Design and Fabrication of Magnetic Coolant Filter

B.N. Prashanth[1]

[1]*Dept of Mechanical Engineering, Amrita School of Engineering, Bengaluru, Amrita Vishwa Vidyapeetham, Amrita University, India*

Corresponding author: prashanth.pdm@gmail.com

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. Above being the case, a magnetic coolant filter is developed which 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. Magnetic coolant filters use the principle of magnetic separation to purify the used coolant. The developed magnetic coolant separation has the capability of purifying 40 litres 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 proposed design is well justified by the cost savings in production. 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 lose 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 the tray. This attracts the ferrous particles and builds up a cake of ferrous material and finally taken away by the scraper. The moving permanent magnets mounted on the shaft attracts ferrous chips and slide them on to plate and then to the discharge end or sludge bin. The coolant separated from chips flow back to the coolant tank. 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 developed model of 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.

Keywords: Filter, Coolant, Magnet, Chip.

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:

- 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 entrepreneurs cannot buy such set up.
- The present design does not offer a large surface area to maximize exposure to magnetic fields. In addition, the magnets used in these machines are conventional and therefore have a very short life and inefficient filtration.

- The magnets used in the conventional coolant filters lose their properties when subjected to high heat, high vibration application. The heat and vibration often kill the magnetic fields of weaker magnets.
- 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.
- For the shops with many machine tools each machine requires a separate coolant.

Following are the main considerations which have to be 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 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 installed near the grinding machine.
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 have 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.

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 lose 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 the tray. This attracts the ferrous particles and builds up a cake of ferrous material and finally taken away by the scraper. The moving permanent magnets mounted on the shaft attracts ferrous chips and slide them on to plate and then to the discharge end or sludge bin. The coolant separated from chips flow back to the coolant tank.

DESIGN ANALYSIS

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 aluminium 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 the machine. This filtration system is a very simple design. The electrical consumption is 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 magnet 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 aluminium 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 aluminium 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 aluminium. Magnets used are permanent in nature and produce magnetic field 30mm above the tray/ coolant container. The magnetic material used will not lose its strength even after a number of years of use.

The moving permanent magnets 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 through this very strong magnetic surface, assures optimum clearing efficiency.

Design Features of Magnetic Coolant Filter

The capacity of coolant filter which is to be design is of 40 liters/ min.

Aluminium Tray

The main function of the aluminium 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 40 liters of coolant. The design procedure for the tray is as follows:

Selection of the Aluminium Sheet: It is a light metal having specific gravity 2.7 and melting point 658°C. The tensile strength of the metal varies from 90 MPa to 150 MPa. The high resistance to corrosion and its non-toxicity and non-magnetic character makes it a useful metal for magnetic coolant filter.

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 aluminium sheet.

$\mu = 0.105$

Also, $\mu = \tan\theta$

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

$\theta = 60^0$

Dimension of the Tray: Tray is to be designed for 40 liters capacity, so taking the factor of safety and designing the tray for 120 liters.

Let, l = Length of the tray

b = width of the tray

h = Height of the tray

But, $300 \leq b \leq 420$

Therefore. taking average value of b

$b = (300+420) / 2 = 360\text{mm}$

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. Through solving, the final dimension is l = 190 mm, b = 360 mm, h = 150 mm.

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 aluminium tray i.e. 6o side of the frame will lie on machine tool side.

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 magnetic roller + weight of the driven roller + drag force due to metallic chips conveyed by magnets.

Total fluid area over the tray = 68,400mm sq. and about 50% of area will always contains a layer of the chips having thickness of 2mm at maximum. Therefore,

Volume of chips in tray at any instant, $V = 68{,}400\times2 = 136{,}800\ \text{mm}^3 = 13.6\times10^{-5}\ \text{m}^3$

Aluminium density $\rho = 2700\text{kg/m}^3$

a) Mass of chips on tray at any instant = $13.6 \times 10^{-5} \times 2700 = 0.367$ kg
b) Mass of the magnetic roller = 9 kg

c) Mass of the driven roller = 0.4 kg

Therefore, Total weight, W = 9 + 0.4 + 0.367 = 9.767 kg

The required torque is 9.767. Based on the torque required, the TYPE Y2-631-2 motor is selected with 10 kg torque capacities.

Design of Roller Shaft

Speed of shaft, N = 15 rpm, torque requirement T = 9.767 kg

The shaft is designed for torque transmission. Taking shaft material: EN 31

Allowable shear stress $f_s = 41160000\ N/m^2$

Power, P = 0.25 HP

= 746 x 0.25

= 186.5 Watts

$P = 2\pi N M_t/60$

$M_t = 117146.67 N\text{-}mm$

$M_b = WL/4 = 4250\ N\text{-}mm$

d= [16/πτed{(KbMb)2+(KtMt)2}1/2]1/3

d = 23 mm

Height of shoulder = 0.07d+3mm

= 4.61 mm

Width of shoulder = 1.4 x height

= 6.45 mm

Flow Rate, V = (2gh)1/2

= 2.21 m/s

Q = AV

= $1.99 \times 10^{-3}\ m^3/s$ It can withstand upto $2 \times 10^{-3}\ m^3/s$

Flow rate due to pump, Q = 40 lpm = $0.66 \times 10^{-3}\ m^3/s$.

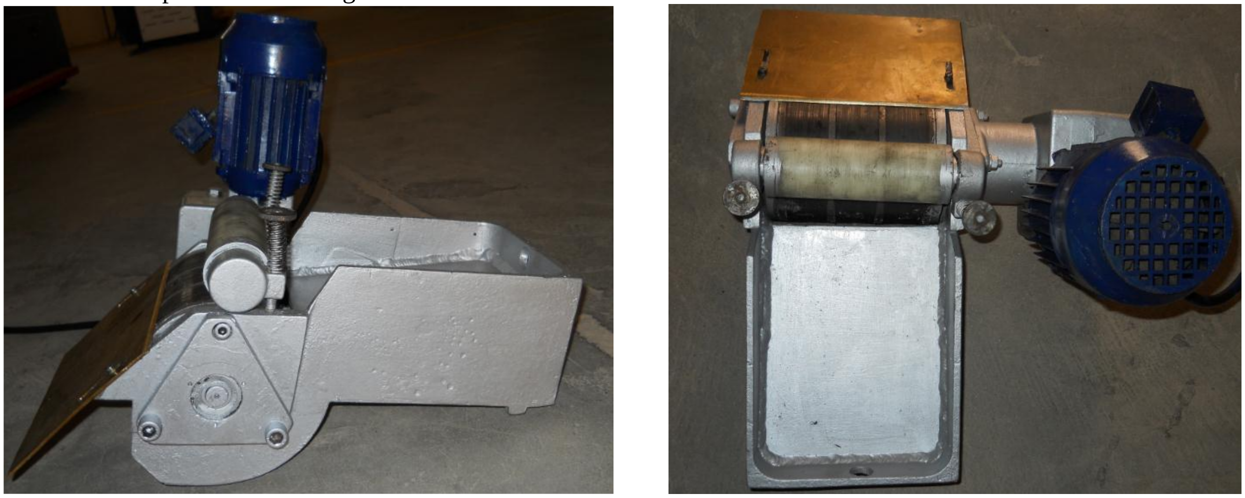
One constraint for the selection of the ball bearing is the shaft diameter d = 23 mm.

Therefore, d=23 mm, D=53 mm, B=14 mm and ISI bearing.

Bearing no.23BC03 Deep groove ball bearing is selected.

FABRICATION OF MAGNETIC COOLANT FILTER

Based on the design features, the fabrication of the magnetic coolant filter is carried out. Below figures shows the fabricated component of the magnetic coolant filter.



(a) (b)

FIGURE 1. (a) Side View of Magnetic Coolant Filter (b) Top View of Magnetic Coolant Filter

FIGURE 2. Front View of Magnetic Coolant Filter

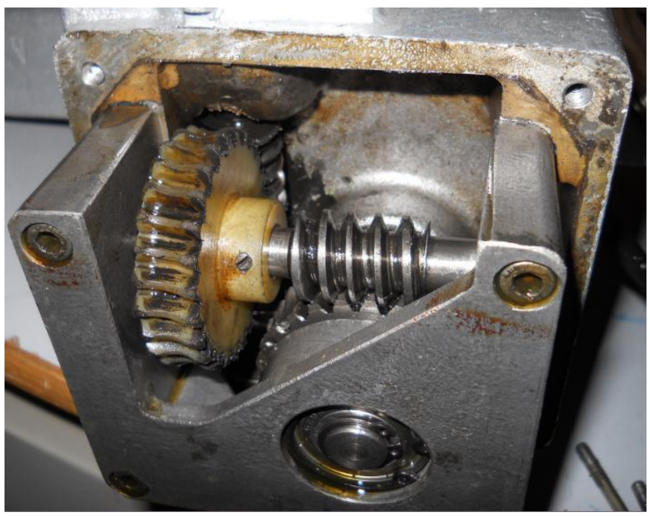


FIGURE 3. Double Reduction Worm Gear

FIGURE 3. Grinding Machine

RESULTS AND DISCUSSION

The magnetic coolant filter is designed as per the parameters shown below:

TABLE 1. Specifications of Magnetic Coolant Filter

TRAY	**Material: aluminium sheet**
	Angle of inclination: 6^0
	Dimension of tray: l = 180 mm, b = 360 mm, h = 90 mm
FRAME	**Material: aluminium**
	Angle of inclination: 6^0
	Dimension of frame: L = 190 mm, h = 90mm, b =400mm
MAGNETS	**Material: Samarium cobalt (SmCo5)**
	Number of magnets: 3
	Length: 58 mm
	Weight: 3 kg (each)
ROLLER RINGS	**Material: Mild steel**
	Width: b = 10 mm
	Number of rings: 4
MOTOR	**Type: type Y2-631-2, AC Synchronous motor, 240V,3 phase,50hz**
	Speed: 1000 rpm
	Torque: 10 kg
	Weight: 2 kg
	Power: 0.25 HP
SHAFT	**Material: EN 31**
	Speed: 15 rpm
	Length: 200 mm
BALL BEARING	**Type: ISI Deep groove ball bearing no. 23BCO3**
	Diameter: inner = 23 mm, outer = 47 mm
	Width: 14 mm

The filter is capable of removing all ferromagnetic chips up to the flow rate of 40 litres per minute. In the above 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 the 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 the 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 the filter is very less. Since the only costly part is magnetic roller. Other parts such as motor etc. are very rugged so they are cost effective. Also the design of the 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 the developed filter is a good compromise with cost and filtering material and so it is very cost effective with ferromagnetic materials.

CONCLUSION AND FUTURE SCOPE

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.
The 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 color. 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.

ACKNOWLEDGEMENTS

The authors express their gratitude towards Management of Amrita School of Engineering, Bangalore, for their support and encouragement during this research study.

REFERENCES

[1] Coolant Maintenance for Machining Operations, University of Minnesota,2000 Oak Street SE, Suite 350,pp.1-2,2001.
[2] N.R. Dhār , M. Kamruzzaman, Mahiuddin Ahmed, Effect of minimum quantity lubrication (MQL) on tool wear and surface roughness in turning AISI-4340 steel Department of Industrial & Production Engineering, Bangladesh University of Engineering & Technology (BUET), Dhaka, Bangladesh, pp.1 -6, 2005.
[3] Daniel Norrgran & Johan Mackowski , Magnetic particle filtration for metal working fluids , pp.3-20,2000.
[4] R.S.Khurmi , J.K.Gupta ,A Text Book of Machine Design, Eurasia Publishing House (Pvt) Limited,Ram Nagar, New Delhi,2005.
[5] P.C Sharma ,D.K.Aggarwal ,Machine Design, S K Kataria & sons Publishers of Engineering & Computer books ,2003.
[6] http://www.magtoolsindia.org/magnetic-coolant-filters.htm,copyright 2008- 2010,magtools hubli. As sited on 06/03/2011.
[7] http://www.jkmagnetics.com/magneticcoolent.html, Jayakrishna Magnetic Pvt Ltd, Magnetic Equipments as sited on 04/02/2011.