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[54] **PROCESSES FOR THE FABRICATION OF 7000 SERIES ALUMINUM ALLOYS**

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[58] **Field of Search** ..... 148/11.5 A, 12.7

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[57] **ABSTRACT**

Improved 7075 aluminum alloy sheet or plate having a very fine grain structure, and fabricated by processes suitable for use with both wrought or as-cast ingot material, the processes including an intermediate thermal mechanical treatment wherein the ingot, for example, is prehomogenized at a relatively high temperature to precipitate out the chromium and then annealed to precipitate zinc, magnesium and copper out of solution as coarse compounds, the prehomogenization and annealing steps rendering the ingot amenable to one or more subsequent deformation-recrystallization steps to provide additional grain structure refinement.

17 Claims, No Drawings

PROCESSES FOR THE FABRICATION OF 7000 SERIES ALUMINUM ALLOYS

The invention described herein may be manufactured, used, and licensed by or for the Government for governmental purposes without the payment to us of any royalty thereon.

This invention relates to aluminum alloys and more particularly concerns intermediate thermal mechanical treatment for 7,000 series aluminum alloys to provide a fine grained alloy having improved mechanical properties.

Major shortcomings of commercial high strength wrought 7,000 series aluminum alloys have been characterized by low ductility, low toughness and poor stress corrosion resistance, especially in the short transverse direction. Elimination of second phase constituents induced substantial improvements in ductility, toughness and fatigue resistance at equivalent strength levels. These improvements were attributable to the use of high purity materials, controlled solidification techniques to achieve a small dendrite arm spacing, and optimum homogenization techniques.

A recently developed technique, termed intermediate thermal mechanical treatment (ITMT) by Istituto Sperimentale dei Metalli Leggeri (ISML) (Italy) produces a wrought product having finer grains and substantially improved properties than those obtained by conventional processing. The intermediate thermal mechanical treatment involves a new concept of ingot processing, i.e., the original cast grain boundaries are eliminated by a recrystallization step prior to conventionally working the material into the final wrought product. This intermediate thermal mechanical treatment process involves partially homogenizing the ingots, working at relatively low temperatures, recrystallizing, homogenizing, and then conventionally hot working into wrought products. The limited success of this process is predicated upon rendering the chromium in the alloy ineffective in retarding recrystallization of the worked ingot into a fine grained structure. This is accomplished by maintaining most of the chromium in supersaturated solid solution in the aluminum-rich matrix during both the partial homogenization and low temperature deformation stages. Subsequent recrystallization and homogenization produces a fine grain structure followed by precipitation of the remaining chromium. This fine grain structure is not produced during conventional processing because the chromium precipitates during the initial thermal treatment prior to working. The occurrence of dynamic recovery during the working operation also hinders recrystallization into a fine grain structure.

The aforedescribed ISML process is unsatisfactory because ingot material is always required as the starting material, the ingots being inherently brittle. Ingots are required because the anti-recrystallization element (chromium) must be in solution in the aluminum matrix prior to deformation and recrystallization, and ingots are the only available product from suppliers which have the chromium in solution in aluminum. Further, in the ISML process aforedescribed, once the chromium is precipitated out of solution by the recrystallization step, it cannot be redissolved by subsequent thermal treatment and thus limits the deformation-recrystallization sequence to a single occurrence. Such limitation is unfortunate since a series of deformation-recrystallization steps could lead to further grain refinement and hence, further improvements in properties.

Currently, there is a need for wrought aluminum alloys having high strength and high toughness for use in critical Army applications such as cartridge cases, rocket motor cases, components of artillery ammunition, structural aircraft parts, and the like.

It is therefore an object of this invention to provide such alloys for use in such critical United States Army and other military applications.

Another object of the invention is to provide a commercially desirable process for producing good 7,000 series aluminum alloys from either conventionally processed or as-cast ingot alloys.

Still another object of the invention is to provide such alloys wherein the process for their fabrication is not dependent upon maintaining chromium in the conventionally processed or as-cast ingot alloy in a supersaturated solid solution in the aluminum matrix, thus permitting a multiplicity of recrystallization steps to yield good grain refinement.

Other and further objects of the invention will become apparent as the invention is further described hereinafter.

In accordance with the above objects, we have discovered that the anti-recrystallization effect of chromium, when present as a precipitate, may be overcome in 7075 ingots by proper control of the distribution of the major alloying elements, i.e., zinc, magnesium, and copper, prior to the low temperature deformation and recrystallization of the ingot.

More specifically, we have discovered that, in the presence of the chromium-containing phase, if the zinc, magnesium and copper are present as coarse precipitates prior to deformation of the ingot, fine grain 7075 sheet and plate will be produced having properties and grain sizes equivalent to those produced by the ISML process and superior to those obtained in conventionally processed materials. Thus, our invention relates to an intermediate thermal mechanical treatment wherein the ingot is prehomogenized at a relatively high temperature, i.e., 860°F, when 7075 alloy is used. The chromium will be precipitated out as the E phase ($Al_{18}Cr_2Mg_3$) and the interdendritic networks of Zn–, Mg–, and Cu– bearing compounds will be dissolved. The ingot is then slowly cooled to 775°F in about 3 hours and then subjected to the standard O anneal (3–5 hours at 775°F, slowly cooled to 450°–500°F, and held 4 hours in that temperature range). This treatment precipitates substantially all the zinc, magnesium, and copper out of solution as coarse compounds. The ingot will then be deformed at a low temperature of about 400°–500°F, rapidly recrystallized and homogenized. The wrought product so formed may be utilized in this form (as-recrystallized condition) or may be processed further by subjecting it to plastic deformation by conventional mill practice (as-recrystallized and hot rolled condition). In either condition, the material is then heat treated to the desired temper. Although our intermediate thermal mechanically treated 7075 sheet and the prior art intermediate thermal mechanically treated 7075 sheet have generally equivalent grain sizes and properties compared to conventionally processed sheet, our process is considerably more commercially feasible and desirable because:

a. The ITMT process developed by ISML is unsatisfactory because this procedure requires the starting material to be ingot material which is inherently brittle. In the ISML-ITMT process the anti-recrystallizing element, Cr, must be in solution in the aluminum matrix prior to deformation and recrystallization and ingots are the only products available from suppliers which have the Cr in solution in Al.

b. Chromium need not be maintained in the supersaturated solution in the aluminum matrix. Thus, in contrast to the prior art ISML process which can only employ the recrystallization step once, our process permits the utilization of the recrystallization step many times to give rise to the possibility of further grain refinement.

c. Our process or method may readily be applied to conventionally processed wrought products. For example, conventionally processed 7075-T6 plate, 2 inches thick, was processed in accordance with our invention to produce a sheet 0.063 inches in thickness. In the T6 temper (1 hr/900°F, cold water quench, 5 days natural age, 24 hrs/250°F), our sheet made in accordance with our inventive process steps had equivalent strength, finer grain size, and significantly better ductility and toughness than conventionally processed 7075-T6 sheet, the toughness essentially equivalent to that of 2024-T351 aluminum alloy but with significantly higher yield and tensile strengths.

In further clarification of our invention, billets, 1½ inches thick by 2½ inches wide by 4½ inches long, were sectioned from a 500 pound, 6 inches thick by 16 inches wide by 56 inches long, direct chilled ingot of 7075 alloy which had been stress relieved at 650°F for 12 to 14 hours. The ingot contained the following weight percentages of elements: 5.50 Zn, 2.50 Mg, 1.57 Cu, 0.20 Cr, 0.01 Ti, 0.01 Si, 0.00 Fe and remainder Al. Metallographic examination revealed that the dendrite arm spacing of the ingot ranged from 30 to 50 microns. Rolling was used as the means of deformation. All heat treatments were carried out in a salt bath, except for aging to the T6 temper which was done in an electric circulating air furnace. Ingot thermal mechanical processing treatments on 7075-T6 sheet, 0.160 inch thick, were:

Treatment A. The billet was homogenized 7 hrs./860°F + 17 hrs./900°F, furnace cooled to 800°F, reduced in thickness 89.5 percent by rolling at 800°F and air cooled to room temperature. Intermediate reheats of 15 min/800°F were used after reductions in thickness of 47.5 percent and 54.5 percent, respectively. Treatment A represents the conventional thermal mechanical treatment (CTMT).

Treatment B. The billet was soaked 1 hr/625°F, reduced in thickness 70.5 percent by rolling at 625°F without any intermediate reheats, air cooled to room temperature, recrystallized by rapidly heating to 860°F, homogenized 7 hrs/860°F + 17 hrs/900°F, furnace cooled to 800°F, reduced in thickness 64 percent by rolling at 800°F (total reduction 89.5 percent), and air cooled to room temperature. An intermediate reheat of 10 min/800°F was used in the latter rolling after a reduction in thickness of 32 percent. Treatment B represents the intermediate thermal mechanical treatment (ITMT) developed by ISML.

Treatment C_1. The billet was homogenized 7 hrs/860°F + 17 hrs/900°F, quenched in cold water, soaked for 1 hr/625°F, reduced in thickness 70.5 percent by rolling at 625°F without any intermediate reheats, air cooled to room temperature, homogenized 7 hrs/860°F + 17 hrs/900°F, furnace cooled to 800°F, reduced in thickness 64 percent by rolling at 800°F (total reduction 89.5 percent), and air cooled to room temperature. An intermediate reheat of 10 min/800°F was used in the latter rolling operation after a reduction in thickness of 32 percent.

Treatment C_2. Same as C_1 except that the second homogenization treatment was for 1 hr/900°F.

Treatment C_1 and C_2 verifies the theory of ISML, i.e., if Cr is out of solution during processing, recrystallization will not occur. The principal difference between Treatments B (ITMT) and C is that the material is initially given a long time homogenization in Treatment C in order to precipitate the Cr out of solution. It may be concluded that the distribution of the Cr is the major factor in determining whether or not recrystallization will occur in the processing of ingots of 7075 alloy. However, whether the Cr is in solid solution or present as precipitates is not the entire solution in obtaining recrystallization in strain hardened 7075. The distribution of the major alloying elements (Zn, Mg and Cu) must also be taken into consideration. Thus, Treatments D_1, D_2, E_1 and E_2 were carried out wherein the Cr was out of solution as was the Zn, Mg and Cu. Even though the Cr is out of solution, it is possible to obtain fine equiaxed recrystallized grains which can then be processed by conventional means into fine pancake shaped grains. It should be noted that Treatment E could easily be adopted as a commercial practice since rolling was done at an elevated temperature rather than at room temperature.

Treatment D_1. The billet was homogenized 7 hrs/860°F + 17 hrs/900°F, furnace cooled to 775°F, soaked 5 hrs/775°F, furnace cooled to 500°F, air cooled to room temperature, reduced in thickness 70.5 percent by rolling at room temperature, recrystallized by rapid heating to 860°F, homogenized 7 hrs/860°F + 17 hrs/900°F, furnace cooled to 800°F, reduced in thickness 64 percent by rolling at 800°F (total cumulative reduction 89.5 percent), and air cooled to room temperature. An intermediate reheat of 10 min/800°F was used in the latter rolling operation after a reduction in thickness of 32 percent.

Treatment D_2. Same as D_1 except that the recrystallization temperature was 900°F and that the second homogenization treatment was for 1 hr/900°F.

Treatment E_1. The billet was homogenized 7 hrs/860°F + 17 hrs/900°F, furnace cooled to 775°F, soaked 5 hrs/775°F, furnace cooled to 500°F, reduced in thickness 70.5 percent by rolling at 500°F without any intermediate reheats, recrystallized by rapid heating to 860°F, homogenized 7 hrs/860°F + 17 hrs/900°F, furnace cooled to 800°F, reduced in thickness 64 percent by rolling at 800°F (total reduction 89.5 percent), and air cooled to room temperature. An intermediate reheat of 10 min/800°F was used in the latter rolling operation after a reduction in thickness of 32 percent.

Treatment E_2. Same as E_1 except that the recrystallization temperature was 900°F and that the second homogenization treatment was for 1 hr/900°F.

The distribution of the Zn, Mg and Cu has an important effect on the recrystallization behavior of 7075. A study of Table I will indicate that the Zn, Mg and Cu does play an important part in recrystallization, possi-

bly even more so than the presence of Cr.

TABLE I

Effect of Zn, Mg and Cu and Cr Distribution on Recrystallization

Treatment	Zn, Mg and Cu Distribution	Cr Distribution	Recrystallization
B	Out of Solution	In Solution	Yes*
C_1 and C_2	In Solution	Out of Solution	No
D_1 and D_2	Out of Solution	Out of Solution	Yes**
E_1 and E_2	Out of Solution	Out of Solution	Yes**

* Only a single recrystallization possible
** Multiple recrystallizations possible

In Table II below, the effect of various ingot thermal mechanical treatments with respect to the mechanical properties of high purity homogeneous 7075-76 sheet of 0.16 inch thickness is presented:

TABLE II

Effect of Various Ingot Thermal Mechanical Treatments on the Mechanical Properties of High Purity Homogeneous 7075-T6 0.16" Thick Sheet

Thermal Mechanical Treatment	U.T.S. Ksi	Y.S. (.2% Offset) Ksi	E in 0.45" %	R.A. %
A	83.3	69.8	12.8	31.1
B	84.0	71.0	14.6	44.5
C_1	82.9	70.7	14.6	38.3
C_2	84.3	71.4	12.8	29.8
D_1	81.2	69.0	14.8	42.1
D_2	83.2	69.2	16.2	44.0
E_1	84.1	71.8	14.9	42.6
E_2	85.7	73.5	14.7	44.4

Strength characteristics such as yield strength and ultimate tensile strength of Treatments B through E_2 are not appreciably different from the conventionally processed material of Treatment A. The finer grained wrought products (Treatments B, D, E) have better ductility characteristics then the coarse grained products (Treatments A and C). The ductility characteristics of Treatment C are not better than those of Treatments B, D and E, but are slightly superior to those of Treatment A, which is to be expected since the grain size of the specimens given Treatments C_1 or C_2 is slightly finer than those of the conventionally processed material. Treatments D_2 and E_2 yield properties somewhat equivalent to those obtained with Treatments D_1 and E_1.

Due to the beneficial effect of ITMT on the properties of 7075-T6 sheet and realizing that ITMT may have a greater impact on plate than on sheet because of the larger grain size in conventionally processed plate, work was carried out in which our process, along with the ISML process, was used to produce ITMT processed plate. The initial work on 1 in. thick plate showed that the degree of deformation necessary to produce a fine grain structure in the sheet was not sufficient to produce the same fine grain structure in the 1 in. thick plate when equivalent temperatures of deformation were used. Hence, the deformation was increased to about 80 percent. The Treatments carried out, i.e., Treatments F, G, H and I, for both processes are described in detail in Table III below:

Thermal Mechanical Processing Schedules for the Production of 1 Inch Plate of 7075 Alloy

Treatment	Process	Billet Thickness in.	Initial Homogenization Treatment hrs/°F	Initial Deformation %/°F	Thickness After Initial Deformation in.	Recrystallization Homogenization Treatment hr/°F	Final Deformation %/°F	Final Thickness in.
F	ISML-ITMT-(as-recrystallized)	5.35	16/750, Q.	81/625 (W.R.), A.C. to R.T.	1.00	48/860, Q.	—	1.00
G	ISML-ITMT-(as-recrystallized + hot-rolled	9.00	16/750, Q.	81/625 (W.R.), A.C. to R.T.	1.67	48/860, Q.	40/800, Q.	1.00
H	Invention (as-recrystallized	5.35	24/860, F.C. to 775, 5-6/775, F.C. to 500 (16 hrs), 4/500, Q.	81/500 (W.R.), A.C. to R.T.	1.00	48/860, Q.	—	1.00
I	Invention (as-recrystallized + hot-rolled)	9.00	24/860, F.C. to 775, 5-6/775, F.C. to 500 (16 hrs), 4/500, Q.	81/400 (W.R.), A.C. to R.T.	1.67	48.860, Q.	40/800, Q.	1.00

Q - Quenched in water at room temperature.
W.R. - Without reheating.
A.C. to R.T. - Air cooled to room temperature.
F.C. - Furnace cooled. All of the billets were 12 in. wide × 24 in. long. The initial homogenization and the recrystallization-homogenization treatments were carried out in a salt bath. Plastic deformation was accomplished by rolling in one direction.

The grain size of our processed material in the as-recrystallized condition (Treatment H) is finer than that of commercial 7075-T651 one inch thick plate. There is a duplex structure in the as-recrystallized plates processed in accordance with the ISML method (Treatment F). However, the overall grain structure is also finer than that of commercial 7075-T651. Although the duplex structure is not present in our processed material, the grain size is somewhat larger than that in the fine grained areas of the duplex structures of the ISML-ITMT material. The reason for this may be related to the differences in the two ITMT processes or to differences in the temperatures of working. With regard to the as-recrystallized + hot-rolled condition, there is no indication of a duplex structure in plates processed by either method (Treatments G and I). Also, there appear to be no significant differences between the grain structures of the materials produced using either ITMT process although both have a finer grain size than conventionally processed material.

The tensile properties and the plane strain fracture-toughness values of our process plate and the ISML process plate in both the as-recrystallized + hot-rolled conditions are shown in Table IV below for the T6, T76 and T73 tempers.

spect to fracture toughness, the as-recrystallized plates are generally slightly better than the conventionally processed material. However, in the as-recrystallized + hot rolled plates, the fracture toughness values increased substantially.

We claim:

1. A commercially feasible, intermediate thermal mechanical treatment for 7,000 series aluminum alloys for improving ductility and fracture toughness thereof without concomitant reduction in their strengths, said treatment being applicable to as-cast ingot alloy or wrought alloy, plate or sheet, said treatment steps comprising

prehomogenizing said alloy at 860°F for 8 to 48 hours to dissolve the interdendritic networks of Zn–Mg–and Cu– bearing compounds and to precipitate Cr out of solution,

slowly cooling said prehomogenized alloy to 775°F in about 3 hours,

annealing said cooled prehomogenized alloy at 775°F for 3 to 5 hours; slowly cooling said annealed alloy to a temperature range of about 450° to 500°F and holding at said temperature range for 4 hours to precipitate the Zn, Mg and Cu out of solution as coarse compounds to render the alloy amenable to plastic deformation,

plastically deforming said stabilized alloy at least 50 percent at a temperature from ambient to 500°F to generate sufficient stored energy therewithin to enable recrystallization of said stabilized alloy into a fine grained structure, and

rapidly recrystallizing and homogenizing said deformed alloy at a temperature ranging between 860° to 900°F for 24 to 48 hours to provide said deformed alloy with a fine grained recrystallized structure.

TABLE IV

Properties of Conventional and ITMT Processed 7075 Plate (1.0" Thick) in the T6, T76 and T73 Tempers

Treatment	Process	Condition [1]	Longitudinal					Long transverse				
			Y.S. (.2% offset), k.s.i.	U.T.S., k.s.i.	E in 2" percent	R.A., percent	K_{Ic}, k.s.i. $\sqrt{in.}$	Y.S. (.2% offset), k.s.i.	U.T.S., k.s.i.	E in 2" percent	R.A., percent	K_{Ic}, k.s.i. $\sqrt{in.}$
T6 temper:												
Conventional	Conventional [3]	HR	76.4	85.2	10.0	14–17	25.5	72.8	82.5	9.5	14–16	20.5
F	ISML–ITMT	AR	74.6	83.6	17.5	29.4	27.6	73.7	83.2	18.2	29.6	30.7
G	ISML–ITMT	AR+HR	76.4	85.7	16.0	32.0	[2] 42.5	73.8	82.6	16.8	38.9	34.0
H	Invention	AR	73.7	83.3	18.0	29.8	28.1	73.9	83.0	19.0	35.1	25.4
I	do	AR+HR	73.4	82.7	15.7	31.0	[2] 41.0	72.9	82.1	17.8	40.8	26.6
T76 temper:												
Conventional	Conventional	HR	68.0	78.0	12.0	------	27.1	------	------	------	------	23.8
F	ISML–ITMT	AR	71.9	80.2	16.5	43.8	33.2	72.1	80.1	14.8	37.3	30.2
G	ISML–ITMT	AR+HR	70.5	79.7	14.3	42.4	[2] 59.9	68.6	77.2	14.0	38.9	[2] 46.9
H	Invention	AR	68.9	78.1	16.3	44.0	34.2	69.5	78.6	15.5	39.5	33.3
I	do	AR+HR	69.5	79.0	17.5	48.4	[2] 52.0	67.2	76.3	15.3	43.3	[2] 46.9
T73 temper:												
Conventional	Conventional	HR	66.3	76.7	12.0	29.0	31.5	64.6	74.9	10.5	20.0	28.2
F	ISML–ITMT	AR	67.4	76.4	16.5	50.0	[2] 46.9	66.6	75.5	14.5	38.4	[2] 39.5
G	ISML–ITMT	AR+HR	65.9	75.4	16.1	51.2	[2] 65.3	65.3	74.5	15.1	41.6	[2] 59.4
H	Invention	AR	67.9	76.7	16.5	48.5	[2] 46.6	66.5	75.6	16.0	45.1	[2] 40.4
I	do	AR+HR	64.3	74.0	17.0	49.6	[2] 59.4	64.6	74.2	15.4	42.9	[3] 53.3

[1] HR=Hot Rolled; AR=As-recrystallized; AR+HR=As-recrystallized plus Hot Rolled.

[2] K_Q=Excess Plasticity.

[3] Conventional tensile data obtained from Kaufman, J. G. and Holt, M., *Fracture Characteristics of Aluminum Alloys*, Tech. Paper No. 18, Alcoa Research Labs, 1965, and fracture toughness data obtained from Report No. MCIC-HB-01, December 1972, *Damage Tolerant Design Handbook*, Metals & Ceramics Information Center, Battelle Columbus Labs., Columbus, Ohio.

As in the case of sheet, the ITMT plate as processed by both techniques have equivalent strengths and significantly better elongation and reduction in area than the conventionally processed commercial material in the T6, T76 and T73 tempers. The tensile properties of the ITMT plates in the as-recrystallized condition (Treatments F and H) are equivalent to those in the as-recrystallized + hot rolled condition (Treatments G and I). Also, the tensile properties of the plates produced in accordance with our inventive techniques are equivalent to those of plates processed in accordance with the ISML method in each of the tempers. With re-

2. The method as described in claim 1 further characterized by said recrystallized alloy being further plastically deformed about 40 to 60 percent by conventional mill practice.

3. The method as described in claim 1 further characterized by said recrystallized alloy being heat treated to a desired temper.

4. The method as described in claim 2 further characterized by said plastically deformed by conventional mill practice alloy being heat treated to a desired temper.

5. The method as described in claim 1 further characterized by a plurality of annealing-deformation-recrystallization steps subsequent to said recrystallization step to provide further grain refinement.

6. An intermediate thermal mechanical treatment for producing 7075 aluminum sheet alloy having improved ductility without concomitant reduction in its strength, said alloy having a reduction in area of 42.1 percent, said treatment comprising the steps of
prehomogenizing said alloy at 860°F for 7 hours and at 900°F for 17 hours,
furnace cooling said prehomogenized alloy to 775°F and soaking thereat for 5 hours,
additionally furnace cooling said alloy to 500°F,
air cooling said furnace cooled alloy to room temperature,
initially rolling said air cooled alloy at room temperature to reduce the thickness thereof,
recrystallizing said initially rolled alloy by rapidly heating to 860°F,
homogenizing said recrystallized alloy at 860°F for 7 hours and at 900°F for 17 hours,
furnace cooling said recrystallized and homogenized alloy at 800°F,
finally rolling said furnace cooled alloy at 800°F,
air cooling said finally rolled alloy at room temperature, and
heat treating said air cooled alloy to a T6 temper.

7. The method as described in claim 6 wherein said initial rolling step reduces the thickness of the alloy approximately 70 percent and said final rolling step reduces the final cumulative thickness of the alloy approximately 90 percent.

8. An intermediate thermal mechanical treatment for producing 7075 aluminum sheet alloy having improved ductility without concomitant reduction in its strength, said alloy having a reduction in area of 44.0 percent, said treatment comprising
prehomogenizing said alloy at 860°F for 7 hours and at 900°F for 17 hours,
furnace cooling said prehomogenized alloy to 775°F and soaking thereat for 5 hours,
additionally furnace cooling said alloy to 500°F,
air cooling said furnace cooled alloy to room temperature,
initially rolling said air cooled alloy at room temperature to reduce the thickness thereof,
recrystallizing said initially rolled alloy by rapidly heating to 900°F,
homogenizing said recrystallized alloy at 900°F for 1 hour,
furnace cooling said recrystallized and homogenized alloy at 800°F,
finally rolling said furnace cooled alloy at 800°F,
air cooling said finally rolled alloy at room temperature, and
heat treating said air cooled alloy to a T6 temper.

9. The method as described in claim 8 wherein said initial rolling step reduces the thickness of the alloy approximately 70 percent and said final rolling step reduces the final cumulative thickness of the alloy approximately 90 percent.

10. An intermediate thermal mechanical treatment for producing 7075 aluminum sheet alloy having improved ductility without concomitant reduction in its strength, said alloy having reduction in area of 42.6 percent, said treatment comprising the steps of
prehomogenizing said alloy at 860°F for 7 hours and at 900°F for 17 hours,
furnace cooling said prehomogenized alloy to 775°F and soaking thereat for 5 hours,
additionally furnace cooling said alloy to 500°F,
initially rolling said furnace cooled alloy at 500°F to reduce the thickness thereof,
recrystallizing said initially rolled alloy by rapid heating to 860°F,
homogenizing said recrystallized alloy at 860°F for 7 hours and at 900°F for 17 hours,
furnace cooling said recrystallized and homogenized alloy to 800°F,
finally rolling said furnace cooled alloy at 800°F,
air cooling said finally rolled alloy at room temperature, and
heat treating said air cooled alloy to a T6 temper.

11. The method as described in claim 10 wherein said initial rolling step reduces the thickness of the alloy approximately 64 percent and said final rolling step reduces the final cumulative thickness of the alloy approximately 90 percent.

12. An intermediate thermal mechanical treatment for producing 7075 aluminum sheet alloy having improved ductility without concomitant reduction in its strength, said alloy having reduction in area of 44.4 percent, said treatment comprising the steps of
prehomogenizing said alloy at 860°F for 7 hours and at 900°F for 17 hours,
furnace cooling said prehomogenized alloy to 775°F and soaking thereat for 5 hours,
additionally furnace cooling said alloy to 500°F,
initially rolling said furnace cooled alloy at 500°F to reduce the thickness thereof,
recrystallizing said initially rolled alloy by rapid heating to 900°F,
homogenizing said recrystallized alloy at 900°F for 1 hour,
furnace cooling said recrystallized and homogenized alloy to 800°F,
finally rolling said furnace cooled alloy at 800°F,
air cooling said finally rolled alloy at room temperature, and
heat treating said air cooled alloy to a T6 temper.

13. The method as described in claim 12 wherein said initial rolling step reduces the thickness of the alloy approximately 64 percent and said final rolling step reduces the final cumulative thickness of the alloy approximately 90 percent.

14. An intermediate thermal mechanical treatment for producing 7075 aluminum alloy plate having improved ductility and fracture toughness without con-

comitant reduction in its strength, said alloy having the following mechanical properties:

T6 Temper

	Longitudinal	Long Transverse
% Elongation	18.0	19.0
% Reduction in area	29.8	35.1
Fracture toughness, ksi $\sqrt{in.}$	28.1	25.4

T76 Temper

	Longitudinal	Long Transverse
% Elongation	16.3	15.5
% Reduction in area	44.0	39.5
Fracture toughness, ksi $\sqrt{in.}$	34.2	33.3

T73 Temper

	Longitudinal	Long Transverse
% Elongation	16.5	16.0
% Reduction in area	48.5	45.1
Fracture toughness, ksi $\sqrt{in.}$	46.6	40.4

said treatment comprising the steps of

prehomogenizing said alloy at 860°F for 24 hours,

furnace cooling said prehomogenized alloy to 775°F and soaking thereat for 5 to 6 hours,

additionally furnace cooling said alloy to 500°F, and soaking thereat for 4 hours,

water quenching said furnace cooled alloy to room temperature,

rolling said water quenched alloy at 500°F to reduce the thickness thereof,

recrystallizing said rolled alloy by rapidly heating to 860°F,

homogenizing said recrystallized alloy at 860°F for 48 hours,

water quenching said recrystallized and homogenized alloy to room temperature, and

heat treating portions of said water quenched alloy to T6, T76 and T73 tempers respectively.

15. The method as described in claim **14** wherein said rolling step reduces the thickness of the alloy approximately 81 percent.

16. An intermediate thermal mechanical treatment for producing 7075 aluminum alloy plate having improved ductility and fracture toughness without concomitant reduction in its strength, said alloy having the following mechanical properties:

T6 Temper

	Longitudinal	Long Transverse
-Continued		
% Elongation	15.7	17.8
% Reduction in area	31.0	40.8
Fracture toughness, ksi $\sqrt{in.}$	41.0	26.6

T76 Temper

	Longitudinal	Long Transverse
% Elongation	17.5	15.3
% Reduction in area	48.4	43.3
Fracture toughness, ksi $\sqrt{in.}$	52.0	46.9

T73 Temper

	Longitudinal	Long Transverse
% Elongation	17.0	15.4
% Reduction in area	49.6	42.9
Fracture toughness, ksi $\sqrt{in.}$	59.4	53.3

said treatment comprising the steps of

prehomogenizing said alloy at 860°F for 24 hours,

furnace cooling said prehomogenized alloy to 775°F and soaking thereat for 5 to 6 hours,

additionally furnace cooling said alloy to 500°F, and soaking thereat for 4 hours,

water quenching said furnace cooled alloy to room temperature,

initially rolling said water quenched alloy at 400°F to reduce the thickness thereof,

recrystallizing said initially rolled alloy by rapidly heating to 860°F,

homogenizing said recrystallized alloy at 860°F for 48 hours,

water quenching said recrystallized and homogenized alloy to room temperature,

heating said water quenched alloy to 800°F,

finally rolling said heated alloy at 800°F,

water quenching said finally rolled alloy to room temperature, and

heat treating portions of said water quenched alloy to T6, T76 and T73 tempers respectively.

17. The method as described in claim **16** wherein said initial rolling step reduces the thickness of the alloy approximately 81 percent and said final rolling step reduces the thickness of the alloy an additional 40 percent, a total reduction of about 89 percent.

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