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*dry drilling, aluminium alloys,
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EXPERIMENTAL ANALYSIS OF CUTTING FORCES IN DRY DRILLING OF UNS A92024 ALLOY

Dry drilling is a process of interest in order to eliminate the lubrication fluids. Also the aeronautical industry has been expected to these advantages. This paper analyses the cutting forces obtained during the dry drilling of aluminium alloy plates, in particular UNS A92024-T3. Experiments were performed in CNC milling and several HSS Co drills were utilised with different diameters. Cutting forces were measured by means of a piezoelectric dynamometer Kistler. This analysis provides a statistical study, by means of multi-sample comparison, in particular, F-test in the analysis of variance. Results provide evidence that can provide information about hole drilling with a tool without wear, so forces are statistically similar.

1. INTRODUCTION

Dry drilling is a process of interest in order to eliminate the lubrication fluids [1,3]. In recent years, the aeronautical industry has been interested in these advantages [6,7]. This paper analyses cutting forces obtained during the dry drilling of aluminium alloy plates, in particular UNS A92024-T3. Experiments were performed in CNC milling, programmed using Emco-code, and several HSS Co drills were used with different diameters. Cutting forces were measured by means of a piezoelectric dynamometer Kistler.

Although this alloy has been studied previously [2,4,5], this study provides a statistical analysis, which was carried out by means of multi-sample comparison analysis to determine the validation of the forces data during the drilling. Thus, this research suggests the possible use of statistical methods to reduce the test of lifetime of the tools. Results provide some evidences to forecast the cutting forces.

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2. EXPERIMENTAL PROCEDURE

The drill (see Fig. 1) consisted of HSS Co Garant -HSS-Co, Ti AIN, DIN 1897 Type FS, diameters of 4 and 6.3 mm, of habitual use in aerospace industry. Drilling was performed in workpieces such as plates of 6.5 mm of thickness, of UNS A92024-T3 material.

The drilling force was measured with a piezoelectric dynamometer, Kistler type 9257B, and a multi-channel charge amplifier Kistler type 5070A (see Fig. 1). The DASYLab software was used to record the experimental results.

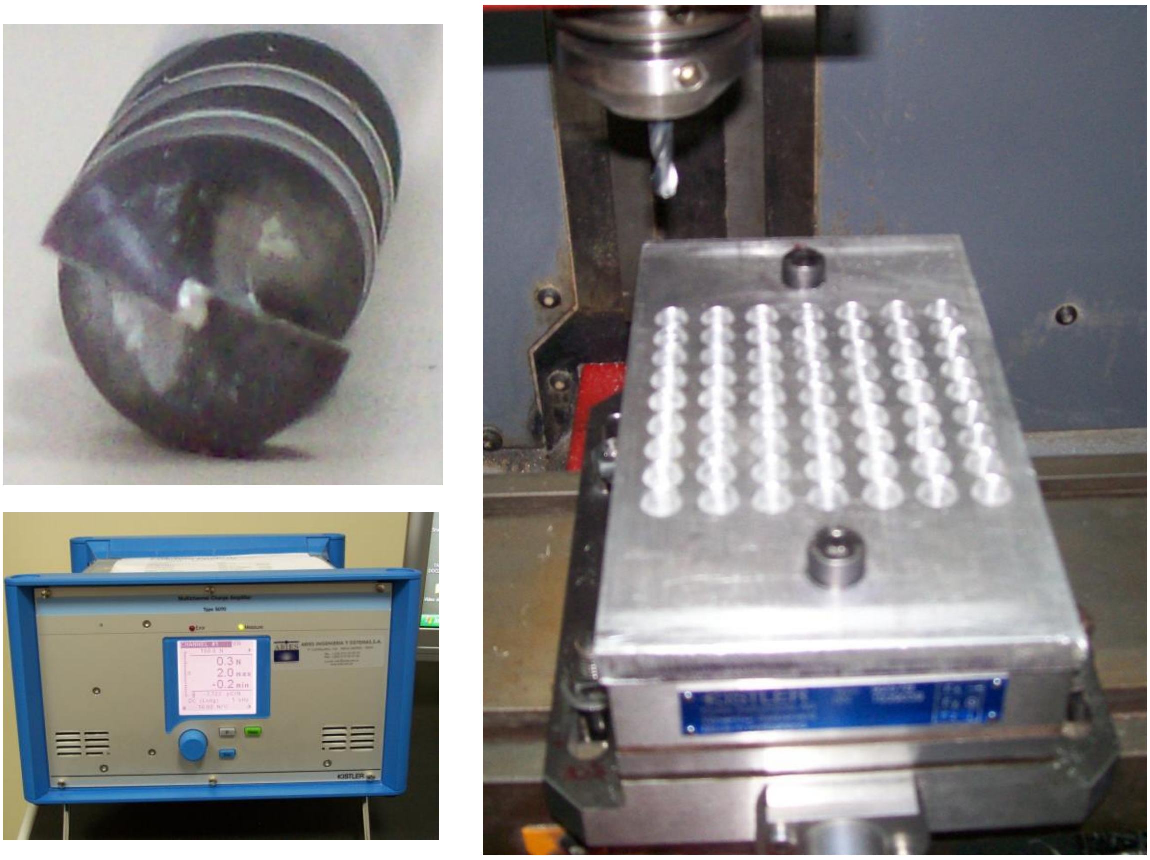

Fig. 1. Drill, workpiece, dynamometer and channel amplifier

3. EXPERIMENTAL RESULTS

Experimental tests were carried out in plates of UNS A92024-T3. Drills of diameters 4 and 6.3 mm were used. The drilling conditions (cutting speed, feed rate and revolution) are shown in Table 1. Fig. 2 and Fig. 3 show the cutting forces obtained in the nine first holes, with drills of diameters 4 mm and 6.3 mm.

Table 1. Cutting conditions

Diameter drill (mm)	Cutting speed Vc (m/min)	Feed rate f (mm/rev)	Revolution N (rpm)
4	50.2	0.175	4000
6.6	79.2	0.175	4000

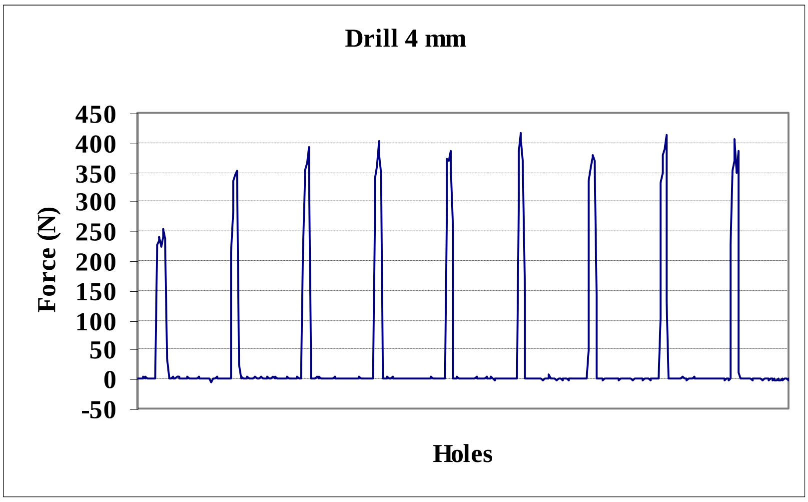

Fig. 2. Cutting forces for drill of diameter 4 mm

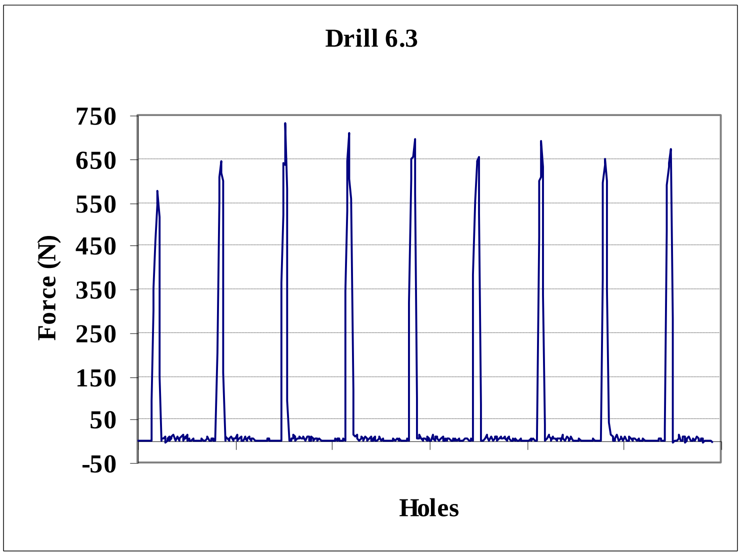

Fig. 3. Cutting forces for drill of diameter 6.3 mm

We can appreciate (Fig. 4 and Fig. 5) that the same drill provokes very different forces during the drilling in only nine holes. In order to determinate reliability of results, we have carried out a multi-sample comparison and its F-test in the ANOVA table. It tests whether there are any significant differences amongst the means. Because the instruments are calibrated, the F-test allows determination if the samples are similar and in this case the tool wear did not influence the forces.

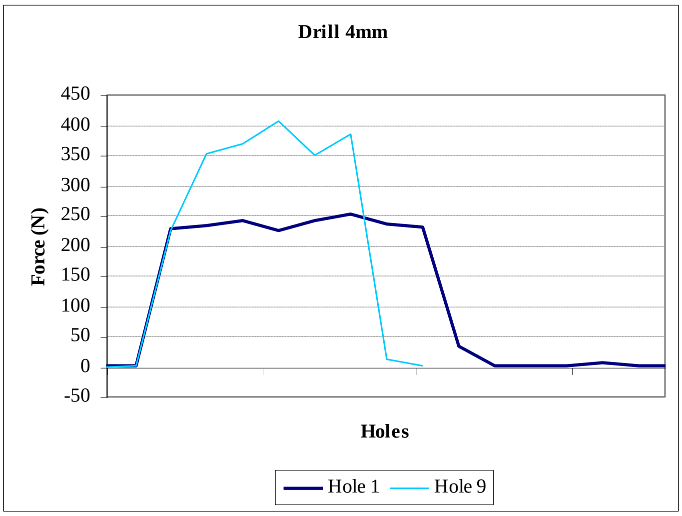

Fig. 4. Force for the drilling of two holes (drill 4 mm)

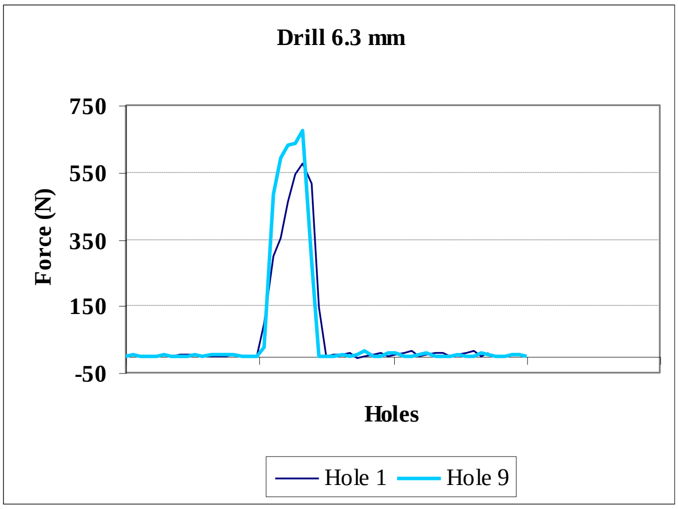

Fig. 5. Force for the drilling of two holes (drill 6.3 mm)

Table 2. Drill 4 mm. Analysis of Variance: ANOVA Table

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
Between groups	2759.68	8	344.959	0.03	1.0000
Within groups	5.37236E6	484	11099.9		
Total (Corr.)	5.37512E6	492			

The ANOVA table decomposes the variance of the data into two components: a between-group component and a within-group component. The F-ratio, which in this case equals 0.03108 (see Table 2, drill 4), is a ratio of the between-group estimate to the within-group estimate. Since the P-value of the F-test is greater than 0.05, there is not a statistically significant difference between the means of the 9 holes at the 95.0% confidence level. We can realize similar considerations with respect to the F-ratio for the 6.3 mm drill (see Table 3), the F-ratio in this case is equals 0.1557. Since the P-value of the F-test is higher than 0.05, there is not a statistically significant difference between the means of the 9 holes at the 95.0% confidence level.

Table 3. Drill 6.3 mm. Analysis of Variance: ANOVA Table

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
Between groups	36829.6	8	4603.7	0.16	0.9961
Within groups	1.38991E7	470	29572.5		
Total (Corr.)	1.39359E7	478			

4. CONCLUSIONS

Preliminary conclusions were:

i. Statistical analysis can give data that allows the collection and analysis of information of first forces and to verify the calibration of instruments.
ii. Also, analysis can provide information about hole drilling by means of a tool without wear.

Finally, in future research, the authors will complete a more comprehensive study to find out the most influential parameters thus achieving a perspective to minimize the number of tests.

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REFERENCES

[1] DASCH J.M., ANG C.C., WONG C.A., CHENG Y.T., WEINER A.M., LEV L.C., KONCA E., *A comparison of five categories of carbon-based tool coatings for dry drilling of aluminium*, Surface & Coatings Technology, 2006, Vol. 200, 2970-2977.

[2] HAMADEA R.F., SEIFA C.Y., ISMAILB F., *Extracting cutting force coefficients from drilling experiments*, International Journal of Machine Tools and Manufacture, Vol. 46, 2006, 387-396.

[3] KELLY J.F., COTERRELL M.G., *Minimal lubrication machining of aluminium alloys*, Journal of Materials Processing Technology, Vol. 120, 327-334.

[4] NOUARI M., LIST G., GIROT F., COUPARD D., *Experimental analysis and optimisation of tool wear in dry machining of aluminium alloys*, Wear, Vol. 255, 2003, 1359-1368.

[5] NOUARI M., LIST G., GIROT F., GEHIN D., *Effect of machining parameters and coating on wear mechanisms in dry drilling of aluminium alloys*, International Journal of Machine Tools & Manufacture, Vol. 45, 2005, 1436-1442.

[6] PEÑA B., ARAMENDI G., RIVERO A., LOPEZ DE LACALLE, L.N., *Monitoring of drilling for burr detection using spindle torque*, International Journal of Machine Tools & Manufacture, Vol. 45, 00. 2005, 1614-1621.

[7] SANCHEZ J.M., RUBIO E., ALVAREZ M., SEBASTIAN M.A., MARCOS M., *Microstructural characterisation of material adhered over cutting tool in the dry machining of aerospace aluminium alloys*, Journal of Materials Processing Technology, Vol. 164-165, 911-918.