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MACHINING TESTS ON TI-6A1-4V MATERIAL

by

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SUMMARY OF RESULTS

Samples of Ti-6Al-4V material machined readily with both high-speed-steel and carbide cutting tools. A set of cutters containing diamond particles held in a steel matrix was supplied for trial by Duomac Industries. These cutters did not cut the sample material but caused smearing of the surface and consequently generated too much heat.

It is recommended that no change be made to the spindle of the vertical-spindle grinding machine to hold the diamond cutters. If it is decided to use a head on which either h.s.s. or carbide inserted-tooth blades will be employed, then evaluation regarding cutter size and power requirements will be necessary.

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PURPOSE

At the request of Mr. Ian McCallum of Duomac Industries a series of machining tests was carried out on the above material, supplied by Duomac. At the time of Mr. McCallum's original visit to us, it was stated that his prime interest was in stock-removal investigations as opposed to finish machining. At present plates are being successfully finished by grinding; for this reason therefore, no consideration was given to obtaining any specified surface roughness, however, the roughness of the specimens has been recorded for reference purposes only. The results from these tests are shown in TABLE II.

The characteristics of the grinding machine now in use are;

Wheel Dia 54 in.	- Periphery 14.15 ft,
Max. rpm 232	- Speed 3280 ft/min,
Min. rpm 36	- Speed 480 ft/min,
Max. feed rate 12 ft/min	- 144 in./min,
Min. feed rate 0 ft/min	- 0 in./min,
Max. downfeed per pass .0048 in..	

EQUIPMENT

The samples of material tested were approximately 7 in. long x 3 in. wide x ½ in. thick and were held in a vise for machining on a vertical-spindle Cincinnati milling machine No. 315-15. To the milling machine spindle for one set of tests, was attached a holder containing a number of impregnated diamond cutters supplied by Duomac Industries. For the other two sets of tests a 6-in.-dia (1)Lovejoy Cutter No. 6GXAR8-1 employing high-speed-steel inserts and General Electric Grade 895 carbide inserts No. SPE 422 was used; The Lovejoy cutter had the following geometry: -

7°	Positive Axial Rake,
2°	Positive Radial Rake,
1°	Lead Angle,
12	Teeth.

Prior to conducting the machining tests it was necessary to cut the samples to a constant width and length and this operation was performed on a Campbell No. 342 Horizontal Abrasive Cut-off machine which has a 15-hp motor, employs cut-off wheels up to 20 in. diameter and Cincinnati Cimcool was used as a coolant. The observations from this operation are shown in TABLE I.

It was understood from the initiation of this undertaking that our means of testing would be qualitative rather than quantitative in nature.

METHOD

In order to determine which wheels on hand could best be used to cut the material a sample piece 3 inches wide, was used for cutting tests on the Campbell cut-off machine. The wheels were advanced through the work at such a speed that the maximum load carried by the wheel motor was 80% of its rated capacity, as read on a loadmeter; the time for the wheel to pass through the 3-in.-wide piece of material was then recorded. In the case of specimen G3 the wheel advance was so rapid that a loadmeter reading of only 60% could be recorded before the wheel started to run out of the work. The results of each of these cutting tests is detailed below together with wheel specifications and data.

Specimen G 1.

A heavy burr developed and discolouration of the cut surface took place.

Specimen G 2.

A smaller burr was evident on this specimen and discolouration on the cut surface was negligible.

Specimen G 3.

Very little burr was present but some discolouration of the cut face was present. There was, however, considerable wheel wear.

TABLE 1

	Wheel Manuf.	Wheel Marking	Wheel Size	Power Consumed	Cutting Time (Sec.)
G1	Norton	A46-M6R50	16 in. x 3/32 in.	80%	15
G2	Norton	37C601-N6R50	20 in. x 1/8 in.	80%	12
G3	Alison	C90 - NRW3	16 in. x 3/32 in.	60%	12

After the specimens had been cut to size they were placed in a vise on the Cincinnati 315-15 milling machine and a series of cutting tests carried out. The first series of tests was with a set of diamond-impregnated cutters supplied by Duomac Industries. The second series of tests used a

Lovejoy cutter with h.s.s. inserts and the third series of tests used the same Lovejoy cutter but with carbide inserts. A depth of cut of .002 in. was used on the tests employing the diamond, the speed used was the fastest available on this machine and gave a lineal velocity of 2600 ft/min, which would be a little over the mid-speed of the grinding machine, in use at Duomac Industries at present. The slowest feed available and another arbitrarily chosen feed were employed and loadmeter readings taken during the cut.

A series of tests using a h.s.s. cutter were then performed, the speeds being arbitrarily chosen, the feed rate being kept constant at .004 in./tooth and the depth of cut constant at .015 in..

Another series of tests using carbide inserts but with higher speeds and a feed rate of .007 in./tooth were run. These tests were all carried out using a coolant solution of Kutwell 45, and for each test the h.s.s. or carbide insert was changed so that a new cutting edge was used. During the course of each cut the amount of movement on the loadmeter was recorded; due to the coarse scale of the loadmeter and the very small movement involved the lower values shown in the table are close approximations of the meter reading. The amount of machining and the observations made on the cutter blades and samples are listed below together with a table showing the machining conditions.

Specimen D 1.

The diamond cutters when inserted into the holder were uneven in length so that only 50% were actually cutting. A small area was cut or, more properly, ground but the test was discontinued as the feed was far too low for economical usage.

Specimen D 2.

Using the same cutting conditions as for the previous sample the feed rate was increased. A noticeable increase in power was required and considerable smearing and burring of the surface was evidenced.

Specimen S 1.

No difficulty was encountered in machining; only two cuts were taken on this specimen.

Specimen S 2.

The same characteristics was shown as for specimen S 1 and duration of the test was the same.

Specimen S 3.

On this specimen several cuts were made in order to obtain a measure of cutter life. There was no noticeable breakdown in the cutter after 23 cuts.

Specimen C 1.

Ten cuts were made and, due to the high feed rate, the cut surfaces were rough.

Specimen C 2.

The conditions were the same as for specimen C 1 except that the feed and speed were increased.

Specimen C 3.

The speed was too high for effective cutting - sparking of the chips occurred and heavy wear of the carbide took place.

TABLE II

Cutter	Specimen	Speed rpm	Speed ft/min	Feedrate In./Min.	Depth of Cut In.	Loadmeter Readings %	Surface Roughness Microinch
Diamond Nibs	D 1	1325	2600	3/8	.002	5	100
Diamond Nibs	D 2	1325	2600	3 3/4	.002	20	---
H.S.S. Blades	S 1	16	25	13/16	.015	0	112
H.S.S. Blades	S 2	22	45	1 5/16	.015	0	68
H.S.S. Blades	S 3	42	66	1 7/8	.015	0	38
Carbide Blades	C 1	114	179	9	.015	5 max.	145
	C 2	136	213	11	.015	0	89
	C 3	221	347	19	.015	10	170

CONCLUSIONS

This material machines readily at the speeds and feeds specified in the literature available (2) (3). Duomac are considering the possibility of modifying the head of their grinding machine for greater stock removal. This can only be achieved by a chip-producing operation as opposed to an abrasive technique using either a segmental grinding wheel or the diamond nibs which were unsuccessful. The chip-producing operation would require a cutter that would need to be scaled up from the one used in the test, but it is unknown

what the horsepower consumption of such a cutter would be. The size of the cutter would be limited by the cutting speed and would need to be something less than the 54-in. wheel diameter when using the slowest spindle speed. As the machine in question has no means of cross-feed this cannot be considered. It is therefore recommended that, under the existing conditions, the spindle of the grinding machine not be modified at all.

REFERENCES

(1) Lovejoy Tool Co.Inc., Springfield, Vermont.
(2) Vol.3, ASM Handbook "Machining" - Machining of Titanium Alloys.
(3) D.M.I.C. Memorandum 191, 2 February 1965.