EXPERIMENTAL STUDY OF WATER JET PUMP USED TO SUCK UP FLOATING OILS

I. A. El-Sawaf[1], M.A. Halawa[2], M. A. Younes[3], M.A.Hashim[4]

[1]Professor of Mechanical Power Engineering Department, Faculty of Engineering, Port-Said University, Egypt
[2]Associate Professor, Mechanical Engineering Department, Faculty of Engineering Al-Azhar University, Egypt
[3]Professor, MERI, NWRC, Egypt, Madel5@yahoo.com
[4] Assistant Researcher, MERI, NWRC, Egypt, Mofrehhahshim@yahoo.com

ABSTRACT

This research covers the experimental results obtained in the current work. A set of experiments were carried out to study the effect of some parameters on the performance of jet pump used to suck up floating oils. These parameters such as: area ratio, distance between the end of driving nozzle to the beginning of mixing chamber, one mixing chamber was used with 25.4 mm diameter Also, diffuser outlet angle In addition, the experimental study also includes the performance of the jet pump at different driving pressure. One type of floating oil used with a specific gravity of 0.92. Furthermore, one suction chamber with six inches diameter was used. A special experimental test rig has been designed and built to study the effect of these parameters experimentally. The performance of the jet pump is described by two sets of curves. The first shows the relationship between the head ratio (N) and the mass flow ratio (M). The second set shows the relationship between the jet pump efficiency (η) and the mass flow ratio. It has been shown that the jet pump works satisfactory with an optimum efficiency at driving pressure of 1 bar, distance 1 of driving nozzle diameter, diffuser angle 5.5° and area ratio 0.22.

Keywords: jet pump, area ratio, suck up, floating oil

1. INTRODUCTION

The jet pump is being used in many fields for different purposes because of its simple construction and easy operation. Jet pumps have been used frequently in deep pumping, booster pumping, dredging, tail water suppressors, as a recirculation device in atomic reactors and many other systems. In general, pumping action is actuated by converting the pressure energy in driving line to velocity energy with the help of a nozzle and thereby reducing pressure at the driving nozzle. The reduction in pressure at the nozzle causes the flow of the driven fluid which mixes in main flow. So will concern to use of jet pump to remove floating oil. Recovering of oil spillage can be carried out by mechanical, chemical and thermal processes. Mechanical processes are consisting of skimming operations and collecting booms. It is considered as one of the methods adapted without side effects in oil removing operations. Spilled oil is generally better treated while it is still floating onto the water surface. If it comes nearer to the shore, the cost of fighting will be drastically high and expensive, and more complicated. It is therefore wise to control the oil spill from spreading over the water and hence, increases the affected area. The performance of jet pumps in which the driving fluid is of similar properties to the entrained fluid has been studied closely with recommendations for their design. Little however is known about the performance to be expected of a water driven jet pump used to entrain and pump oil spills. This research gives details of tests made on water driven jet pump floats over water surface to entrain and pump oil spills. It is possible in the tests to vary the principle dimensions and observe the external behavior of containment process.

Gosline and O'Brien [1] performed a detailed study on theory and design of jet pumps, where they have been developed a theory for predicting water jet pump performance by using the basic equations of fluid mechanics. Mueller [2] recommended that the driving and suction nozzles should have velocity coefficient of 0.95 or better. Best result was obtained when the nozzle distance is equal to driving nozzle diameter. The mixing chamber length of 7.15 times mixer diameter should be adopted if a diffuser with total included angle of 5^0 is used. Vyas and Subir Kar [3] concluded that for specified delivery head, Suction rate, driving line characteristic and velocity ratio, the design of whole jet pump is possible. In addition to that, the testing procedure including the efficiency definitions, standard methods of measurements and instruments to be used for determination of the complete system characteristic was discussed.

Abdelnour et al [4] presented data on the effect of oil film thickness and total mixture flow rate on the percentage oil concentration in recovered oil. Their results indicate that the oil concentration decreases rapidly with the mixture flow rate, and increases with increasing slick thickness. Yano et al [5] presented theoretical and experimental investigation on a certain type of water jet pump called the bend - type jet pump (without any diffuser part) using three different area ratios of 0.141, 0.165 and 0.91. Also, they studied the performance of this type of jet pumps theoretically and experimentally. Lorenzo et al [6] concluded that weir skimmers were influenced less by variations in oil viscosity for non-emulsion oil, but varied significantly when operating with an emulsion. El-Sawaf [7] presented some measurements and visual observation study of the system is presented. The paper describes also the related laboratory development work of the system for different oil viscosities, amounts and water surface speeds. Wanga, et al [8] concluded the threat of economic and environmental devastation from oil spill has lead to the development of a number of cleanup alternatives. Hammoud [9] discusses the enhancement of weir skimmer capacity on spill oil recovery by introducing a tangential water jet along the inside bottom of a weir chamber.

FUJITA, YOSHIE [10] discuss basic performances of the steam jet suction device and its potential application to the spilled oil recovery. The experiments were carried out on suction and ejection performance of the steam-driven jet pump as well as its other benefits such as breaking emulsion or an application to a beach cleaning device.

They discussed fundamental characteristics of the steam jet-pump and its secondary benefits intending its application to the spilled oil recovery, oil property reformation or beach sand cleaning. A steam-jet pump is basically suitable to recover and transfer high viscosity spilled oil because it has large suction power as well as very rapid heating which will resolve the difficulty related to the high viscosity caused by the emulsification. The present investigation showed that these parameters affect the oil spill spreading and the performance of the recovery system. It has been shown that the floating jet pump works satisfactory.

2. EXPERIMENTAL INVESTIGATION

Schematic diagrams of the experimental test rig and jet pump are shown in Figures (1), (2) and its photograph is shown in Figure (3). The test rig is consists of, the flowing flume, centrifugal pumps, jet pump, ultrasonic flow meter, magnetic flow meter, digital indicator, gage pressure, and piping system. The centrifugal pump (2) draws water from suction tank (5), then discharging the water into the driving line where it is first passes through control valve (4), then it is divided into two branches. One of these branches passes through the bypass line (6), the other branch passes through the ultrasonic flow meter (7), then through the gage pressure (9) and finally to the jet pump (8). In the jet pump the driving flow combined with the secondary flow, to make the delivery flow, which is discharged to the discharge line, where it passes to the gage pressure, then passes through the magnetic flow meter (13), and finally, it discharged to the sample vessel (14). The flowing flume (1) has the following working parameters: length, width and depth of working section were 3 m, 0.5 m and 1 m respectively. The water in the flume is circulated by means of circulating centrifugal pump (15), but it was not used during experiments.

The centrifugal pump (2) has 5.5 hp electric motor delivering 8 m^3/hr at 62 m head of water the ultrasonic flow meter (7) has a span of reading from zero to 12 m/sec. The magnetic flow meter (13) has a span of reading from 0-100 m3/hr, and output signal (0-20mA) The gage pressure (9) has a span of reading from (-1 to 7 bar). The digital indicator (10) is used to reading the pressure. The piping system consists of two parts: the driving line (3) which consists of one inch nominal size galvanized pipe and the delivery line (11), which consists of three inch nominal size galvanized pipe.

The floating oil level inside the flowing flume was first measured; the jet pump centerline was set at a depth of 40 mm under the oil level above the surface water and a height of 200 mm from the flume floor. In the case of oil jet pump, medium oil at specific gravity (0.92) and water levels were first set to the required level, then the centrifugal pump were turned on, and by means of control valve, the driving pressure was adjusted to be one bar while the discharge valve was closed, then the discharge valve was partially opened until the jet pump draws the suction fluid, the driving pressure again was adjusted to be maintained at one bar. After steady state conditions were reached, the readings of ultrasonic flow meter, the digital indicator of the discharge pressure, and the magnetic flow meter of the delivery side were taken.

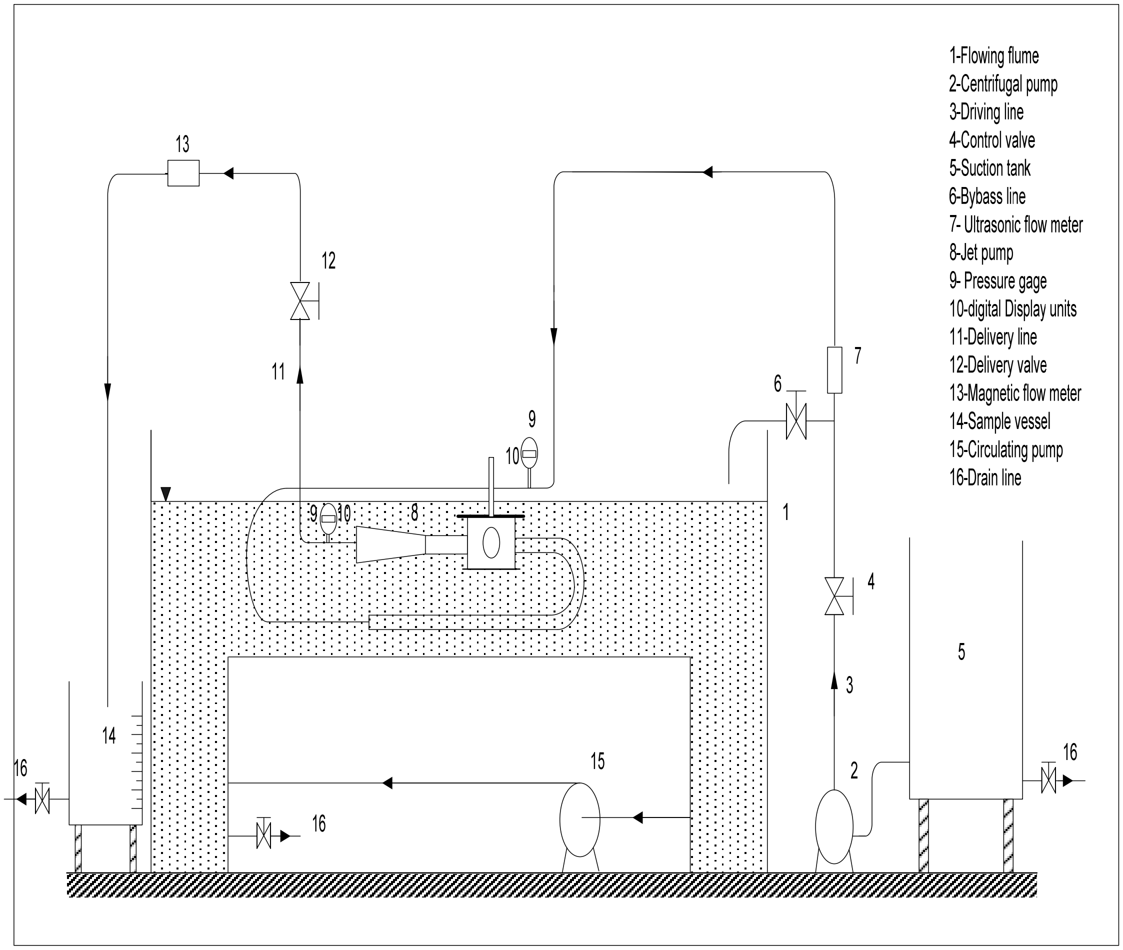

Fig. (1) Schematic diagram of experimental test rig

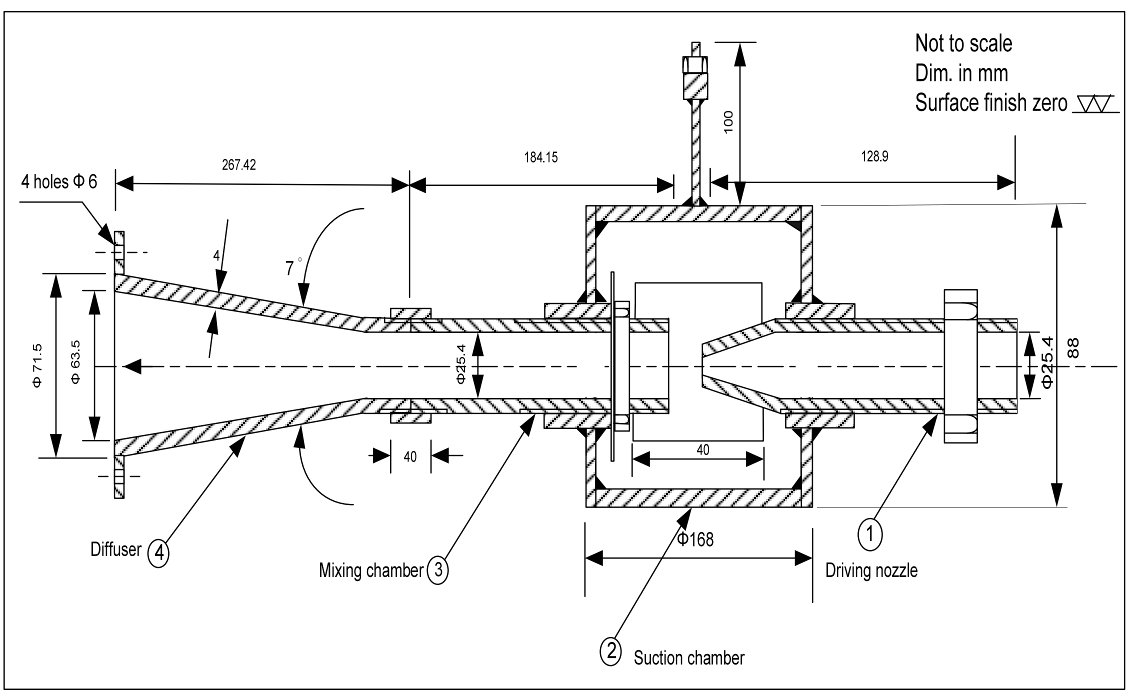

Fig. (2) Schematic diagram of the Jet pump

Fig. (3) Photo of the jet pump used in the experimental test rig

Table (1) Combination parts of floating jet pump

Ex. No.	oil type	L_{mc} (mm)	L (-)	θ_d (°)	D (mm)	R(-)	L (mm)	X(-)
1	medium oil	184.15	7.25	7	8.8	0.12	0	0
2	medium oil	184.15	7.25	7	8.8	0.12	8.8	1
3	medium oil	184.15	7.25	7	8.8	0.12	17.6	1.5
4	medium oil	184.15	7.25	7	11.9	0.22	0	0
5	medium oil	184.15	7.25	7	11.9	0.22	11.9	1
6	medium oil	184.15	7.25	7	11.9	0.22	17.85	1.5
7	medium oil	184.15	7.25	7	15	0.35	0	0
8	medium oil	184.15	7.25	7	15	0.35	15	1
9	medium oil	184.15	7.25	7	15	0.35	22.5	1.5
10	medium oil	184.15	7.25	5.5	8.8	0.12	0	0
11	medium oil	184.15	7.25	5.5	8.8	0.12	8.8	1
12	medium oil	184.15	7.25	5.5	8.8	0.12	17.6	1.5
13	medium oil	184.15	7.25	5.5	11.9	0.22	0	0
14	medium oil	184.15	7.25	5.5	11.9	0.22	11.9	1
15	medium oil	184.15	7.25	5.5	11.9	0.22	17.85	1.5
16	medium oil	184.15	7.25	5.5	15	0.35	0	0
17	medium oil	184.15	7.25	5.5	15	0.35	15	1
18	medium oil	184.15	7.25	5.5	15	0.35	22.5	1.5
19	medium oil	184.15	7.25	4	8.8	0.12	0	0
20	medium oil	184.15	7.25	4	8.8	0.12	8.8	1
21	medium oil	184.15	7.25	4	8.8	0.12	17.6	1.5
22	medium oil	184.15	7.25	4	11.9	0.22	0	0
23	medium oil	184.15	7.25	4	11.9	0.22	11.9	1
24	medium oil	184.15	7.25	4	11.9	0.22	17.85	1.5
25	medium oil	184.15	7.25	4	15	0.35	0	0
26	medium oil	184.15	7.25	4	15	0.35	15	1
27	medium oil	184.15	7.25	4	15	0.35	22.5	1.5

A sample from the discharged flow was taken in a certain time, and weight and volume were measured, the readings were repeated twice again and the average values were taken. The time of experimental run was from thirty to one hour. The discharge valve was partially opened until it was fully opened, the procedure were repeated every time the discharge valve was opened. After that the nozzle distances were adjusted to 0 and 1.5 D, and the same procedure was carried out as described before. The procedure was repeated every time the jet pump parts were replaced, the replacement of oil jet pump combination parts was as that as given in Table (1).

3. RESULTS AND DISSCUSION

In this research paper, the effect of changing driving nozzle distance on the jet pump performance for three different area ratios R= 0.12, 0.22 and 0.35 were studied experimentally at the following conditions:

- Three driving nozzle distances X= 0, 1, and 1.5.
- Three diffuser angles θ_d= 7°, 5.5°, 4°.

3.1. Effect of changing area ratio (R) on floating jet pump performance

In this study three different driving nozzles with different exit diameters of 8.8, 11.9 and 15 mm were used in combination with one constant mixing chamber diameter of 25.4 mm, which gives three area ratios of 0.12, 0.22 and 0.35.

Figure (4) shows the results of the effect of changing area ratio on the performance of floating jet pump having the following specifications: mixing chamber length ratio 7.25 and diffuser angle 5.5º. It clear from this figure for the same jet pump combination parts increasing the area ratio the efficiency are increased too.

The efficiency increases also with increasing the mass flow rate ratio. The highest values of efficiency are for area ratio of 0.22 at "X"=1 as shown in Fig. (4). It is also clear that the area ratio of 0.22 gives the best performance compared to area ratio 0.35 which gives the lower efficiency. This may be because the jet pump with area ratio of 0.22 draws more driving fluid than that with area ratio 0.35 for the same driving pressure.

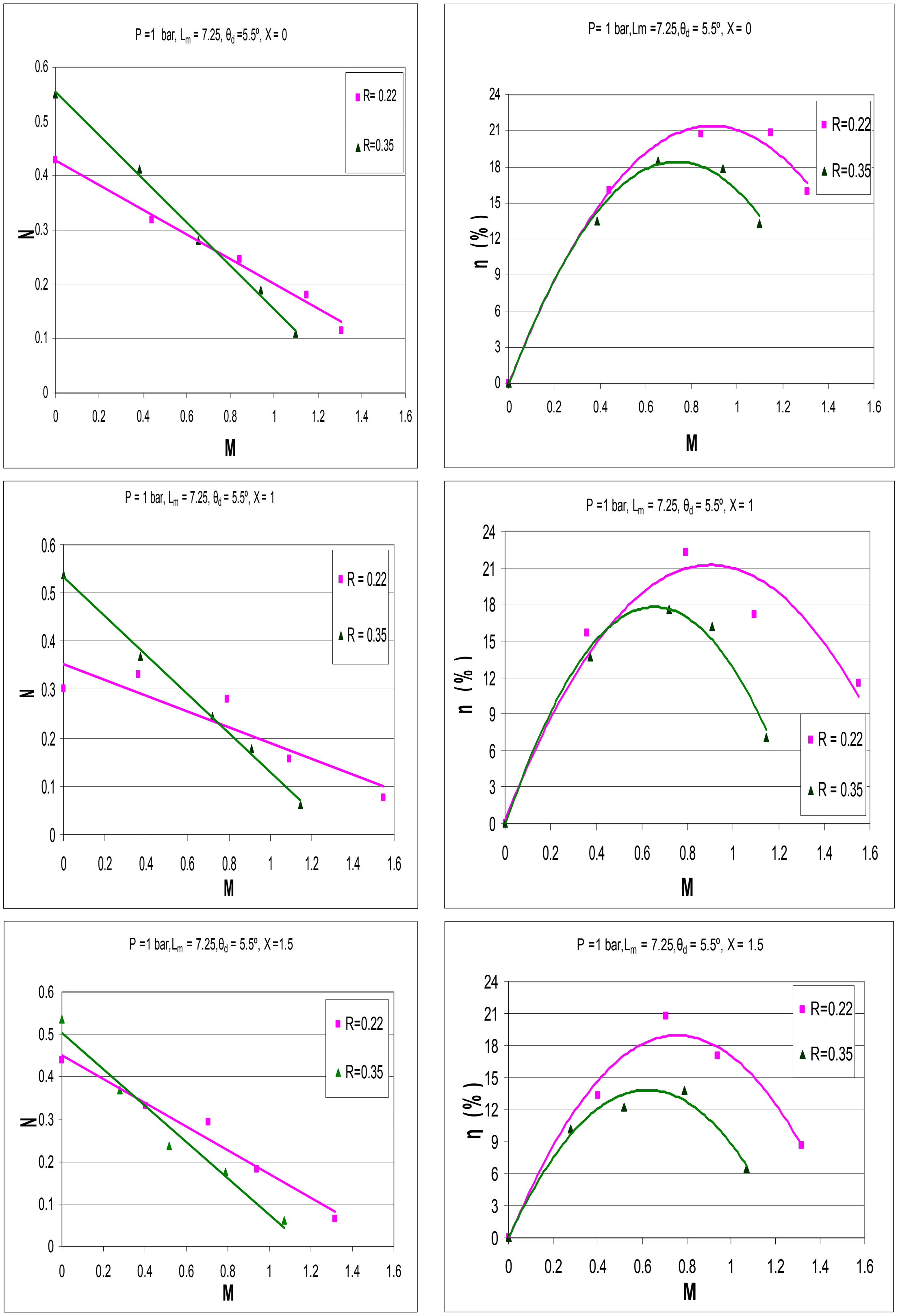

Fig. (4) Jet pump performance for different area ratio (R) at constant motive pressure, when pumping floating oil at θ_d = 5.5° and mixing chamber ratio (L_m/D_m =7.25).

3.2. Effect of nozzle-to-throat spacing to nozzle diameter ratio "X" on jet pump performance

Figures (5) and (6) show that the flow ratio is inversely proportional to the head ratio and as the drive pressure decreases from 2.5 to 1 bars, the head ratio of the jet pump increases.

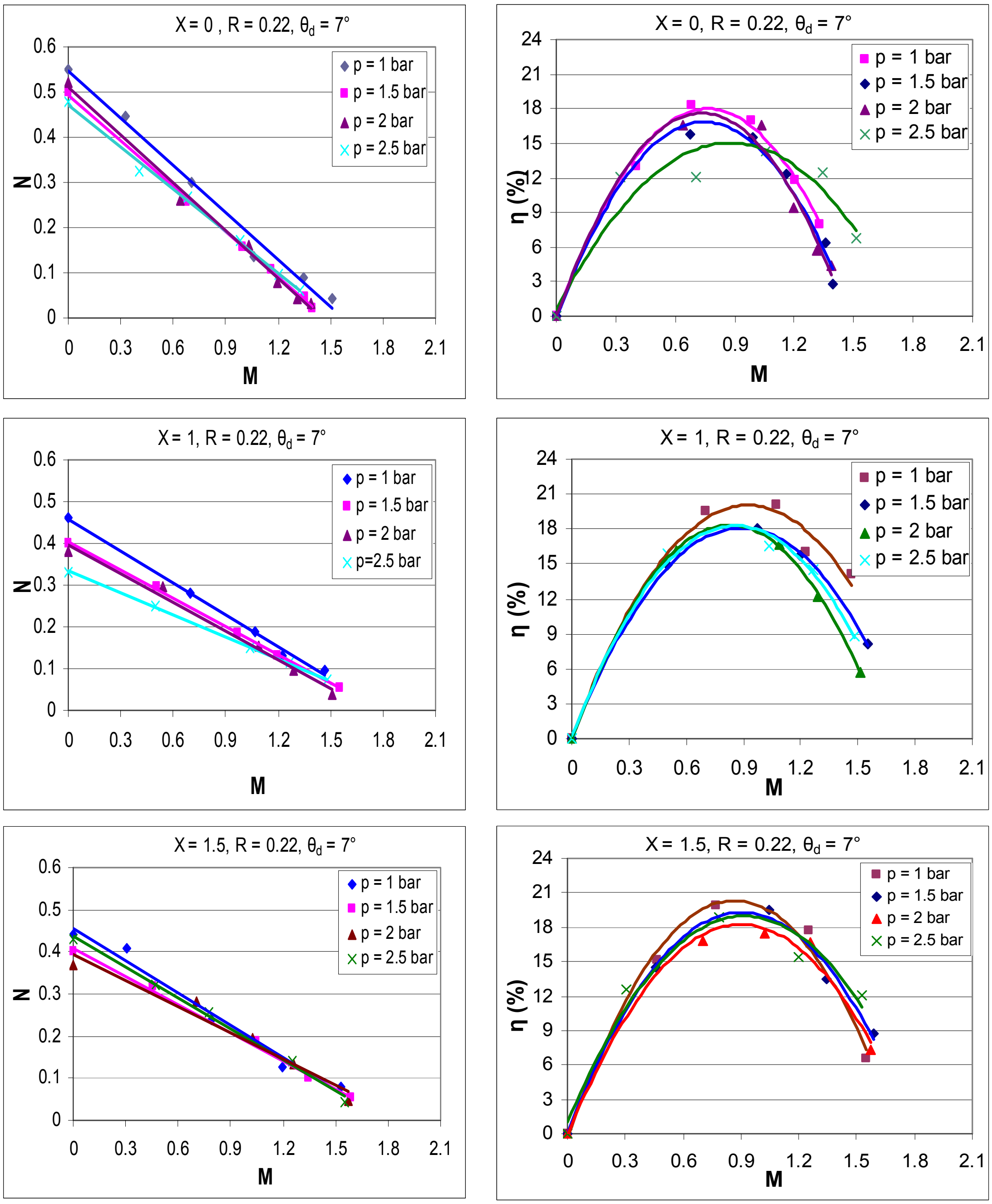

Fig. (5) Jet pump performance for different motive pressure at a specific nozzle distance (X), when pumping floating oil at constant area ratio (R=0.22) for θ_d=5.5° and mixing chamber ratio (L_m/D_m =7.25.

For nozzle-to-throat spacing to nozzle diameter ratio "X" = 1, it was found that, the maximum head ratio of the jet pump is obtained for a drive pressure of 1 bar which is 0.55 head ratio at a flow ratio of 0 and the minimum head ratio is 0.09 which corresponds to a flow ratio of 1.51. However, when the driving pressure was increased to 2.5bar, the maximum head ratio of the jet pump drops to 0.34 at a flow ratio of 0 and the minimum head ratio is 0.08 at a flow ratio of 1.49. The probable explanation of the significant jet pressure reduction at high pump driving pressure is the increase in the head loss in the jet pump which cause swirl and eddy losses inside the jet pump. Also in Fig. (5), the effects of flow ratio and driving pressure on the jet pump efficiency are presented. The maximum pump efficiency obtained for nozzle-to-throat spacing to nozzle diameter ratio "X" = 1 and driving pressure of P = 1 bars is about 20.89 % at a flow ratio of 1.2. Whereas for P= 2.5 bar the maximum efficiency is 16 % at a flow ratio of 1.15. This indicated a little reduction in jet pump efficiency. Typical results of the pump performance was obtained for nozzle-to-throat spacing to nozzle diameter ratio "X" = 0 and 1.5. In all cases the maximum flow ratio of the pump is obtained at a driving pressure of 1 bar.

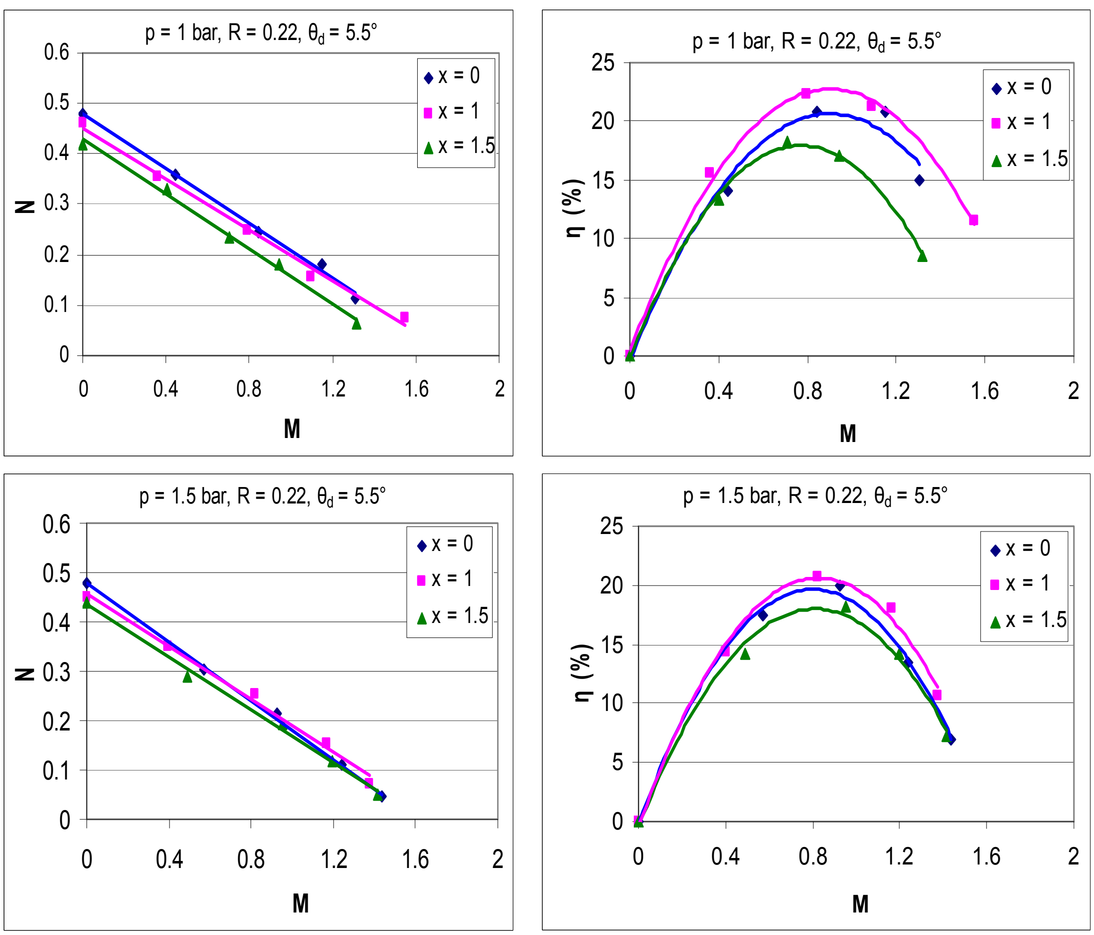

Fig. (6) Jet pump performance for different a specific nozzle distance (X) at constant motive pressure, when pumping floating oil at constant area ratio (R=0.22) for θ_d = 5.5° and mixing chamber ratio (L_m/D_m = 7.25).

3.3. Effect of changing diffuser angle (θ_d) on jet pump performance

The diffuser is a gradually diverging passage which converts the kinetic energy of the mixed stream to potential energy. In this study three diffuser lengths (L_d) of 227.42, 197.8 and 155.15 mm were tested, the inlet diameter and outlet diameters of the diffusers are 25.4 and 63.5 mm respectively, having diffuser angles (θ_d) of 4°, 5.5° and 7° respectively.

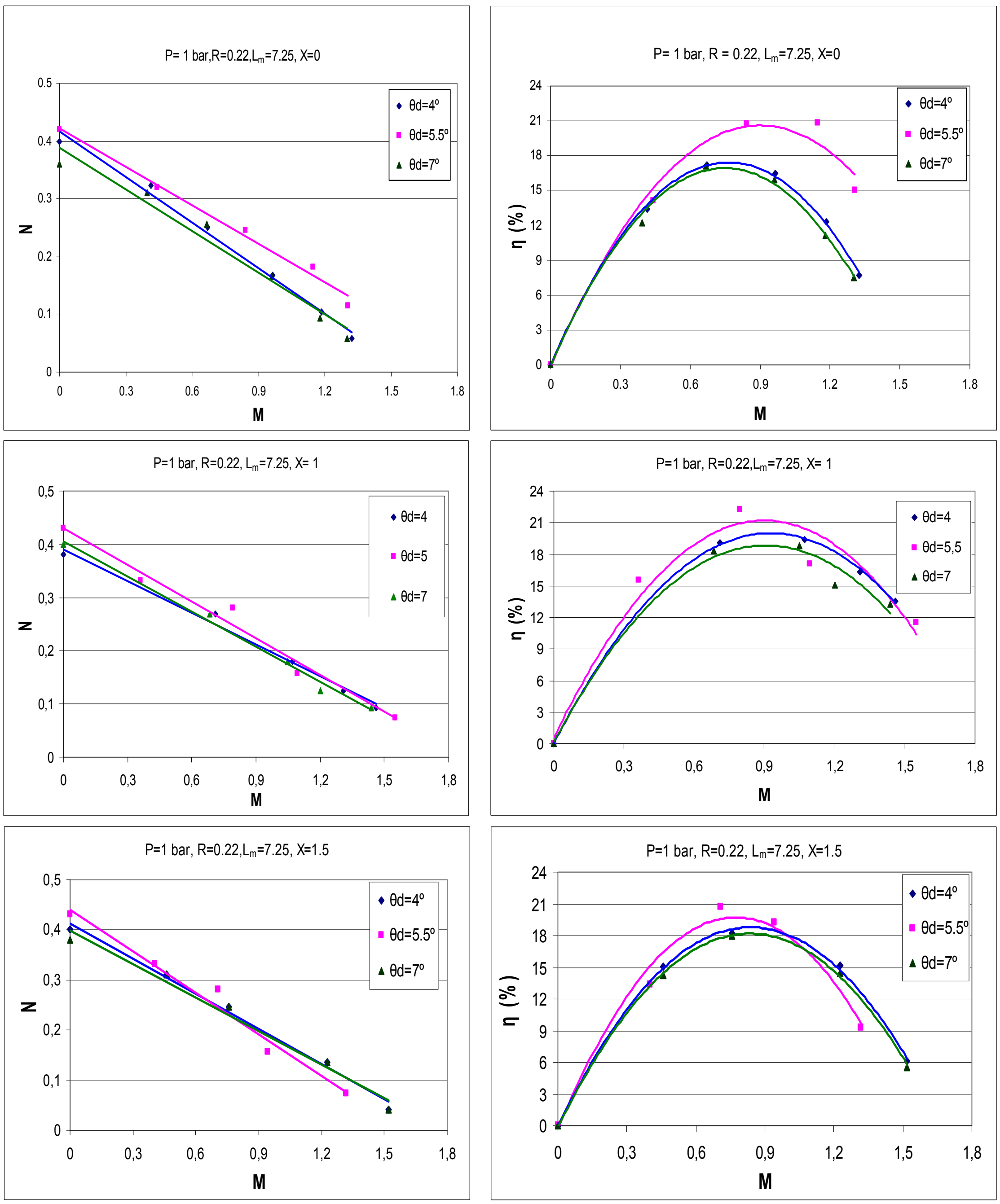

Fig. (7) Jet pump performance for different diffuser angle (θ_d) at

constant motive pressure, when pumping floating oil at mixing chamber ratio (L = 7.25) and area ratio (R = 0..22).

Figure (7) shows the results of the effect of changing diffuser angle (θ_d) on the performance of water jet pump for the following configuration: area ratio of 0.12 and diffuser angle θ_d=5.5°. It is clear from this figure that the diffuser angle of θ_d=5.5° D_m have a maximum efficiency rather than that of θ_d=4° and θ_d=7° at nozzle-to-throat spacing to nozzle diameter ratio "X" = 1 for all tested driving pressure and area ratio. For a given area ratio as the angle increases to θ_d=7° the losses due to separation increases but as the angle decreases to θ_d=4° the length of the diffuser increases and correspondingly the friction loss increases.

4. CONCLUSION

- The optimum efficiency at driving pressure of 1 bar, at distance of one driving nozzle diameter, diffuser angle 5.5° and area ratio 0.22.
- It is considered as one of the methods adapted without side effects in oil removing operations.
- It has been shown that the jet pump works satisfactory for suction of the oils.
- The net jet pump head and the head ratio decrease with increasing suction capacity.
- The diffuser angle of 5.5º gives the highest delivered oil concentration at heavy oil.

Nomenclature

Roman letters

A_J	= Cross sectional area of the jet, m^2
A_m	= Cross sectional area of the mixing chamber, m^2
D	= Nozzle (jet) diameter, m
D_m	= Mixing chamber diameter, m
l	= Nozzle-to-throat spacing.
L	= Mixing chamber length to mixing chamber diameter ratio (L_m/D_m)
L_m	= Length of the mixing chamber, m
L_d	= Diffuser length, m
P	= Driving pressure = P_d - P_s
P_m	= Motive pressure, (Pa)
P_d	= Discharge Pressure, (Pa)
C_{vs}, C_{vd}	= Concentration by volume on suction and discharge lines respectively
SG	= Specific gravity
N	= Head ratio
P_s	= Suction Pressure, (Pa)
M	= Flow ratio
R	= Area ratio = A_j/A_m, (area of nozzle to area of mixing chamber).
X	= Ratio of nozzle-to-throat spacing to nozzle diameter (l/D)
θ_d	= Diffuser angle

Greek letters

γ	= Specific weight (N/m^3)
η	=Pump efficiency = M x N

Subscripts

d, m, s	= Discharge, driving (main) and suction lines respectively
t	= Mixing chamber (throat)
w	= Water
1, 2	= Driving and suction nozzles exit at mixing chamber entrance
3	= Exit of mixing chamber
d	= Discharge
j	= Nozzle tip
mix	= Mixing chamber

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