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MACHINING AND SIMULATED SERVICE TESTING OF THREE FORGED ALUMINUM ALLOY 81-MM MORTAR BASE PLATES

by

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SUMMARY OF RESULTS

The lightest plate submitted was machined to the minimum permissible thickness of the flange and the remaining two overweight plates were machined to the weight of 24.4 ± 0.25 lb. All three plates were tested according to specification CA-P-208 and the two overweight plates, which had been machined, failed at loads lower than specified. It is believed that the heat treatment may be primarily responsible for the low properties obtained, rather than machining off the excess weight.

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INTRODUCTION

Standard forged aluminum alloy mortar base plates were found to vary in weight from approximately 24.5 lb to approximately 27 lb (without the socket). This variation in weight is presumably due to some variation in clearance between the die faces if the dies are not pressed into contact. This results in slightly higher arms and a thicker flange of the plate. To restore the proper weight of the plates, it was proposed to remove excess weight by some machining of the top of the flanges, and to test these plates under simulated service conditions.

In a letter dated 30 August 1966, File No. L 2511-2-3-5 (DAEL-3-3), it was requested that the flange of the lightest plate, No. 1, be machined to the minimum allowable thickness (15/64 in.); that the other plates, Nos. 2 and 3, be machined to the weight of 24.4 ± 0.25 lb;* and that all three plates be tested under 4-point support condition according to specification CA-P-208. The purpose of testing was to evaluate the possible effect of the machining on properties of the plates.

MACHINING

The base plate was positioned on the lathe with the aid of a special centering plug fitted into the socket of the plate. This made it possible to remove the plate for weighing and reposition it on the lathe for additional machining. Since only the top side of the flange of the plate was to be machined, some shimming of the legs was found necessary to compensate for unevenness of the plate. Also, since the inner portion of the flange is subjected to higher stresses in actual use and in testing, this part was used as a guide for the levelling of the plate on the lathe. The description of machining steps are given below for each plate, respectively.

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* In Mines Branch Investigation Reports IR 59-64, dated February 1, 1959, and IR 62-118, dated November 15, 1962, the average weight of the base plate is given as 26.5 lb <u>with</u> socket and rings. The weight of the socket and rings is given as 1 lb. According to these reports the <u>net weight</u> of the base plate should be <u>25.5 lb</u>. Therefore, the weight of 24.5 lb should be considered as the minimum or desirable weight.

Plate No. 1

(a) One light cut was made across the flat surface on the top of the flange. The thickness of the inner portion of the flange was measured and appropriate shims were inserted under the legs to ensure that after machining the flange would be as uniform in thickness as possible.

(b) The flange was machined to a mean of 0.235 inch.

(c) The circular groove on the top of the flange was machined to a depth specified on the drawing, and the sides of the groove cleaned with a contoured cutter. The weights before and after machining, and thickness of the flange after machining, are given in Table 1.

Plate No. 2

The step (a) above was followed by machining of the flange to 0.235 inch on the inside and 0.230 inch on the outside part. The circular groove was machined as described under (c) above. Approximately 3/16 inch was machined from the periphery of the plate. The plate was removed and the weight was found to be 24.75 lb. The plate was repositioned on the lathe and an additional 0.010 inch on the inside and 0.012 inch on the outside part of the flange was removed. The groove was deepened by 0.010 inch and an additional 0.050 inch was removed from the periphery of the plate. The weights and dimensions are given in Table 1.

Plate No. 3

The step (a) was followed by machining of the flange to 0.235 inch on the inside and 0.230 inch on the outside part. The groove was machined as described in step (c) and the plate was machined to 21-7/32 inches diameter. The weights and dimensions are given in Table 1.

4-POINT SUPPORT TESTING

The 4-Point Support Testing was carried out on all three plates according to Canadian Army Equipment Specification CA-P-208, Plate, Base, 81-mm Mortar, CDN, MK1, dated 23 October, 1963. The steel socket used in the test was found to be jammed in each plate after it broke and it was necessary to drill a hole through which a steel rod could be inserted to push the socket out.

Plate No. 1 fractured in the flange along the circular groove and is shown in Figure 1. The plate showed a high degree of deformation. Plates Nos. 2 and 3 broke through the arm close to the socket, which is typical for this test. Both plates showed substantially less deformation than plate No. 1. The mode of fracture is presented in Figure 2. The breaking loads and yield strengths are given in Table 1.

Brinell hardness was determined on the samples cut from the outside part of the flange in the middle between the arms, as these places did not exhibit any noticeable deformation. The results are given in Table 1. In order to obtain some idea about the strength of the material in the plates, flat test bars, having 2-inches gauge length and 0.5-inch width, approximately 0.28 inch thick, were machined from the tension side of the unbroken arms. The results are presented in Table 2.

In addition, grain size was measured on the samples cut from the flanges used in hardness determinations. Also, on the same samples, a count was made of the per cent of the second phase using a quantitative television microscope. The results are given in Table 2.

DISCUSSION OF RESULTS

Plate No. 1 (lowest weight) when machined on the top of the flange to the minimum thickness permissible, was approximately 0.45 lb less than the 24.4 lb required. The strength of the plate when tested under 4-point support condition was 185,500 lb, and the yield strength 99,000 lb, both above the minimum specified, but below typical values. The Brinell hardness of 124 was below the typical, given as 135. The mode of fracture in the flange along the circular groove is not typical, and it is believed that the machining of the circular groove was responsible due to either excessive removal of the metal, improper positioning of the groove in relation to the reinforcing rib underneath the groove, or the reinforcing rib not being perfectly circular. It is of interest to note the extensive deformation of the plate, indicating high ductility of the plate, which coincides with the lower yield strength of the plate and hardness (values obtained on the test pieces).

Plate No. 2 was machined on the top of the flange to slightly below minimum thickness and on the periphery to 21-7/32 inches diameter, in order to bring the weight of the plate to 24.36 lb. The plate broke under the load of 172,000 lb, which is below the minimum specified, although the yield strength of 108,000 lb was above the minimum, and the Brinell hardness of 136 is typical for this material. The fracture was typical for this test, but substantially less deformation than in plate No. 1 occurred. This coincides with higher yield strength and hardness of plate No. 2. It is believed that machining of the flange should decrease the strength of the plate to some extent, since the flange does give some limited support to the legs. However, not enough data or experience are at hand to predict if this plate would meet strength requirements had it not been machined. The machining, however, did not change the mode of fracture and this plate broke in the same manner as unmachined plates, which were tested previously.

Plate No. 3 was similar in machining and testing to plate No. 2, showing a still lower breaking load of 166,000 lb, slightly lower yield strength of 106,000 lb, but higher Brinell hardness of 143. The broken plate showed about the same amount of deformation as plate No. 2 and broke in the same manner. It is believed that the strength of the plate might still have been below the minimum of 180,000 lb, had it not been machined to remove excess weight.

The results of tensile testing of samples cut from the broken plates should be taken with some reservation as a basis for the evaluation of strength of the material in the base plates. Firstly, the samples were subjected to cold deformation during testing of the plates (plate No. 1, in particular) and, secondly, samples could not be obtained from broken arms in plates 2 and 3, which obviously had the lowest strength. Nevertheless, the results obtained indicate that the material in plate No. 3 has properties lower than typical for this alloy and condition, and on one occasion even lower than the minimum specified. Lower elongation values may be partly due to the shape of the bar (flat instead of round bar) and partly because of cold deformation during testing of the base plate. Higher yield strength in test bars from plates 1 and 2 is probably due to cold deformation. The variation in the grain size of the material could be due to variable forging temperature and/or solution heat treating conditions. The variation in the amount of the second phase could be due to the chemistry of the alloy and, also, to forging and heat treating conditions.

CONCLUSIONS

Since the variation in the plates was obviously a function of the manufacturing operation, the opportunity was taken to discuss the whole investigation with a representative of the manufacturer (Aluminum Company of Canada Limited).

Arising from this discussion, from the results of the investigation, and from previous examination of the base plates, the following conclusions can be drawn:

1. The machining of the top of the flange of the overweight plates should not appreciably affect the strength of the plate. The incomplete forging of the plates results in the increased height of the beams, which adds appreciably to the strength of this section, and this would compensate for the decrease in the strength of the plate due to reduction of the thickness of the flange.

2. The low strength of the overweight plates after machining is unlikely to be due to incomplete forging or variation in the chemical composition, but probably is due to variations in the heat treatment, especially solution heat treatment and/or subsequent quenching.

3. The relatively low mechanical properties obtained on samples from the beams of some of the plates suggest that some of the existing plates may not meet the strength requirements. However, this could not be established without further extensive testing.

BL/gm

TABLE 1

Plate No.	Net Weight Before Machining, lb	Net Weight After Machining, lb	Thickness of Flange, inches (after machining)						Plate Diameter, in.	4-Point Support Test		Brinell Hardness
			Inner Portion			Outer Portion				Yield, lb	Breaking Load, lb	
			max.	min.	ave.	max.	min.	ave.				
1	24.88	24.00	.244	.234	.239	.258	.231	.246	21-5/8 *	99,000	185,500	124
2	27.08	24.36	.233	.225	.230	.259	.227	.242	21-7/32	108,000	172,000	136
3	26.98	24.41	.264	.230	.241	.253	.231	.239	21-7/32	106,000	166,000	143
Typical										120,000	190,000	135
Minimum CA-P-208										95,000	180,000	-

* approximately

TABLE 2

Plate No.	Ultimate Tensile Strength, kpsi			0.2% Yield Strength, kpsi			Elongation, % in 2 in.			Grain Size Diameter, 0.001 in.	Second Phase Area, %
	max.	min.	ave.	max.	min.	ave.	max.	min.	ave.		
1	71.0	69.4	70.2	68.0	65.4	66.2	5.5	3.0	4.1	7.0	6.5
2	71.0	69.4	70.4	65.8	63.9	65.2	7.0	3.5	5.7	5.5	8.0
3	67.8	64.5	66.5	62.0	55.3	59.3	5.5	4.0	4.7	3.5	12.0
Typical			70.0			60.0			13.0		
Minimum Specified		65.0			55.0			10.0			

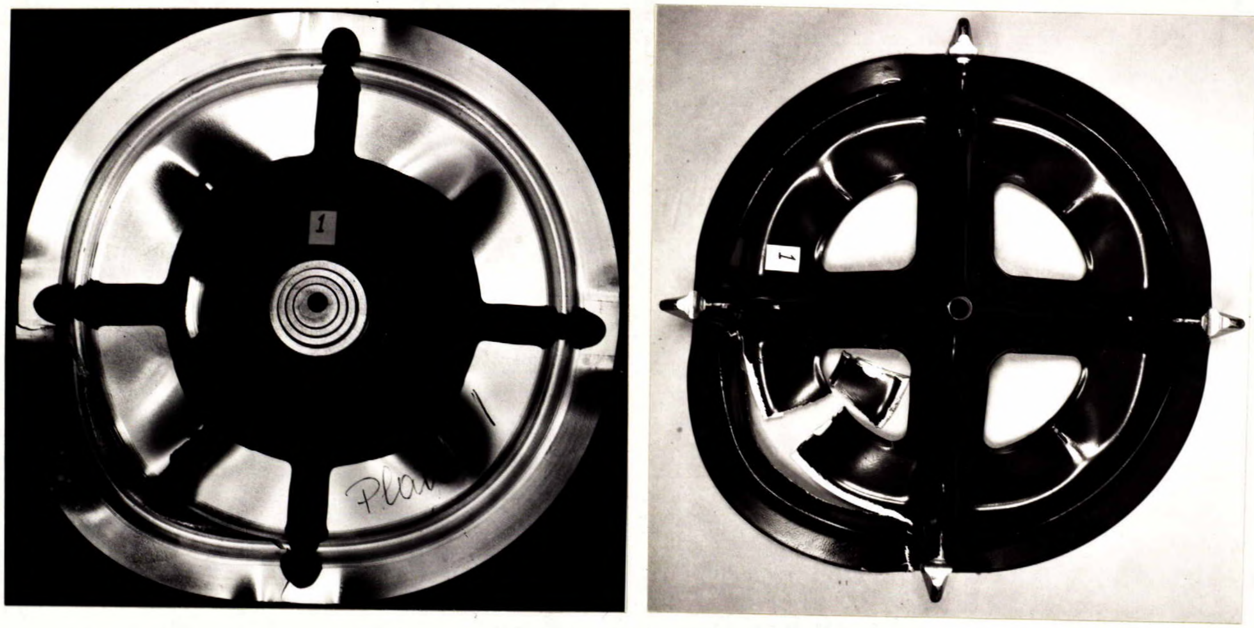

Figure 1. Fracture of plate No. 1.

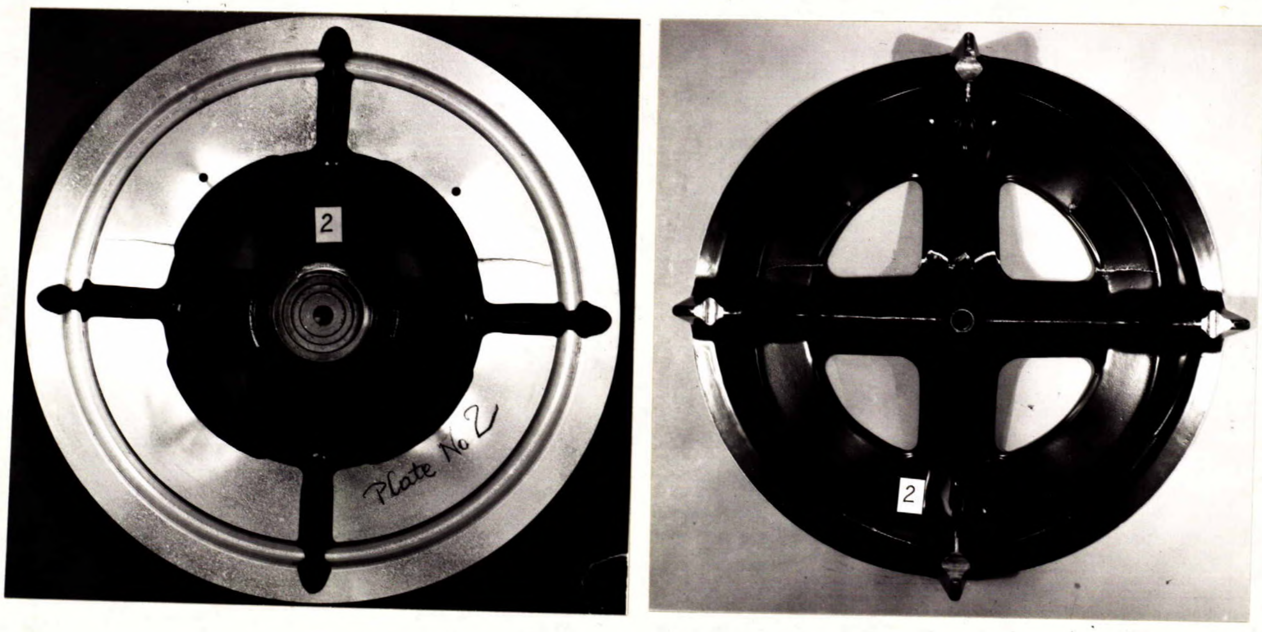

Figure 2. Typical fracture of plates No. 2 and 3.