, producing a vortex that forces denser solid down and out. The clean coolant rises up the swarf is collected at the bottom of the cone. Since there are no moving parts, it is maintenance free.

The classification begins when the dirty fluid is pumped at a pressure of 2kg/cm into the uniquely designed head. The head provides permits the dirty fluid to begin rotation as soon as it enters in to the helical axial distributor band, where it induces dirty fluid into the cell in a narrow thin band. This section reduces the intersecting angle between the incoming dirty fluid and reduces undesirable turbulence and aids to ensure maximum clarification through lower energy loses as the dirty fluid flows through the helical distributor band; a free primary vortex develops along the outer wall of the carefully designed cell and accelerates downwards. Due to high cyclonic action the solid particle accumulated near the inner wall of the cell are carried downwards and discharged with about 25% of liquid through the outer orifice. Due to orifice opening a differential pressure generate between the in let and outlet. The opening allows air to enter in to the cell creating a secondary rising low pressure vortex. Clean fluids rise through the center opening of the distributor vane and is discharged out through the outlet of the head. The discharged solids with a small amount of liquid are collected in the sludge trolley.

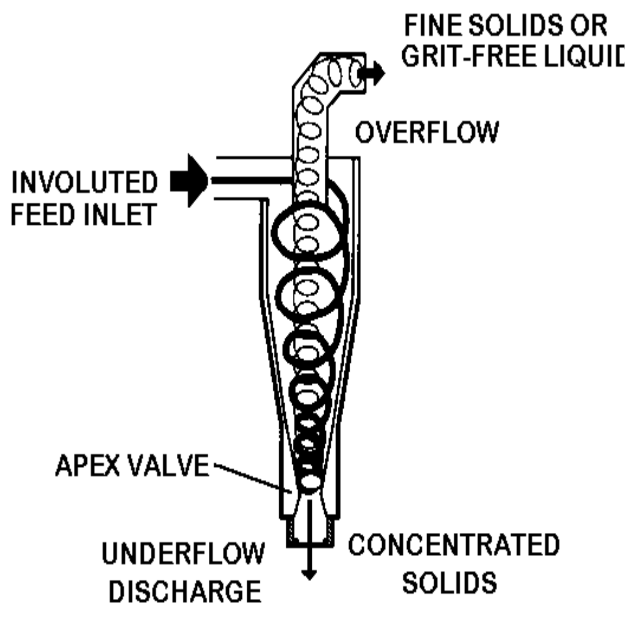

Figure1: Cyclone filters.

D) CENTRIFUGES

Centrifuges provide excellent separation of very fine contaminants from water and low viscosity oil based coolant. Centrifuges use a spinning bowl to develop the centrifugal force needed for contaminant removal. Some centrifuge units can be removing free, dispersed and emulsified tramp oil as well as bacteria. The disadvantages of centrifuges are the intensive maintenance required for the system and the cost. In addition to it under certain conditions, centrifuges used for the removal of emulsified tramp oils also separate fluid concentrate from the working solution. Fluid suppliers should be consulted before hand to ensure centrifuging would not have a detrimental impact on the fluid

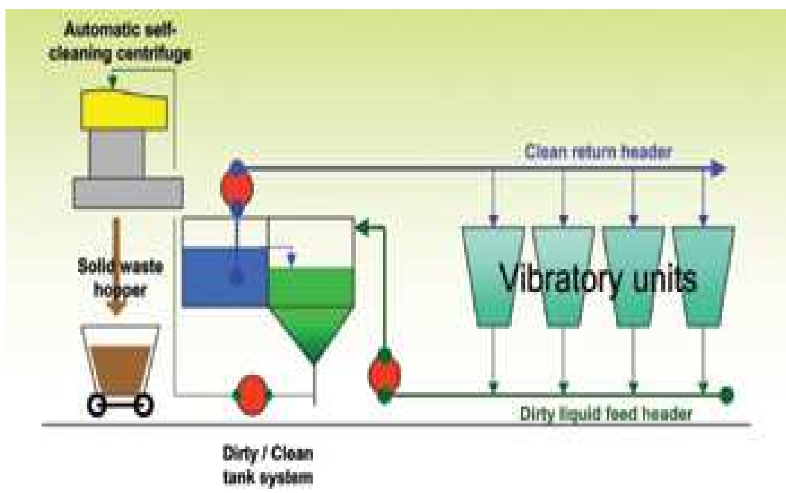

Figure2: Centrifuge filter.

Small metal chips are continuously and regularly fed into the centrifuge funnel by a feeding conveyor. The chip slide into the fast spinning wringer bowl and are accelerated into the bowl RPM. High force drives the chips up the bowl side wall and over the coolant exits lots towards the upper edge of the bowl. In this process the coolant is wrung off the chips and forced out via the coolant exit slots. The dried chips passed over the upper bowl edge and guided via the wringer housing and discharge funnel into an extractor conveyor or swarf bin.

D) MAGNETIC SEPERATORS

Effective magnetic particle filtration can be achieved in several ways. In order to choose the appropriate method for a specific application, several factors should be taken into account including the level of filtration, types of materials that have to be removed, and the type of coolant being cleaned. A systematic diagram of the magnetic coolant separator is given below. Magnetic coolant filters are used to remove ferrous particles from machine tool coolants. Dirty coolant flows past a slowly rotating magnetic drum which removes the metal particles from the coolant. The metal swarf is stripped from the drum by adjustable scrapers and forced off the end of a discharge chute.

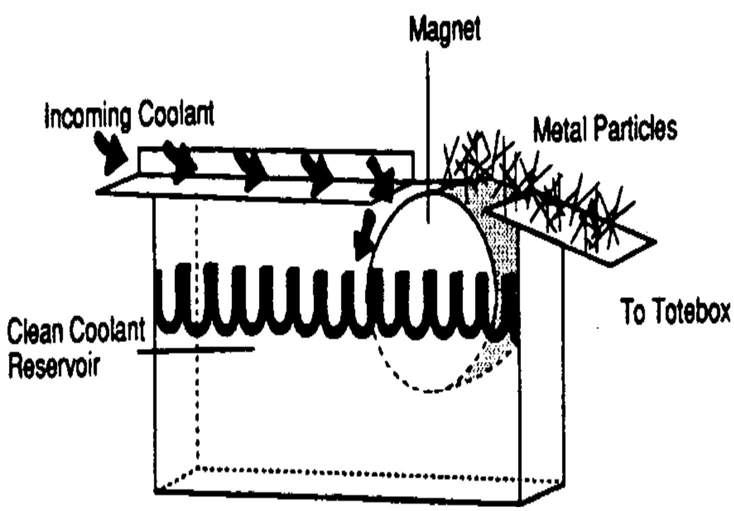

Figure3: Drum type magnetic separator.

1.3.2 FILTRATION EQUIPMENT.

Filtration involves passing cutting fluid through a permeable material for particulate removal. Filters are typically made from materials such as wedge wire, micro screens, paper, cloth and manmade fibers such as nylon, polypropylene or polyester. In some applications it may be necessary to use a series of progressively finer filters in order to achieve the desired level of particulate removal. Filtration systems used for recycling cutting fluid include vacuum, pressure and gravity filtration. They are discuss below as follows.

A) GRAVITY BED FILTERS.

This is a continuous self cleaning gravity filter. It offers automatic operation and utilizes low cost roll media, which are well suited to applications with moderate contaminate levels. Contaminated liquid flows through non woven synthetic filter fabric supported by a belt conveyor. Solids are removed as liquid flows through the filter media and are then discharged in a relatively dry condition into an outside container. An endless conveyor carries the filter media. The conveyor’s slopping sides create a pool for the liquid, while an inclined discharge ramp provides carry off for the liquid, collects in the tank and is returned to the service by the pump. Applications of such type of filters are in creep feed grinding, surface grinding, carbide grinding and abrasive belt grinding.

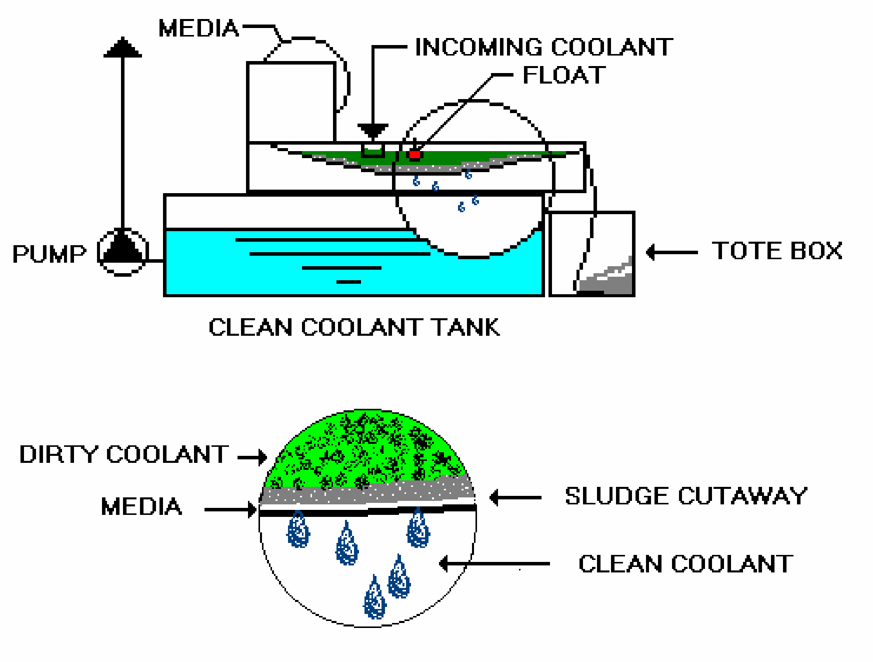

Figure4: Gravity bed filters.

In actual operation paper bed or gravity filters index on an automated basis. As coolant laden with steel and wheel grit accumulates on the filter media. The coolant flow through the media begins to slow. Eventually, the filter cake becomes too dense to allow any flow of coolant through to the clean tank and the pool of coolant in the curved area of the bed begins to rise. Because it's not cool to let coolant Overflow on the floor a level probe or float signals to the controls to automatically index the filter media. The float or probe works much like a toilet bowl float and controls the on or off of the system. As the media indexes the coolant level begins to drop immediately because the clean paper is permeable.

B) VACUUM FILTERS.

The underlying premise in regards to vacuums is that they use hydraulic vacuum to maximize cake generation. Simply put, liquid is drawn through a supported media which in turn creates an ideal medium (thick cake) to remove finer particulate compared to gravity based filtration systems. Applications of such type are in Grinding of all types. Center less, Cylindrical, Roll Grinding, Surface, Belt, Double Disc, Honing Tube Mills and Saws

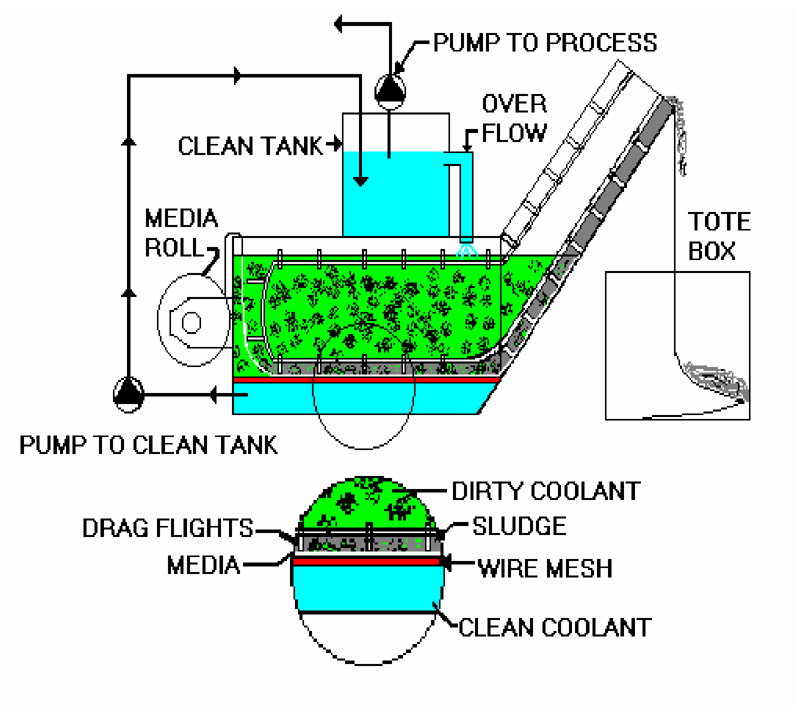

Figure5: Vacuum filters

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1.3.3 FLOTATION.

Flotation is a process in which cutting fluid is aerated to achieve contaminant separation. During aeration, oil and particulate matter adhere to the air bubbles and are carried to the surface where they are mechanically skimmed off. This contaminant removal process is typically used after larger and heavier particulates have been removed by settling

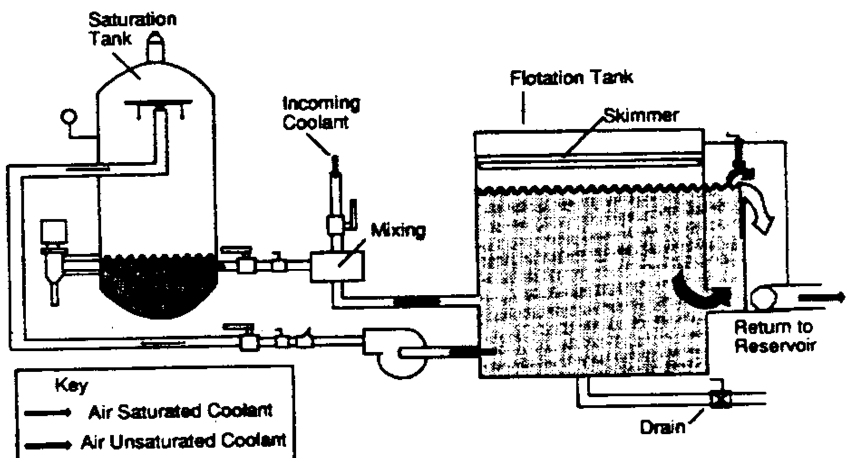

Figure6: Air flotation unit

Principles of Operation are as follows:

- Contaminated coolant is either gravity fed our pumped to the filter.
- Particulate or dirt settles to the bottom of the tank where media resides.
- A pump draws the liquid through the supported media (supported by wire mesh, perforated sheet or wedge wire).
- Coolant is essentially sucked hydraulically through the lower section of the tanks; the cake builds a matrix of finer and finer particulate conglomeration to capture even smaller particles.

- The coolant that has been drawn through the media barrier is usually sent directly to the overflow clean tank then to process namely the grinders or machining process.
- Eventually the media is blinded or unable to permit coolant to pass through. At that time a pressure differential switch reads a pressure drop and sends the filter into index. Vacuums index by either time or pressure

1.4 MAGNETIC SEPARATORS.

Magnetic separators or filters remove ferrous swarf (iron particles) from the metalworking fluid mix by attracting it to the magnetized surface of a rotating drum. The cleaned" fluid returns to the machine, and a scraper blade removes the particles from the drum. Magnetic separators are used predominantly with individual machines or in combination with positive filters.

Magnetic coolant filters are essential for capturing and removing ferrous metal chips and particles from water based coolants. These coolants are used in various grinding and rotary machine to separate ferrous contaminants and to obtain products free from any tramp iron materials.

Coolant filter consists of stationary magnet with a continuous rotating outer drum shell. As the coolant flows into the reservoir and under the drum, ferrous metal chips and particles are captured by the drum's powerful magnetic field. The contaminants from the coolant are brought out by the outer drum. The contaminants are then squeezed by the squeegee roller. Captured particles rotate to the non-magnetic side of the drum to the rake plate for smooth discharge of sludge. The outlet can be located on the right, left or bottom of the unit. The coolant first pass through the filter to remove course sediments. Later it enters the magnetic inlet of the separator. The coolant drum housing permanent magnets rotates at a very slow speed opposite to the flow of liquid. The strong magnetic poles attract the fine ferrous particles. The scraper at the other end of the machine scraps and collects the captured ferrous particles in a separate box. Sludge build up on chute assembly is prevented by scraper blade which prevents magnetic interference from the drum. The systematic diagram is given below.

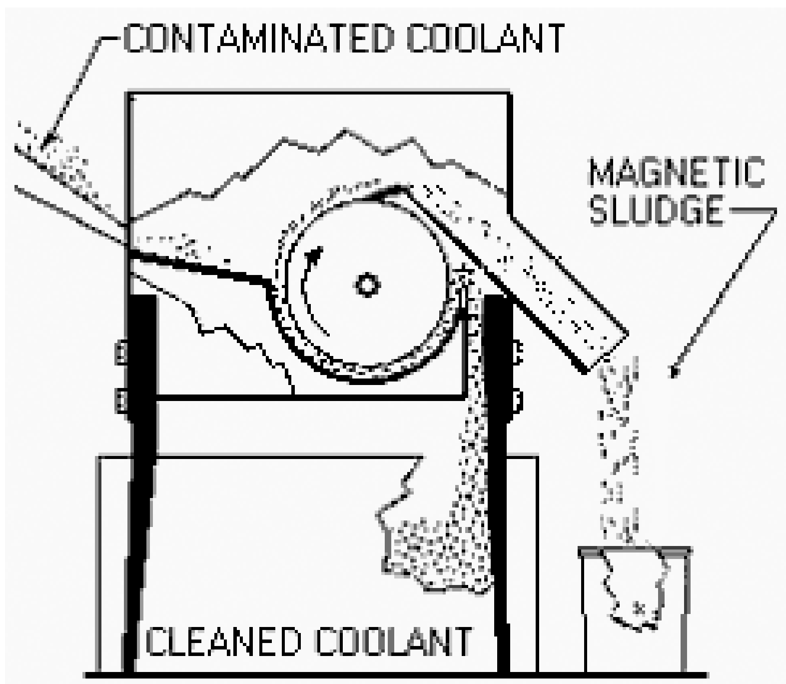

Figure7: Magnetic coolant separators.

1.5 ADVANTAGES OF MAGNETIC COOLANT FILTERS.

The magnetic filter is designed with the requirements and profit of the customer in mind. Particular attention is paid to reduce initial start-up costs, floor space requirements, and operating costs. On the production using a magnetic filter system can achieve a payback of less than one year by drastically reducing coolant and machine tool expenses. This magnetic chip separator will coolant and reduces downtime. Savings will be in the form of reduced machine time and tooling wear and the increase in quality parts. Properly cleaning and filtering coolant will lead to longer lasting of machine tools, reduced production time and lower coolant disposal costs. In addition, removing metal chips dramatically reduces expenses damage to machine tools while it increases productivity. The right method of magnetic particle filtration will make an impact on any metal working facility. The advantages of magnetic coolant filters are discussed as follows;

A). LONGER MACHINE LIFE.

A machine that can go ten years without a problem in a clean shop may need a major rebuild in as few five years in a dirty shop. Precision machine are priced from a few thousand dollars to many millions. The life of the machine as well as the life between rebuilds is an important economic consideration. An inescapable fact is that all machines are sensitive to wear. All materials in any machine are susceptible to wear from diamond, and carbide dust as well as other particles. No machine can entirely eliminate exposure to particles if the particles are small enough. Machining and grinding produce large number of very small particles, chips and dust from carbide, ceramics or cobalt chrome alloys. Test show that most of these particles are fewer than ten microns in size. Ten micron particles easily get under seals and work their way into bearings, slides, ball screws, bushing ways and hydraulic cylinders. Dirty coolant can cut the life of machine into half. A large number of these particles are produced in the original operation. If the coolant is not filtered, then the dirty coolant carries particles back up into the work area. As the coolant gets between the work piece, and the work, these particles are ground and reground. They are finer and finer. The finer they get the easier it is for them to get into critical spaces, and destroy machine tolerances.

B). LESS DOWNTIME.

As the machine wears out, it will break down more often which means more downtime. The coolant filtration unit automatically removes swarf from the coolant. Eliminating the downtime usually required to manually removing swarf from the machine settling tank.

C). FASTER OPERATION.

D). FASTER CYCLE TIMES.

E). FEWER TOOL REPLACEMENTS.

Dirty coolant losses its lubricity, which means it allows more heat to be generated. In addition, dirty coolant also losses its ability to carry heat away from the work area. Increased friction, increased heat, and impact with particles in dirty coolant all contributes to greatly increased tool wear. The microscopic grit produced during machining is like fine sand.

You can run faster at cooler temperature if you are using coolant that does not have sand in it. Your tool will last longer if they are just cutting metal without having to work with sand and grit in it.

F). BETTER QUALITY.

This can be measured as the smoothness on the worked surface. It produces overall better quality work. Clean coolant means less staining. Better work the first time resulting in reduces rework. It also reduces scraps promoting tighter tolerances and reduced defective parts.

G). GREATER LUBRICITY WITH CLEAN COOLANT.

Lubricity obviously reduces friction which reduces heat. Greater lubricity means less drag and tool grip during machining and greatly help to reduce chatter.

H). REDUCED CONSUMABLE COSTS.

That means longer tool run life per sharpening, longer tool life and longer coolant life. Properly managed coolant can be used for months and sometimes years. Clean coolant lasts much longer than dirty coolant. This is a big saving on coolant for most shop and even bigger saving on labor. Longer grinding wheel life and require fewer dressings because unlike contaminated coolant, clean

Coolant won’t load the surface of the wheel with abrasive waste particles. The oil and greases in dirty clog grinding wheels and dull tools, which means they wear out faster. Dirty coolant is slurry of metallic sand. A sharp tool that is run in clean coolant will stay sharper longer than the same tool that is run in slurry of coolant and metallic sands. Tools of any kind wear faster if there is abrasive in the coolant. Even fine abrasive such as the low micron range will wear a tool out faster. The longer a tool stays sharp the longer it will be between replacements and sharpening or dressing. Dressing and sharpening wear tools out so the more you can cut with the fewer sharpening or dressings the better off you are.

I).REDUCED LABORS.

Less machine maintenance as machines run better, longer as there are fewer breakdowns. Properly managed coolant dramatically reduces the need for coolant changes and sump clean. Less finishing operations, better finishes of the machine, means less post machining work.

J).CLEANER WORKPLACE.

There are million of people who are exposed to various metal working operations. The coolants and their contaminants cause skin rashes, allergic reactions, epidermal scarring, lung scarring, emphysema and death. Top quality, trained, healthy employees are valuable assets to a firm. An unfiltered sump could end up about 25 to 30% more sludge and particles that do physical damage. Recycling of coolants gives safety to operators. Proper coolant management removes bacteria before they grow much. Bacteria grow in dirty sumps as the sludge is an excellent place for its growth. Filtering coolant prevents bacteria growth by removing the sludge where bacteria grow. This also eliminates bad smell and reduces non-coolant waste and waste disposal costs.

1.6 APPLICATIONS OF MAGNETIC COOLANT FILTERS:

The magnetic is perfect for those applications that require the transportation of metallic materials i.e. Metallic chips. It is mainly used where large volumes of chips are produced, such as in multi spindle automats, CNC machining center, CNC turning center, etc. Fine light and sharp chips generated from gear, shaves Hobbes, splines cutting machines, honing, deep hole drilling machines, broaching machines, screw machines, press shops get mixed up with the cutting fluid and magnetic conveyors helps to attract ferrous chips and the conveyor acts as a magnetic filter for the coolant. It can also be used for rolling mills for filtering coolant which helps to improve the surface finish to the sheets. So in brief following are some of the processes in which magnetic coolant filter find its application.

1 Multi spindle automats.

2 CNC machining center.

3 CNC turning center.

4 Milling machines.

5 Gear shaving and hobbing machines.

6 Deep hole drilling machines.

CHAPTER-2

LITERATURE REVIEW

2.1 COOLANTS.

Cutting fluids have been used in the machining process with the purpose to improve the tribological characteristics of the work piece–tool–chip system. It is interesting to note that the use of coolants for machining was first reported by Taylor in 1907, who achieved up to 40% increase in cutting speed when machining steel with high speed steel tools using water as coolant (Taylor, 1907).

Nowadays metal cutting fluids (MCFs) are widely used in metal industries, such as rolling mills, forge and metal workshops, because these fluids provide the combined cooling and lubrication required by different metal working operations. MCF is also used to carry away chips and fines produced in machining and cutting operations. A MCF concentrate usually contains a mineral oil, a surfactant mixture, in some cases water and various additives, which are included to meet the specifications of commercial concentrates such as resistance to bacterial growth and low corrosion capacity [8, 9].

Machining coolants are an important component of metal working operations. Coolants improve machinability, increase productivity and extend tool life by cooling and lubricating the part and cutting tool. When performing these functions coolants can quickly become contaminated with foreign materials, causing coolants to lose effectiveness and develop foul odors. As a result, many coolants are used only for a short time then discarded. The practice of discarding and replenishing coolants can be costly and wasteful. Developing and implementing a coolant maintenance program can help minimize contamination, prolong coolant life and reduce cost [1].

Cutting fluids or coolants have been used extensively in metal cutting operations for the last 200 years. In the beginning, cutting fluids consisted of simple oils applied with brushes to lubricate and cool the machine tool. Occasionally, lard, animal fat or whale oil were added to improve the oil's lubricity. As cutting operations became more severe, cutting fluid formulations became more complex. Today’s cutting fluids are special blends of chemical additives, lubricants and water formulated to meet the performance demands of the metalworking industry [2].

A coolant does more than lubricate the cutting tool/workpiece interface and limit the amount of heat generated during machining. It also performs the essential job of flushing chips from the cutting zone. Chips must be flushed continuously to prevent them from being recut and to minimize tool breakage and the marring of finished surfaces. Efficient lubrication of the cutting zone reduces external friction and, to a lesser extent, internal friction. The result is improved metal cutting. The cooling effect provided by a coolant keeps parts thermally stable, which aids in controlling their size. And given the number of parts being finished today without secondary operations, such as engine blocks and transmission cases, a cutting fluid’s capacity to keep parts dimensionally stable during machining is critical. Additionally, a coolant extends tool life by preventing it from exceeding its critical temperature while in the cut. Above the critical temperature, coatings fail and tools soften, wear too rapidly, and fail to deliver specified surface finishes and part tolerances. As coolant becomes dirty, it degrades and stops providing many essential benefits, such as lubricity and the ability to control heat, bacteria, staining and rust. Therefore, filtering should be part of a total coolant-management program [3].

Around 97% of the energy consumed in some metal machining processes is transformed into heat; the remaining 3% is stored in the tool or metal chips as residual stresses. Heat is generated from plastic deformation of the metal piece and friction with the machine tool. Tool failure and welding may result if the contact temperature reaches more than 1000 ◦C. Cooling and lubrication of the machining zone reduce machine wear and cutting fluids provide both features[4].

During the machining processes of a ductile metal, a considerable quantity of heat is generated, mainly due to the high plastic deformation in the primary shear zone, and to the friction of the chip on the tool rake face. These conditions of friction and temperature cause tool wear, resulting in a poor surface finish and an incorrect dimensions. Cutting fluids are used to reduce the detrimental effects of heat and friction on both tool and work piece. The cutting fluid produces three positive effects in the process: heat elimination, lubrication on the chip–tool interface and chip removal [5].

The duties of coolant lubricant in the grinding process can be categorized into lubrication, cooling, transportation of chips, cleaning of the grinding wheel and minimizing the corrosion. These criteria have a great influence on the process temperature, grinding forces, surface structure of the work piece, and on tool wear [6]. Cutting fluid is usually used to reduce cutting force, lower cutting temperature, prolong tool life and enhance machining efficiency and surface finish quality during machining [7].

2.2 FUNCTIONS OF COOLANT.

The primary function of cutting fluid is temperature control through cooling and lubrication. Application of cutting fluid also improves the quality of the work piece by continually removing metal fines and cuttings from the tool and cutting zone [2]. Cutting metal generates friction that causes the temperature of the work piece and tool to rise. Excessive heat can result in a number of undesirable consequences, including improper part size and shape, a poor finish and unsatisfactory tool life. To prevent these problems, the cutting fluid must cool and lubricate the tool/work piece interface, as well as flush chips from the cutting zone. The cooling effect provided by a coolant keeps parts thermally stable, which aids in controlling their size. And given the number of parts being finished today without secondary operations, such as engine blocks and transmission cases, a cutting fluid’s capacity to keep parts dimensionally stable during machining is critical [3].

2.2.1 TEMPREATURE CONTROL.

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. As cutting fluid is applied during machining operations, it removes heat by carrying it away from the cutting tool/ workpiece 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/workpiece 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 [2]. If the heat and friction are not reduced, the tools used in the process are quickly damaged and/or destroyed. Also, the quality of the products made is diminished because of inefficient tools and damage to the product while it is being manufactured. Coolants reduce friction at the tool/substrate interface and transfer heat away from the tools and the material being processed, reducing the time to process the metal, increasing the quality of the workmanship, and increasing tool life[10].

An experimental result done by K.P. Rajurkar, results that using of liquid nitrogen as a cutting fluid lowers the temperature. By taking titanium-aluminum-vanadium (Ti-6Al-4V) and reaction-bonded silicon nitride (RBSN), which are very difficult to turn and treating them with liquid nitrogen coolant while turning, extended the tool life. Figure 6 depicts cutting temperatures measured in the machining of (RBSN). Tool temperature increased with the cutting time when liquid-nitrogen coolant was not used. When the tool was used for a second cut, the temperature increased at a much higher rate than in the first cut because of the increased tool wear. When the turning process was subjected to liquid-nitrogen coolant, the measured temperature (-160° to -170° C) remained almost constant. Figure 7 depicts cutting temperatures measured in the machining of Ti-6Al-4V. A maximum of about 210° C was measured without liquid nitrogen coolant, opposed to a peak value of 120° C with liquid-nitrogen coolant [11].

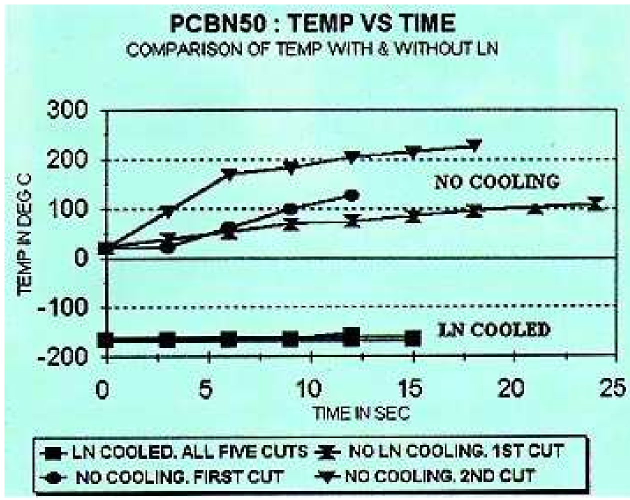

Figure 8: Temperatures measured in turning RBSN

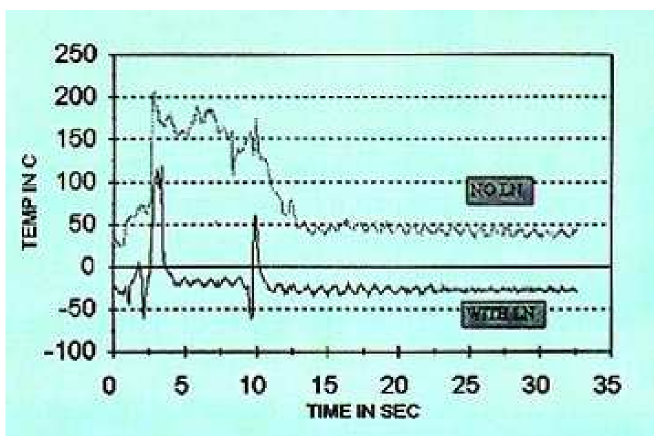

Figure 9: Temperatures measured in turning Ti-6Al-4V

2.2.2 REMOVAL OF CUTTINGS AND PARTICULATES.

A secondary function of metalworking fluid is to remove chips and metal fines from the tool/workpiece interface. To prevent a finished surface from becoming marred, cutting chips generated during machining operations must be continually flushed away from the cutting zone [2].

Application of cutting fluid also reduces the occurrence of built-up edge (BUE). BUE refers to metal particulates which adhere to the edge of a tool during machining of some metals. BUE formation causes increased friction and alters the geometry of the machine tool. This, in turn, affects workpiece quality, often resulting in a poor surface finish and inconsistencies in workpiece size. Metalworking fluids decrease the occurrence of BUE by providing a chemical interface between the machine tool and workpiece. Cutting oil prevents rust from forming but does not cool as effectively as water. Water is the best and most economical coolant but causes parts to rust unless rust inhibitors are added. All chemical cutting fluids now contain rust inhibitors, which inhibit or Prevent the process of rusting. It also provide a means to control rancidity [2,3].

Cutting fluids play a significant role in machining operations and impact shop productivity, tool life and Quality of work. With time and use, fluids degrade in quality and eventually require disposal once their efficiency is lost. Waste management and disposal have become increasingly more complex and expensive.

Environmental liability is also a major concern with waste disposal. Many companies are now paying for Environmental cleanups or have been fined by regulatory agencies as the result of poor waste disposal Practices.

Fortunately, cutting fluid life may be extended significantly by implementing an effective fluid management program. The primary objective of fluid management is to maintain fluid quality and performance through administration, monitoring, maintenance and recycling practices. This allows machine shops to make the most cost-effective use of their fluid. It is also the best pollution prevention technology available. Overall, fluid management provides a means to:

1 .Operate in a more environmentally sound manner;

2. Improve productivity and reduce costs;

3. Increase competitiveness;

4. Maintain environmental compliance and reduce environmental liability;

5. Consistently manufacture quality products; and

6. Provide a healthier and safer work environment for employees.

Proper management of cutting and grinding fluids may also prevent them from being declared a hazardous Waste at the end of their useful life. With increasing environmental regulation, a reduction in cutting fluid Waste is an economical, practical and achievable goal.

2.3 PROPERTIES OF FLUID.

In addition to providing a good machining environment, a cutting fluid should also function safely and effectively during machining operations.

A) CORROSION PROTECTION.

Cutting fluids must offer some degree of corrosion protection. Freshly cut ferrous metals tend to rust rapidly since any protective coatings have been removed by the machining operation. A good metalworking fluid will inhibit rust formation to avoid damage to machine parts and the workpiece [12]. It will also impart a protective film on cutting chips to prevent their corrosion and the formation of difficult-to-manage chunks or clinkers [13].

B) STABILITY CONTROL.

No matter how good the engineering qualities of a coolant, if it develops an offensive odor, it can cause problems for management. The toxicity of a fluid may also increase dramatically if it becomes rancid due to chemical decomposition, possibly causing the fluid to become a hazardous waste. Fluid rancidity shortens fluid life and may lead to increased costs and regulatory burdens associated with fluid disposal. A good cutting fluid resists decomposition during its storage and use. Most cutting fluids are now formulated with bactericides and other additives to control microbial growth, enhance fluid performance and improve fluid stability [2,13].

C) TRANSPERANCY AND VISCOSITY.

In some operations, fluid transparency or clarity may be a desired characteristic for a cutting fluid. Transparent fluids allow operators to see the workpiece more clearly during machining operations. Viscosity is an important property with respect to fluid performance and maintenance. Lower viscosity\ fluids allow grit and dirt to settle out of suspension. Removal of these contaminants improves the quality of the fluid recirculating through the machining system. This can impact product quality, fluid life and machine shop productivity [2,3].

D) HEALTH AND SAFETY CONSIDERATIONS.

Workers in machining operations are continually exposed to cutting fluid. A fluid must be relatively non-toxic, non-flammable and non-misting to minimize health and safety risks. A fluid should have a high flashpoint to avoid problems associated with heat damage, the production of smoke, or fluid ignition. High speed metalworking operations such as grinding may atomize fluid, creating a fine mist which can be an inhalation hazard for machine tool operators. Misting also creates a dirty work environment by coating equipment and the surrounding work area. Non-misting fluids provide safer working conditions for the machine operator [5]

2.4 CLASSIFICATION OF CUTTING FLUID.

A) STRAIGHT OILS (100% petroleum oil)

Straight oils, so called because they do not contain water, are basically petroleum, mineral, or ag-based oils. They may have additives designed to improve specific properties [12,13].

Generally additives are not required for the easiest tasks such as light-duty machining of ferrous and nonferrous metals. For more severe applications, straight oils may contain wetting agents (typically up to 20% fatty oils) and extreme pressure (EP) additives such as sulfur, chlorine, or phosphorus compounds. These additives improve the oil's wet ability; that is, the ability of the oil to coat the cutting tool, workpiece and metal fines They also enhance lubrication, improve the oil's ability to handle large amounts of metal fines, and help guard against microscopic welding in heavy duty machining. For extreme conditions, additives (primarily with chlorine and sulfurized fatty oils) may exceed 20%. These additives strongly enhance the antiwelding properties of the product [2].

ADVANTAGES - Excellent lubricity; good rust protection; good sump life; easy maintenance; rancid resistant

DISADVANTAGES - Poor heat dissipation; increased risk of fire, smoking and misting; oily film on workpiece; limited to low-speed, severe cutting operations

B) SOLUABLE OILS (60-90% petroleum oil).

Soluble oils (also referred to as emulsions, emulsifiable oils or water-soluble oils) are generally comprised of 60-90 percent petroleum or mineral oil, emulsifiers and other additives. A concentrate is mixed with water to form the metalworking fluid. When mixed, emulsifiers (a soap-like material) cause the oil to disperse in water forming a stable “oil-in-water” emulsion. They also cause the oils to cling to the workpiece during machining. Emulsifier particles refract light, giving the fluid a milky, opaque appearance [2, 13].

ADVANTAGES- Good lubrication; improved cooling capabilities; good rust protection; general purpose product for light to heavy duty operations

DISADVANTAGES - More susceptible to rust problems, bacterial growth, tramp oil contamination and evaporation losses; increased maintenance costs; may form precipitates on machine; misting; oily film on workpiece

C) SYNTHETIC OILS (0% Petroleum oil).

Like soluble oils, synthetics are provided as a concentrate which is mixed with water to form the metalworking fluid. These fluids are designed for high cooling capacity, lubricity, corrosion prevention, and easy maintenance. Due to their higher cooling capacity, synthetics tend to be preferred for high-heat, high-velocity turning operations such as surface grinding. They are also desirable when clarity or low foam characteristics are required. Heavy-duty synthetics, introduced during the last few years, are now capable of handling most machining operation [2].

ADVANTAGES - Excellent microbial control and resistance to rancidity; relatively nontoxic; transparent; nonflammable/nonsmoking; good corrosion control; superior cooling qualities; reduced misting/foaming; easily separated from work piece/chips; good settling/cleaning properties; easy maintenance; long service life; used for a wide range of machining applications

DISADVANTAGES - Reduced lubrication; may cause misting, foaming and dermatitis; may emulsify tramp oil; may form residues; easily contaminated by other machine fluids

D) SEMISYNTHETIC OILS (2-30% petroleum oil).

Semisynthetics (also referred to as semi-chemical fluids) are essentially a hybrid of soluble oils and synthetics. They contain small dispersions of mineral oil, typically 2 to 30 percent, in a water-dilutable concentrate. The remaining portion of a semi-synthetic concentrate consists mainly of emulsifiers and water. Wetting agents, corrosion inhibitors and biocide additives are also present. Semisynthetics are often referred to as chemical emulsions or preformed chemical emulsions since the concentrate already contains water and the emulsification of oil and water occurs during its production. The high emulsifier content of semisynthetics tends to keep suspended oil globules small in size, decreasing the amount of light refracted by the fluid. Semisynthetics are normally translucent but can vary from almost transparent (having only a slight haze) to opaque . Most semisynthetics are also heat sensitive. Oil molecules in semisynthetics tend to gather around the cutting tool and provide more lubricity. As the solution cools, the molecules redisperse [2, 13].

ADVANTAGES - Good microbial control and resistance to rancidity; relatively nontoxic; nonflammable/ nonsmoking; good corrosion control; good cooling and lubrication; reduced misting/foaming; easily separated from workpiece/chips; good settling/cleaning properties; easy maintenance; long service life; used for a wide range of machining applications

DISADVANTAGES - Water hardness affects stability; may cause misting, foaming and dermatitis; may emulsify tramp oil; may form residues; easily contaminated by other machine fluids.

2.5 ANALYSIS OF CUTTING FLUID.

Cost, the effect on the environment, and health issues are all relevant when considering the choice of a lubricant and application system in a modem metal cutting process. The need to use less, limit the disposal and operator contact are all now very important. A.R. Machado and J. Wallbank show the results of preliminary tests using very low quantities (200-300 ml $h10^{-1}$) of lubricant when machining steel. The low quantities were applied in a fast flowing air stream. The results are compared to traditional flood cooling as a benchmark with 5.2 min^{-1}.The results show that surface finish, chip thickness and force variation are all affected beneficially with the low coolant volume compared to flood cooling. The results with the mixture of air + water are encouraging. This avoids the pollution of the environment and related problems of health and safety, and drastically reduces lubricant costs, although it may cause problems of corrosion [14].

Environmental and economic considerations have emphasized the trend for more dry machining. Advanced wear-resistant coatings with increased oxidation resistance such as PVD TiAlN offer an advantage for dry machining of cast iron and alloyed steel. The combination of hard/soft coating layers allows improved chip flow with a lowered coefficient of friction and reduced cutting force. Today, dry machining is one of the most discussed topics related to production engineering. The motivation for this technology is a strong ecological and economical reason. In dry cutting operations tests have shown that the lifetime of tools could be increased by using a tool that is coated by a combination of a hard and lubricant layer. Mainly, in dry machining conditions for materials like alloys of aluminum or steel, positive results could be achieved [15].

Graphite can also used as a lubricant specially during grinding this is because Conventional flood cooling is often ineffective due to the relative inaccessibility of the fluid to the actual grinding zone, film boiling etc. Further these fluids are also a source of health hazards. An investigation on using graphite as a lubricating medium to reduce the heat generated at the grinding zone showed that grinding force, energy and temperature are reduced [16]. Application of conventional cutting fluid may not effectively control the heat generation in milling Solid lubricant assisted machining is an environmental friendly clean technology for desirable control of cutting temperature. The role of solid lubricant assisted machining with graphite and molybdenum disulphide lubricants on surface quality, cutting forces and specific energy while machining AISI 1045 steel using cutting tools of different tool geometry .The performance of solid lubricant assisted machining has been studied in comparison with that of wet machining. The results indicate that there is a considerable improvement in the process performance with solid lubricant assisted machining as compared to that of machining with cutting fluids [21].

Green cutting has become focus of attention in ecological and environmental protection. Water vapor is cheap, pollution-free and ecofriendly. Therefore water vapor is a good and economical coolant and lubricant. The experimental results showed that with water vapor as coolant and lubricant the cutting force is further reduced, the friction coefficient, the chip deformation coefficient and the surface roughness value decreased and the cutting temperature lowered. Kinetic model of penetration capillary in tool–chip interface of cutting fluid revealed that the lubricity effect is much better with water vapor as coolant and lubricant because of its excellent penetration performance and forming of low shearing strength lubrication layer. Therefore, the use of water steam as coolant and lubricant proves to be a green cutting technique. Experimental results of water vapors compared with different coolants are shown in the figure below [17].

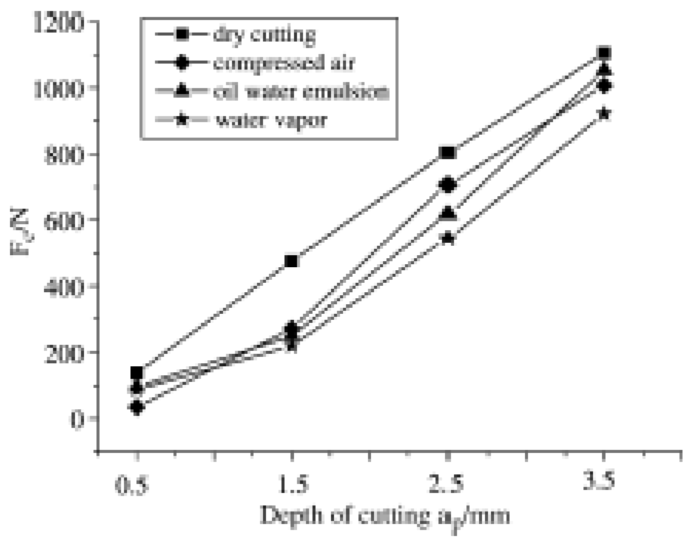

Figure 10: The cutting force Fc comparison.

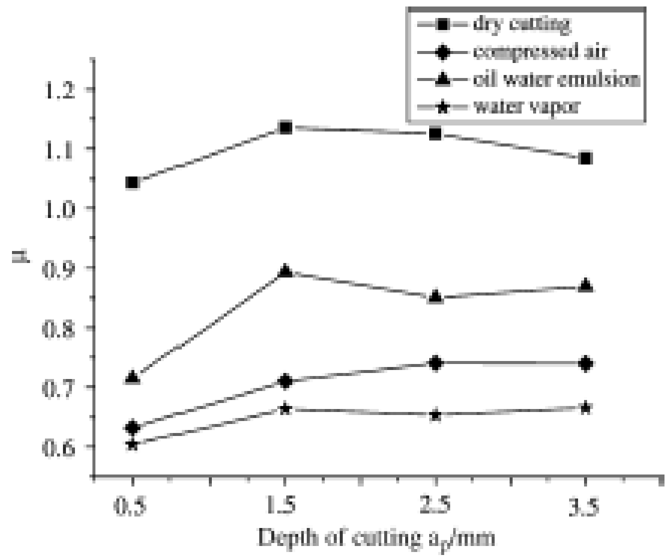

Figure.11: the friction coefficient m comparison.

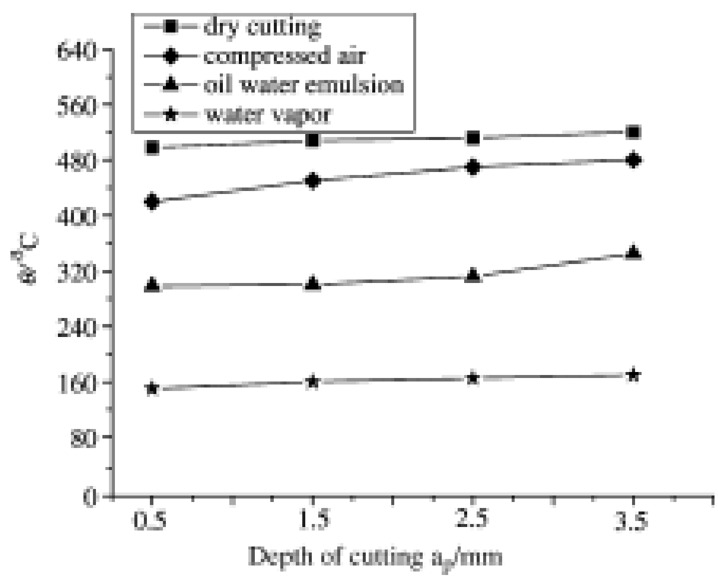

Figure12: The cutting temperature θ comparison.

Coconut oil is also being compared with another two cutting fluids namely an emulsion and a neat cutting oil (immiscible with water).The results indicated that in general, coconut oil performed better than the other two cutting fluids in reducing the tool wear and improving the surface finish [17,18].Interest in vegetable oil-based metalworking fluids is growing. The application of vegetable oil Metal working fluid MWFs may be driven by environmental and safety issues also it improves surface finish and gives longer tool life. Vegetable oil-based MWFs can be used in the same operations as mineral based, or petroleum-based, fluids. However, compared to mineral oil, vegetable oil can enhance cutting performance, extend tool life and improve part surface finish. The environmental benefits, though important, are secondary. Vegetable oil provides machining performance that is superior to that of mineral oil in most applications [22].

The concept of minimum quantity lubrication (MQL) has been suggested since a decade ago as a means of addressing the issues of environmental intrusiveness and occupational hazards associated with the airborne cutting fluid particles on factory shop floors. Investigation on the role of MQL on tool wear and surface roughness in turning AISI-4340 steel at industrial speed-feed combination by uncoated carbide insert. The encouraging results include significant reduction in tool wear rate and surface roughness by MQL mainly through reduction in the cutting zone temperature and favorable change in the chip–tool and work–tool interaction. (MQL) technique in turning gives some advantages in terms of tool wear reduction. The results obtained show that when MQL is applied to the tool rake, tool life is generally no different from dry conditions, but MQL applied to the tool flank can increase tool life [19,20].

2.6 FLUID SELECTION.

It is important to select the proper type of coolant. For example, using an unsuitable coolant may lead to tool failure or produce an undesirable finish on tools, and it may shorten the useful life of the coolant. Therefore, when selecting a coolant, determine if it is suitable for the type of metal and machining operation used, and if it will produce the desired finish quality. Operational requirements are dictated for the most part by the material to be machined, the process to be used, the tool material, the quality requirements and the amount of machining required. Other items, such as type of filtration, water quality and chemical restrictions, may also influence the selection of a fluid. Some materials may not require any metalworking fluid. Some alloys may require only a little tapping fluid when threaded or tapped. In certain cases, water alone can be used as a coolant and finish. In most cases, however, use of a metalworking fluid will deliver higher production rates and extend tool life [25].

It is important to carefully select the metalworking fluid most suitable for the particular application to maximize its performance and fluid life. Fluid selection should be done from plant-wide perspective to find the best products and minimize the number of different fluids in use. The broad applications of some high quality fluids sometimes make it possible to employ only one type in an entire plant with different concentrations appropriate to the specific application. This will simplify operations, minimize contamination, and maximize purchasing power. Figure 14 outlines the most basic issues that firms should address during the fluid selection process. [24].

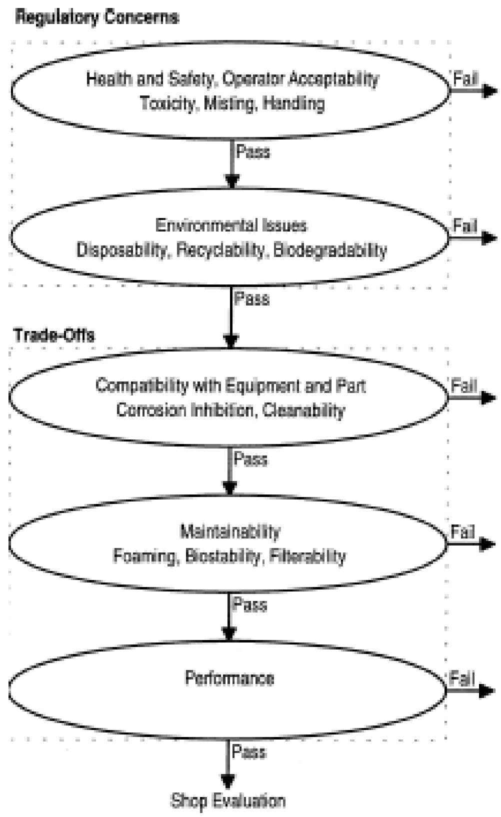

Figure13: Metalworking Fluid Selection Process.

The following factors should be considered when selecting a fluid [2, 23].

- Cost and life expectancy
- Fluid compatibility with work materials and machine components
- Speed, feed and depth of the cutting operation
- Type, hardness and microstructure of the metal being machined
- Ease of fluid maintenance and quality control
- Ability to separate fluid from the work and cuttings
- The product’s applicable temperature operating range

- Optimal concentration and pH ranges
- Storage practices
- Ease of fluid recycling or disposal

2.7 CUTTING FLUID MANAGEMENT.

Monitoring and maintaining fluid quality are crucial elements of a successful fluid management program. A fluid must be monitored to anticipate problems. Important aspects of fluid monitoring include system inspections and periodic measurements of fluid parameters such as concentration, biological growth, and pH. Changes from optimal fluid quality must be corrected with appropriate adjustments (such as fluid concentration adjustments, biocide addition, tramp oil and metal cuttings removal, and pH adjustment). A change in pH can quickly deteriorate coolant quality, corrode metals and irritate skin. Proper coolant pH operating ranges are specified by the manufacturer. For most coolants this range is 8.5 to 9.0. Within the proper pH range, corrosion and bacterial growth are minimized. Drops below the recommended limit may be a symptom of a bigger problem and are most likely caused by excessive bacteria or excessive diluting. Using low-cost tools for monitoring pH levels such as portable pH meters and pH paper can help determine when pH needs adjusting. For specific recommendations about maintaining coolant pH, contact chemical or coolant suppliers [27].

Maintaining the proper coolant-to-water ratio i.e. the coolant concentration, it is critical because coolants are designed to perform best at specific concentrations. Overly diluted coolant may reduce tool life, and concentrated coolant results in using more coolant than necessary. Refractometers can provide accurate measurements to determine the coolant-to-water ratio and are fairly inexpensive and simple to operate. Titration kits, supplied by some coolant manufacturers, are another way to maintain proper concentration. Coolant metering or feed pumps can also improve the rate at It is important to know what changes may take place in your system and why they occur. This allows fluid management personnel to take the appropriate steps needed to bring fluid quality back on-line and prevent fluid quality problems from recurring [2,27].

In addition to monitoring pH and coolant concentration, a comprehensive coolant maintenance program should include monitoring tramp oil concentration, suspended solids, alkalinity, and spot corrosion of parts and bacteria count. Srimongkolkul emphasized oil maintenance in particular, because he estimates that 80 percent of machine problems are caused by faulty oil. “Oil maintenance is job No. 1. Now a days fluids-monitoring software or the “proactive maintenance,” which can be defined as “monitoring and correcting the root causes of failure, such as contamination of fluids. Maintenance software for oil and lubrication products does the following. offers best practices for machine lubrication; performs scheduling tasks and stores oil specs for each machine in the shop; consolidates the number of oils used to the fewest types; oversees lubrication equipment tracking; incorporates oil disposal and reclamation procedures; and offers tips on which laboratory to use along with guidance on what actions to take depending on the lab results. The software also indicates when outside analysis of fluids is needed and what types of analysis should be undertaken, and it can help map a daily maintenance routine within a shop, minimizing backtracking and overall time spent on maintenance chores[28].

The volume of machine coolant waste can be reduced through maintenance. Coolants are generally considered a waste due to rancidity, not due to a loss of their cooling properties. Maintenance involves the removal of tramp oils from the machine's coolant sump, control of bacterial growth and recyclying [26,27]. Waste oils, which come from the machine or surfaces of the raw materials, are picked up by the metalworking fluid and are referred to as "tramp oils". Tramp oil sources are: hydraulic fluid, way oils, lubrication oils, tapping oils, gear box oils, etc. These oils seal off the surface of the sump from the air, speed up the degradation of the metalworking fluids and promote microbial growth. This microbial growth leads to rancidity problems which require metalworking fluids to be disposed of prematurely. The best way to reduce tramp oil is by regular inspection and replacement of gaskets, wipers and seals and skimmers [29].

2.7.1 FLUID MAINTENANCE.

Effective programs can keep metalworking fluid as clean as the initial raw product, significantly prolonging its service life. In addition to waste reduction, a number of other incentives exist for establishing a fluid-management program. These include [32].

1. Reduced environmental liability due to less waste and reduced off-site disposal.
2. Easier compliance with environmental regulations.

3. Reduced fluid consumption (up to 40%) and reduced purchase costs and disposal expenses.
4. Improved productivity due to decreased downtime and tool wear, more consistent machining tolerances, and higher quality finished parts.
5. Cleaner machines that require less maintenance and repair Longer cutting tool life;
6. A healthier and safer work environment for the machine operator

Whenever several machines use the same type metalworking fluid, the economics of a central replenishment and recirculating system should be investigated. The use of a central system assists in starting a fluid management program. A central system allows for convenient, proper monitoring of concentrations and microbial growth. Central systems can also make it economically feasible to install filtration equipment that removes tramp oils and other contaminants. Contaminants may be removed by processing the coolant with an “in-line” (continuous flow) or an “off-line” (batch type) coolant recycling system. Both can be equally effective. Used coolant flows directly to a recycling system and cleaned coolant flows directly back to the metalworking machine with an “in-line” system. Used coolant must be physically removed from metalworking machines and returned after recycling with “off-line” systems. With both systems, the recycling systems consist of various combinations of filters, coalescers, separators, skimmers, and high speed centrifuges to remove tramp oil,.fine particulate matter and bacteria. “In-line” systems can require a significantly higher equipment investment than “off-line” systems due to the added cost of a centralized filtration system, which requires in-floor flumes and clean coolant distribution piping. Coolant recycling equipment needs should be based on the volume of coolant in use, whether the coolant is contained within individual machine sumps or in one or more central filtration systems, the fineness of filtration needed for optimism cutting or grinding performance and the amount of money available for equipment purchase.

Figure below provides an example of the process flow in an integrated coolant recovery system [29].

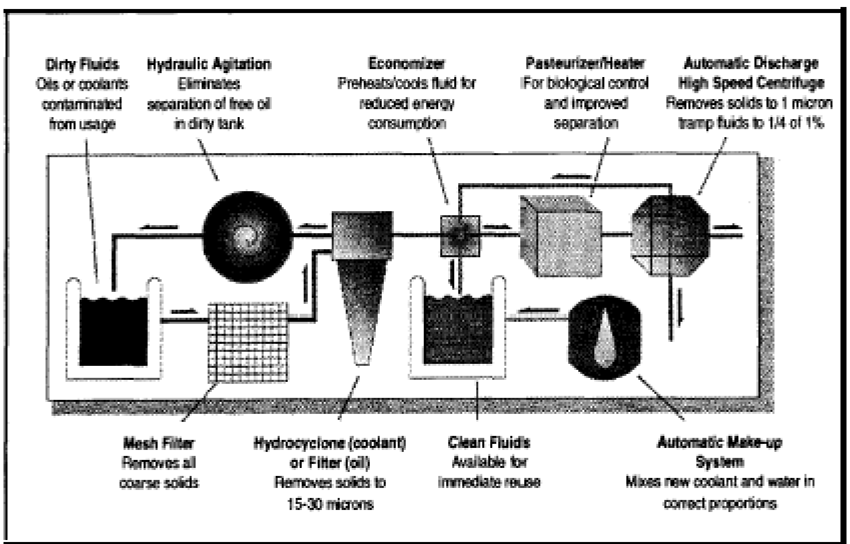

Figure14: Process Flow Diagram of an Integrated Coolant Recovery System.

The usable life of the metalworking fluid can be extended by filtering out contaminants and reusing (recycling) the cleaned metalworking fluid. Fluid maintenance can be done either on-line or by a batch process. For larger machines or small groups of machines, a large settling tank, skimmer, and/or filter can be added in the return lines to continuously clean the fluid. For smaller sumps, it is generally more cost effective to have a small, stand-alone system that may also include coalescer, hydrocyclone or other technologies. Coolants are most frequently contaminated by, chips and fines, tramp oil, bacteria and dissolved salts. By removing these contaminants, machining facilities can reduce costs by prolonging the life and effectiveness of coolants [29].

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Filtration of particulates and metal fines helps keep the coolant clean, aids in keeping surface finishes high, maintains tool life and reduces skin contamination to metal fines. Metal fine contamination is the most common cause of dermatitis and skin sensitization, more so than chemicals. The fines penetrate into cuts/abrasions in the skin and cause redness, sores and blistering. Proper cleaning with each coolant change and good filtration to prevent sludge accumulation can help keep bacterial growth under control. [30] A shop that has properly implemented a high-pressure coolant system may be quite pleased with the cycle-time reduction that it sees as a result. But if it does not update its coolant maintenance routines as well, its jobs still may not be running at peak efficiency. A coolant system that maintains consistent temperatures and fluid concentrations using safe coolants may still be hindering shop performance if filtration is inadequate [31].

2.8 FILTER ATION SELECTION CRITERIA.

In coolant filtration, the end user is generally interested in four primary criteria when selecting filter media: durability, efficiency, capacity, and cost [33].

1. Durability may be defined as sufficient strength to withstand the physical rigors of the filter system without tearing or rupturing in the filter bed, or causing difficulty in extracting from the filter system.
2. Efficiency may be defined as the retention of particles of **a** certain size and the rate of their removal.
3. Capacity may be defined as the amount of contaminants removed per unit area of filter media, before the media's permeability reaches its useful life.

4. Cost may be defined as unit price time’s usage, plus maintenance and disposal.

2.9 MAGNETS

The use of magnets for removing ferrous contaminants in an industrial environment first began in the 1940s when Orange F. Merwin developed a flat magnetic product to help farmers trap and remove metal contaminants from their grain chutes. Ferrous metal contamination damages process equipment and creates impure product that must be scrapped or sold at less than full value. The contamination may originate within the plant due to material processing, grinding, crushing or general abrasion. The problems associated with ferrous metal contamination can be reduced or eliminated by using magnetic separation equipment. Selecting the proper magnetic separator requires an understanding of magnetic properties, the process application and environmental elements that exist in each specific installation.

2.9.1 TYPES OF MAGNET.

Magnet material generally refers to the magnetic pressings or castings used to develop the magnetic field within the separator. This material may be cut and arranged in a linear fashion using other materials to create a magnetic circuit. Depending on the desired outcome, circuits may be designed to cast a shallow wide magnetic field; a deep-narrow field or anywhere in between. This is why it is often difficult to compare competing products made of only similar material. Once the circuit is assembled, it is usually encased within stainless steel to protect the magnet material from wear associated with product flow, damage or from contaminating the feed material. Since the 1940s, there has been substantial change in the materials used to manufacture permanent magnetic separators for industry. The following is a brief description of the most common magnetic materials used over the past 60-plus years.

1. ALNICO.

Alnico is one of the earliest magnet materials used for ferrous separation. These magnets are commonly recognized by their horseshoe shape. This material is a casting of Aluminum, Nickel, Cobalt and Iron. Although seldom used today, as there are more economical magnet sources, Alnico may still be used in applications involving temperatures in excess of 400 degrees Fahrenheit (204 degrees Celsius). This material is comparable in strength to ceramics and used to remove relatively large pieces of ferrous metals, such as nuts or bolts.

2. CERAMIC

In the late 1960s, the price of cobalt began to rise and manufacturers began looking for a substitute for Alnico. At this time, manufacturers considered using a ceramic material in their magnetic separators, which became the standard until the early 1980s. Ceramic was easy to work with because it could be cut in any direction, assembled into a circuit and then charged as a complete unit. Its strength in the tube magnets is comparable to Alnico castings, and its only basic limitation was that it had a greater reversible loss at high temperatures. Ceramic-type magnet material is best when the goal is to remove relatively large pieces of ferrous metals because it has minimal holding strength on small particles, which, even if captured, would be washed off by the product flow in a short period of time.

3. RARE EARTH

Originally thought to be rare, the metallic elements with an atomic number between 57 and 71 are classified as "rare earth." Because samarium cobalt (number 62 on the periodic table) was the first material used to make these magnets, they were called "rare earth." Samarium cobalt could produce more than 4100 surface gauss in a tube magnet circuit compared to 1,000 and 2,000 gauss for standard Alnico and ceramic. (*Gauss* is a unit measuring electromagnetic force.)

The newest generation of rare earth magnets consists of neodymium iron boron. (Neodymium is number 60 on the periodic table.) The first neodymium iron boron magnet that came to market developed a surface gauss of approximately 4800 in a tube-type circuit.

Some general guidelines for magnetic field requirements are shown in Table below.

1500 Gauss.	Relatively coarse (+50 micron) ferromagnetic iron of abrasion.
2500 Gauss.	Fine (-50 micron) ferromagnetic iron of abrasion or scale
5,000 Gauss	Very fine (submicron) ferromagnetic iron of abrasion or scale, or paramagnetic contaminants such as iron-bearing minerals or nickel and cobalt compounds
10,000 Gauss	Fine paramagnetic contaminants

Table 2: Guidelines for magnetic field requirements.

2.9.2 DIFFERENT METHODS OF FILTERATION.

Effective magnetic particle filtration can be achieved in several ways. In order to choose the appropriate method for a specific application, several factors should be taken into account including the level of filtration, types of materials that have to be removed, and the type of coolant being clean.

A) MAGNETIC PIPLINE TRAPS.

Magnetic pipeline traps use high energy, rare-earth permanent magnetic collect ferrous contaminants in fluid line. The “ in-line “ traps contains a series of magnetic tubes that are generally one inch in diameter and extends down through the entire diameter of the pipe to provide complete contact with the fluid. The tubes house a circuit of rare-earth permanent magnets altering with steel slugs. The steel slugs concentrate the magnetic flux, producing regions of very high magnetic gradient. Because of this high gradient, ferrous contaminant will collect at the point of the magnetic tube where a steel slug is situated. The thickness of the rare earth magnets and the steel slugs are just at the point of magnetic saturation, utilizing the full potential of the rare earth permanent magnets. Traditionally, magnet traps have been used in industries other than metal working and installed directly in front of the coolant pump. Magnetic traps can be used in the central coolant system as a final clean up. One major benefit of the magnetic traps is that they work well with both water-based and oil-based coolant.

B) MAGNETIC CHIP AND PARTS CONVEYOR

Magnetic chip and parts conveyors can provide a low maintenance method of moving and elevating ferrous chips, turning, small part and stampings. Powerful permanent magnetic inside the conveyor housing slide the material along the surface, and there are no external moving parts to jam or break. A wide variety of conveyor configurations, in many sizes, widths and magnetic strengths, are available for hard-to-reach areas under presses, milling machines and other machine tools. Specific to the metal working industry, chip and parts conveyors can be provide assistance to those who have problems separating chips and coolant. Typically, a hinged steel belt conveyor allows coolant to flow through with the chips staying on top of the conveyor and then being carried out of the machine.

C) CERAMIC COOLANT CLEANERS.

Permanent magnetic coolant cleaners remove grinding swarf and turning fines, helping machine tools run longer and maintain accuracy, with lower costs per unit produced. Indexing units, with either a smooth-faces or extended-pole roll, when both ferrous and non ferrous contaminants are present. Coolant cleaners are designed for use with surface grinders, gear grinders, honing and lapping machines and wherever clean coolant is needed. Coolant cleaners are designed for use with surface grinders, gear grinders, honing and lapping machines, broaches, milling and drilling machines, face grinders, oil-reclaiming machines and wherever clean coolant is needed

D) RARE-EARTH COOLANT CLEANERS.

A coolant cleaner, whose power source is a high quality rare-earth permanent magnetic material, develops magnetic fields many times stronger than conventional ceramic or alnico magnets. In operation, liquid contaminated with fine ferrous particles enters the sump area and flows past a counter-rotating magnetic drum. Particles attracted to the drum are held tight and lifted to the top, where a mechanical discharge mechanism moves them to a discharge chute. Cleaner liquid is discharged from the bottom of the separator.

Fine magnetic particles suspended in the dirty liquid tend to flocculate when introduced to the strong magnetic field, thus increasing separation efficiency. Accordingly, this coolant cleaner is effective even on moderate or paramagnetic particles. The efficiency of magnetic separators such as this one depends on the magnetic susceptibility and concentration of the contaminants, as well as the viscosity of the liquid. The rare-earth coolant cleaner helps machine tools run longer and maintain accuracy by removing grinding swarf.

E) MAGNETIC-CYCLONE FILTERS.

When machining both ferrous and nonferrous materials on the same grinding machine, an additional level of filtration is necessary. For example, with a water-based coolant, the Eriez magnetic-cyclone filter removes particles down to 5 microns. This kind of filter is especially effective at handling the high stock removal rates of through-feed, centerless, surface and small double disc-type grinders. It also removes steel wool from the coolant used by ID, abrasive belt and free abrasive grinders. Dirty coolant from the machine tool enters a reservoir and flows through a magnetic coolant cleaner. Ferrous particles, the bulk of the contaminant, are collected on the magnetic roll and discharged into a swarf bucket. The coolant and nonferrous contaminants fall into a tank below. The filter then pumps the almost-clean coolant to a manifold, which evenly distributes it to the second stage filter, the hydro cyclone. The filtered particles, along with a small amount of coolant, are discharged from the nozzle and fall into a portable swarf tank. The clean coolant leaves the hydro cyclone through the top and is sprayed into the clean coolant tank, where the clean coolant pump returns it to the machine tool, completing the cycle.

vi) PAPER BAND CUM MAGNETIC COOLANT FILTERS:

In this type of filter the entire units are fixed on a coolant tank with a pump to supply coolant liquid that first passes through the magnetic filter which separates almost 95% of the ferrous particles. The liquid further passes through the filter paper by gravity where all the non-ferrous particles like grinding grid, stainless steel, brass or aluminum are filtered. When the paper is clogged by contaminants the coolant level raises on the filter paper and actuates the float switch, which starts the geared motor and fresh paper from the roll is pulled forward automatically.

CHAPTER-3

DESIGN OF MAGNETIC COOLANT FILTER

3.1 INTRODUCTION

In order to carry out the design procedure it is necessary to understand the drawbacks of available filters so that their solution may be found in new design. So we need to consider other effects such as cost, surface finish of products. So given below are the problems with filtration available.

1. At present the coolant filtration units are used in large-scale industries where metal cutting operations are done on CNC machines whose production rate is very high and coolant filters attached to it is very costly and small entrepreneur can buy such set up.
2. The present design does not offer a large surface area to maximize exposure to magnetic fields. In addition, the magnets used these machines are conventional and therefore have a very short life and inefficient filtration.
3. The magnets used in the conventional coolant filters loose their properties when subjected to high heat, high vibration application. The heat and vibration often kill the magnetic fields of weaker magnets.
4. For filtration of very fine metal particles (i.e. less than 10 microns) you need an extremely powerful magnetic field because of small mass of the particles and the high flow situation and the conventional magnets fail in such conditions.

5. For the shops with many machine tools each machine requires a separate coolant filtration unit which is a very costlier for a small workshop.

3.2 DESIGN CRITERIA.

Following are the main considerations which we have taken while designing the magnetic coolant filter.

1. FILTRATION LEVEL.

The device must be able to remove at least 95-98% of the total chips suspended in coolant, because anything below this would harm the surface finish of the product. The filter must have the capacity to not only remove the chips but also to dispose them to a sludge bin.

2. COST.

The cost of filter is also a major concern. It must be within the reach of small entrepreneurs. The cost should be so less that it can be used even with ordinary machines.

3. MAINTENANCE.

The filter should be maintenance free i.e. The maintenance costs musts must be negligible. For this purpose the filter should be as few as possible. The parts should be cheap and their replacement should be less frequent

4. SPACE REQUIREMENTS.

The filter should not consume large space. It should be placed within the machine so that the operations appear to be neat and clean. It must be tiny so that it may install somewhere near the bed or so.

5. LIFE.

The life of equipment is also a major concern. The life of equipment should be such that it gives significant payback of the money spent. The parts should be wear resistance for this purpose.

6. CAPACITY.

The filter must designed according to a given flow rate of coolant. Because this enables us to employ the filter over a range of machines in which the average flow rate is less than or equal to the capacity designed.

3.3 WORKING PRINCIPLE OF MAGNETIC COOLANT FILTER.

Magnetic coolant filter utilizes high energy permanent magnets to develop a dense magnetic field along a narrow flow path into which the contaminated coolant is directed. The ferromagnetic particles captured and aligned by the dense magnetic field, from the efficient filter medium. This enables the unit to remove ferromagnetic particles from the coolant.

The magnetic field produced by permanent magnets will be throughout the area underneath the reservoir. This produces magnetic field 30mm above the coolant reservoir. Very fine particles are arrested without slip. The magnetic material used will not loose its strength even number of years of use.

Dirty coolant is fed from the machines in to the reservoir of the coolant filter either by a pump or taken by the gravity and flows under on the tray. This attracts the ferrous particles and builds up a cake of ferrous material and finally takes away to the chip/ sludge bin.

The moving permanent magnets mounted on endless chain underneath the stationary stainless steel sheet attract ferrous chips and slide them on plate to the discharge end/ sludge bin. The coolant separated from chips flow to the coolant tank through an overflow so that even floating chips get attracted by moving magnets and get conveyed.

3.4 DESIGN/ ANALYSIS.

3.4.1 DESIGN FEATURES OF MAGNETIC COOLANT FILTERS.

Coolant filters are required in the modern metal working factory environment in order to recycle metal cutting fluids. The filter is developed for the shops having many machines tools with individual coolant reservoir. The materials selected are stainless steel and other high grade material suited for corrosion resistance type applications and extra longevity for acidic environment.

Magnetic coolant filter being sleek in construction can be introduced in to small cross sectional openings in machine tools. As seen in the diagram this filtration system is very simple design. The coolant filter in start up condition, needing only electrical hook up and filtered city water for coolant proportioned. Since the only power is that of the belt drive, electricity costs are almost negligible.

This filter has no external moving parts. Because there are no sharp moving edges. There are no places to jam or wedge, providing virtually maintenance free operation.

The unit use a generation of rare earth magnets that provide the flexibility of applying magnets of various strengths for specific applications. This design employ magnets designed especially for high heat resistance, high vibrations applications. While heat and vibration often kills the magnetic field of weaker magnets, these rare magnets can withstand those conditions and operate effectively.

The magnetic filter is manufactured with 26 gauges stainless steel sheet and high strength rare earth magnets that render it capability of withstanding constant operational temperature of 300^{o}F in addition to providing resistance to vibration.

The magnetic coolant filter was developed for shops having many machine tools with individual coolant reservoirs and is used as a central coolant filtration system. The frame/ body on which all parts are mounted are made of angle. These angles are welded by arc welding to get required shape as per drawing. Cover sheets are manufactured from stainless steel whose main function is to avoid accidents and to give a good look to machine. The tray on which the dirty coolant is made of stainless steel sheet of 26 gauges size. Magnets used are permanent in nature and produce magnetic field 30mm above the tray/ coolant container. The magnetic material used will not loose its strength even number of years of use.

The moving permanent magnets mounted on endless conveyor underneath the Stationary stainless sheet/ trays attract ferrous chips and slide them on plate to the discharge end. The coolant separated from the coolant tank through an overflow so that even floating chips get attracted by moving magnets and get conveyed. Approximately 200 sq inches of magnetic surface area are in contact with the loaded coolant at all times. Coolant flows for a distance of 35.2 through this very strong magnetic surface, assures optimum clearing efficiency.

3.4.2 CAPACITY OF COOLANT FILTER

The capacity of coolant filter which is to be design is of 10 liters/ min.

3.4.3 STAINLESS STEEL TRAY

The main function of the stainless steel tray is to hold the dirty coolant which is fed from the coolant reservoir. Also the material of the sheet should be non magnetic and at the time it should have enough strength to hold about 10 liters of coolant. The design procedure for the tray is as follows.

A). SELECTION OF THE STAINLESS STEEL SHEET GRADE.

As the grade of stainless steel sheet increases its thickness decreases and above 24 gauges, the behavior of the sheet changes i.e. becomes non magnetic. Therefore we have a range from 24 to 30 gauges. Also above 26 gauges the thickness of sheet becomes very less that can sustain the load of the coolant. And therefore for our coolant filter we have selected the stainless steel sheet with 26 gauges thickness.

B). ANGLE OF INCLINATION OF TRAY WITH HORIZONTAL.

The angle of inclination of the tray depends upon the value of coefficient of friction between coolant chip mixture and stainless steel sheet.

$\mu = 0.105$

[Ref: Magnetic particle filtration for metal working fluids by Daniel Norrgran & Johan Mackowski].

Also, $\mu = \text{Tan}\,\theta$

$\theta = \text{Tan}^{-1}(\mu) = (0.105)$

$\theta = 6^0$

C) DIMENSION OF THE TRAY.

We have to design the tray for 10 liters capacity, so taking the factor of safety and designing the tray for 11.5 liters.

Let, l= Length of the tray

b= width of the tray

h= Height of the tray

But, 300≤b≤420

[Ref: Magnetic particle filtration for metal working fluids by Daniel Norrgran & Johan Mackowski].

Therefore taking average value of b

b= (300+420)/ 2 = 360mm

Since magnets can attract ferromagnetic particles only 30mm above it therefore taking height of coolant as 25mm. considering clearance between conveyor and tray as 5mm and 10mm for overflow height of tray now becomes 35mm. Solving we get the final dimension as

L = 913 mm, b = 360 mm, h = 35 mm

3.4.4 BODY FRAME

The body frame is not designed according to the strength point of view, but according to the convenient positioning of whole machine on any machine tool. Therefore the design is carried out as per the required dimension. The angle of inclination of the structure is same as the stainless steel tray ie 6^{o} side of the frame will lie on machine tool side.

Taking average value of h1= 315mm and taking l= 60mm extra for accommodation of driver and driven roller and driver gear.

$L = 913+60 = 973$ mm

$h_2 = h_1+h_{2'}$

$\sin\theta = h_{2'}/L$ or $h_{2'}$ => $\sin\theta \times L = \sin 6^0 \times 973$, $h_2' = 102$ mm

Therefore $h_2=102+315= 417$ mm

3.5 DESIGN OF DRIVER AND ROLLER.

A) CENTER DISTANCE BETWEEN ROLLERS.

From the drawing of the frame the length of the driver and driven roller

$L_1=L_2= 300$ mm

Taking the rollers of standard diameter as used in the conventional designs

$d_0= 58$ mm

[Ref: Magnetic particle filtration for metal working fluids by Daniel Norrgran & Johan Mackowski]

Center distance between the rollers

$c= 913 \pm 4$ mm.

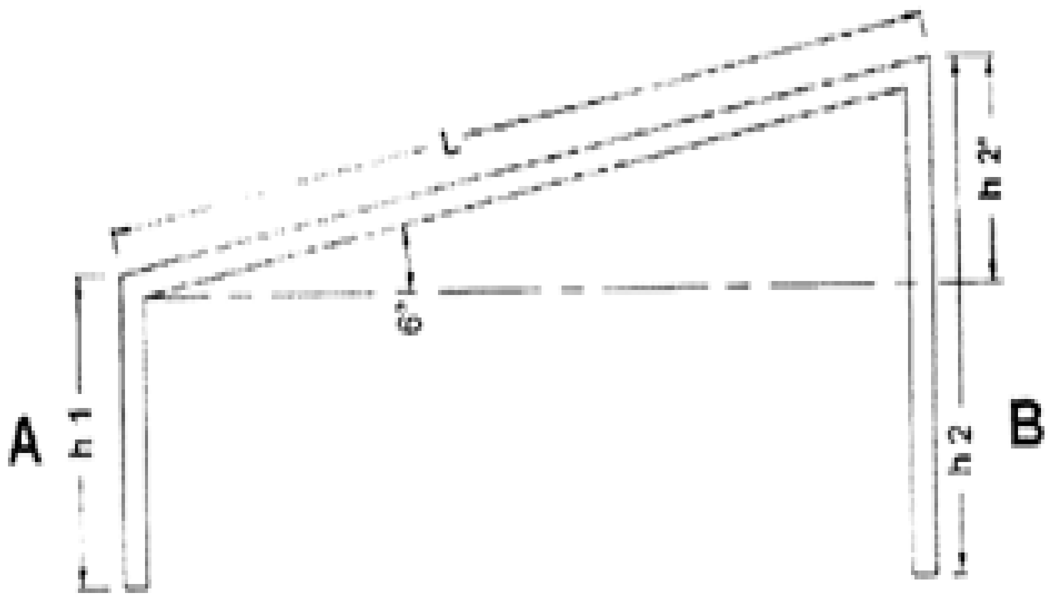


Figure15: Frame

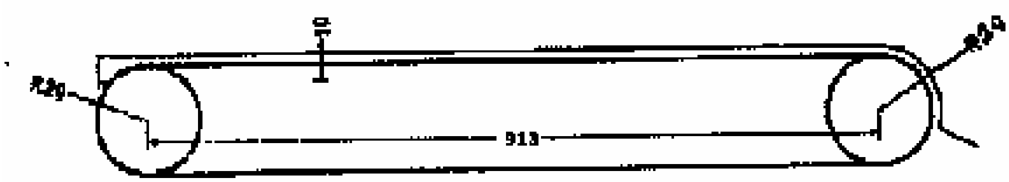


Figure16: Roller

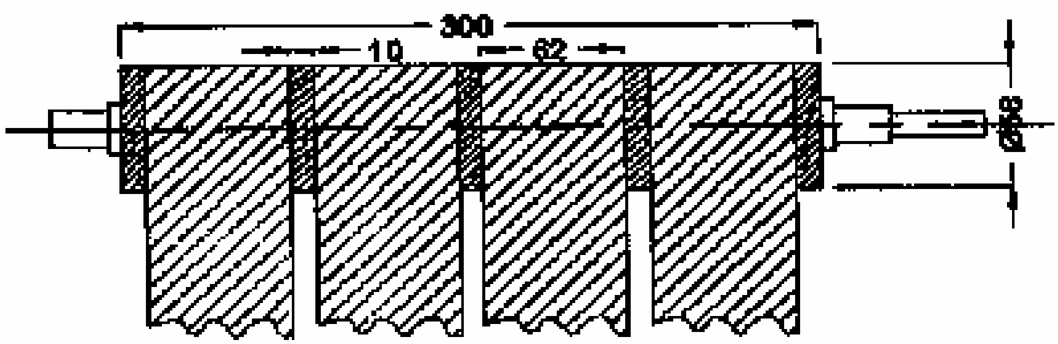


Figure17: Arrangement of conveyor belt

.B) SPEED CALCULATION FOR DRIVER AND DRIVEN ROLLER.

For the efficient filtration of the coolan6t the speed V of the belt should be 30mm/s.

[Ref: Magnetic particle filtration for metal working fluids by Daniel Norrgran & Johan Mackowski]

Now, $V = \pi DN/60$ =>$N = V \pi D60/\pi D$

$N = 0.03 \times 60 \times 1000/ \pi \times 0.058 = 9.87 \approx 1O$ rpm

As $D_1 = D_2$ therefore $N_1 = N_2 = 10$ rpm

3.6 TOTAL NUMBER OF MAGNETS ON CONVEYOR

Let area of fluid in contact with tray= A

Then A= 500×360=180,000 mm^2

Here 500mm is taken as length because it is the distance the coolant supposes to be in contact with tray. For efficient filtration of coolant, about 70% of coolant should be in contact with the magnets.

[Ref: Magnetic particle filtration for metal working fluids by Daniel Norrgran & Johan Mackowski]

Let A' be the 70% area which is in contact with the magnets

Therefore A'=180,000×0.7= 126,000 mm^2

Now the width of the conveyor belt is 62 mm and therefore the length or width of the magnet piece should be less than 62 mm selecting the standard magnet which fits the requirement.

Let the dimension of the magnet be

L = 58 mm, b = 40mm, t =10 mm

[Ref: Data book of REA Rajkot engineers association].

Therefore number of magnets required = 126,000/58×40= 54.31 No.

Since there are 4 conveyors, number of magnets per conveyor

= 54.31/4 = 13.57 ≈ 14 magnets.

There are the number of magnets on one side of the conveyor therefore total number of magnets=14 ×2×4=112 magnets

3.6.1 SELECTION OF CONVEYOR BELT.

Here the conveyor belt is not used for transmitting power but used for conveying magnets underneath the stainless steel tray. Therefore here we select the standard conveyor belt. Now if we select a conveyor belt of width b= 300 mm and Thickness t= 1.5 mm then due to weight of magnets and its own weight it will bend. So solution to this problem is using the 4 magnet conveyors instead of single one and separating them by the help of roller rings. Then the arrangement will be as shown in the figure. From the standard cotton fabric conveyor we select a conveyor of width b = 62 mm, and thickness t = 1.5 mm. So the number of roller rings = 5, outer diameter = 62, inner diameter=58 mm, width=10mm

3.7 TORQUE REQUIREMENT

To calculate the torque requirement of the machine we have to calculate the total weight which the motor should have to carry, which include the weight of the magnet + wt of the driver and driven rollers + drag force due to metallic chips conveyed by magnets.

Total fluid area over the tray=180,000mm sq and about 50% of area will always contains a layer of the chips having thickness of 2mm at max..Therefore, volume of chips in tray at any instant.

$V = 900{,}000 \times 2 = 180{,}0000\ mm^3 = 18 \times 10^{-5}\ m^3$

Cast iron density ρ = 700kg/m cube

[Ref: design book k Mahadevan]

a) Mass of chips on tray at any instant $=18 \times 10^{-5} \times 7000 = 1.26$ kg…………… (1)

Mass of 1 magnet = 40 gms

b) Therefore mass of 112 magnets = 40×112/1000 = 4.48 kg………………… (ii)

c) Mass of driver and driven roller

We have d_0 = 58 mm =0.054 m = r_0= 0.027m.

$V = \pi\ (0.029 \times 10^2 - 0.027 \times 10^2) \times 0.30 = 0.000105\ m^3$

Roller are made up of stainless steel (18-8) whose density is 7750 kg/m^3

Therefore W=0.00105×7750=0.81 kg.

And combine weight of driver and driven roller=0.81 × 2=1.62kg………………. (iii)

d) Weight of roller rings

We have d_i = 58 mm = 0.058 m= r_i = 0.029 m

And d_0 = 62 mm = 0.062 m= r_o = 0.031m

$V = \pi\ (0.031 \times 10^2 - 0.029 \times 10^2) \times 0.01 = 0.00000377\ m^3$

W = 0.00000377×7750 = 0.029 kg

Total weight of roller rings = 0.029×10 =1.29 kg………………………….. (iv)

Therefore total weight will be by combining equation (i), (ii), (iii), (iv)

W=1.26+4.48+1.62+0.29=7.65kg

This is the required torque.

3.7.1 MOTOR SELECTION.

1. Type SYN 981, AC Synchronous motor, 240V, 1 Phase, 50 Hz, 160 ma max, 60 rpm, 0.006 HP, Torque 10 kg,Weight 2KG. Cost Rs1800.
2. Type ABA 923, AC Synchronous motor, 240V, 1 Phase, 50 Hz, 140 ma max, 60 rpm, 0.005 HP, Torque 6.5 kg ,Weight 2KG. Cost Rs1200.
3. Type APPLE APSM 3, AC Synchronous motor, 240V, 1 Phase, 50 Hz, 125 ma max, 60 rpm, 0.003HP, Torque 3 kg ,Weight 2KG. cost Rs800.

[Ref: Data book of REA Rajkot engineers association].According to our required we have selected the TYPE SYN 981, With 10 kg, torque capacities.

3.8 DESIGN OF DRIVE AND DRIVEN ROLLER SHAFT

We have speed of shaft N = 10 rpm, torque requirement T =10 kg.

The shaft is designed for torque transmission.

Taking shaft material: mild steel

Allowable shear stress f_s = 41160000 N/m^2

[Ref: design data book by: K.Mahadevan].

$T = (\pi f_s d^3)/16 = 10.7$ mm

On referring the design data book by: K.Mahadevan and standardizing the shaft diameter. We get,

D≈ 11mm.but due to high cost of the shaft with 11mm diameter and high machining cost we have selected the shaft with diameter 17mm.

Length of shaft L_S = 360+40 mm, for mounting gear = 400mm.

Here we are incorporating mild steel strips to couple shaft and driver and driven rollers.

Total number of strips if there are four strips on each side of rollers = 4×2×2= 16

Length of each strip = (58-17)= 20.5 mm

Taking 3.5mm extra for welding purpose length = 24 mm

Width of strip=5mm

3.8.1 SELECTION OF BALL BEARING.

Here for the selection of the ball bearing one constraint is the shaft diameter d=17mm.

Therefore d=17mm, D=47mm,B=14mm and ISI bearing.

Bearing no.17BC03 Deep groove ball bearing.

3.9 GEAR DESIGN

Since the pinion is installed on motor shaft speed of pinion N_P = 60 rpm.

We have already calculated the speed of conveyor as well as speed of gear N_g = 10 rpm.

Data available for gear designs are as follows:

Speed of pinion N_p= 60 rpm, speed of gear N_g = 10 rpm, V = 0.063m/sec

Profile of teeth = 20^0 stub involutes, power P_{max}= 4.47 watts.

Pinion material: plastic (Celeron) = σ_p = 58.8 N/mm sq.

Gear material; plastic (Celeron) = σ_g = 58.8 N/mm sq.

Assumed distance between two shafts of pinion and gear =70 mm.

Therefore l = Dg/2+D_P/2 = 70 mm

now velocity ratio = $D_{g/}$ D_P= N_p/ N_g= Z_g/Z_P = 60/10 = 6=> Z_g= 6 Z_P

Therefore D_P = 20mm

And pitch line velocity $V = \pi D_P N_p/60$ = 0.063m/sec

3.9.1 MINIMUM NUMBER OF TEETH ON PINION AND GEAR.

Now condition of minimum number of teeth n pinion and gear to avoid

Interference between the teeth of pinion and gear while transmitting motion.

Let Z_P=Number of teeth on pinion and Z_g = number of teeth on gear.

$Z_P^2 + 2\ Z_P\ Z_g = 4\ \ K_1(Z_g + K_1)/\ \sin^2\alpha$

[Referring design data book by: K.Mahadevan pg 162. Eq: 12.10]

$Z_P^2 + 2\times Z_P \times 6\ Z_P = 4\times 0.8\ (6\ Z_P + 0.8)/\ \sin^2 20^0$

$Z_P^2 - 12.63\ Z_P - 1.68 = 0$

On solving above equation we have,

$Z_P = 14$ and therefore $Z_g = 84$

3.9.2 STRENGTH OF PINION AND GEAR

Form factor corresponding to 20^0 stub teeth

$Y = 0.175 - (0.95/Z)$

[Referring design data book by: K.Mahadevan]

On solving we get $Y_P = 0.107$ and $Y_g = 0.163$

$\sigma_g.\ \ y_g = 58.8 \times 0.163 = 9.5844$ N/mm sq

$\sigma_p.\ \ y_p = 58.8\times 0.107 = 6.2916$ N/mm sq.

$\sigma_g . y_g > \sigma_p . y_p$ therefore pinion is weaker and should be designed first

3.9.3 DETERMINING MODULE AND WIDTH OF GEAR

Now applying the modified Lewis equation for static strength.

$Pt' = \pi. m. b. \sigma_p. Y_{P.}C_V$ Referring design data book by: K.Mahadevan]

Where Pt'= tangential tooth load, C_S= service factor, m= module, C_V=velocity factor, b= face width.

As, Pt'= 1000PCS/V [Referring design data book by: K.Mahadevan]

C_S= service factor, V= pitch line velocity, taking C_S=1.25 for light shocks and 8-10 hrs working per day.

Pt'=1000 ×0.00447 ×1.25/0.063 = 88.8N

Also, $9.5 \leq b/m \leq 2.5$ [Referring design data book by: K.Mahadevan]

Take b/m=11 or b=11m

Berths formula for nonmetallic gears as recommended by AGMA

$$C_V = \frac{0.7625}{1.0162 + V}$$

C_V = 0.7062

Now $Pt' = \pi.\ m.\ b.\ \sigma_p\ .Y_{P.}C_V\ _= \pi\times m\times 11m\times 6.2916\times 0.7062 = 88.8$

On solving gives m= 0.760mm

Now to find out the number of teeth corresponding to the above module and velocity.

$V = \pi\ D_p\ N_p/60 = D_p = 60V/\pi\ N_p/ = 20mm$

$Z_p = D_p/m = 20/0.76 = 26.31 = 27 = Z_p$

Therefore $Z_g=162$

Again according to new module

$D_p = Z_p \times m = 27 \times 0.76 = 20.52$ mm

$D_g = Z_g\times m = 163\times 0.76 = 123.12$ mm

And velocity to new D_p

$V = \pi\ D_p\ N_p/60 = \pi\times 20.52\times 60/60\times 1000 = 0.064m/s$

Therefore, $Pt'=1000\times P\times C_s/V=1000\times 0.00447\times 1.25/0.06 = 87.30N$

And new velocity factor $C_V = 0.7625/(1.0167+0.064 = 0.70$

$Pt' = \pi\ m.b.\ \sigma_{p.}\ Y_{P.}C_V$

$87.3 = \pi\times 0.76\times b\times 6.2916\times 0.70$

B=8.30mm=9mm

Check: $9.5 \leq b/m \leq 12.5$ i.e. $b/m = 10.92$

Therefore the design is safe.

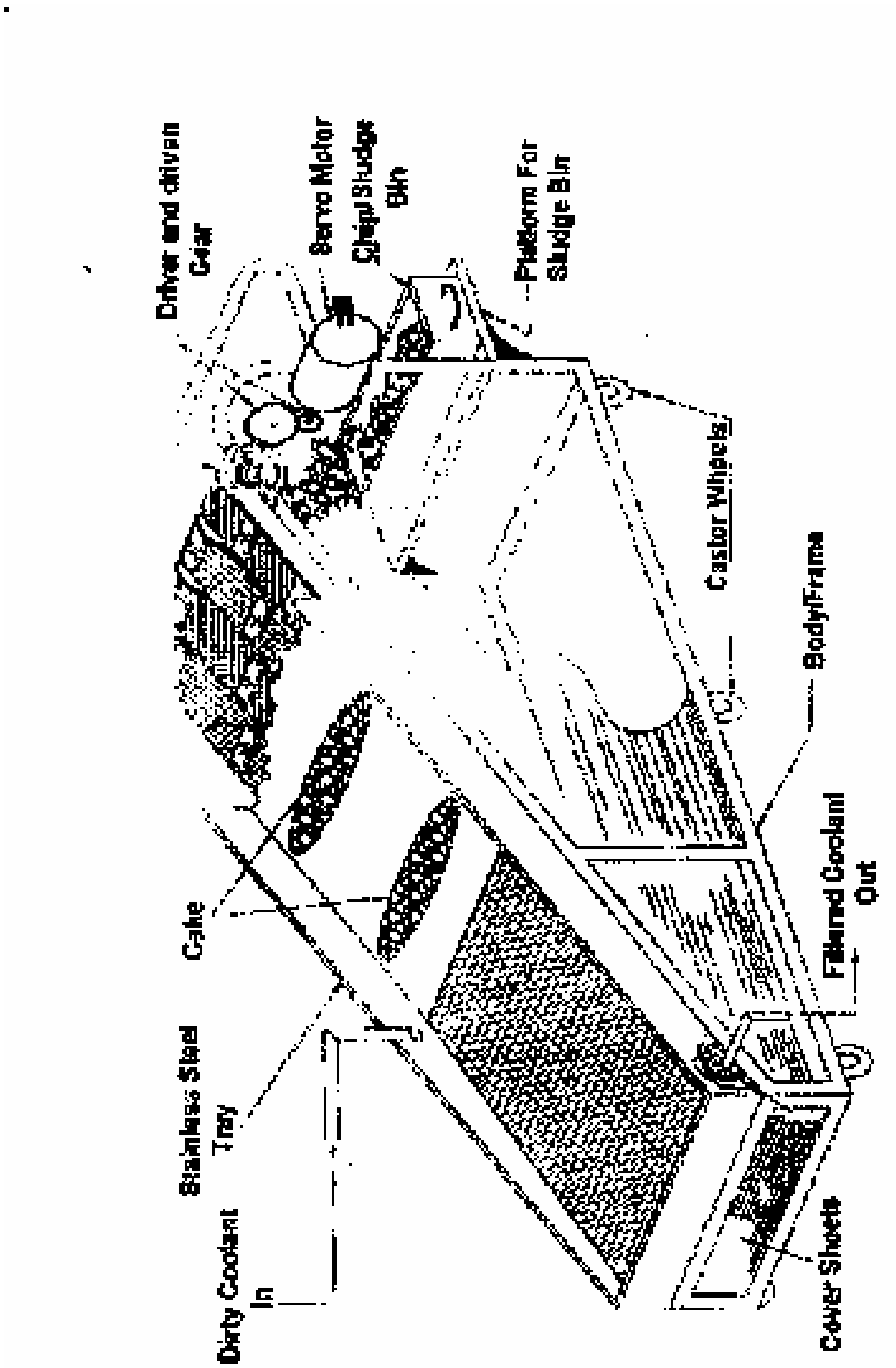


Figure18: Magnetic coolant separator

CHAPTER-4

RESULTS AND DISCUSSION

4.1 RESULTS.

TRAY

Material : Stainless steel sheet with 26 gauges

Angle of inclination : 6^0

Dimension of tray : l = 913 mm, b = 360 mm, h = 35 mm

FRAME

Material : mild steel 30 × 30 × 30

Angle of inclination : 6^0

Dimension of frame : L = 973 mm, h_1 = 315 mm, h_2 = 417 mm

ROLLERS

Material : stainless steel (18-8)

Length : L_1 = 300 mm

Center of distance : c= 913 ± 4 mm.

Roller diameter : d_i = 54 mm, d_0 = 58 mm

Speed : N= 10 rpm

CONVEYOR BELT

Material	:	cotton fabric
Number	:	4
Width	:	b = 62 mm
Thickness	:	t = 1.5 mM

MAGNETS

Material	:	Samarium cobalt ($SmCo_5$)
Number of magnets	:	112
Length	:	58 mm
Width	:	40 mm
Thickness	:	10 mm
Weight	:	0.04 kg (each)
Strength	:	1500 micron

ROLLER RINGS

Material	:	Stainless steel (18-8)

Diameter : inner = 58 mm, outer = 62 mm

Width : b = 10 mm

Number of rings : 5

MOTOR

Type : SYN 981, AC Synchronous motor, 240V,1 phase,50hz

Speed : 60 rpm

Torque : 10 kg

Weight : 2 kg

Power : 0.006 HP

SUPPORTING STRIP

Material : Mild steel

Number : 8

Length : 24 mm

Width : 5 mm

SHAFT

Material : mild steel

Speed : 10 rpm

Length : 400 mm

BALL BEARING

Type : ISI Deep groove ball bearing no. 17BCO3

Diameter : inner = 17 mm, outer = 47 mm

Width : 14 mm

PINION AND GEAR

	Pinion	Gear
No of teeth	27	162
Pitch circle diameter	20.52	123.12
Module	0.76 mm	0.76 mm
Width	9 mm	9 mm
Material	Plastic (Celeron)	Plastic (Celeron)

4.2 DISCUSSION.

The magnetic coolant filter designed is shown as shown in the figure above. This filter is capable of removing all ferromagnetic chips up to the flow rate of 10 liters per minute. In this design special attention is paid on the selection of materials. Materials selected are hard and abrasion resistant. Further there are very less moving parts in this filter. The whole separation mechanism is separated from the chips and the coolant. Therefore it is expected the maintenance required is negligible.

It is obvious from the design that this filter is very good on ferromagnetic particles. On the other hand it barely removes non ferromagnetic chips. Therefore it is strongly recommended that it should be used while machining ferrous material only.

The cost of this filter is very less. Since the only costly part is motor. Other parts such as conveyor belt etc.. Are very rugged so they are cost effective. Also the design of this filter is compact so it can be easily installed in small spaces.

The filter with slight modification can be used as a central filtering unit of whole shop. The operation of filter is automatic and only intervention is required to remove the chips from the sludge bin.

From the above discussion it is clear that this filter is a good compromise with cost and filtering material and so it is very cost effective with ferromagnetic materials

4.3 SOURCE CODE

```
/* Dimensions of Tray*/
 #include<stdio.h>
#include<conio.h>
int main() {
	int bl = 300;
	int bh = 420;
	int b;
	int height = 35;
	float vol = 11.5;
	clrscr();
	b = (bl + bh) / 2;
	float l = vol / (b * height);
	printf("%f meters\n", l);
	return 0;
}
```

```
/*Design of Body/Frame*/

#include<stdio.h>

#include<math.h>

#include<conio.h>

int main() {

	int l1 = 913;

	int l2 = 60;

	int theta = 6;

	int h1 = 315;

	double h2;

	clrscr();

	h2 = (sin (theta * (3.14 / 180)) * (l1 + l2)) + h1;

	printf("%f mm\n", h2);

	return 0;

}

// Speed Calculator for Driver & Driven Roller
```

```
// By: Tia Sempo

#include<stdio.h>

#include<conio.h>

#include<math.h>

int main() {

    float v = 0.030;   // in meters

    float d = 0.058;   // in meters

    clrscr();

    double n = (v * 60) / (3.14 * d);

    printf("%f rpm\n", n);

    printf("Since D1 = D2, Therefore N1 = N2 = %f RPM\n", ceil(n));

    return 0;

   }

// Total Number of Magnets on Conveyor

// By: Tia Sempo

#include<stdio.h>

#include<conio.h>

#include<math.h>

int main() {
```

```
float area;

int b = 360;     // as calculated in previous programs

int l = 500;     // assumed

clrscr();

area = float(l) * float(b);

printf("Area = %f mm sq.\n", area);

//Let A' be the area which is in contact with the magnets

//therefore

float area1 = area * 0.7;

printf("A' = %f mm sq.\n", area1);

int lm = 58;            // magnet length in mm

int bm = 40;            // megnet breadth

int tm = 10;            // magnet thickness

//Therefore number of magnets required

float m = area1 / (lm * bm);

printf("Magnets required = %f\n", m);

//since there are 4 conveyors, number of magnets per conveyor

double m1 = ceil (m / 4);

printf("No. of magnets per conveyor = %f", m1);
```

```
    //Therefore total number of magnets

    int m2 = int(m1) * 2 * 4;

    printf("Total number of magnets = %d", m2);

    return 0;

}

//   Torque Requirement

//      By: Tia Sempo

#include<stdio.h>

#include<conio.h>

#include<math.h>

int main() {

    clrscr();

    float Vc = 0.00018;    //900000 * 2 mm cube = 1.8 * pow(10,-4) Meter cube

    int density = 7000;    // Kg/m cube

    //mass of chips on tray at any instant

    float mass = Vc * density;

    printf("Mass of chips on tray at any instant = %f Kg.\n", mass);

    //Mass of 1 magnet = 40 gms.

    //Therefore mass of 112 magnets
```

```
float mass1 = 40.0 * 112.0 / 1000.0; // Kg

printf("Mass of 112 magnets = %f Kg.\n", mass1);


//Mass of driver & driven roller

//we have do = 58 mm, therefore ro = 29 mm

//and di = 54mm, therefore ri = 27mm

float doo = 0.058, dii = 0.054;

float ro = doo/2;

float ri = dii/2;

float V = 3.14 * ( pow(ro, 2) - pow(ri, 2) ) * 0.30;

printf("Volume = %f mt cube\n", V);

//rollers are made of stainless steel whose density is 7750 Kg/m cube

float W = V * 7750;

//combined weight of driver & driven roller

float weight = W * 2;

printf("Combined Weight = %f Kg.\n",weight);

//weight of roller rings

//we have dii = 58 mm, therefore ri = 29mm

//and do = 62 mm, therefore ro = 31mm.
```

```
    ro = 0.031, ri = 0.029;

    V = 3.14 * ( pow(ro, 2) - pow(ri, 2) ) * 0.01;

    printf("Volume = %f m cube\n", V);

    W = V * 7750;

    //Total weight of roller rings

    float tot_w = W * 10;

    //Therefore total weight

    W = mass + mass1 + weight + W;

    printf("Total torque required = %f\n", W);

    return 0;

}

//  Torque Requirement

//      By: Tia Sempo


#include<stdio.h>

#include<conio.h>

#include<math.h>


int main() {
```

```
clrscr();

float Vc = 0.00018;    //900000 * 2 mm cube = 1.8 * pow(10,-4) Meter cube

int density = 7000;     // Kg/m cube

//mass of chips on tray at any instant
float mass = Vc * density;
printf("Mass of chips on tray at any instant = %f Kg.\n", mass);

//Mass of 1 magnet = 40 gms.
//Therefore mass of 112 magnets
float mass1 = 40.0 * 112.0 / 1000.0; // Kg
printf("Mass of 112 magnets = %f Kg.\n", mass1);

//Mass of driver & driven roller
//we have do = 58 mm, therefore ro = 29 mm
//and di = 54mm, therefore ri = 27mm
float doo = 0.058, dii = 0.054;
```

```
float ro = doo/2;

float ri = dii/2;

float V = 3.14 * ( pow(ro, 2) - pow(ri, 2) ) * 0.30;

printf("Volume = %f mt cube\n", V);



//rollers are made of stainless steel whose density is 7750 Kg/m cube

float W = V * 7750;



//combined weight of driver & driven roller

float weight = W * 2;

printf("Combined Weight = %f Kg.\n",weight);



//weight of roller rings

//we have dii = 58 mm, therefore ri = 29mm

//and do = 62 mm, therefore ro = 31mm.



ro = 0.031, ri = 0.029;

V = 3.14 * ( pow(ro, 2) - pow(ri, 2) ) * 0.01;

printf("Volume = %f m cube\n", V);
```

```
	W = V * 7750;


	//Total weight of roller rings
	float tot_w = W * 10;
	//Therefore total weight
	W = mass + mass1 + weight + W;
	printf("Total torque required = %f\n", W);
	return 0;
}
//	Gear Design
//	By: Tia Sempo
#include<stdio.h>
#include<conio.h>
#include<math.h>
int main() {
	float Np = 60;		// calculated before
	float Ng = 10;		//	do
	clrscr();
	//Assumed distance between pinion and gear
```

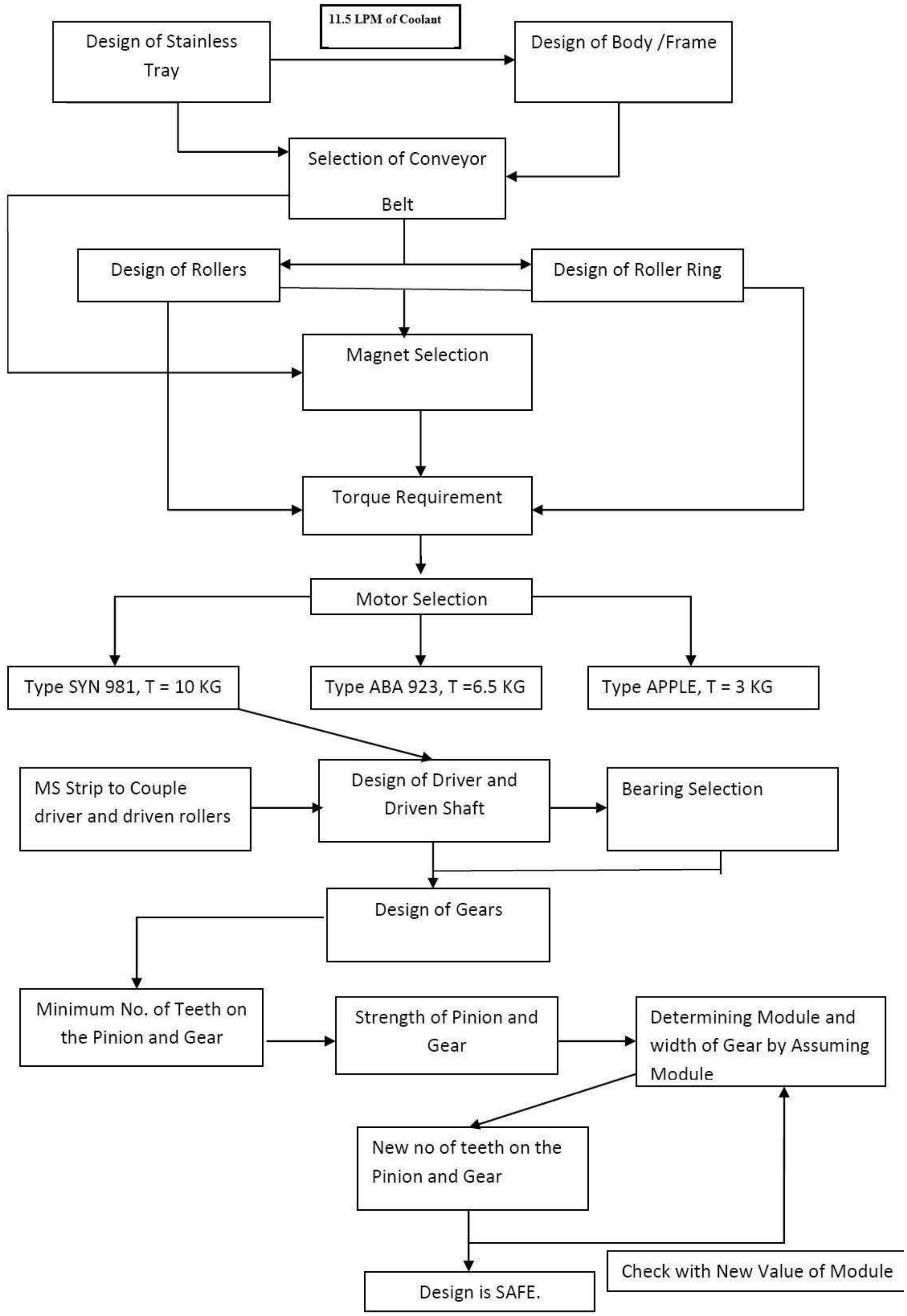
```
	float dist = 70;

	//Therefore l = Dg/2 + Dp/2 = 70

	// Dg/Dp = Np/Ng = Zp/Zg = 60/10 = 6

	// Zg = 6Zp

	// Dg/Dp = 6

	// Solving Equations.

	float Dp = 20;

	float Dg = 6 * Dp;

	float pitchLine = 3.14 * Dp * Np / 60;

	printf("Pitch Line Velocity = %f mm/sec\n", pitchLine);

	return 0;

}

// Minimum Number of Teeth on Pinion and Gear

//	By: Tia Sempo

#include<stdio.h>

#include<math.h>

#include<conio.h>

int main() {

	clrscr();
```

```
        return 0;
}
//      Strength of Pinion and Gear
//      By:     Tia Sempo
#include<stdio.h>
#include<math.h>
#include<conio.h>
int main() {
        clrscr();
        float Yp = 0.107;
        float Yg = 0.163;
        float SigmaP = 58.8;
        float SigmaG = 58.8;
        if (SigmaG * Yg > SigmaP * Yp)
                printf("Pinion is weaker and should be redesigned first\n");
        else
                printf("Gear should be designed first\n");
        return 0;
}
```

```
//	Determining Module and Width of Gear

//	By:	Tia Sempo


#include<stdio.h>

#include<math.h>

#include<conio.h>

int main() {

	clrscr();

	float P = 0.00447;

	float Cs = 1.25;

	float V = 0.063;		//calculated before

	float Pt1 = 1000 * P * Cs / V;

	printf("Pt' = %f\n", Pt1);

	float Cv = 0.7625 / (1.0167 + V);

	//Pt1 = Pie * m * b * SigmaP * Yp * Cv

	//and b/m = 11 => b = 11m

	//m = pow( (Pt1 / (Pie * SigmaP * Yp * Cv * 11.0)), 1.0/2.0);

	float m = pow( (Pt1 / (3.14 * 58.8 * 0.107 * 0.7062 * 11.0)), 1.0/2.0);

	printf("m = %f\n", m);
```

```
//V = Pie * Dp * Np / 60 => Dp = 60 * V / (Pie * Np)

float Dp = 60 * 0.063 / (3.14 * 60);

printf("Dp = %f meters\n", Dp);

Dp *= 1000;

float Zp = ceil(Dp / m);

printf("Zp = %f\n", Zp);

//now Zg/Zp = 6 => Zg = 6Zp

float Zg = 6 * Zp;

printf("Zg = %f\n", Zg);

//According to new module

Dp = Zp * m;

float Dg = Zg * m;

//& velocity according to new Dp

//V = Pie * Dp * Np / 60 mm/sec

V = 3.14 * Dp * 60 / 60;

V /= 1000;

printf("V = %f\n", V);

Pt1 = 1000 * P * Cs / V;

printf("Pt' = %f\n", Pt1);
```

```
	// & new velocity factor Cv

	Cv = 0.7625 / (1.0167 + V);



	//Pt' = Pie * m * b * SigmaP * Yp * Cv

	//Therefore

	float b = ceil( Pt1 / (3.14 * m * 58.8 * 0.107 * Cv) );

	printf("b = %f\n", b);

	if( b/m <= 12.5 && b/m >= 9.5)

		printf("Therefore the design is safe\n");

	else

		printf("The design is not safe\n");

	return 0;

}
```



Block Diagram for Design of Magnetic Separator

CONCLUSION:

After going through the aspects of design, we have learnt many things and our main object is to remove the metallic chips efficiently so as to increase the coolant life. As per the design it can be used only for removing ferromagnetic metal chips. These magnetic chip separators will safe both the coolant and downtime. Since there is no cleats and sharp edges and hence, it can give a maintenance free operation.

Well in this fast changing growth of metal working operation the recycling of cutting fluids become very important for the management of coolant. With the help of this magnetic coolant separator we can get highly efficient way of filtration guarantying fine finish, dimensional accuracy and increased tool life. The most significant role of this filter is that, it will reduce the waste disposal of coolant and a net profit for the production industries.

FUTURE WORK:

This design gives an efficient filtration of coolants, but still it can be improved and made environmental friendly with compatibility. Our design is applicable to separate only ferrous particulate but provision of removal of non ferrous particulates, bacteria and tramp oil can be made in conjunction with our present conventional design. While going through various processes a coolant gets contaminated due to which it changes colour. Hence a provision of fabric filter can be made due to which our design will become more versatile. Another important aspect to our design is to make synchronization of motor speed and flow rate of coolant and this can be achieved by using sensors and transducers. These features will make the design more compatible, efficient and clean environment

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