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A Review on Possible Increment of Heat Transfer Rate for Hydraulic Oil Used in Plastic Injection Moulding Machine

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Abstract: ***In present study, the effect of oil temperature of the hydraulic system for Plastic Injection Moulding Machine is studied. Traditionally, in India, the hydraulic oil VG-68 for Plastic Injection Moulding Machine is used, which has an optimum temperature range with desired effective viscosity property in between 40°C to 50°C. The oil temperature goes higher up to 55°C and even higher than that during the summer, which is not desirable for the machine operations. It is found that the operation of the machine gets sluggish as the oil viscosity get decreases due to continuous flow and heavy production schedule. The oil needs to be cooled down as fast as possible from the elevated temperature to required temperature. The problem was initially solved by use of a heat exchanger which turned out to be a costly affair. The alternative method for getting the temperature drop up to the desired level is extended surface heat transfer through the flow of oil in the return path. The method is prominently permissive for elimination of the expensive heat exchanger usage. This paper critically examines the feasibility of such alternative methods on the basis of reported work of the past with similitude.***

Keywords: Hydraulic system, VG-68, Plastic Injection Moulding Machine, Viscosity Grade oil, Heat Transfer Rate Increments, Heat Sink

1. Introduction

At present, the main focus of all the manufacturers is to manufacture the products in an optimised way with least cost of production. Keeping this factor in mind, most of the industrialist adapted plastic to replace the metal in the manufacturing process. This modification turns into the huge demand for the plastic processing machines. In markets, although, electrical injection moulding machines are available for the production, the hydraulic machines are more preferred due to their less initial cost and ease of maintenance. In practical manufacturing processes, the actual operating cost of the machine is much higher than the theoretical costs. The actual operating cost of production can be determined more precisely by considering critical factors, i.e., type of material used for plastic processing, hydraulic circuit design, mechanical design, tonnage requirements, etc. One of the most important parameter used in determining the actual operating cost is the viscosity of the hydraulic oil. Effectiveness of the overall system is dependent on the retention of the viscosity over the temperature range and is the major challenge for researchers. On the basis of viscosity, the selection of the adequate hydraulic oil has critical role which depends upon the conditions and the requirements of the system. To select the appropriate VG oil, having a desired viscosity at a known temperature, a graph [13] can be referred as shown in Fig. 1. From the past literature and survey, it is seen that in India or the Asian countries, VG-68 oil, is most suitable amongst all for hydraulic system for plastic injection moulding machine. The properties[14] of various viscosity grade oil and comparison between them is listed in a Table 1, as mentioned below.

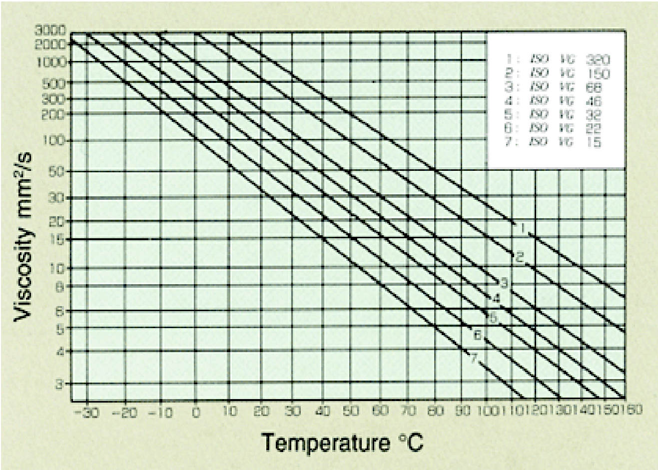

Figure 1: Viscosity versus Temperature [13]

2. Hydraulic Oil Overheating

It is found that VG-68 has an optimum operating temperature range between 40°C to 50°C, but due the high productivity requirements, poor quality plastic resins selection for finished product and due to use of less effective heat exchangers in Plastic IMM particularly in India during summer, as mentioned earlier VG-68 oil temperature reaches above 55°C, which is not desirable for machine operations.

Table 1: Properties and comparison of hydraulic oils

Properties	*Unit*				
ISO Viscosity Grade	-	22	32	46	68
Absolute Density, 15 °C	kg/m^3	863	870	874	880
Kinematic Viscosity, 40 °C	mm^2/s	22	32	46	68
Kinematic Viscosity, 100 °C	mm^2/s	4.28	5.33	6.72	8.66
Viscosity Index	-	98	98	98	97
Flash Point	°C	202	208	222	246
Pour Point	°C	-30	-30	-30	-30

Hassani et al. [01] concluded that the hydraulic oil,which passes through any orifice produces heat. The factor which produces heat are pressure valves, relief valves, pipes with small diameters, dirty filters, internal leakage in the hydraulic system and friction. The hydraulic system in Plastic Injection Moulding Machine consists of circuits to accomplish various task in cylinders like mould clamp cylinder, retraction cylinder, injection cylinder, auxiliary cylinder etc[16]. Every of these circuits cause temperature rise because of pressure drop due to the resistance of the circuit comprising ingredients against fluid flow, the existence of throats (contracting) on the fluid passage and so on while the hydraulic system is working. Since the mentioned circuits have a common pump and reservoir, therefore the heat production in either circuit will affect other ones.The areas of heat generation in plastic injection moulding machine can be easily understood by generating a fishbone diagram, where bones are indicating the causes of heat generation.

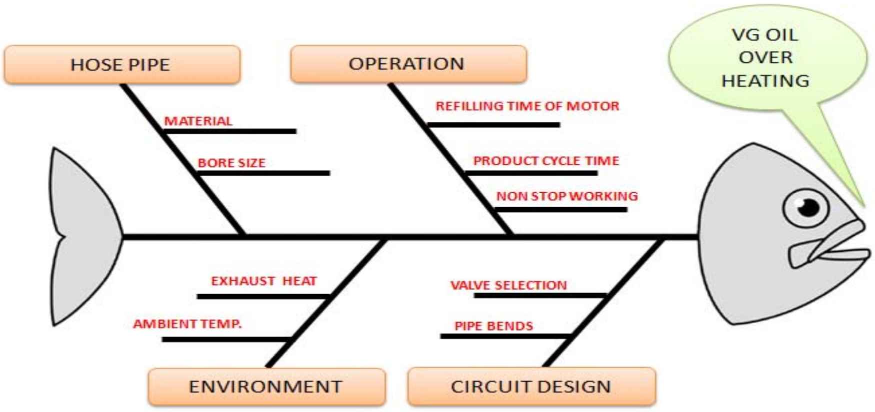

Figure 2: Fishbone diagram illustrating the causes of heat genration of hydraulic oil in IMM

To get better idea about the problem some machine are investigated, which are having 24 hours of working load condition and results are enlisted into a Table 2.

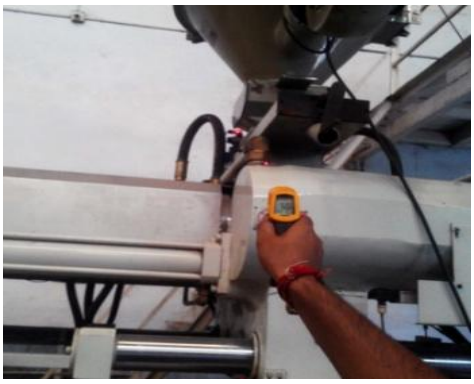

Figure 3: Reading on injection cylinder inlet/outlet port

From the experiments, when the ambient temperature was 39°C, it is founded that some oil passage ports of hydraulic system of Plastic IMM are having temperature of 50°C and above. So it is clearly understood that during summer when ambient temperature reaches above 45°C, the VG-68 oil temperature will be higher than 55°C. From the Table 2, it is concluded that pump and the thrust unit of the Plastic Injection Moulding Machine are generating the most of the heat. So it is important to reject heat from those areas as much possible to make the system more effective.

Table 2: Experimental readings of Plastic IMM

TEMPERATURE READING (°C)									
S.NO.	Machine	Pump	Clamp Cylinder	Ejector	Injection Cylinder	Retraction Cylinder	Thrust Unit	Oil Tank	Water
1	HMT-220T	43	41.5	40	43	43	42.5	40	30
2	JSW-220	50.5	48.5	39.5	44	47	51	51	32
3	SPRINT-650	51	48.5	37.5	48	49	50	47.8	30

Nomenclature

VG: Viscosity Grade
IMM : Injection moulding machine
h: Coefficient of heat transfer
T∞: Fluid surrounding temperature
FEA: Finite element analysis
FEM: Finite element method
Q: Heat Transfer rate
ISO; International organization for standardization
BG: Bond Graph
°C: Degree Centigrade
m: Meter
mm: Millimetre

3. Methods of Heat Transfer Increment

To maintain the oil temperature within 50°C, heat exchangers should not be the only option. It is desirable to find out the ways to maintain the VG-68 oil temperature within 55°C without affecting the cost, the following survey is required for the above mentioned problem.

Simulation of the hydraulic system is essential to find out the heat generation value. However there are lots of researches are done by using FEA & FEM simulation method but for the large hydraulic system, it is always difficult to find out the exact heat generation value and temperature rise. TOMIOKA et al. [02]states that to predict the temperature rise of the system, it is important to find out the simple and precise method. Author used Bond graph and Finite Element Method to conclude a coupled BG and FEM method, which will useful to simulate the hydraulic system. When the total heat generation is known, the amount of heat transfer rate increment for the system would not be difficult. It is mentioned that heat transfer can be increased by three means[06], where first is to increase *h*but that require the installation of a fan or a pump. Second is to reduce T_∞, which is often impractical and third is to increase surface area across the which the convection will take place. Another author Kreith F. et al.[17] revised the basics into more technical words and he states that the techniques for increasing the heat transfer rate can be divided in three categories. First is passive the method in which twisted tapes, helical screw tape inserts, rough surfaces, extended surfaces, additives for liquid and gases. The second is active method that requires external power like mechanical aids, surface fluid vibration, and use of electrostatic fields. Passive methods are found more inexpensive as compared to other group. The third is combined application of active and passive techniques to obtain enhancement in heat transfer that is greater than that produced by either of them when used individually, is termed as compound enhancement.

It was concluded by Hassani et al. [01] that in order to optimize the system it would not be essential to mount an oil cooler. From author‟s experiments it is found that steel pipe instead of non-metallic coated hoses are much better for heat transfer and enough to reject much of the heat generated in the system. Meganathan et al. [04]took a performance test of heat exchanger by using twisted tape and he found that heat transfer increase compare to the heat exchanger without twisted tape, he also states that the length of pipe is directly proportional to heat transfer (Q), when the length of fluid flow increases, heat transfer rate also increases [04], [06]. The experiment result of heat transfer rate for different length of pipes by author [04] is shown in fig.4.

Figure 4: Length of pipe in (m) vs. Heat transfer rate (Q) [04]

Along with length of pipe, internal diameter and external diameter a pipe also plays an important role in effecting the heat transfer rate. The local Nusselt number is increased when Gül et al. [10]increases oscillating frequency. The experimental oscillating generator is not only efficient to enhance the heat transfer in the duct flow but also in a significant pressure drop increase. The exergy loss is decreased with the increase of Reynolds number however exergy loss is affected slightly from the increase of oscillating frequencies. Such type of research is done by lots of researchers [17], [18], [19],[20]and [04] where the researchers used the passive method by inserting twisted tape, screw tape because according tothe recent studies, these are known to be economictool in the field of heat transfer increment. Dewan et al. [19]has reviewed Techniques of heat transfer augmentation such as passive, active and combination of passive and active methods. Heat transfer rate increment in a pipe flow by inserts such as twisted tapes, ribs, wire coils and dimples is mainly due to flow blockage, partitioning of the flow and secondary flow. Manglik et al [20] used twisted tape induced helical swirl flows for enhancement of forced convective heat transfer in single phase and two phase flows. The author presented the heat transfer coefficient and friction factor correlations for both laminar and turbulent regimes, and also highlighted the damping effect of swirl on the transition region. Chowdhuri et al. [21]used a special geometry inside the tube for turbulent flow. The test section of tube is electrically heated, and then the air is allowed to flow as the working fluid through the tube by means of blowers. Same experiment is carried out to determine heat transfer through the same tube without any insert. Comparing the results obtained from these two different sets of experiments, author has found that heat transfer through tubes can be enhanced by using inserts inside the tube up to 9.8 times than tube without insert with turbulent flow.Totala et al.[26]conducted experiments by providing threads in the inner pipe and observed that Nusselt number and heat transfer coefficient were increased for the threaded pipe but at the same time pumping power required also increased compared to the plain tube. These are economical tool for heat transfer increment but pressure drop is noticed which of course is not desirable for inlet ports of hydraulic system of plastic injection moulding machine. For the outlet ports and return channel to the oil reservoir the method is suitable where the pressure drop is not so important.

Another option is to apply the fins over the pipes of the pipeline of the hydraulic system. The use of fin (extended surface) with extensions, provide efficient heat transfer [05],[06], [22], [23], [24], [25],Singh et al. [05]concludes 5 % to 13% more enhancement of heat transfer, when fin with extensions provided as compare to fin without extensions. From the experiments of Author on different shapes of fin extension, it is concluded that rectangular extension has the higher heat transfer as compared to others. Effectiveness of the rectangular fin extension is higher.A comparison table is generated by the author [05], which helps to decide the shape of extension for the fin.

Table 3: shows that comparison of temperatures of fin with different types of extensions corresponding to the length of fin [05]

Length of fin (mm)	Fin with different types of extensions (Temp. in °C)				
	Rectangular	Trapezium	Triangular	Circular	No Extensions
5	53.90396	53.94466	53.93874	53.9446	53.91441
10	53.53861	53.59288	53.58499	53.5928	53.55255
15	53.17327	53.2411	53.23124	53.241	53.19069
20	52.80792	52.88932	52.87748	52.8892	52.82883
25	52.44257	52.53754	52.52373	52.5374	52.46696
30	52.07723	52.18576	52.16998	52.18561	52.1051
35	51.71188	51.83398	51.81623	51.83381	51.74324
40	51.34654	51.4822	51.46247	51.48201	51.38138

Thermal Analysis on Spiral fins of heat pipe module shows the maximum amount of heat transfer rate. Wankhede et al.**[**03**]**used piping with spiral fins on it and checked the results by changing the flow rates of oil through it, where he found that overall heat transfer coefficient increases with the increase in mass flow rate. Analysis result is shown in fig. 5.

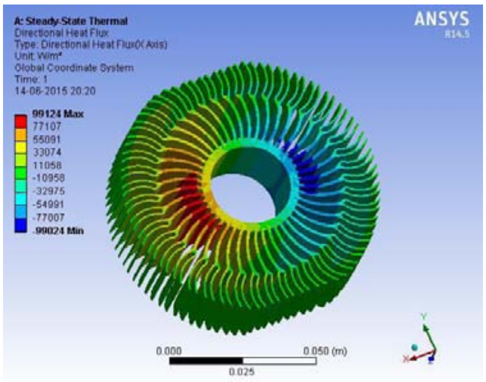

Figure 5: Rate of Heat flux Transfer through Fins [03]

Khannan et al. [27] studied three different configurations on the outside surface of the outer tube of annular ring, spiral rod and rectangular projection. It was observed by varying mass flow rates that the heat transfer rate was increased for a finned tube and fin with annular ring showed better performance than other methods.

4. Conclusion and Future Task

For the Indian hot conditions, when the ambient temperature will rise up to 45°C, and the Injection moulding machines operating with heavy load, the oil temperature will rise about 55°C and above and that is not desirable for the machine operation as there will be viscosity retention problem and the proper viscosity is vital for the machine operation. Passive methods for increasing heat transfer rate for hydraulic oil looks promisive, but inserts for pipe has limitation of installation in the machine, due to huge pressure drop. Pipe with surface area extension will be a good choice to increase heat transfer rate. The scope of this review for heat transfer increment is the implementation of techniques on the machine wherever it is possible and find out the results of applicability. However these techniques are also applicable to other applications of machine, whichever is powered by hydraulic oil.

5. Acknowledgement

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