Heat Transfer Enhancement by Forced Convection in the Hydraulic Press

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Abstract— When the hydraulic press is used to deliver force on the soft gel pad used as medical cushion which is already heated, there is significant reduction of life of hydraulic seals due to thermal stresses. These stresses are also harmful to other parts of presses which are in direct contact with heaters .The challenge is to remove heat out from the press parts without affecting the component temperature. In this paper authors have differently dealt with the problem. In first way they have restricted the flow of heat from the hot components to the press components and then forced convection has been used with optimum to eliminate the problem.

Index Terms— Computational Fluid Dynamics, Fan, Heat transfer enhancement, Hydraulic RAM.

Nomenclature

A, B, C, D	Cartridge heater at Top Plate
E, F, G, H	Cartridge heater at Bottom Plate
T1, T2, T3, T4	Thermocouple mounted at Top plate
B1, B2, B3, B4	Thermocouple mounted at Bottom plate
Nu	Nusselt number
Pr	Prandtl number
Lc	Characteristic or corrected length
H	Convection Heat transfer coeff. $W/m^2.K$
K	Thermal conductivity,$W/m^2.K$
ϑ	Kinematic viscosity,m^2/s
β	Volume expansivity,1/K

I. INTRODUCTION

The project aims to deliver a working hydraulic press as a process equipment to manufacture soft gel interface on a non-invasive ventilation mask. The same process equipment could also be utilized for the manufacture of soft gel pads for use during surgery and longer hospital stays. The soft gel interface will provide soft cushioning on the patients skin while reducing the force needed to tighten the headgear without compromising ventilator delivery air pressure and volume. Growing popularity with the positive-pressure ventilation delivered through a mask in patients with obstructive sleep apnea led to this type of ventilator support. Initially this method was widely used in patients with neuromuscular respiratory failure. Success led to its adoption in other conditions, and noninvasive ventilation became especially promising in the treatment of patients with chronic obstructive pulmonary disease. Noninvasive positive-pressure ventilation delivered through a mask has been widely adapted, to the point where it is a first-line therapy in some medical centers.

Advantages of non-invasive ventilation

- Easier to administer compared to end tracheal intubation. Hence it is also easier to remove allowing for intermittent use.
- Reduces the need for sedation
- Drastically improves patient comfort
- Oral Patency (preserves speech, reduces the need for nasoentric tubes)
- Avoids the resistive work imposed by the end tracheal tube.

Plan of work and methods and techniques to be used:-

A custom hydraulic press machine will be developed with the assistance of a qualified vendor.

The main design and structure of the hydraulic press will be done using 3D CAD .The press will consist of several components which will enable in the production of the final part. In addition to the hydraulic press, the main components include a heated bottom cavity plate and a heated top plate. The bottom cavity plate will be designed to secure a thin film in place and will be connected to a vacuum plenum to form the thin film in the mold cavity. Once the soft gel is dispensed, another layer of film will be placed over the mold cavity. A separate mechanism will be designed to move the bottom plate in and out of the hydraulic press. This mechanism could be pneumatically or hydraulically operated. Once the bottom plate is placed in the press, the top plate will be pressed on the bottom plate at a determined pressure. The top plate and the bottom plate will also be maintained at determined temperatures. The pressure and temperature of the top and bottom cavity plate will be calculated analytically using CAE methods. An insulating material will be chosen to be placed with the top and bottom plate to prevent rapid dissipation of heat. The heat transfer between the top plate and the ram plate will be studied determined using CAE methods.

II. CONCEPT DESIGN & DEVELOPMENT OF THERMAL REQUIREMENT OF HYDRAULIC PRESS

A. Observations during press operations

It is observed that while operating press high temperatures @600^{0}C are developed at top ram plate & bottom plate. Such high temperatures developed at bottom plate will not have immediately adverse effect as there are no hydraulic system elements in contact with bottom plate area .but in case of Top plate it has been observed that such high temperatures is having detrimental effect on hydraulic system elements such as ram operating cylinder heating, oil temperature rise, hydraulic seal failure. Following Six Important Service Properties of oil getting detoriated due to heat transfer to top ram plate (1) viscosity; (2) viscosity index (3) Demulsibility ; (4) oxidation stability; (5) lubricity or lubricating value; and (6) rust- and corrosion-preventive qualities.

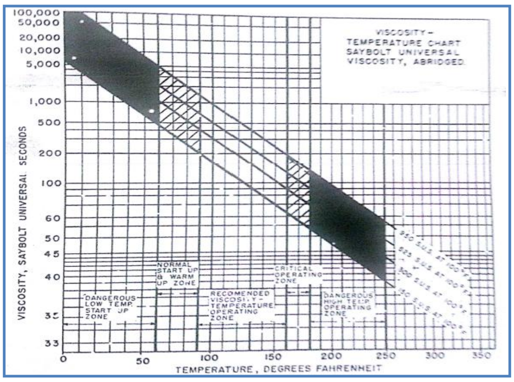

Fig. 1. Temperature v/s Viscosity Graph

III. SELECTION OF INSULATING MATERIAL TO AVOID HEAT TRANSFER TO TOP AND BOTTOM PLATE

Thermal conductivity is property of the material it is depend upon material structure (chemical composition, physical state and texture), moisture content and density of the material and operating conditions of pressures and temperatures. The value of thermal conductivity may range from 0.0083 w/m-deg for gases and as great as 410w/m-deg for metals such as silver

.For the solution experimentation has been done with cost-effective insulations and finally suitable material has been selected as asbestos impregnated plate (0.17 W/mK) of 8 mm thickness.

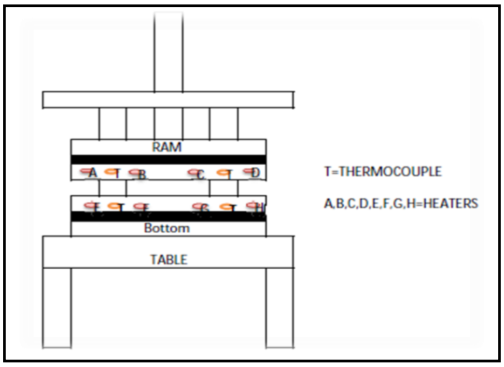

Fig. 2. Schematic arrangement of the system

Observations during press operations

Observations: Here temperatures are varying with time . There is temperature at top plate because of heaters, the heat transfer is restricted due to asbestos impregnated sheet.

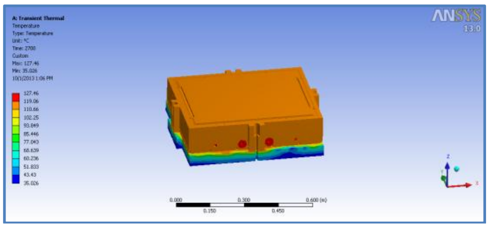

Fig. 3. Temperature distribution

A. Study of transient thermal Analysis of bottom plate after insulation for 5000seconds

Observations: Same temperature distribution is seen at different time after 5000 seconds.

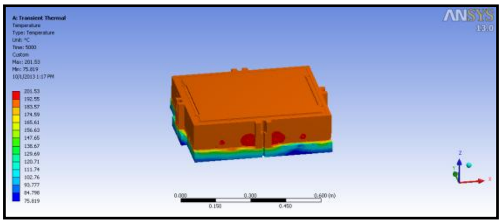

Fig. 4. Temperature distribution

B. Observations during press operations

It has been observed that temperature of Top ram plate successfully reduced to 221 ℃ from 600℃

IV. NUMERICAL ANALYSIS FOR NATURAL CONVECTION

Considering horizontal plate of length 1.4 m with width 0.6 meter and 0.02 meter and Laminar flow of air is considered so first going through natural convection

Lc = Characteristic length of a rectangular plate

T_s = Temperature of a solid plate

T_a = Ambient temperature

T_f = Mean fluid Temperature= $(T_s+T_a)/2$

$\beta = 1/ Tf = 1/ (90+273) = 0.00275/K$

The thermo physical properties of the air seen at 90°C are ϑ = 22.10 x10 -6 m2/s

k= 0.03217 W/mK,

Pr = 0.690,

$Nu = 0.45(Gr \times Pr)^{.25}$

$Gr = (Lc^3 \times g \times \beta \times \Delta T)/\vartheta^2 = 3.2182 \times 10^{11}$

$Nu = (Gr \times Pr)^{.25} = 308.9085$

Nu = hl/k

But this is not the reduction what we expect .To reduce further temperature we must opt for forced convection method

Now using forced convection

The thermo physical properties of the air seen at 60 ^{0}C are ν = 1.995 x105 m2/s , Pr =0.71

Density = 1.059kg/m3, Cp =1007 J/kgK

Thermal conductivity = k =0.02808 W/mK

Kinematic viscosity = 1.798 x10-5 m2/s, velocity =U=6 m/s

Pr = 0.7228, Lc =0.20m

Re = UL/ν = (6 x0.20)/ 1.798 x10-5 =66666.66

Hence flow is laminar,

So average Nusselt no. = Nu = 0.664(Re)0.5(Pr)0.33 =153.83

Nu = hlc/k, 153.83 = h(0.2)/0.028

k= 0.02881 W/m-K,

β=1/ Tf=1/ (90+273) =0.00275/K

$Nu = 0.102 \times Re^{0.675} \times Pr^{0.33}$

V = 6 m/s.

h = 21.53 W/m^{2}K

By natural convection h = 5.82 W/m^{2}K

Therefore % increase in h by 73% in forced convection.

V. PERFORMANCE ANALYSIS

A. Permance Analysis through software CFD

The Results obtained from mathematical calculations are compared with CFD analysis output

The following are results has been observed

In following Fig.5, Blue color represents four guide ways of press. Blower is mounted on slotted ram above the top ram plate and below the press structure. In CFD analysis blower is having Left inlet and right outlet. Upper most blue portion is of air ranging temperature 300 K. Here we can see that temperature of joint hydraulic cylinder is seen at safer temperature so failure of the joint is avoided.

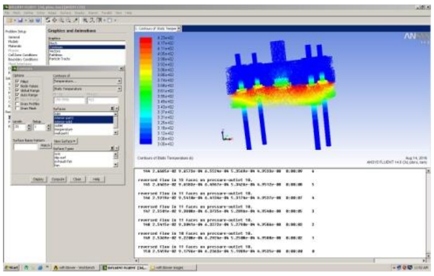

Fig. 5. Set Up

In fig.6, course and fine structure is shown. Nodes are 51745 and elements are 50883. Skewness lies between 0.22 to 0.7

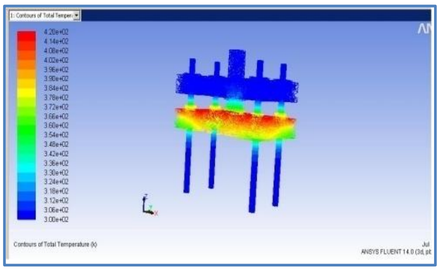

Fig.6 Meshing

As shown in Fig.7, red zone is having highest temperature 420K. with help of centrifugal blower mounted in the slotted ram temperature to cylinder joint has been reached to 370 K. So cylinder joint and hydraulic system is in safer zone for the operation

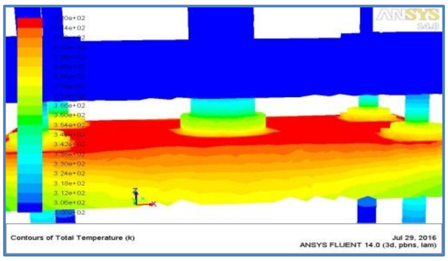

Fig.7. Contours of total temperature

B. Observed during Experimental tests

T_A= temperature of plate

T_B=Temperature after insulation

T_c=Temperature at Ram & cylinder coupling

After trial for 1 hour we have observed following temperatures

T_A= temperature of plate =600°C

T_B=Temperature after insulation=221°C

T_c=Temperature at Ram & cylinder coupling=74°C

VI. RESULTS AND CONCLUSION

Centrifugal blower mounted in slotted ram provided an effective means of enhancing the heat transfer in low convective regions. In this study, the characteristics of three dimensional heat & fluid flow fields generated by centrifugal blower are examined by CFD analysis &

experimental measurements.

The results from analytical calculations, CFD software and Experimental results are showing that centrifugal blower improves the heat transfer coefficient .

1. Heat transfer from heaters at hydraulic press to coupling joint through aluminium plate, top ram plate is studied through analytical method by using heat transfer principles.
2. Analytical calculations have shown that with modifications, the heat transfer is reduced to 90%. Due to this, the temperature at the surface of coupling joint is reduced to 45°C
3. Heat transfer from heaters at hydraulic press to coupling joint through aluminium plate, top ram plate is studied through CFD. The temperatures contours are drawn through CFD.
4. The results of CFD simulation indicates with use of forced convection, the heat transfer is reduced to 88%. Due to this, the temperature at the surface of coupling joint is reduced to 51°C
5. By comparing results achieved from analytical study and results from CFD simulation, we found the results are approximately matching.
6. By reducing high temperature at the surface of coupling joint, undesirable effects to hydraulic components are eliminated. With this improvement, premature failures of hydraulic seals are eliminated.
7. As temperature is at recommended operating level, adverse effects of high temperature is eliminated. With this improvement, working life of hydraulic oil is increased.

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