International Journal of Scientific & Technical Development
(A Peer-Reviewed Bi-Annual Journal) ISSN: 2348-4047

THE DEVELOPMENT OF A SIMPLE HYDRAULIC CIRCUIT FOR ABRASIVE FLOW MACHINING

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Abstract
Abrasive flow machining is a non-traditional finishing method to smooth or glossy made metal components utilizing a semi-liquid paste which consists an abrasive particle in a definite proportion and in which complex or miniaturised parts demanding high surface finish can be economically produced.In this process, the media is extruded backward and forward over the surface with the assistance of the pre-defined hydraulic pressure.In this paper a hydraulic circuit for two-way AFM has been developed and testing of the hydraulic circuit has been done on an actual machine.It ensured a simple,reliable,error free fittings and cost effective circuit and also reduce the experimentation duration
Keywords: AFM -Abrasive Flow Machining, A hydraulic circuit, Hydraulic pressure

INTRODUCTION

1.1 Abrasive Flow Machining

Abrasive flow machining (AFM) process is a non-traditional machining method introduced in the USA by the “Extrude Hone Corporation” in 1960, which have brilliant capabilities for enhancing the interior structure of components,unsymmetrical surfaces and for the purpose of abrading the internal surface to remove the burrs [4]. Abrasive flow machining is a surface finishing process in which a liquid abrasive polymer fluid keeps moving over the inner surface of the work-piece. The liquid polymer uses abrasive particles as grinding media which is also known as abrasive laden media [1]. The effect of key parameters such as abrasive medium and type, total number of cycles, abrasive mesh size, extrusion pressure, design of work-piece holding device and suitable hydraulic circuit have influence the outcome parameters such as material abrasion and better surface finishing.

1.2 AFM Technology:

In the two-way AFM, an abrasive media extrudes through pathway build by the work-piece and tooling with the aid of a hydraulic pressure system using hydraulic actuators.When the media goes in and moves through the most restrictive passages then abrasion takes place. The media behaves like a self-modulation abrasive medium with good fluidity and viscidity so the cutting tools are flexile [2].Therefore, the media wear the work-piece in the work holder and fixture.

1.3 AFM Tooling:

Fixture is made of steel, urethane, aluminium, nylon, Teflon, or a combination thereof. And any number of parallel restrictions can be processed simultaneously with suitable tooling [3].

1.4 Abrasives Laden Media:

The main component of the AFM process is abrasive media. The media is made up of non-Newtonian liquid polymer that containing the abrasive particles. For this non-Newtonian liquid polymer serves as a carrier medium and wearing particles serve as a cutting tool that abrades the material from the work -piece. The most used wearing particles are Al2O3, SiC, B4C or diamond. The additives are used to adjust the base polymer in order to achieve optimal flow capacity and rheological character of the medium. The concentration of abrasive particles, the media of flow and viscosity can also be varied.

1.5 AFM Applications:

AFM is suitable for work-pieces with complicated intersections (AFM polishes complex inlet manifolds and ports that leads to smoothness and more precise fuel and air distribution which results into more horsepower and fuel efficiency of the automobile), AFM is also used in extrusion dyes as well as space and aeronautics Industry to remove very thin layers of coatings from the turbine blades for re-coating. AFM is also used in medical technology, an automobile Industry (with the AFM of diesel injector holes made by EDM, holes are of correct radius and ragged edges are removed, thus it minimizes erosion and emission remains consistent for a very long duration [15]). hydraulics and pneumatics, chemical and pharmaceutical Industry also use AFM for deburring, rounding off edges or polishing in difficult-to-reach areas of process components of the brewery, beverages, dairy and food industries requiring high hygiene and sterile manufacturing conditions. AFM is also used in textile Industry, electronics Industry for piercing of many fine holes. AFM is suitable for single pieces and batch production, in improving the surface finish of internal surfaces of Mass Flow Controllers, remove the burrs in spring collets [4] and abrasive machining of advanced technical ceramics [5], etc.

2. Classifications Of AFM Machines:

AFM machines are divided into two categories on the basis of abrasive laden media movement i.e. one way AFM and two-way AFM.

2.1 One-way AFM process:

The One-way, AFM process extrudes the abrasive laden media through the work-piece with the help of hydraulic reciprocating piston in only one direction and allows the media to exit freely from the part.

2.2 Two-way AFM process:

Two-way AFM machine use two hydraulic cylinders and two media cylinders. The hydraulic pressure system extrudes the abrasive media backward and forward through passages formed by the work-piece and tooling .Wherever the medium enters and passes through the most restrictive passages then abrasion occurs [2].

The piston forces the medium in a forward direction in the cylinder and extrudes it through the other cylinder through the work piece. Consequently, the medium abrades the work-piece in a work holder and fixture. Then this process is reversed and the combination of these forward and backward strokes constitute a process cycle

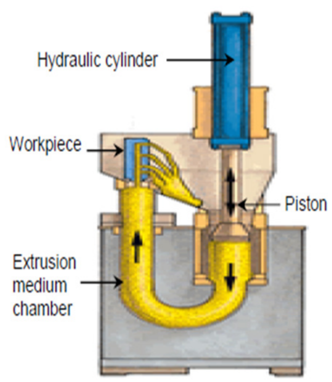

Figure. 1 Schematic of one- way AFM [7]

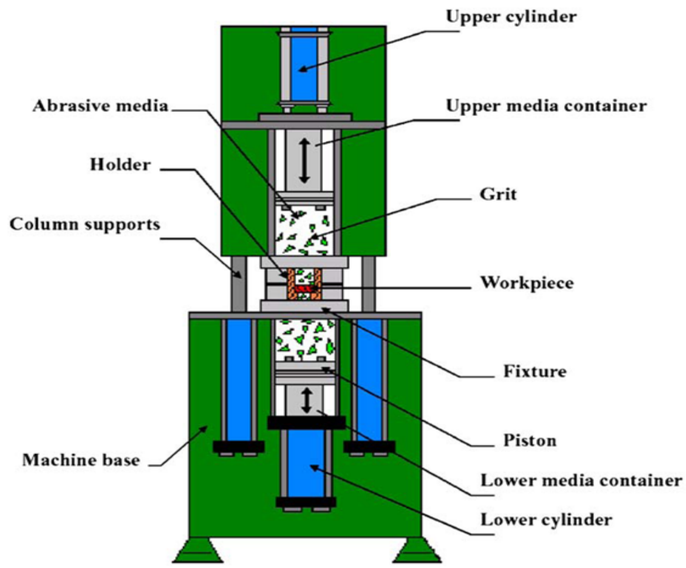

Figure. 2 Schematic of two-way AFM [2]

3. Designing Of Hydraulic Circuit For Two-Way AFM Setup:

In the two-way AFM, two hydraulic cylinders and two media cylinders are placed vertically as shown in figure 2. It is desired to extrude the media top and bottom through the nylon fixture and the work-piece with the help of these cylinders. The setup is designed for maximum media pressure of 25N/mm². The media is to be extruded at different flow rate and at different pressures. The media flow rate and the pressure of the media is adjustable. The media flow rate changes by changing the pressure difference across the two hydraulic cylinders and it also controls the media pressure by changing resistance to the media flow. The media flow is adjustable due to changing back pressure of the opposing cylinder (say the upper cylinder while moving up). If the stroke is complete, then the direction gets reversed due to maintaining the same pressure combinations and thus the lower cylinder maintains the same back pressure. These up and down stroke complete one cycle of the abrasive flow machining. Further after the experiment is completed there should be provision of withdrawal of the pistons of hydraulic cylinders, so that now finished work-piece held in the nylon fixtures can be taken out from the machine without excessive force.

3.1 Description of the Hydraulic Circuit:

The development of a hydraulic circuit of two-way AFM has been developed and extruding media at a high pressure of 25N/mm². The hydraulic cylinder's internal diameter is 100 mm and the abrasive media cylinder's internal diameter is 63 mm and thus their area's ratio is 2.519, which demands low pressure in the hydraulic circuit.

Existing hydraulic power-pack has been modified for the low pressure operation and accordingly a hydraulic circuit fulfilling the direction reversing requirement of the AFM has been developed (Figure 3). This circuit alternatively maintains the same low-high pressure combinations in the two cylinders for upward and downward strokes. Figure 4a shows the diagram of a hydraulic circuit with graphical representation of the hydraulic components [9, 10]. The developed hydraulic circuit has been compared with another hydraulic circuit of AFM as shown in Figure 4b.

The electric motor driven hydraulic pump draws hydraulic oil from the tank through a filter [3] and delivers it to two manually actuated, spring-centered three-position, four-way direction control valves (DCV 1) through the pressure relief valves (PRV 1 &2) respectively of higher pressure rating already fixed on the power-pack. The main motive of direction control valves is to control the direction of motion [11] and the main purpose of pressure relief valves is to control the pressure in a system to the prescribed maximum by transferring some or all of the pump output to the tank, when the set pressure is reached [10,16]. DCV1 has been used for the actuation of up and down movements of the hydraulic cylinders and Rotary Valve is use for the retraction of the pistons of hydraulic cylinders for the disassembly of the work-piece holding nylon fixture. The pressure in the PRV1 is kept slightly above the maximum pressure required in the hydraulic cylinders.

An additional Manifold has been fitted on the power-pack with necessary fittings. The use of manifold has minimized many plumbing problems by locating a large number of connecting lines in the drilled manifold plate [12]. All the flexible hoses and hydraulic fittings are of ½" diameter

Figure. 3 Photograph of AFM Setup

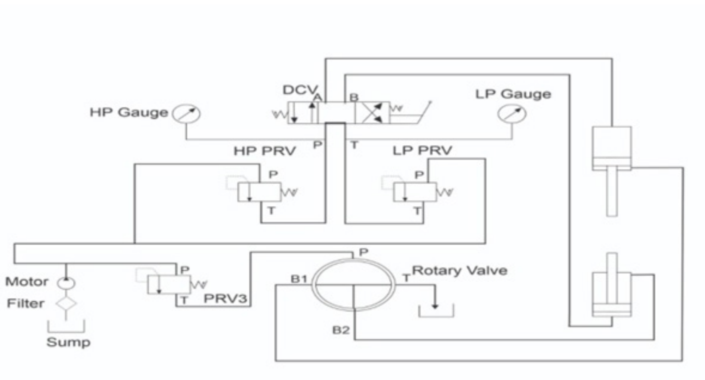

Figure. 4 a Diagram of a two-way hydraulic circuit of AFM

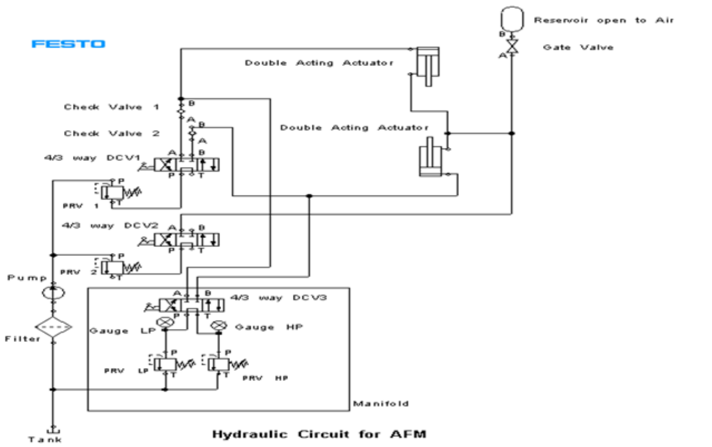

Figure. 4 b Diagram of a two-way hydraulic circuit of AFM in comparison

3.2 Hydraulic Circuit for Control of Direction of Extrusion Process:

For the extrusion of media, double-acting hydraulic actuators have been employed as shown in figure 2. For the upward extrusion, it develops high pressure in the lower hydraulic cylinder and it controls media pressure in the upper hydraulic cylinder by changingthe back pressure. So during the upward extrusion, PRV maintains the lower cylinder at the high pressure (HP) and PRV maintains the upper cylinder at the lower pressure (LP). Fitting additional low pressure relief valves (PRV HP&LP) of 100 kgf/cm² pressure rating and pressure gauges (Gauge HP&LP) of 300 kgf/cm² pressure rating on the manifold maintains safe working pressure.

Motor pumps oil through strainer to a high pressure (HP) relief valve and a lower pressure (LP) relief valve. The primary function of the pressure relief valve is to regulate the system pressure to the desired value. Then this pressurized fluid is sent to DCV where B connects with P and A connects with T. This high pressure fluid is supplied to the upper cylinder with pipes and then the pistons of upper and lower cylinders are pushed as shown in Figure 5. These pistons push media cylinder rods to extrude the media through the work piece

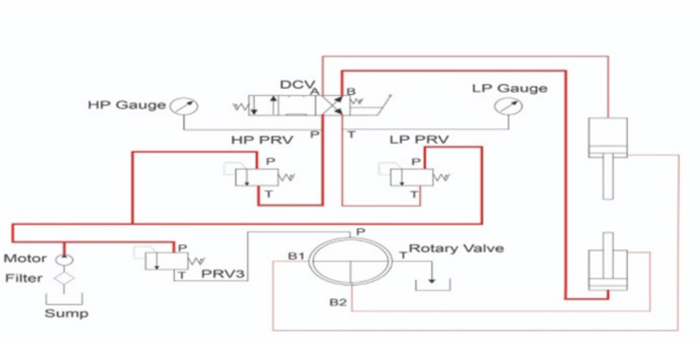

Figure. 5 The High and Low Pressure lines during upwards extrusion

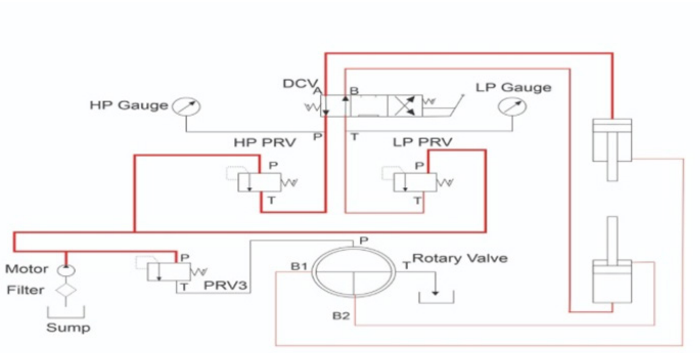

Figure. 6 The High and Low Pressure lines during downwards extrusion

After completing the upward stroke, the media passes through the work-piece from the lower media cylinder to the upper media cylinder and the extrusion process gets reversed by simply reversing the position of a DCV lever in an opposite direction. Thus, the upper cylinder maintains the same combination of pressures is maintained in the two cylinders.] at HP and the lower cylinder is maintain at LP (refer Figure 6).

3.3 Hydraulic Circuit for the retraction of the Hydraulic Actuator rods:

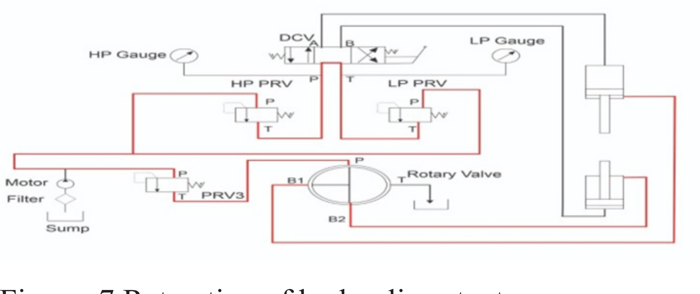

Figure. 7 Retraction of hydraulic actuators

Once the number of cycles is complete, the nylon fixture holding the work-piece is to be taken out. This requires the retraction of the rods of the two cylinders. This is achieving with the help of Rotary Valve. For the retraction, the oil from the motor reaches to PRV3 and then to point P of rotary valve, as the handle is moved in the downward direction. Then point P is connected with point B1 and B2 with T type port which is further connected to side part of hydraulic actuator due to this backward movement of a cylinder occurs (As shown in Figure 7). Once the rods of the cylinder have retracted, then the nylon fixture is to be taken out by loosening the bolts and release the specimen from the fixture.

4. SAFETY MEASURES [13]:

4.1 Safety Measure in the Design:

There is a necessity of safety measures in the design of the Fluid Power System as the medium of energy is in a pressurized condition. It ensures safety by incorporating the limit switches to avoid high pressures, pressure relief valves and extreme movements of actuator rods and overheating of oil which is very inflammable.

4.2 Safety during the operation:

It is assured during the experiment of the machine that there is no noise of the machine and no leakage. The setup is clean. The use of face shields and protective guards is also ensured for personal safety.

5. CONCLUSIONS

It is concluded that the set up operates successfully and it decreases the experimental time with the lesser stress to the operant. Development and prior testing of the hydraulic circuit of a two-way AFM machine has been checked on an actual machine and ensured that it is simple, reliable, error free fittings and thus cost effective circuit. The use of manifold has ensured not only the elimination of many fittings and potential leaks but also error free plumbing. Concepts of this circuit may be used for the development of a new cost effective AFM machine with a few hydraulic components and fittings. The AFM machine can be automated further with the servo-controlled hydraulic circuits [13].

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