NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

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COMPARISON OF STATIC STRENGTHS OF MACHINE COUNTERSUNK RIVETED JOINTS IN 24S-T, X75S-T, AND ALCLAD 75S-T SHEET

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Washington
May 1946

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INTRODUCTION

Flush–riveted joints are often prepared by machining a conical recess in the sheet or plate into which the countersunk head of the rivet is fitted. When this machined recess goes completely or nearly through the thickness of the sheet, there is a knifelike cutting edge on the sheet bearing against the shank of the rivet which tends to reduce the effective shear strength of the rivet. This cutting action seems to become more pronounced when using the "harder" sheet alloys and when using the "softer" rivets. In order to obtain some definite information on this subject, static tests were made as outlined herein on machine–countersunk riveted joints in 24S–T, X75S–T, and Alclad 75S–T sheet using A17S–T and 24S–T rivets. In order to intensify the cutting action, all specimens were made with the depth of countersink just equal to the thickness of the sheet.

It has been noted that the results of the tests in reference 1 show similar weakening of the riveted joints when the depth of the countersink is just equal to the thickness of the sheet and that the shear strengths in reference 1 check those reported here in the few cases that can be directly compared.

OBJECT

The object of this investigation was to compare the static strengths of machine-countersunk riveted joints in 24S-T, X75S-T, and Alclad 75S-T sheet using A17S-T and 24S-T rivets in order to evaluate the differences in cutting action of the sharp edge of the sheet when the machine-countersunk hole was the same depth as the thickness of the sheet.

SPECIMENS AND PROCEDURE

The type of specimen used in this investigation is illustrated in figure 1. It will be noted that two sizes of rivets were used, 1/8 and 3/16 inch, and that the corresponding thicknesses of sheet were nominally 0.040 and 0.064 inch. Special care was taken in the shop to ensure a feather edge at the bottom of all machine-countersunk holes used in this investigation.

The 24S-T rivets were driven in the freshly quenched condition; that is, they were heat treated, quenched, and stored in ice water until ready for driving. All 24S-T driven rivets were aged 4 days at room temperature before testing. The A17S-T rivets were driven in the fully room-temperature-aged condition without subsequent reheat treatment.

All rivets were upset by the squeeze method using a flat driven head having a diameter approximately $1\frac{1}{2}$ times the nominal shank diameter. The fact that the depth of countersink in this investigation was slightly less than the depth of the manufactured head of the rivets is not considered of any importance in interpretation of the test results. The depth of countersink was selected, as already explained, to give the maximum sharpness at the bottom of the countersink and not to give a high degree of flushness in the finished joint.

The joints in this investigation were tested in a 40,000-pound capacity Amsler hydraulic testing machine (Type 20 ZBDA serial no. 4318) using wedge grips of suitable width to accommodate the specimens. As will be noted in the tabulation of results, five to six specimens of each type were tested to establish average values for making the final comparison.

DISCUSSION OF RESULTS

The results of this investigation are shown in detail in table I and in summarized form in table II. It is evident from a comparison of the results for the machine-countersunk joints with typical results from previous tests of protruding-head rivets (not countersunk) that the countersunk rivets are weaker by varying amounts ranging from 23 percent to 39 percent. It is further evident that the cutting action of the machine-countersunk sheet is more pronounced for the harder sheets than for the softer sheets since in the case of both rivet materials the reductions in strength are greater when the rivets are driven in X75S-T sheet (39 and 37 percent) than when the rivets are driven in 24S-T sheet (25 and 34 percent). On comparing the Alclad 75S-T sheet with the X75S-T sheet, it will be seen that the reduction in strength of the A17S-T rivets is much more pronounced when no cladding is present (39 compared to 23 percent). Comparing the percent reductions in strength caused by machine-countersunk sheet on A17S-T rivets with those on 24S-T rivets, no clear superiority is evident for either rivet. It may be significant, however, that the spread in strengths between countersunk rivets driven in 24S-T and in X75S-T sheet is greater in the case of A17S-T rivets than in the case of 24S-T rivets.

It should be remembered that the depth of countersink used in this investigation was deliberately selected to give the maximum cutting action of the sheet on the rivets and consequently the maximum reduction in effective shear strength on the rivets. Previous tests at Aluminum Research Laboratories have indicated that the detrimental action of a countersunk sheet against a rivet is reduced by leaving a small margin between the depth of the countersink and the thickness of the sheet. In the case of 1/8-inch 17S-T 100° head rivets driven in 0.040-inch Alclad 24S-T sheet, the static strength was only 29,200 psi when the machine countersink was full depth of the sheet but increased to 31,000 psi when the countersink was three-fourths of the depth of the sheet. Undoubtedly, an even greater difference would have been found had nonclad sheet been used. Fortunately, in most instances it is unnecessary in practice to countersink completely through the thickness of the sheet, and hence the drastic reductions in shear strength discussed in the preceding paragraph can be avoided. Nevertheless, the trends indicated by this investigation are present to some degree in many machine-countersunk joints and are therefore worthy of some study.

CONCLUSIONS

The following conclusions are based on the data from static tests of machine-countersunk riveted joints in 24S-T, X75S-T, and Alclad 75S-T sheet using A17S-T and 24S-T rivets with the depth of countersink just equal to the thickness of the sheet:

1. The ultimate shear strength of aluminum alloy rivets in machine-countersunk joints is markedly less (23 to 39 percent in this investigation) than the average ultimate shear strengths of protruding-head rivets (not countersunk) of the same alloys, as is indicated by the data in table II. This reduction in shear strength is probably attributable primarily to the cutting action of the edge of the machine-countersunk hole.

2. The reduction in ultimate shear strength caused by the cutting action of the edge of the countersunk hole is greater in the case of hard sheet such as X75S-T than in the case of a softer sheet such as 24S-T.

3. The reduction in ultimate shear strength caused by the cutting action of the edge of the countersunk hole is greater in the case of nonclad sheet (X75S-T) than in the case of alclad sheet (Alclad 75S-T).

4. The percent reduction in ultimate shear strength of A17S-T rivets caused by the cutting action of the edge of the countersunk hole is not consistently greater than that of the harder 24S-T rivets. The comparison seems to be influenced by the sheet in which the rivets are driven.

Aluminum Research Laboratories,
Aluminum Company of America,
New Kensington, Pa., July 12, 1945.

REFERENCE

1. Gottlieb, Robert.: Effect of Countersunk Depth on the Tightness of Two Types of Machine-Countersunk Rivet. NACA RB, Oct. 1942.

TABLE I

INDIVIDUAL TEST RESULTS OF MACHINE-COUNTERSUNK JOINTS

[See fig. 1 for type of specimen]

Rivet Alloy	Rivet diameter (in.)	Sheet alloy	Sheet thickness (in.)	Ultimate load per rivet (lb)	Shear strength[1] (psi)
24S-T	3/16	24S-T	0.064	830	
				755	
				820	
				846	
				798	
				Av 810	28,300
24S-T	3/16	X75S-T	.064	796	
				769	
				804	
				771	
				732	
				Av 774	27,000
A17S-T	1/8	24S-T	.040	310	
				336	
				325	
				321	
				312	
				Av 321	24,800
A17S-T	1/8	X75S-T	.040	255	
				255	
				262	
				258	
				258	
				280	
				Av 261	20,200
A17S-T	1/8	Alclad 75S-T	.040	318	
				341	
				333	
				326	
				332	
				Av 330	25,500

[1]Based on area of hole.

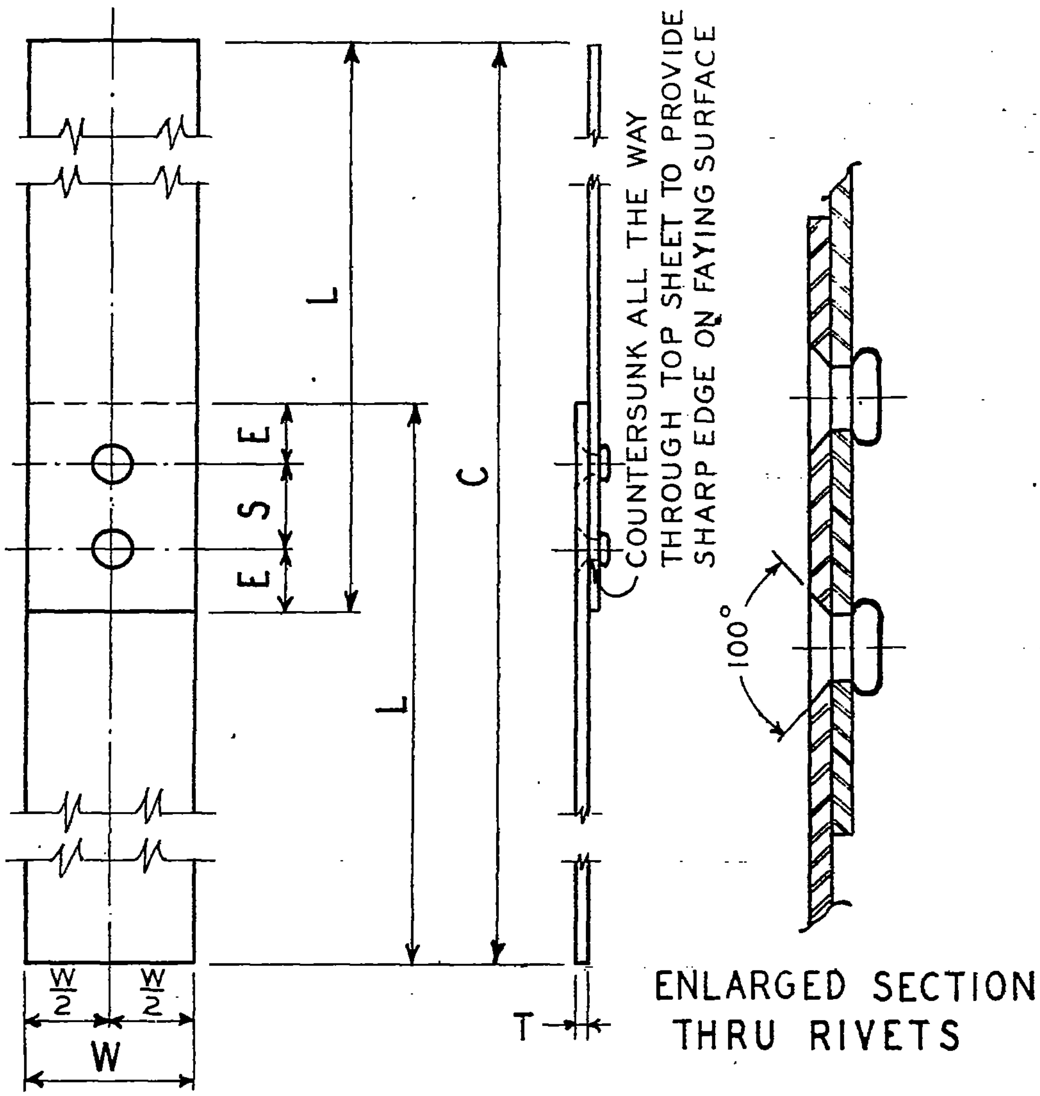
All failures occurred as shear of the rivets.

TABLE II.- COMPARATIVE STATIC ULTIMATE SHEAR STRENGTHS OF A17S-T AND 24S-T RIVETS IN MACHINE-COUNTERSUNK AND NONCOUNTERSUNK JOINTS

[All countersunk rivets referred to below have 100° manufactured heads and are driven in countersunk holes having a depth just equal to the thickness of the sheet. (See table I for detailed test results.)]

Description of joint	Average shear strength of driven rivets based on area of hole, (psi)		Reduction in shear strength of countersunk rivets compared to protruding-head rivets (percent)	
	A17S-T rivets	24S-T rivets	A17S-T rivets	24S-T rivets
Protruding-head rivets[1]	33,000	43,000	-	-
Machine countersunk in 24S-T sheet	24,800	28,300	25	34
Machine countersunk in X75S-T sheet	20,200	27,000	39	37
Machine countersunk in Alclad 75S-T sheet	25,500	----	23	-

[1]Average values from miscellaneous tests of protruding-head rivets at Aluminum Research Laboratories.



NOMINAL RIVET DIA., IN.	HOLE SIZE		DIMENSIONS, IN.					
	DRILL NO.	DIA. IN.	T	W	L	C	S	E
1/8	30	0.1285	0.040	31/32	6 5/8	12	1/2	3/8
3/16	11	0.191	0.064	1 1/2	7	12 1/4	3/4	1/2

FIGURE 1.- SPECIMENS FOR STATIC SHEAR TEST OF 100° RIVETS IN MACHINE COUNTERSUNK HOLES.