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TECHNICAL NOTE

No. 1119

INCREASING THE COMPRESSIVE STRENGTH OF 24S-T ALUMINUM-ALLOY SHEET BY FLEXURE ROLLING

By George J. Heimerl and Walter Woods

Langley Memorial Aeronautical Laboratory
Langley Field, Va.

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INCREASING THE COMPRESSIVE STRENGTH OF 24S-T ALUMINUM-ALLOY SHEET BY FLEXURE ROLLING

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SUMMARY

A method of increasing the compressive strength of 24S-T aluminum-alloy sheet by flexure rolling was investigated. In this method, the sheet was alternately bent and then straightened by rolling in a four-step procedure. The results showed that the greatest increase was in compressive yield stress in the with-grain direction regardless of the direction of rolling; the increase was greater as the radius of flexure rolling became smaller and as the number of steps was increased. The tensile properties, however, were little affected.

INTRODUCTION

The compressive strength of some aluminum alloys may be appreciably increased by compressing the material in the direction in which the increase in strength is desired. (See references 1 and 2.) In the case of sheet material, such a procedure has not been found practicable and other methods of cold working must be employed if the strength is to be increased. One such method which raises both the compressive and tensile yield stress is that employed in the production of 24S-RT aluminum-alloy sheet. In this method, 24S aluminum-alloy sheet is solution heat treated, cold rolled to about a 5.5-percent reduction in thickness, and aged at room temperature. (See reference 3.)

A recent investigation of the effect of brake forming on the strength of 24S-T aluminum-alloy sheet showed that a large increase in compressive strength was obtained in the curved corners of formed Z-sections. (See reference 4.)

This large increase suggested the possibility of another method of raising the compressive strength of flat sheet material by a flexure-rolling procedure which would alternately bend and then straighten out the sheet. Accordingly, in order to study the effect of this type of cold working, 24S-T aluminum-alloy sheet was flexure rolled in a four-step procedure. The effect of rolling in each grain direction was investigated; after each step in rolling, the tensile and compressive properties of the sheet were determined.

SPECIMENS AND METHODS OF TESTING

Pieces of 0.102-inch-thick 24S-T aluminum alloy, cut from the same sheet, were flexure rolled in the directions shown in figure 1 to radius thickness ratios r/t of 240, 180, 120, and 60. In the four successive steps in rolling (fig. 2), the original flat sheet was first bent in one direction, straightened, bent in the opposite direction, and then straightened again. In addition, some pieces were rolled (step 1 only) to r/t ratios of 30, 20, and 10. For steps 2 and 4 in which the sheet was flat, the tensile and compressive properties were obtained for both directions of grain of the material; for steps 1 and 3 in which the sheet was curved, only the properties in the straight direction were determined.

The tensile specimens were of standard size (reference 5) and were tested with flat grips regardless of whether the cross section was flat or curved, since the greatest cross-sectional curvature was very small. In each case, however, failure occurred in the reduced section near the middle of the specimen.

The compression specimens were 0.80 inches wide and 2.51 inches long and were tested in a special compression fixture (fig. 3) designed to support single-thickness specimens which can either be flat or have cross-sectional curvature.

Tuckerman optical strain gages were used to measure the strain for both the tension and the compression tests.

RESULTS AND DISCUSSION

The effect of flexure rolling for rollers cross grain (see fig. 1) on the tensile and compressive properties of 0.102-inch-thick 24S-T aluminum-alloy sheet is shown in figure 4 for each of the four steps in rolling and for radius thickness ratios r/t of 240, 180, 120, and 60. The significant result for rollers cross grain is that the compressive yield stress in the with-grain direction is appreciably increased over that for the original flat sheet, particularly as the radius becomes small, about 11 percent for $r/t = 60$ as compared with about $4\frac{1}{2}$ percent for $r/t = 240$. A comparison of the increase in compressive yield stress in the with-grain direction obtained in step 4 with that for step 2 shows that the increase is greater if four steps instead of only two are used in rolling. The tensile yield stresses were also slightly increased, but the tensile ultimate stresses and elongation in 2 inches were reduced somewhat. The individual results shown are in each case average values obtained from two tests.

The effect of flexure rolling for rollers with grain (see fig. 1) on the tensile and compressive properties is similarly shown in figure 5 for each of the four steps in rolling. For rollers with grain (fig. 5) the compressive yield stress in the with-grain direction was appreciably increased, especially for the smallest radius ($r/t = 60$), as was the case in the with-grain direction for rollers cross grain (fig. 4). Generally, the tensile yield stresses were slightly increased, and the tensile ultimate stresses and elongation in 2 inches were slightly reduced.

Figures 4 and 5 show that, regardless of the direction of rolling, it is possible to raise the compressive yield stress in the with-grain direction of 24S-T aluminum-alloy sheet by a flexure-rolling procedure without at the same time adversely affecting the tensile properties. The compressive yield stress in the cross-grain direction, initially greater than that for the with-grain direction (see fig. 6), is also increased regardless of the direction of rolling although to a lesser degree than for the with-grain direction. (See figs. 4 and 5.) The compressive strength of the sheet is therefore generally improved by this flexure-rolling procedure.

The compressive and tensile stress-strain curves, presented in figure 6 for rolling to an r/t ratio of 60, are markedly changed in shape as a result of the four-step flexure rolling procedure.

The effect of the first step in rolling on the compressive stress-strain curves is shown in figure 7 for small r/t ratios of 30, 20, and 10. A large increase in compressive yield stress of the rolled sheet over the flat sheet is indicated for the with-grain direction.

CONCLUSIONS

As a result of a four-step flexure-rolling procedure in which the sheet is bent in one direction, straightened, bent in the opposite direction, and then straightened again, the compressive yield stress of 24S-T aluminum-alloy sheet is increased in both the with-grain and the cross-grain directions. The increase is greater for the with-grain compressive yield stress, is larger as the radius of flexure rolling becomes smaller and as the number of steps is increased, and is independent of the direction in which the sheet is rolled. The tensile properties, however, are little affected.

Langley Memorial Aeronautical Laboratory
National Advisory Committee for Aeronautics
Langley Field, Va., May 3, 1946

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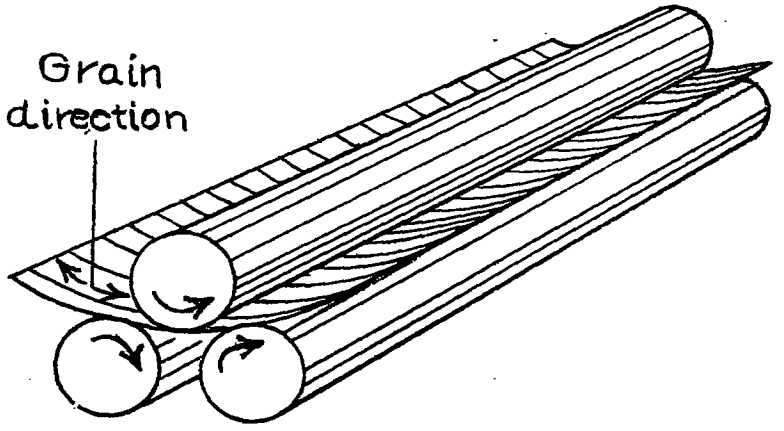
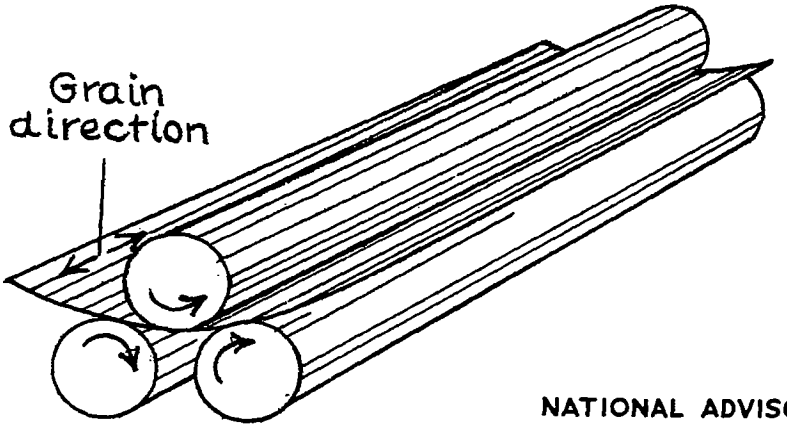


Rollers cross grain



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Rollers with grain

Figure 1.– Directions of rolling.

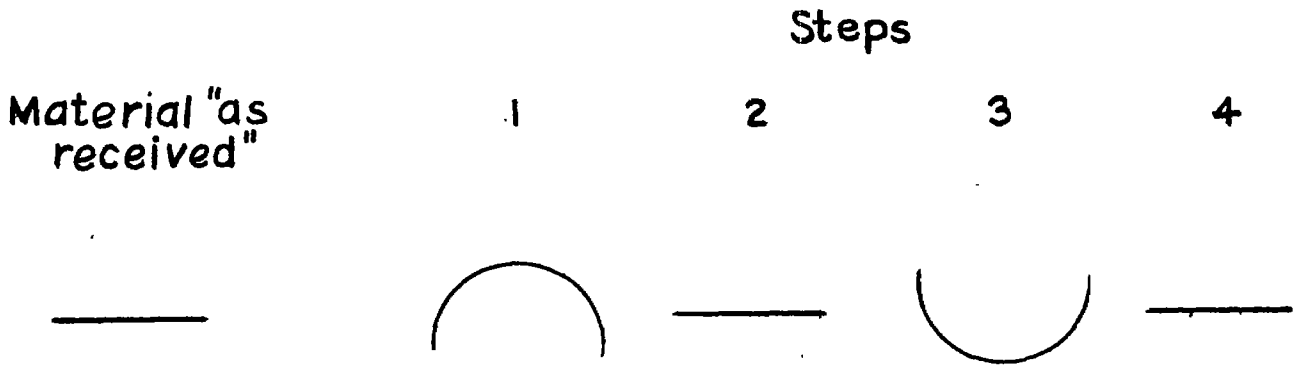

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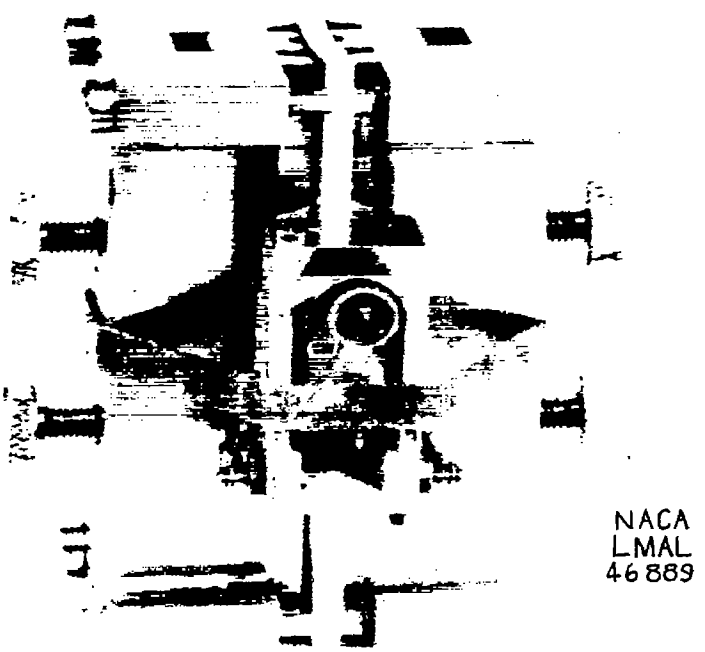
Figure 2.- Steps in rolling.

(a) Unassembled.



(b) Assembled.

Figure 3.- Compression fixture used to support flat or curved single-thickness compression specimens.

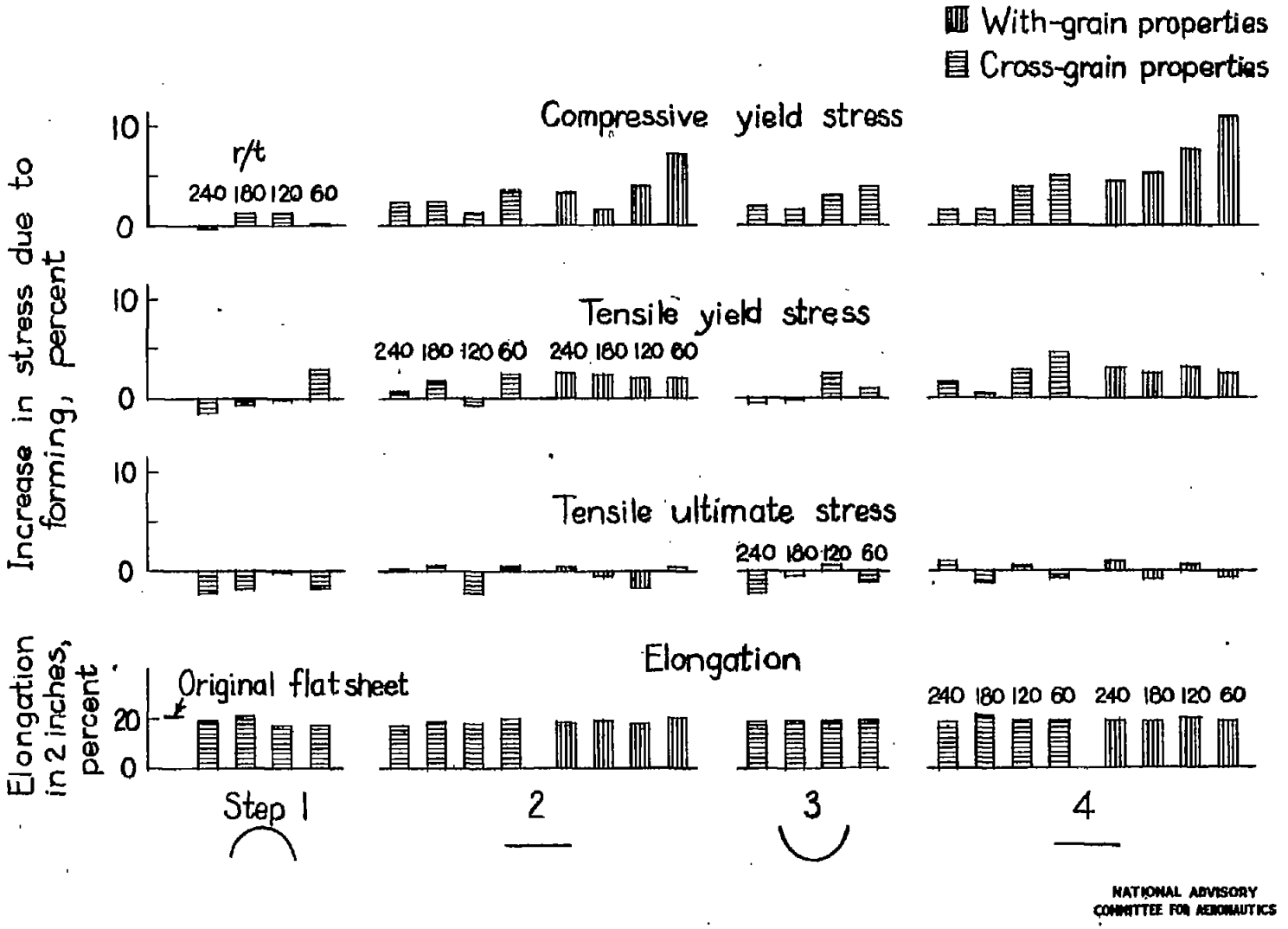


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Figure 4.- Effect of flexure rolling for rollers cross grain on the tensile and compressive properties of 0.102-inch-thick 24S-T aluminum-alloy sheet.

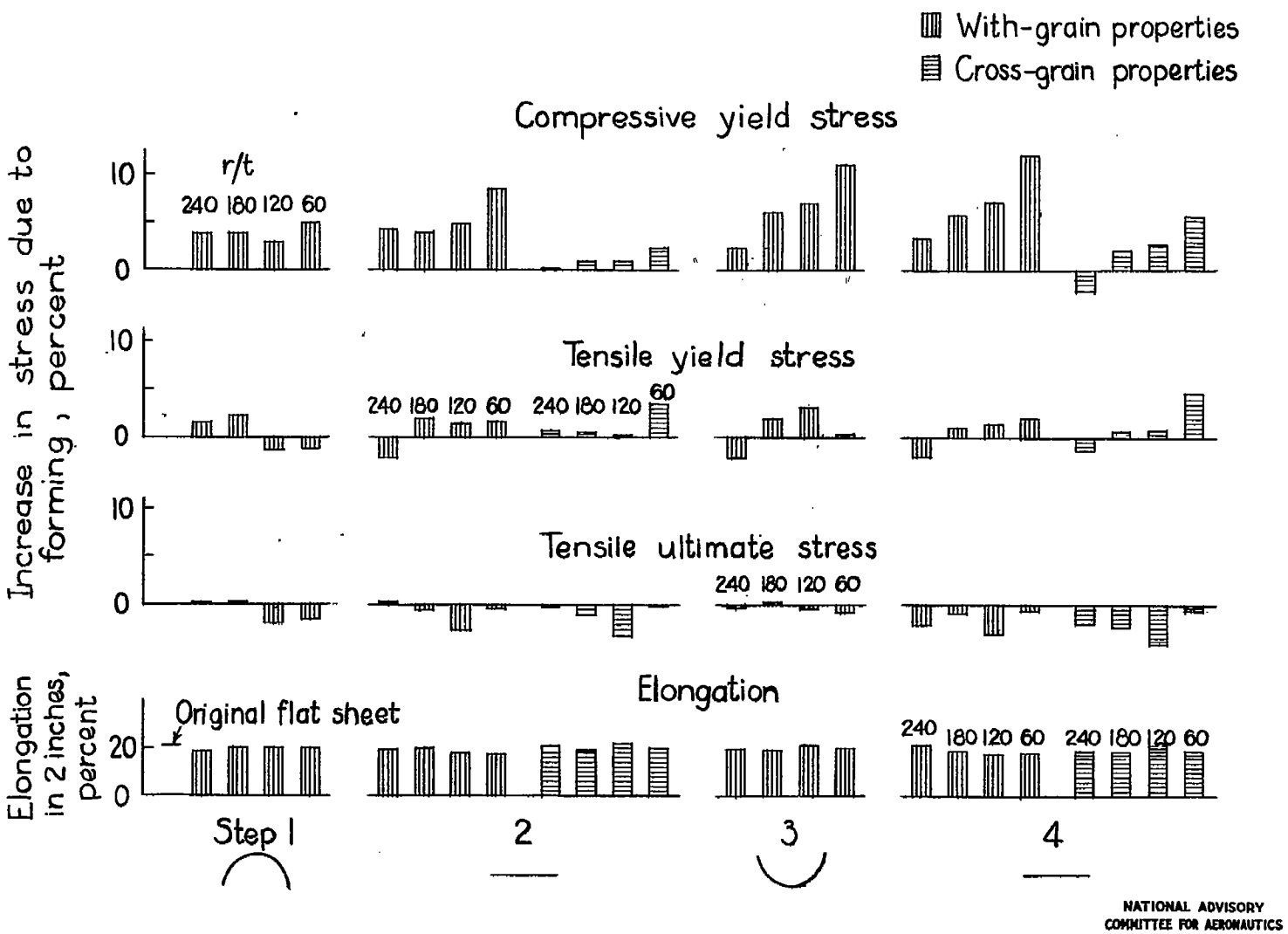
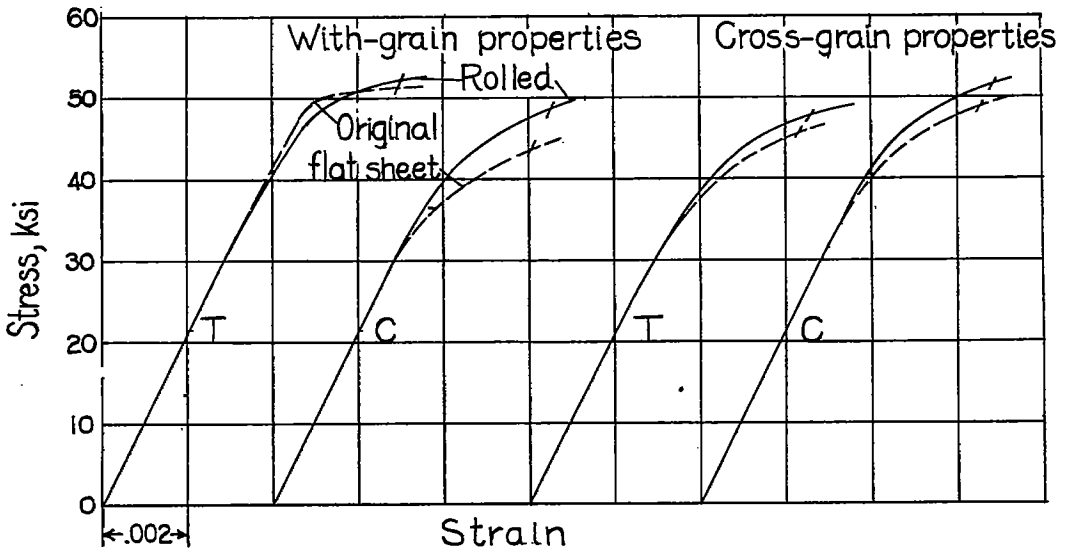
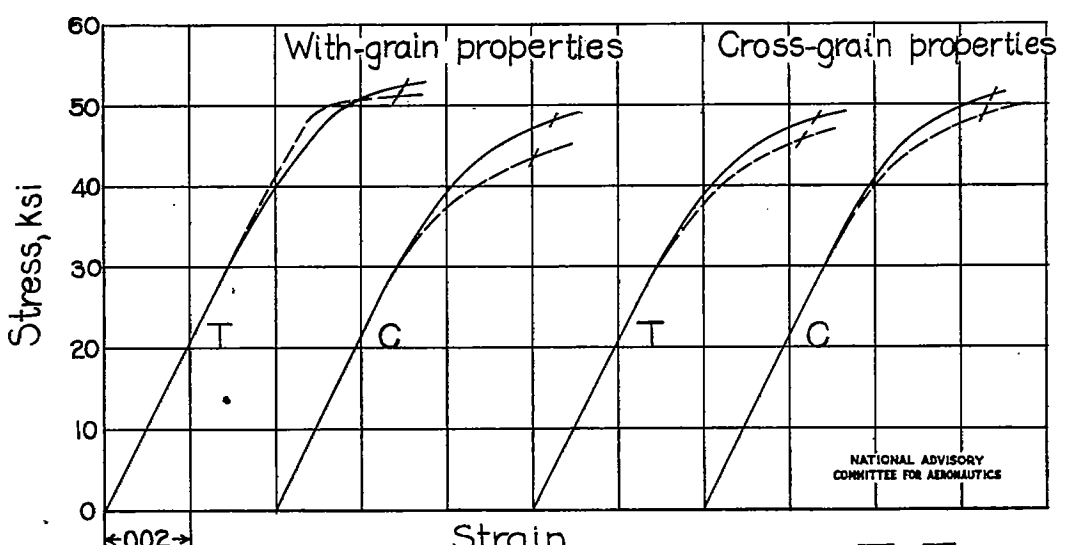


Figure 5.–Effect of flexure rolling for rollers with grain on the tensile and compressive properties of 0.102-inch-thick 24S-T aluminum-alloy sheet.



(a) Rollers with grain.



(b) Rollers cross grain.

T Tension
C Compression
— — Original flat sheet
—— Rolled sheet

Figure 6.—Effect of four-step flexure rolling to an r/t ratio of 60 on the tensile and compressive stress-strain curves for 0.102-inch-thick 24S-T aluminum-alloy sheet. (Sheet is flat in fourth step.)

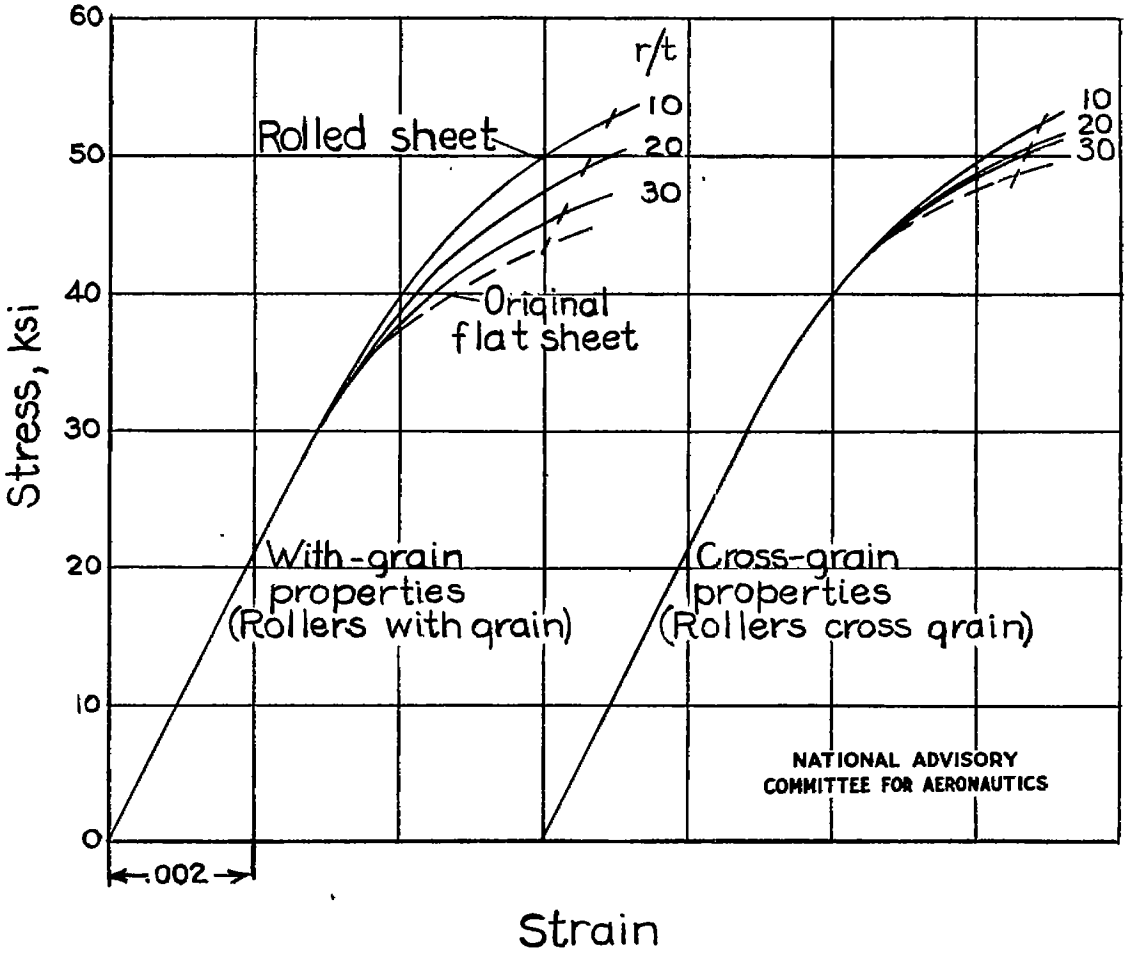


Figure 7.- Effect of one-step flexure rolling to r/t ratios of 10, 20, and 30 on the compressive stress-strain curves for 0.102-inch-thick 24S-T aluminum-alloy sheet.