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# A STUDY OF YARN INSERTION USING TWO AIR JET NOZZLES

" دراسة قذف الخيط بواسطة فوهتين هواء "

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خلاصـــــــــة – فى هذا البحث تم تحليل تأثير ضغط الهواء عند الفوهات ووضع الفوهة الخلفية بالنسبة للفوهة الرئيسية على سحب الهواء الابتدائى والنهائى وقذف الخيط فى نظام يحاكي نظام قذف الهواء متعدد الألوان . ولقد استخدم فى هذا التحليل طريقة بوكس وهانتر ، فى تصميم التجارب. ولقد أوضح التحليل أن ضغط الهواء ووضع الفوهة الخلفية بدلالة بعدها عن الفوهة الرئيسية والزاوية بين محورى الفوهتين لهم تأثير معنوى على سحب الهواء وزمن قذف الخيط . وهذا البحث يساعد فى اختيار وضع مناسب للفوهة الخلفية للحصول على زمن أصغر لقذف الخيط

## ABSTRACT:

In the present work, the mutual effect of air pressure at nozzles and position of back nozzle with respect to main nozzle on initial air drag, final air drag and yarn insertion time is analysed. This simulate a multi color air jet insertion system. Factorial design technique using Box and Hunter method is applied. The analysis shows that the air pressure and the position of the back nozzle in terms of its distance from the main nozzle and the angle between the nozzles axes have a significant effect on air drag and yarn insertion. This helps in selecting a suitable position of the back nozzle to get a small yarn insertion time at a considerable air pressure.

## 1-INTRODUCTION:

The recent years show a remarkable development in air jet weaving. The result is an air jet weaving machine capable of weaving a wide range of fabrics at a high rate of filling insertion, up to 2000 m/min was shown in ITMA 87. Spun and continous filament yarns are inserted by air jet for a large distance without any problems. This is due to the precision design of the air jet filling insertion system and the control of supply air pressure. Three types of filling insertion systems were shown in ITMA 87 in Paris. These systems are, main nozzle and confuser type guide with suction at the other side, main nozzle.

with auxilary nozzles and confuser type guide, and main nozzle with auxilary nozzles and profile reed with suction at the other side. The use of main nozzle and auxilary nozzles increase the yarn velocity during insertion and thus the loom width is increased up to 420 cm at a high running speed up to 500 p.p.m. In the last few years, the multi color filling insertion system has been introduced. For a four color insertion system, it is essential to use four main nozzles to insert four different filling yarns at a certain sequence depending on the fabric construction. Each filling yarn is fed to the nozzle from a seperate yarn feed system behind the main nozzles. In this case, four drum type yarn feed systems are used behind the main nozzles. Normally they are fixed at a certain distance and angle behind the main nozzles. This results in an additional resistance to the yarn movement during insertion, the matter which has an influence on yarn insertion time and thus loom speed is reduced. To overcome the resisting force, another set of nozzles is used. These nozzles are situated behind the main nozzles, at a certain distance and angle to withdraw the yarn from the yarn feed system and to provide it to the main nozzles for insertion. The position of the back nozzle with respect to the main nozzle in terms of the distance and angle is belived to have an influence on the air drag force on yarn and thus, the yarn movement during insertion will be affected.

The purpose of the present work is to investigate the influence of the back nozzle position with respect to the main nozzle on air drag force on yarn and yarn insertion. This is important to adjust the multi color filling insertion system for better running conditions.

## 2-EXPERMENTAL WORK:

### 2.1. Test set-up :

The test set-up which was built earlier by the author [ 1 ] was used in this work. The back nozzle was fixed on a support similar to that of the main nozzle. The air supply to the back nozzle was filtered, regulated and controled from a line as that for the main nozzle. An electromagnetic yarn clamp was built to relese the yarn when insertion started. Figure ( 1 ) shows the diagramatic sketch of the test set-up which was used in this course of study. The main nozzle and back nozzle are similar in shape and construction. These nozzles and the confuser guide were taken from the Elitex air jet weaving machine.

### 2.2. Method of measurements :

The electronic Rothchild tension meter modle 1192R with a measuring head (100 CN) was used to measure the drag force on yarn. The signal from the tensiometer was fed through the Rothchild interface unit (R-2026) to a digital memory ociliscope modle (MS-1650B). A yarn length of 143 cm (Ne. 60/2) was accumulated behind the back nozzle. The air was opend to the two nozzles by the microswitches which operated the solenoid valves. Then, the clamp was opend to relese the yarn for insertion through the confuser guide. The recorded signal in the digital ociliscope was analyzed to get the initial air drag, final air drag and yarninsertion time. Figure ( 2 ) shows the signal ofa yarn insertion plotted on the paper of the chart recorder.

## 3- EXPERMENTAL DESIGN:

The factorial design is used to investigate the effect of the back nozzle position with respect to the main nozzle and air pressure at the nozzles on initial drag, final drag and insertion time. The position of the back nozzle is taken in terms of the distance between the two nozzles and the angle between the axes of the nozzles, as shown in Figure ( 1 ). This technique of experimental design is useful to investigate the interaction between different variables [ 3 - 11 ]. According to Box and Hunter [ 2 ], the variables are selected at five levels; -2, -1, 0, 1 and 2 . The response Y is given by a second order polynomial, i.e. ;

$$Y = b_o + \sum_{i=1}^{k} b_i x_i + \sum_{i=1}^{k} \sum_{j=1}^{k} b_{ij} x_i x_j$$

where $x_i$ = i th variable,

$k$ = number of variables, and

$b_o, b_i$ & $b_{ij}$ = regression coefficients associated with the variable.

In order to determin the regression coefficients, the response Y has to be found by using different experimental combinations of the variables under considration . For the case of three variables, the experimental plan is given in Table ( 1 ), and the actual levels of the variables are given in Table ( 2 ).

## 4-EXPERIMENTAL ANALYSIS:

As shown in the experimental plan in Table ( 1 ), the results obtained for initial drag, final drag and insertion time are shown in Table ( 3 ). These rsults were fed to AT computer, and regression coefficients were determined. The response-surface equations for initial drag, final drag and insertion time are given in Table ( 4 ). Also, the correlation coefficients between the experimental and calculated values obtained from the response-surface equation are shown with the F-test value in Table ( 4 ). Both correlation coefficients and F values are highly significant at the 99% significance level.

## 6-RESULTS AND DISCUSSIONS:

The contour lines at different levels ( -2, 0, 2 ) of Y's and the response surface in three dimension were calculated and drawn by a computer programm.. It was essential to find the contour lines for each dependent variable to clearify the effect of the independent variables $X_1$ . $X_2$ and $X_3$ at different levels. The three dimensional representaion of the response-surface equation is very important to understand the whole phenomenan.

### 5.1. Initial air drag:

Figures ( 3, 4 & 5 ) show the effect of air pressure and distance between nozzles on initial drag for different position angles. The contours clearly show that the initial air drag increases as the air pressure is increased. This is due to the fact that the air velocity at the nozzles increases as the air pressure is increased. Also, the initial air drag icreases as the distance between nozzles is increased. This is because the yarn length in the air stream of the back nozzle is increased. The effect of position angle of the back nozzle is hardly to be seen from figures ( 3, 4 & 5 ). This is because the air pressure has a large influence on the initial air drag compard to the position angle. Figure ( 6 ) shows the effect of position angle and distance between nozzles on initial air drag at air pressure of 60 psi. ( 0 level ). This value of air pressure was selected because it represents the normal supply air pressure at most of air jet weaving machines. The contour lines are ellipses in shape with a true maximum. At all distances between nozzles, nearly up to 10 cm, the position angle has a small influence on the initial air drag. This influence decreases as the distance between nozzles is increased untill the maximum is reached. This is attributed to the fact that the yarn length in the air stream of the back nozzle is alwayes constant (at certain distance between nozzles) for different values of the position angle. However, the length of the conical part of the back jet playes an important role in this respect. Figure ( 7 ) shows the response surface equation in three dimension graph. This shows the variation in the initial air drag at different positions of the back nozzle.

5.2. Final air drag:

Figures ( 8, 9 & 10 ) show the effect of air pressure and distance between nozzles on final air drag for different position angles. The contour lines clearly show that the final air drag increases as the air pressure is increased due to the increase in air velocity. The final air drag increases as the distance between nozzles is increased up to an air pressure of 60 psi. At this value of pressure, a distance between nozzles up to 25 cm has no influence on the final air drag. At higher values of air pressure the effect of distance between nozzles is relatively high. This is attributed to the change in air velocity distribution along the axis of the nozzles when different air pressures are supplied at the nozzles. Also the interaction between the length of air jet in front of back nozzle and the distance between nozzles influences the final air drag. Figure ( 11 ) shows the effect of the position angle and the distance between nozzles on the final air drag at 60 psi air pressure ( 0 level ). The contours confirms to saddle shape (minimax), in which the contour lines increase in one direction and decrease in the other direction. It is clear from the contour lines that the final air drag increases as the position angle is increased at distance between nozzles up to 12.5 cm. Beyond this distance the final air drag decreases as the position angle is increased. This is attributed to the distribution of the air velocity along the axis of the back nozzle and the frictional resistance to yarn movement which results from inclination of yarn through the main nozzle. Figure ( 12 ) shows the variation of final air drag with the position angle and distance between nozzles.

5.3. Insertion time:

Figures ( 13, 14 & 15 ) show the effect of air pressure and distance between nozzles on insertion time for different position angles. The colour lines are ellipses with a center outside the experimental field. The contour lines show that the insertion time decreases as the air pressure is increased. This is due to the increase in air velocity when the supply air pressure at the nozzles is raised. The distance between nozzles has a small influence on the time at 0 position angle ( -2 level ). Distance between nozzles beyond 25 cm is expected to have a substantial influence on increasing insertion time. At position angles 15, 30 ( 0 & 2 levels ), the contour lines show that the rate of reduction in insertion time is low compared to that at position angle 0. This is attributed to the frictional forces which result from yarn inclination through the main nozzle. These forces resist the yarn movement during insertion and thus, insertion time is increased.

Figure ( 16 ) shows the effect of position angle and the distance between nozzles on insertion time at 60 psi air pressure. The contour lines confirm to a saddle shape ( minimax ). The contours show that the insertion time decreases as the distance between nozzles is increased at position angle near to zero. This is due to the increase in air drag. At a distance between nozzles more than 20 cm, the increase in position angle beyond 5 degrees results in an increase in insertion time. This results from the large inclination of yarn through the main nozzle. Figure ( 17 ) shows the variation of the insertion time with position angle and distance between nozzles.

## 6-CONCLUSIONS:

The previous work showed the application of the factorial design technique using Box and Hunter method to get the most suitable running condition using two nozzles air jet filling insertion system. The mutual effect of air pressure, distance between nozzles and position angle is analysed. From the experimental results and analysis, it is clear that a distance between nozzles up to 7.5 cm and position angle up to 30 degrees rpresent the most suitable back nozzle position on a multi colour air jet insertion system similar to that used in this work.

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Table 1: Experimental plan for three variables

| No. | Level of variables $X_1$ | $X_2$ | $X_3$ |
|---|---|---|---|
| 1 | -1 | -1 | -1 |
| 2 | +1 | -1 | -1 |
| 3 | -1 | +1 | -1 |
| 4 | +1 | +1 | -1 |
| 5 | -1 | -1 | +1 |
| 6 | +1 | -1 | +1 |
| 7 | -1 | +1 | +1 |
| 8 | +1 | +1 | +1 |
| 9 | -2 | 0 | 0 |
| 10 | +2 | 0 | 0 |
| 11 | 0 | -2 | 0 |
| 12 | 0 | +2 | 0 |
| 13 | 0 | 0 | -2 |
| 14 | 0 | 0 | +2 |
| 15 | 0 | 0 | 0 |

Table 2 : Actual levels corrosponding to coded levels

| Variable / Level | -2 | -1 | 0 | +1 | +2 |
|---|---|---|---|---|---|
| $X_1$= Supply air pressure, psi | 40 | 50 | 60 | 70 | 80 |
| $X_2$= Angle between axes of nozzles, degrees | 0 | 7.5 | 15 | 22.5 | 30 |
| $X_3$= Distance between nozzles, cm | 5 | 10 | 15 | 20 | 25 |

Table 3 : Experimental results

| No. | Initial drag x 1/40 CN | Final drag x 1/40 CN | Insertion time x 10 MS |
|---|---|---|---|
| 1 | 115.3 | 230.8 | 19.16 |
| 2 | 205.2 | 367.8 | 15.06 |
| 3 | 112.9 | 227.5 | 18.38 |
| 4 | 203.6 | 364.2 | 14.68 |
| 5 | 131.4 | 234.8 | 19.18 |
| 6 | 218.9 | 399.2 | 14.7 |
| 7 | 118.8 | 220.1 | 19.96 |
| 8 | 233.3 | 392.8 | 14.52 |
| 9 | 070.3 | 146.2 | 23.81 |
| 10 | 279.2 | 447.7 | 14.4 |
| 11 | 168.9 | 296.6 | 15.72 |
| 12 | 170.2 | 301.4 | 15.88 |
| 13 | 145.6 | 303.7 | 16.2 |
| 14 | 179.4 | 304.0 | 16.58 |
| 15 | 173.7 | 298.3 | 16.10 |

Table 4 : Response surface equations

| | | Correlation coefficient | F-tes |
|---|---|---|---|
| 1. Initial air drag | $171.3+50.03X_1+0.03X_2+8.3X_3$ $+0.56X_1^2-0.74X_2^2-2.5X_3^2+3.48X_1X_2$ $+2.68X_1X_3+0.73X_2X_3$ | 0.998 | 120.7 |
| 2. Final air drag | $302.86+75.86X_1-1.15X_2+3.58X_3$ $-0.91X_1^2-0.39X_2^2+0.82X_3^2+1X_1X_2$ $+7.93X_1X_3-1.79X_2X_3$ | 0.998 | 132.1 |
| 3. Insertion time | $16.19-2.28X_1-0.02X_2+0.12X_3+$ $+0.74X_1^2-0.09X_2^2+0.06X_3^2-0.07X_1X_2$ $-0.27X_1X_3+0.22X_2X_3$ | 0.998 | 135.4 |

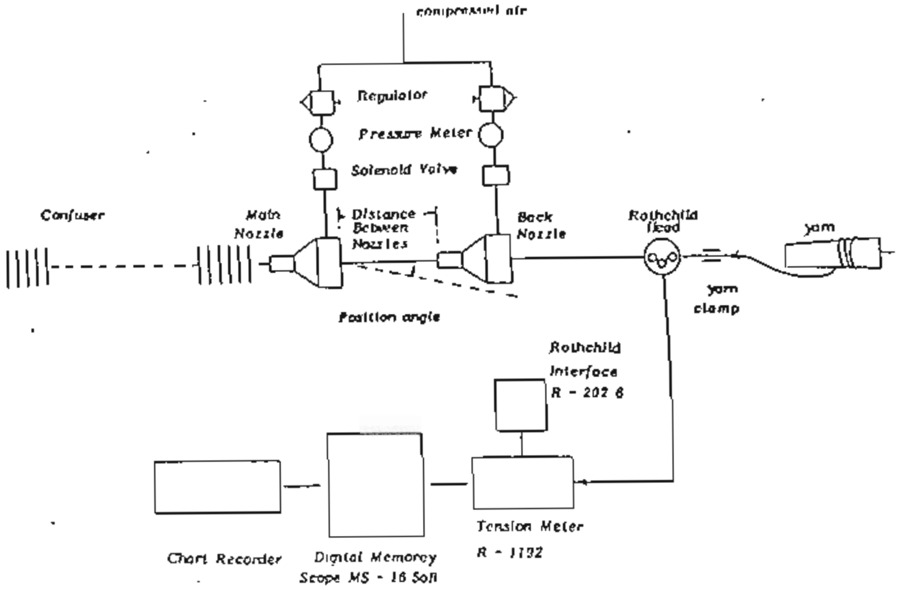


Fig.(1) Test set up and method of measurement.

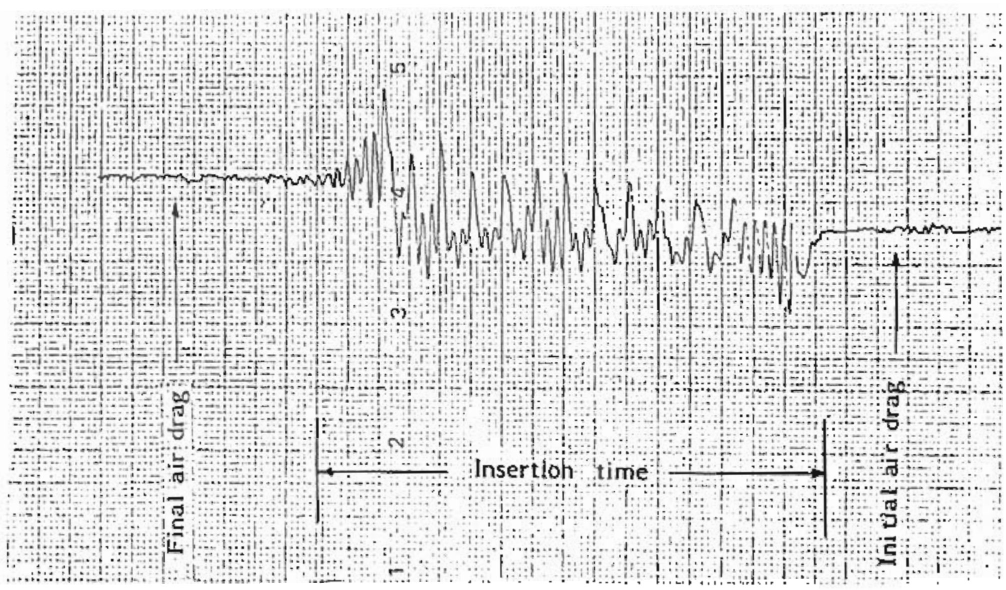


Fig.(2) Signal of yarn insertion .

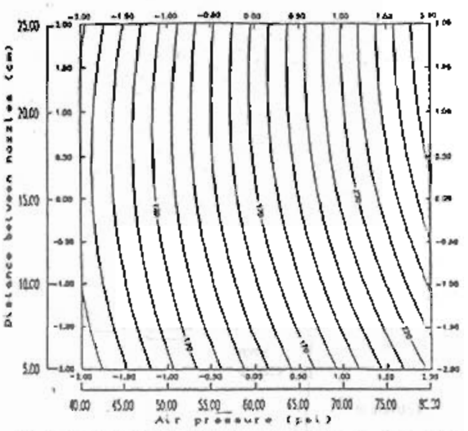


Fig.(3) Contour lines of initial air drag (1/40 CN), position angle 0 degree.

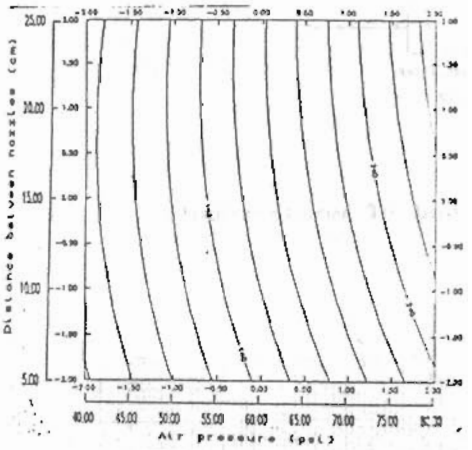


Fig.(4) Contour lines of initial air drag (1/40 CN), position angle 15 degrees.

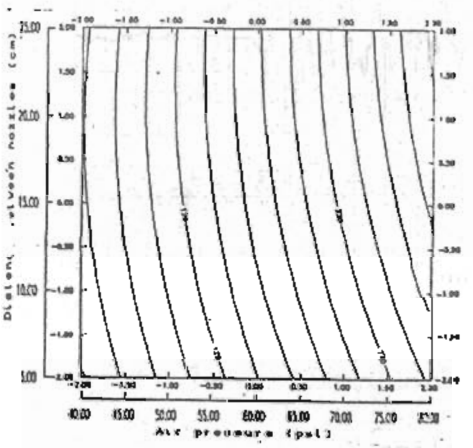


Fig.(5) Contour lines of initial air drag (1/40 CN), position angle 30 degrees.

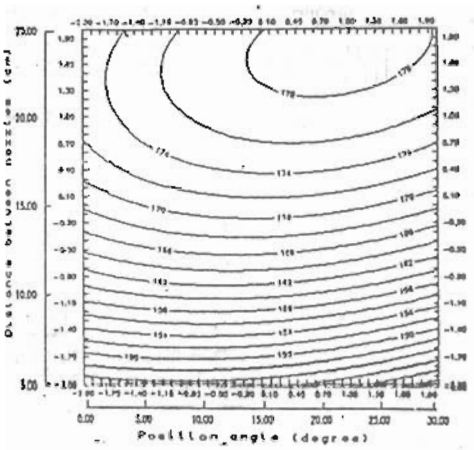


Fig.(6) Contour lines of final air drag (1/40 CN), air pressure 60 psi.

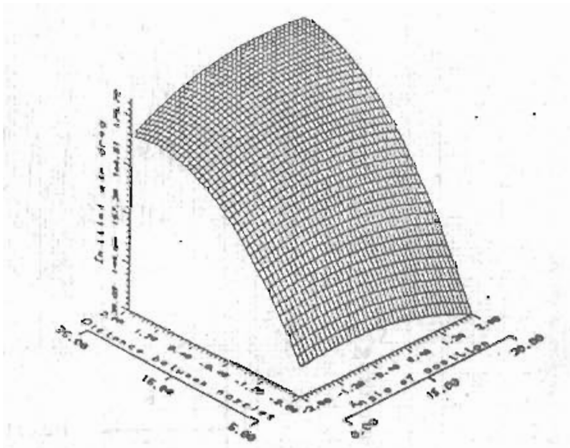

Fig.(7) Effect of position angle (degrees) and distance between nozzles (cm) on initial air drag (1/40 CN), air pressure 60 psi.

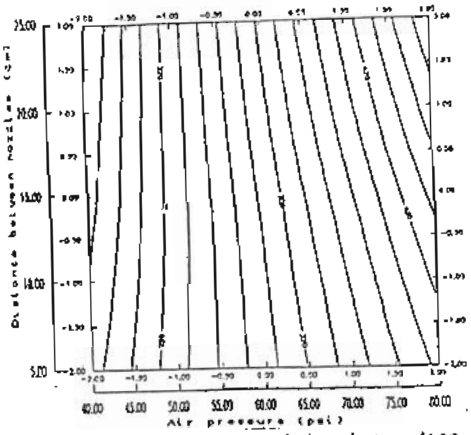


Fig. (8) Contour lines of final air drag (1/40 CN), position angle 0 degree.

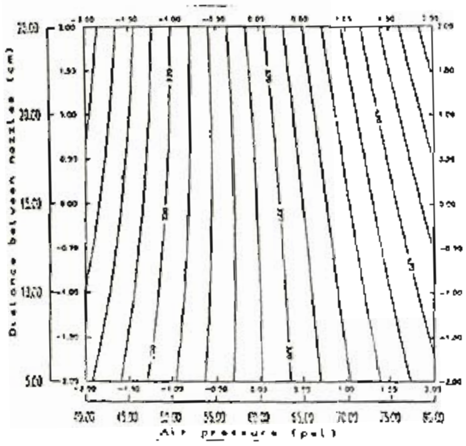


Fig. (9) Contour lines of final air drag (1/40 CN), position angle 15 degrees.

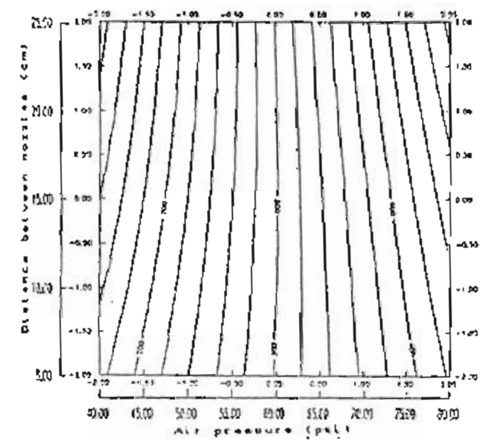


Fig. (10) Contour lines of final air drag (1/40 CN), position angle 30 degrees.

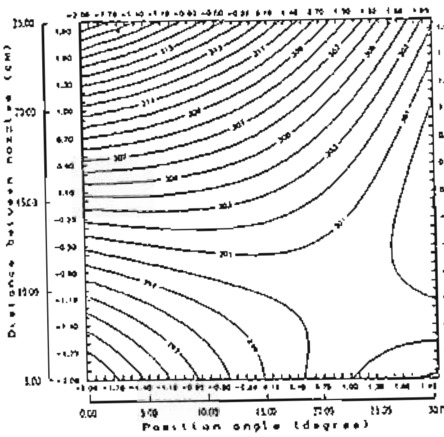


Fig. (11) Contour lines of final air drag (1/40 CN), air pressure 60 psi.

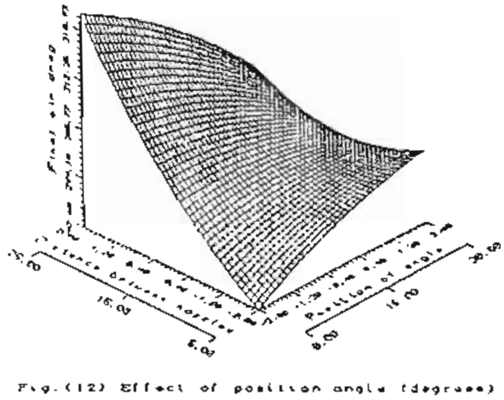


Fig. (12) Effect of position angle (degrees) and distance between nozzles (cm) on final air drag (1/40 CN), air pressure 60 psi.

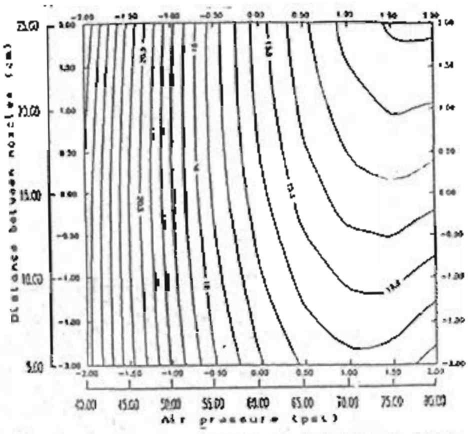


Fig. (13) Contour lines of insertion time (x 10 ms), position angle 0 degree.

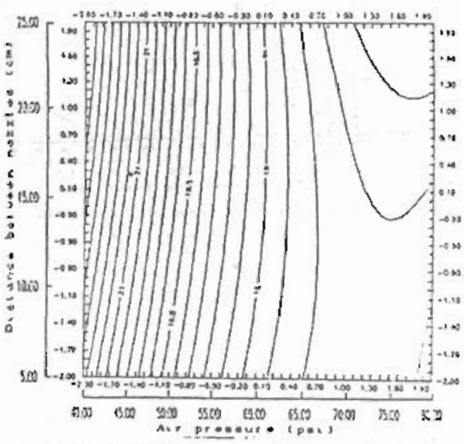


Fig. (14) Contour lines of insertion time (x 10 ms), position angle 15 degrees.

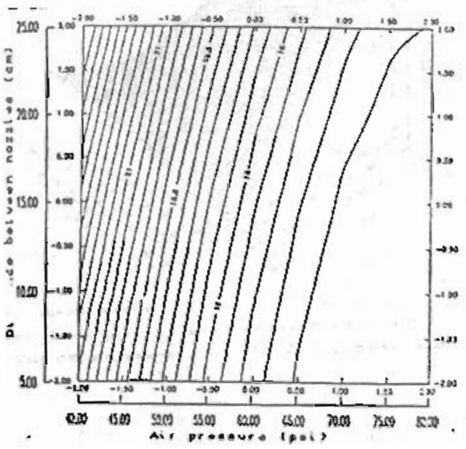


Fig. (15) Contour lines of insertion time (x 10 ms), position angle 30 degrees.

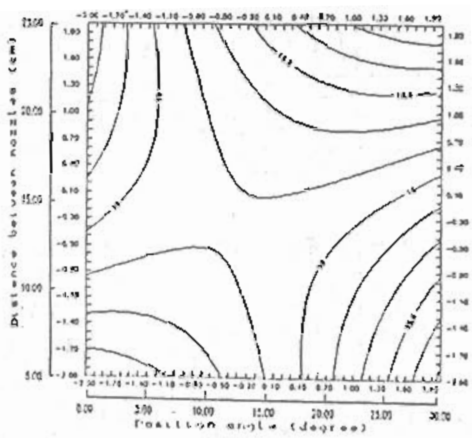


Fig. (16) Contour lines of insertion time (x 10 ms), air pressure 60 psi

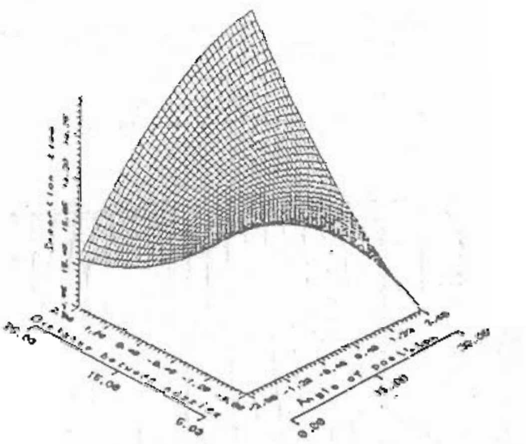


Fig (17) Effect of position angle (degrees) and distance between nozzles (cm) on insertion time (x10 ms), air pressure 60 psi.