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(54) **A method of improving the mechanical properties of a component**

(57) A method (40) of improving the mechanical properties of a component, for example a gas turbine engine turbine disc, (24) comprises isothermally forging (42) a preform to produce a shaped preform with a predetermined shape at a first predetermined temperature, solution heat treating (44) the shaped preform, quench-

ing (46) the shaped preform, forging (48) the shaped preform at a second predetermined temperature to impart a predetermined residual strain in the shaped preform, ageing (50) the shaped preform and finally machining (52) the shaped preform to a finished shape. The second predetermined temperature is less than the first predetermined temperature.

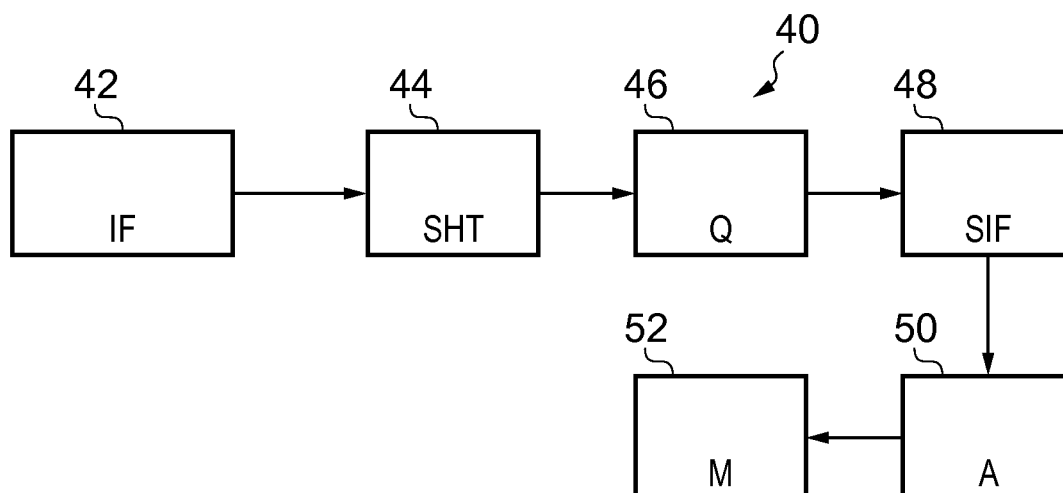


FIG. 3

Description

[0001] The present invention relates to a method of improving the mechanical properties of a component, in particular to a method of improving the mechanical properties of a forged nickel base superalloy article, e.g. a forged nickel base superalloy gas turbine engine turbine disc or a forged nickel base superalloy gas turbine engine compressor disc.

[0002] High strength nickel base superalloys for critical rotor components, e.g. turbine discs or compressor discs, are made by complex powder processing route. Other high strength nickel base superalloys for critical rotor components are made by a cast and wrought route.

[0003] The complex powder processing route comprises vacuum induction melting (VIM) of the nickel base superalloy, inert gas, e.g. argon, atomisation (IGA) to produce a metal powder, sieving of the metal powder, blending of the metal powder, canning of the metal powder, hot isostatic pressing (HIP) of the metal powder, extrusion to form a billet, isothermal forging of the billet to form a forging, solution heat treatment (SHT) of the forging, ageing heat treatment (AHT) of the forging and machining the forging to form the final shape of a component.

[0004] The cast and wrought route comprises vacuum induction melting (VIM), electro slag refining (ESR), vacuum arc remelting (VAR), conversion of the ingot to a billet through multiple upset and heat treatment operations, isothermal forging of the billet to a forging, solution heat treatment (SHT) of the forging, ageing heat treatment (AHT) of the forging and machining the forging to form the final shape of a component.

[0005] Lower strength and/or lower temperature capability nickel base superalloys, such as Waspaloy or IN718, forgings are formed to shape using conventional forging, e.g. press forging. The forgings undergo a complex heat treatment cycle to optimise the grain size and the strengthening precipitate phase distribution. The forging is then machined to the final shape of a component.

[0006] Currently higher strength and/or higher temperature capability nickel base superalloys are optimised to provide maximum creep and fatigue crack growth properties and/or maximum tensile and fatigue properties by altering the grain size of the nickel base superalloy and the volume fraction and size of strengthening precipitates, which results in a trade off in mechanical properties. Therefore, it is desirable to increase the creep properties and/or tensile properties of a high strength nickel base superalloy without altering the grain size of the nickel base superalloy or the size and/or distribution of other strengthening phases in the nickel base superalloy.

[0007] Residual stresses develop in components due to the thermal gradients that develop during the cooling steps of a heat treatment cycle. Solution heat treatments which define the grain size in these components are followed by quenching in air, oil or other medium. The quenching is to minimise the size of the precipitate phase that is responsible for high temperature strength in these nickel base superalloys. By optimising the precipitate size the component is subjected to a large thermal gradient during quenching and this thermal gradient produces large residual stresses in the component. The residual stresses may lead to distortion of the component during subsequent machining. In practice the cooling rates during quenching are reduced to avoid quench cracking. Nickel base superalloys have an ageing heat treatment after the solution heat treatment to optimise the precipitates further and to relieve residual stresses in the component.

[0008] In nickel base superalloys used as turbine discs, or compressor discs, the residual stresses in the disc are added to the stresses induced in the disc by the operation of the gas turbine engine. This combined stress must be maintained below the stress level that would be predicted to cause tensile or fatigue failure of the turbine disc or compressor disc. Thus, the residual stress in the turbine disc, or compressor disc, limits the mechanical stress cycle that the engine is designed for.

[0009] Accordingly the present invention seeks to provide a novel method of manufacturing a component which reduces, preferably overcomes, the above mentioned problem or problems.

[0010] Accordingly the present invention provides a method of improving the mechanical properties of a component comprising the steps of:-

- a) forging a preform to produce a shaped preform with a predetermined shape at a first predetermined temperature,
- b) solution heat treating the shaped preform,
- c) quenching the shaped preform,
- d) ageing the shaped preform,
- e) machining the shaped preform to a finished shape or a semi-finished shape, and
- f) forging the shaped preform at a second predetermined temperature to impart a predetermined residual strain in the shaped preform after step c) and before step e), wherein the second predetermined temperature is less than the first predetermined temperature.

[0011] Step f) may be after step c) and before step d), step f) may be after step d) and before step e) or step f) may be concurrent with step d).

[0012] Preferably the second predetermined temperature is between 700°C and 870°C.

[0013] More preferably the second predetermined temperature is between 750°C and 850°C. More preferably the second predetermined temperature is between 760°C and 810°C. The second predetermined temperature may be 760°C, 802°C or 843°C.

[0014] Preferably the forging step f) imparts a predetermined residual tensile strain or a predetermined residual compressive strain.

[0015] Preferably the forging step f) imparts a strain of less than 10%.

[0016] Preferably step f) comprises isothermally forging.

[0017] Preferably step f) comprises forging at a strain rate between 1×10^{-4} and $1 \times 10^{-2} \text{ s}^{-1}$.

[0018] Preferably step a) comprises isothermally forging.

[0019] In step a) the first predetermined temperature may be up to gamma prime solvus minus 25°C to 50°C. In step a) the forging may be at a strain rate between 1×10^{-4} and $1 \times 10^{-2} \text{ s}^{-1}$.

[0020] Alternatively in step a) the first predetermined temperature may be up to gamma prime solvus minus 55°C to 110°C. In step a) the forging may be at a strain rate between 1×10^{-2} and $5 \times 10^{-1} \text{ s}^{-1}$.

[0021] Preferably the method comprises machining the shaped preform after step a) and before step b).

[0022] Step b) may comprise a subsolvus solution heat treatment and or a supersolvus heat treatment.

[0023] Step b) may comprise a subsolvus solution heat treatment at 1120°C for 4 hours.

[0024] Step d) may comprise an ageing heat treatment at 760°C for 16 hours.

[0025] Step b) may comprise a subsolvus solution heat treatment at 1120°C for 4 hours, followed by quenching, followed by a supersolvus heat treatment at 1204°C for 1 hour.

[0026] Step b) may comprise a supersolvus heat treatment at 1204°C for 1 hour.

[0027] Preferably the component is a compressor disc, a turbine disc, a compressor cone or a turbine cover plate.

[0028] Preferably the component comprises a nickel base superalloy or a titanium base alloy.

[0029] The nickel base superalloy may be RR1000, U720Li, Rene 95, Rene 88DT, ME3, N18, Alloy 10, LSHR and other nickel base superalloys suitable for application as a turbine disc or compressor disc.

[0030] The preform may have been made by a cast and a wrought route or alternatively may have been made by a powder processing route.

[0031] The present invention will be more fully described by way of example with reference to the accompanying drawings in which:-

Figure 1 shows a gas turbine engine having a turbine disc which has been manufactured according to the present invention.

Figure 2 shows is a cross-sectional view through a portion of a gas turbine engine turbine disc which has been manufactured according to the present invention.

Figure 3 is a flow chart of a method of manufacturing a component according to the present invention.

Figure 4 is a flow chart of a further method of manufacturing a component according to the present invention.

Figure 5 is a flow chart of another method of manufacturing a component according to the present invention.

Figure 6 is a bar chart showing the ultimate tensile strength and the 0.2% proof strength in tensile tests for fine grained RR1000 processed conventionally and according to the present invention.

Figure 7 is a bar chart showing the percentage elongation and the percentage reduction in area in tensile tests for fine grained RR1000 processed conventionally and according to the present invention.

Figure 8 is a bar chart showing the ultimate tensile strength and the 0.2% proof strength in tensile tests for coarse grained RR1000 processed conventionally and according to the present invention.

Figure 9 is a bar chart showing the percentage elongation and the percentage reduction in area in tensile tests for coarse grained RR1000 processed conventionally and according to the present invention.

Figures 10A, 10B and 10C are graphs showing the hoop stress, radial stress and axial stress in test pieces at different axial and radial positions in a first cylindrical test piece which was water quenched only.

Figures 11A, 11B and 11C are graphs showing the hoop stress, radial stress and axial stress in test pieces at different axial and radial positions in a second cylindrical test piece which was water quenched, aged and given a low deformation.

Figures 12A, 12B and 12C are graphs showing the hoop stress, radial stress and axial stress in test pieces at different axial and radial positions in a third cylindrical test piece which was water quenched and given a high deformation.

Figures 13A, 13B and 13C are graphs showing the hoop stress, radial stress and axial stress in test pieces at different axial and radial positions in a fourth cylindrical test piece which was water quenched and given a low deformation.

Figures 14A, 14B and 14C are graphs showing the hoop stress, radial stress and axial stress in test pieces at different axial and radial positions in a fifth cylindrical test piece which was oil quenched, aged and given a medium deformation.

Figures 15A, 15B and 15C are graphs showing the hoop stress, radial stress and axial stress in test pieces at different axial and radial positions in a sixth cylindrical test piece which was oil quenched and aged.

[0032] A turbofan gas turbine engine 10, as shown in figure 1, comprises in axial flow series an intake 12, a fan section 14, a compressor section 16, a combustion section 18, a turbine section 20 and an exhaust 22. The turbine section 20 comprises a turbine disc 24, which carries a plurality of circumferentially spaced turbine blades 26. The gas turbine engine is quite conventional and its construction and operation will not be described further.

[0033] The gas turbine engine turbine disc 24, as shown more clearly in figure 2, comprises a hub, or cob, 26, a web 28 and a rim 30. The hub 26 is at the radially inner end of the turbine disc 24, the rim 30 is at the radially outer end of the turbine disc 24 and the web 28 extends radially between and interconnects the hub 26 and the rim 30. The rim 30, in this example, has a plurality of circumferentially spaced slots 34 to receive the roots of turbine blades 26, shown in figure 1, and circumferentially spaced posts 32 are provided on the rim 30 of the turbine disc 24 to define the sides of the slots 34. The slots 34 may be firtree shape, or dovetail shape. The turbine disc 24 comprises a high strength nickel base superalloy, for example RR1000.

[0034] A first method 40 of improving the mechanical properties of a component, for example a gas turbine engine turbine disc, 24 according to the present invention, as shown in figure 3, comprises isothermally forging 42 a preform to produce a shaped preform with a predetermined shape at a first predetermined temperature, solution heat treating 44 the shaped preform, quenching 46 the shaped preform, forging 48 the shaped preform at a second predetermined temperature to impart a predetermined residual strain in the shaped preform, ageing 50 the shaped preform and finally machining 52 the shaped preform to a finished shape. It is to be noted that the second predetermined temperature is less than the first predetermined temperature.

[0035] A second method 40B of improving the mechanical properties of a component, for example a gas turbine engine turbine disc, 24 according to the present invention, as shown in figure 4, comprises isothermally forging 42 a preform to produce a shaped preform with a predetermined shape at a first predetermined temperature, solution heat treating 44 the shaped preform, quenching 46 the shaped preform, ageing 50 the shaped preform, forging 48 the shaped preform at a second predetermined temperature to impart a predetermined residual strain in the shaped preform and finally machining 52 the shaped preform to a finished shape. It is to be noted that the second predetermined temperature is less than the first predetermined temperature.

[0036] A third method 40C of improving the mechanical properties of a component, for example a gas turbine engine turbine disc, 24 according to the present invention, as shown in figure 5, comprises isothermally forging 42 a preform to produce a shaped preform with a predetermined shape at a first predetermined temperature, solution heat treating 44 the shaped preform, quenching 46 the shaped preform, simultaneously forging 48 the shaped preform at a second predetermined temperature to impart a predetermined residual strain in the shaped preform and ageing 50 the shaped preform and finally machining 52 the shaped preform to a finished shape. It is to be noted that the second predetermined temperature is less than the first predetermined temperature.

[0037] In the three methods discussed above the second predetermined temperature is between 700°C and 870°C (1300°F and 1600°F), more preferably the second predetermined temperature is between 750°C and 850°C (1380°F and 1560°F), even more preferably 760°C to 810°C (1400°F to 1490°F). The forging 48 step may be arranged to impart a predetermined residual tensile strain or a predetermined residual compressive strain. The forging 48 step imparts a strain of less than or equal to 15%, e.g. 5% or 10% strain.

[0038] The three methods mention above may comprise machining the shaped preform after the isothermal forging 42 and before the solution heat treatment 44.

[0039] Although the three methods mentioned previously have mentioned a gas turbine engine turbine disc, the component may be a compressor disc, a compressor cone or a turbine cover plate. The component may comprise a nickel base superalloy, a titanium base alloy or other suitable alloy.

[0040] The preform used in the previously mentioned methods may have been made by a cast and a wrought route or alternatively may have been made by a powder processing route.

[0041] The forging 48 may comprise isothermal forging, hot die press forging or hammer forging and the forging 48 may comprise applying a mechanical load, a fluid load or a thermal gradient via any conventional forging apparatus or process. The isothermal forging may use an isothermal forging press and the die for the isothermal forging press may comprise TZM molybdenum or other suitable material.

[0042] The final machining 52 may comprise any suitable machining, e.g. turning, grinding, milling, drilling, polishing etc.

[0043] The isothermal forging 42 is preferred, but may be replaced by other suitable types of forging.

[0044] The present invention is described more fully with reference to an example. RR1000 consists of 18.5wt% cobalt, 15wt% chromium, 5wt% molybdenum, 2wt% tantalum, 3.6wt% titanium, 3wt% aluminium, 0.5wt% hafnium, 0.015wt% boron, 0.06wt% zirconium, 0.027wt% carbon and the balance nickel plus incidental impurities. RR1000 has a gamma prime solvus temperature of 1145°C to 1150°C. Thus, a turbine, or compressor, disc consisting of RR1000 is produced by initially producing a billet, using either powder metallurgy, or cast and wrought, techniques.

[0045] The RR1000 billet is then isothermally forged, at step 42 in figure 3, to produce a shaped preform which is near to the final shape of the disc at a temperature up to gamma prime solvus minus 25°C to 50°, at a strain rate between 1×10^{-4} and $1 \times 10^{-2} \text{ s}^{-1}$ or at a temperature up to gamma prime solvus minus 55°C to 110°C at a strain rate between 1×10^{-2} and $5 \times 10^{-1} \text{ s}^{-1}$. The RR1000 shaped preform is then solution heat treated, at step 44, at a temperature in the range of gamma prime solvus minus 15°C to 35°C up to gamma prime solvus plus 25°C to 60°C for times between 0.5 and 8 hours. The shaped preform is cooled or quenched, at step 46, from the solution heat treatment temperature at a rate suitable to avoid quench cracking at stress concentrations, for example at a rate between $0.1 \text{ }^{\circ}\text{C s}^{-1}$ and $10^{\circ}\text{C s}^{-1}$. The shaped preform is then isothermally forged, at step 48, at a temperature between 700°C (1292°F) and 870°C (1598°F), at a strain rate between 1×10^{-4} and $1 \times 10^{-2} \text{ s}^{-1}$ to impart a predetermined residual strain to the shaped preform. The shaped preform is then given an ageing heat treatment, at step 50, at a temperature between 650°C (1202°F) and 800°C (1472°F) for between 2 and 30 hours. Finally the shaped preform is machined to final shape at step 52.

[0046] A series of tests were carried out on samples of fine grained and coarse grained RR1000 nickel base superalloy, which were initially forged. Samples 1 and 2 of RR1000 were given a conventional subsolvus solution heat treatment at 1120°C (2048°F) for 4 hours, then air cooled, followed by an ageing heat treatment at 760°C (1400°F) for 16 hours and then air cooled as a baseline. Other samples, samples 3 and 6, of RR1000 were given a subsolvus solution heat treatment at 1120°C (2048°F) for 4 hours, then air cooled, followed by an ageing heat treatment at 760°C (1400°F) for 16 hours and then strained at 760°C (1400°F) at 5% or 10% strain respectively. Other samples, samples 4 and 7, of RR1000 were given a subsolvus solution heat treatment at 1120°C (2048°F) for 4 hours, then air cooled, followed by an ageing heat treatment at 760°C (1400°F) for 16 hours and then strained at 802°C (1475°F) at 5% or 10% strain respectively. Other samples, samples 5, 22 and 8, of RR1000 were given a subsolvus solution heat treatment at 1120°C (2048°F) for 4 hours, then air cooled, followed by an ageing heat treatment at 760°C (1400°F) for 16 hours and then strained at 843°C (1550°F) at 5%, 10% or 15% strain respectively. Additional samples, samples 17 and 11, of RR1000 were given a subsolvus solution heat treatment at 1120°C (2048°F) for 4 hours, then air cooled, then strained at 760°C (1400°F) at 5% or 10% strain respectively, followed by an ageing heat treatment at 760°C (1400°F) for 16 hours. Another sample, sample 12, of RR1000 was given a subsolvus solution heat treatment at 1120°C (2048°F) for 4 hours, then air cooled, then strained at 802°C (1475°F) at 5% strain, followed by an ageing heat treatment at 760°C (1400°F) for 16 hours. Another sample, sample 13, of RR1000 was given a subsolvus solution heat treatment at 1120°C (2048°F) for 4 hours, then air cooled, then strained at 843°C (1550°F) at 5% strain, followed by an ageing heat treatment at 760°C (1400°F) for 16 hours.

[0047] Samples, samples 9 and 10, of RR1000 were given a conventional subsolvus solution heat treatment at 1120°C (2048°F) for 4 hours, then air cooled, followed by a supersolvus heat treatment at 1204°C (2200°F) for 1 hour, then air cooled, followed by an ageing heat treatment at 760°C (1400°F) for 16 hours and air cooled as a baseline. Further samples, samples 14 and 19, of RR1000 were given a subsolvus solution heat treatment at 1120°C (2048°F) for 4 hours, then air cooled, followed by a supersolvus heat treatment at 1204°C (2200°F) for 1 hour, then air cooled, followed by an ageing heat treatment at 760°C (1400°F) for 16 hours and then strained at 760°C (1400°F) at 5% or 10% strain respectively. Other samples, samples 15 and 20, of RR1000 were given a subsolvus solution heat treatment at 1120°C (2048°F) for 4 hours, then air cooled, followed by a supersolvus heat treatment at 1204°C (2200°F) for 1 hour, then air cooled, followed by an ageing heat treatment at 760°C (1400°F) for 16 hours and then strained at 802°C (1475°F) at 5% or 10% strain respectively. Other samples, samples 16 and 24, of RR1000 were given a subsolvus solution heat treatment at 1120°C (2048°F) for 4 hours, then air cooled, followed by a supersolvus heat treatment at 1204°C (2200°F) for 1 hour, then air cooled, followed by an ageing heat treatment at 760°C (1400°F) for 16 hours and then strained at 843°C (1550°F) at 5% or 10% strain respectively. These samples were air cooled after the supersolvus heat treatment at a rate of $0.81 \text{ }^{\circ}\text{C s}^{-1}$. In all the above samples the samples were air cooled after the subsolvus heat treatment at a rate of $0.76 \text{ }^{\circ}\text{C s}^{-1}$.

[0048] In all cases the samples were held at the appropriate temperature for 1 hour before any strain was applied.

[0049] The subsolvus heat treatment, followed by ageing heat treatment produced fine grains in the nickel base superalloy and the subsolvus heat treatment, followed by the supersolvus heat treatment and ageing heat treatment produced coarse grains in the nickel base superalloy as is well known to those skilled in the art.

[0050] Then standard test pieces were taken from each of the large samples of RR1000 and the test pieces of the samples were then subjected to tensile tests at a temperature of 650°C (1202°F) to determine the ultimate tensile strength and the 0.2% proof strength of the samples and to determine the percentage elongation and percentage reduction in area of the samples. The results are recorded in Table A below and some of the results are shown in figures 6, 7, 8 and 9.

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Table A

	Sample	Thermal History	Strain Temp (°F)	Strain (%)	Ultimate 0.2% Tensile Strength (MPa)	Proof Strength (MPa)	% Elong	% Red Area
5	1	Sb + A	-	-	1382	1004	25	35
	2	Sb + A	-	-	1381	1000	21	25
	3	Sb + A + St	1400	5	1502	1211	12	37
10	4	Sb + A + St	1475	5	1484	1251	17	26
	5	Sb + A + St	1550	5	1464	1176	22	36
	6	Sb + A + St	1400	10	1598	1365	9	34
	7	Sb + A + St	1475	10	1503	1249	13	33
	22	Sb + A + St	1550	10	1499	1265	16	38
15	8	Sb + A + St	1400	15.5	1487	1138	13	31
	17	Sb + St + A	1400	5	1549	1277	15	27
	12	Sb + St + A	1475	5	1489	1238	15	34
	13	Sb + St + A	1550	5	1462	1225	21	33
20	11	Sb + St + A	1400	10	1498	1229	7	15
	9	Sb+Su + A + St	-	-	1356	846	22	25
	10	Sb+Su + A + St	-	-	1365	852	22	24
25	14	Sb+Su + A + St	1400	5	1494	1209	9	18
	23	Sb+Su + A + St	1550	5	1431	1129	13	27
30	19	Sb+Su + A + St	1400	10	1485	1240	4	12
	20	Sb+Su + A + St	1475	10	1476	1218	9	17
	24	Sb+Su + A + St	1550	10	1541	1253	11	29

(Sb - subsolvus heat treatment, Su - supersolvus heat treatment, A - ageing heat treatment, St - strain heat treatment)

[0051] The above results show that the present invention has increased the ultimate tensile strength and the 0.2% proof strength of a fine grained nickel base superalloy above that of a fine grained nickel base superalloy given a conventional subsolvus heat treatment followed by an ageing heat treatment. The above results show that the present invention has increased the ultimate tensile strength and the 0.2% proof strength of a coarse grained nickel base superalloy above that of a nickel base superalloy given a conventional subsolvus heat treatment, followed by a supersolvus heat treatment followed by an ageing heat treatment.

[0052] Another series of tests were carried out on samples of RR1000 nickel base superalloy, which were initially forged. This series of tests used the method described with respect to figure 4. The quenching, step 46, of the nickel base superalloy was chosen to be either an oil quench or a water quench to impart a high level of strain into the isothermally forged, step 42, and solution heat treated, step 44, nickel base superalloy. The ageing heat treatment, step 50, was a conventional age at 760 °C (1400°F) for 16 hours. The isothermal forging, step 48, was conducted within the preferred temperature range at a temperature less than 760°C (1400°F).

[0053] In order to investigate the effect of strain, three different strain values were investigated. Residual stress was measured using a neutron diffraction technique, which allows for non-destructive evaluation of the nickel base superalloys. The residual stresses were measured at a number of locations in three different orientations, the orientations were hoop, axial and radial. The test pieces were cylindrical and nominally had a diameter of 75mm and a height, or thickness, of 25mm. The residual stress was measured at locations at 5mm, 12mm and 19mm height from one face of the cylindrical test piece and at radial locations of 0mm, 10mm, 19mm, 30 and 33mm from the centre of the cylindrical test piece. Table B shows the residual hoop stress levels, in MPa, at different radial locations at a height of 12mm from the surface of the cylindrical test pieces, for different quenching, ageing and deformation conditions. All the deformations are less than or equal to 10% strain.

TABLE B

Test Piece	Quench		Age	Deformation (mm)	Height	Radial	Position (mm)		
					0	10	19	30	33
1	Water	-	-	12	1300	1400	1550	500	-300
2	Water	Aged	Low	12	675	750	850	350	0
3	Water	-	High	12	250	260	400	510	480
4	Water	-	Low	12	1000	1000	1200	600	-200
5	Oil	Aged	Medium	12	700	725	760	175	-200
6	Oil	Aged	-	12	750	-	800	-	-250

Test piece 1, which was water quenched, but was not aged and was not deformed is considered a baseline and it is seen that test piece 1 has high levels of residual stress present at all radial locations. Test piece 2, which was water quenched, aged and given a low deformation has a much lower levels of residual stress at all radial positions compared to test piece 1 due to the combination of a conventional age and a low deformation and low temperature mechanical stress relief. Test piece 4, which was water quenched and given a low deformation has levels of residual stress intermediate that of test pieces 1 and 2 except for the 30mm radial position. Test piece 3, which was water quenched and given a high deformation has lower levels of residual stress than test piece 2 at the 0mm, 10mm and 19mm radial locations. Comparing test pieces 1, 2 and 4 it can be seen that the deformation alone and the ageing and deformation produce a reduction in the residual stress and therefore that the combination of deformation and ageing produces a greater reduction in the residual stress. Test piece 5, which was oil quenched, aged and given a medium deformation has lower levels of residual stress than test piece 6, which was oil quenched and aged. Figures 10 to 15 are graphs showing the hoop stress, radial stress and axial stress for test pieces 1, 2, 3, 4, 5 and 6 respectively at locations at 5mm, 12mm and 19mm axially, height, from one face of the cylindrical test piece and at radial locations of 0mm, 10mm, 19mm, 30 and 33mm from the centre of the cylindrical test piece. This data shows the effectiveness of the present invention at controlling the residual stresses.

[0054] The present invention allows the imparted strain levels to be accurately controlled. The present invention is applicable to components with all microstructures commonly found in nickel base superalloy components, e.g. fine grains, medium grains, coarse grains or dual microstructures. The present invention is applicable to high strength nickel base superalloys for example RR1000, U720Li, Rene 95, Rene 88DT, ME3, N18, Alloy 10 and LSHR.

[0055] U720Li consists of 15wt% cobalt, 16wt% chromium, 3wt% molybdenum, 1.25wt% tungsten, 5wt% titanium, 2.5wt% aluminium, 0.015wt% boron, 0.015wt% carbon and the balance nickel plus incidental impurities.

[0056] Rene 95 consists of 8.12wt% cobalt, 12.94wt% chromium, 3.45wt% molybdenum, 3.43wt% tungsten, 2.44wt% titanium, 3.42wt% aluminium, 3.37wt% niobium, 0.012wt% boron, 0.05wt% zirconium, 0.07wt% carbon and the balance nickel plus incidental impurities.

[0057] Rene 88DT consists of 13.1wt% cobalt, 15.8wt% chromium, 4wt% molybdenum, 3.9wt% tungsten, 3.7wt% titanium, 2wt% aluminium, 0.7wt% niobium, 0.016wt% boron, 0.045wt% zirconium, 0.05wt% carbon and the balance nickel plus incidental impurities.

[0058] ME3 consists of 20.6wt% cobalt, 13wt% chromium, 3.8wt% molybdenum, 2.1wt% tungsten, 2.4wt% tantalum, 3.7wt% titanium, 3.4wt% aluminium, 0.03wt% boron, 0.05wt% zirconium, 0.04wt% carbon and the balance nickel plus incidental impurities.

[0059] N18 consists of 15.4wt% cobalt, 11.1wt% chromium, 6.44wt% molybdenum, 4.28wt% titanium, 4.28wt% aluminium, 0.5wt% hafnium, 0.008wt% boron, 0.019wt% zirconium, 0.022wt% carbon and the balance nickel plus incidental impurities.

[0060] Alloy 10 consists of 17.93wt% cobalt, 10.46wt% chromium, 2.52wt% molybdenum, 4.74wt% tungsten, 1.61wt% tantalum, 3.79wt% titanium, 3.53wt% aluminium, 0.028wt% boron, 0.07wt% zirconium, 0.027wt% carbon and the balance nickel plus incidental impurities.

[0061] LSHR consists of 20.8wt% cobalt, 12.7wt% chromium, 2.74wt% molybdenum, 4.37wt% tungsten, 1.65wt% tantalum, 3.47wt% titanium, 3.48wt% aluminium, 0.028wt% boron, 0.049wt% zirconium, 0.024wt% carbon and the balance nickel plus incidental impurities.

[0062] The present invention is also applicable to titanium base alloys, for example Ti6246, Ti6242 or other alloys where increased tensile properties or creep properties are required.

[0063] The present invention may be used to reduce, or eliminate, residual stresses developed by the solution heat treatment process. The present invention may be used to produce unique residual stress profiles in a component. The present invention may be used to support increased precipitation kinetics if it is applied before the ageing. The present invention may be used to selectively alter the retained strain or precipitation kinetics within a superalloy disc. The present

invention increases the mechanical strength of the alloy component by introducing dislocations, structural disturbances to the crystal structure, which in turn present obstacles to the creation and movement of further dislocations and hence increases mechanical strength.

[0064] The present invention enables turbine discs, compressor discs, compressor cones or turbine cover plates to be produced with enhanced proof and tensile strength and creep properties or reduced residual stress levels. This enables an increase in the operating life of the component, enables an increase in the operating rotational speed of the component, enables a decrease in the size of the component for an identical gas turbine engine cycle or enables a reduction in weight of the component for the same operating life. The improved properties allow an increase in overspeed capability.

Claims

1. A method of improving the mechanical properties of a component (24) comprising the steps of:

- a) forging (42) a preform to produce a shaped preform with a predetermined shape at a first predetermined temperature,
- b) solution heat treating (44) the shaped preform,
- c) quenching (46) the shaped preform,
- d) ageing (50) the shaped preform,
- e) machining (52) the shaped preform to a finished shape or a semi-finished shape, **characterised by**
- f) forging (48) the shaped preform at a second predetermined temperature to impart a predetermined residual strain in the shaped preform after step c) and before step e), wherein the second predetermined temperature is less than the first predetermined temperature.

2. A method as claimed in claim 1 wherein step f) is after step c) and before step d), step f) is after step d) and before step e) or step f) is concurrent with step d).

3. A method as claimed in claim 1 or claim 2 wherein the second predetermined temperature is between 700°C and 870°C.

4. A method as claimed in claim 3 wherein the second predetermined temperature is between 760°C and 810°C.

5. A method as claimed in any of claims 1 to 4 wherein the forging step f) imparts a predetermined residual tensile strain or a predetermined residual compressive strain.

6. A method as claimed in any of claims 1 to 5 wherein the forging step f) imparts a strain of less than 10%.

7. A method as claimed in any of claims 1 to 6 wherein the method comprises machining the shaped preform after step a) and before step b).

8. A method as claimed in any of claims 1 to 7 wherein step f) comprises isothermally forging.

9. A method as claimed in any of claims 1 to 8 wherein step f) comprises forging at a strain rate between 1×10^{-4} and $1 \times 10^{-2} \text{ s}^{-1}$.

10. A method as claimed in any of claims 1 to 9 wherein step a) comprises isothermally forging.

11. A method as claimed in any of claims 1 to 10 wherein in step a) the first predetermined temperature is up to gamma prime solvus minus 25°C to 50°C and step a) comprises forging at a strain rate between 1×10^{-4} and $1 \times 10^{-2} \text{ s}^{-1}$.

12. A method as claimed in any of claims 1 to 10 wherein in step a) the first predetermined temperature is up to gamma prime solvus minus 55°C to 110°C and step a) comprises forging at a strain rate between 1×10^{-2} and $5 \times 10^{-1} \text{ s}^{-1}$.

13. A method as claimed in any of claims 1 to 12 wherein step b) comprises a subsolvus solution heat treatment and or a supersolvus heat treatment.

14. A method as claimed in claim 13 wherein step b) comprises a subsolvus solution heat treatment at 1120°C for 4

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hours, a subsolvus solution heat treatment at 1120°C for 4 hours, followed by quenching, followed by a supersolvus heat treatment at 1204°C for 1 hour or a supersolvus heat treatment at 1204°C for 1 hour.

5 **15.** A method as claimed in any of claims 1 to 14 wherein step d) comprises an ageing heat treatment at 760°C for 16 hours.

16. A method as claimed in any of claims 1 to 15 wherein the component is a compressor disc, a turbine disc, a compressor cone or a turbine cover plate.

10 **17.** A method as claimed in any of claims 1 to 16 wherein the component comprises a nickel base superalloy or a titanium base alloy.

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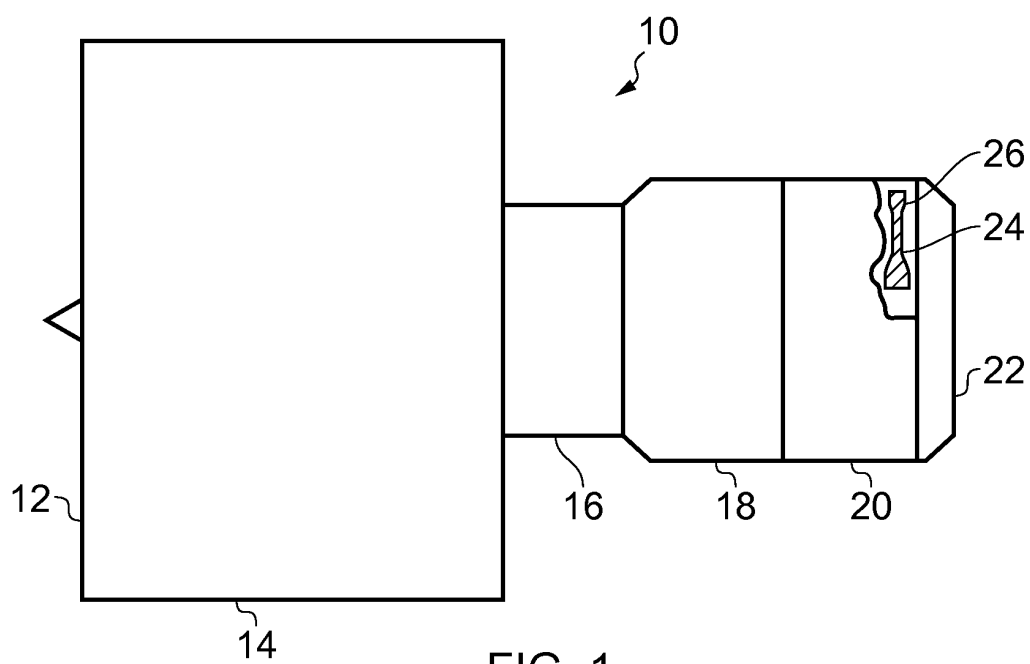


FIG. 1

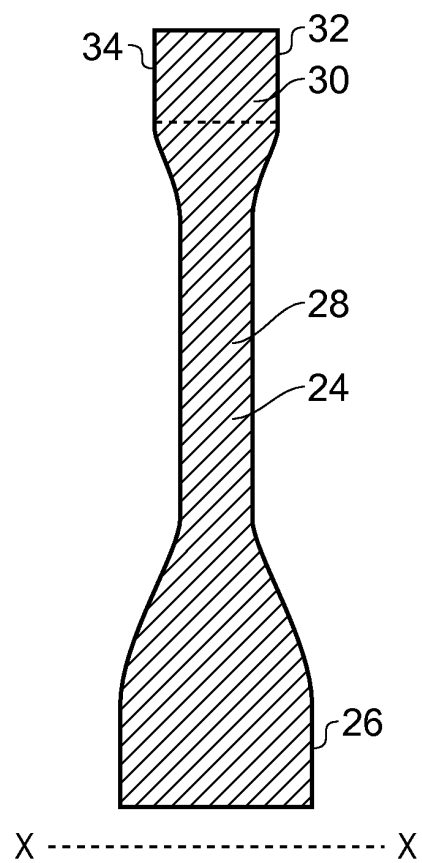


FIG. 2

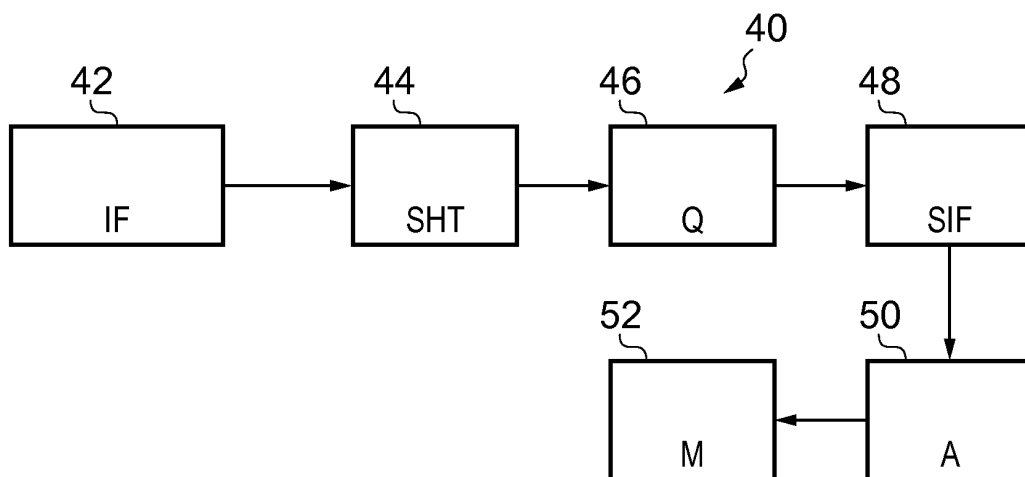


FIG. 3

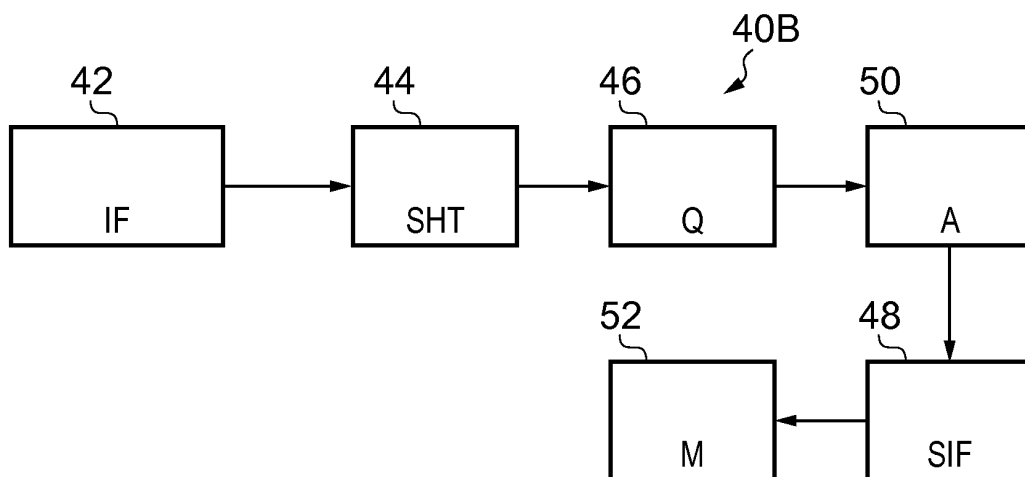


FIG. 4

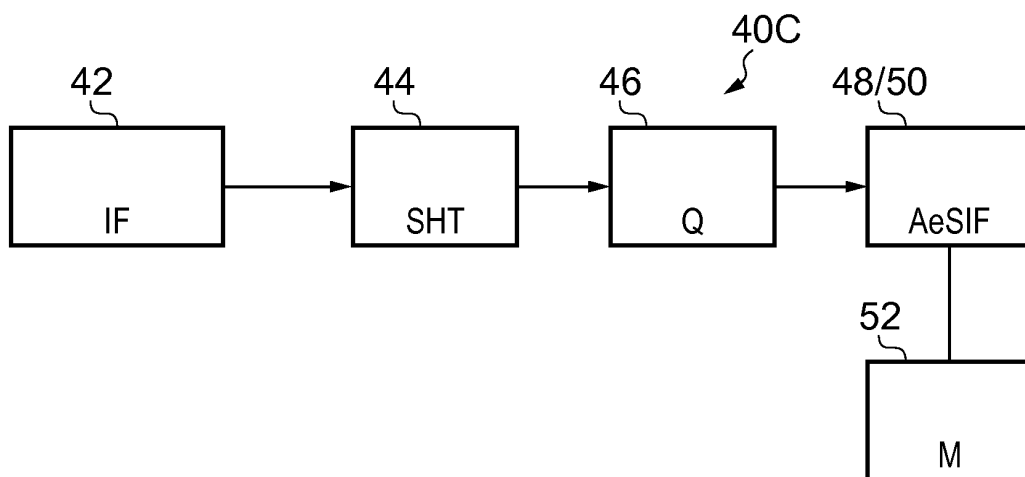


FIG. 5

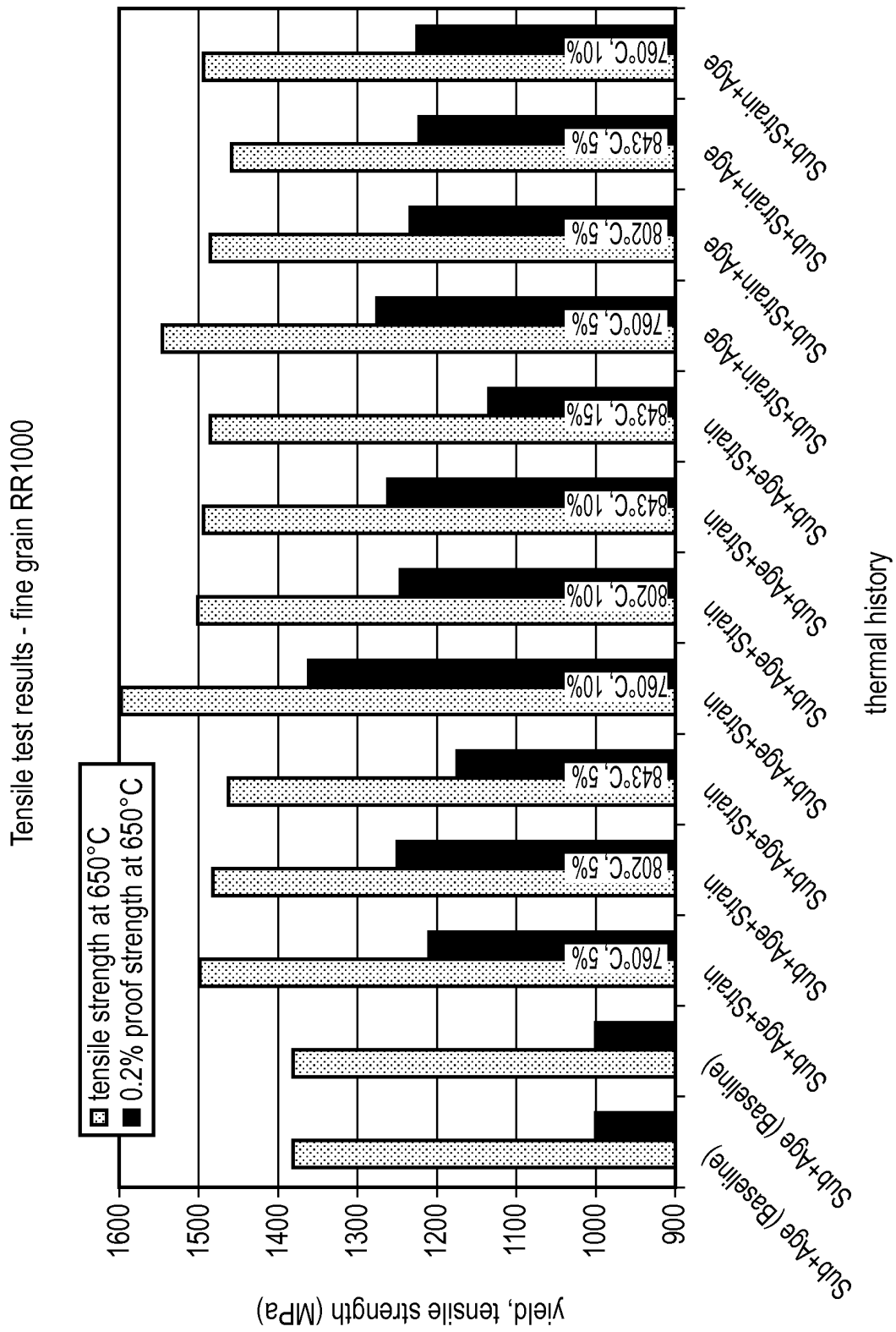


FIG. 6

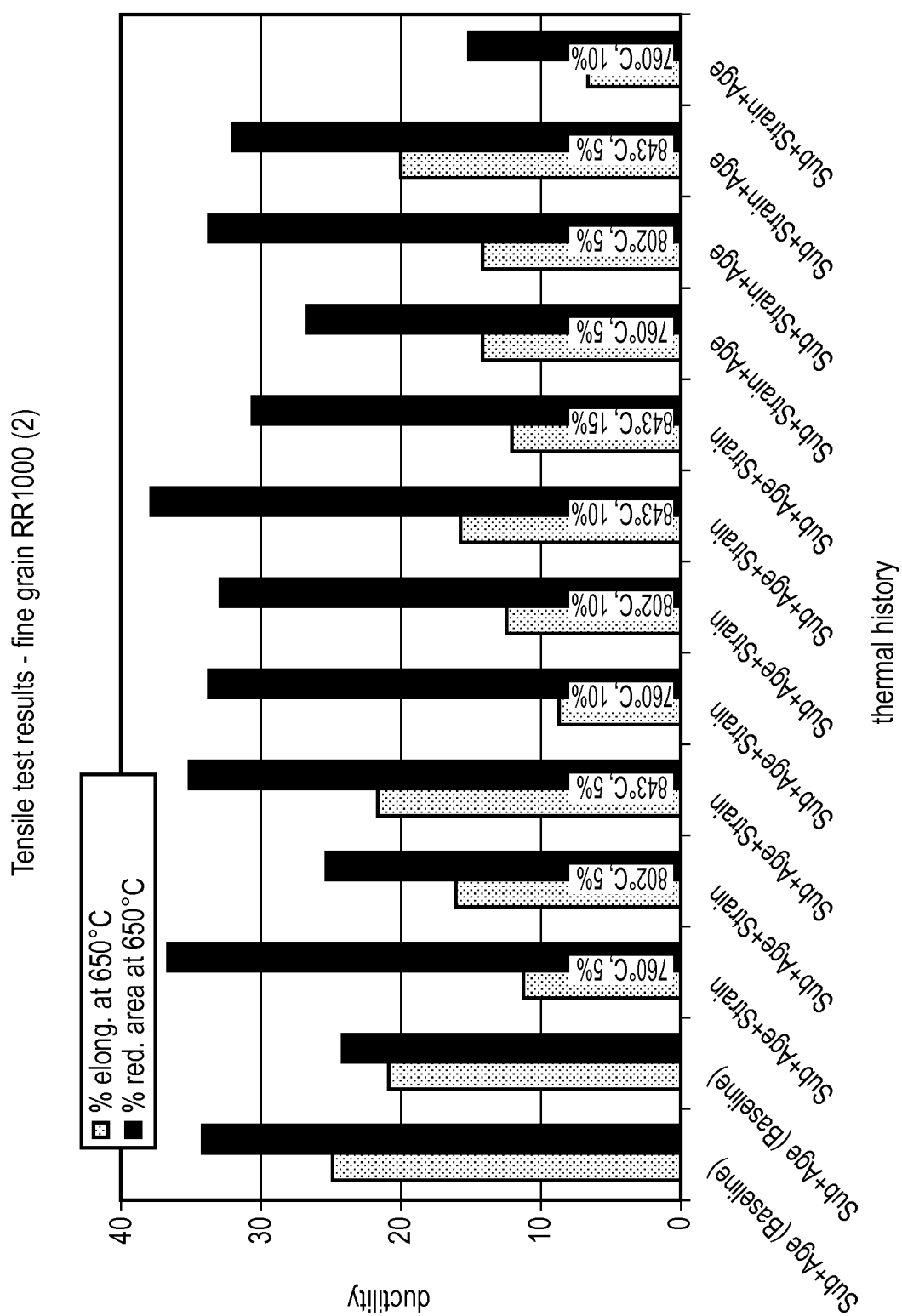
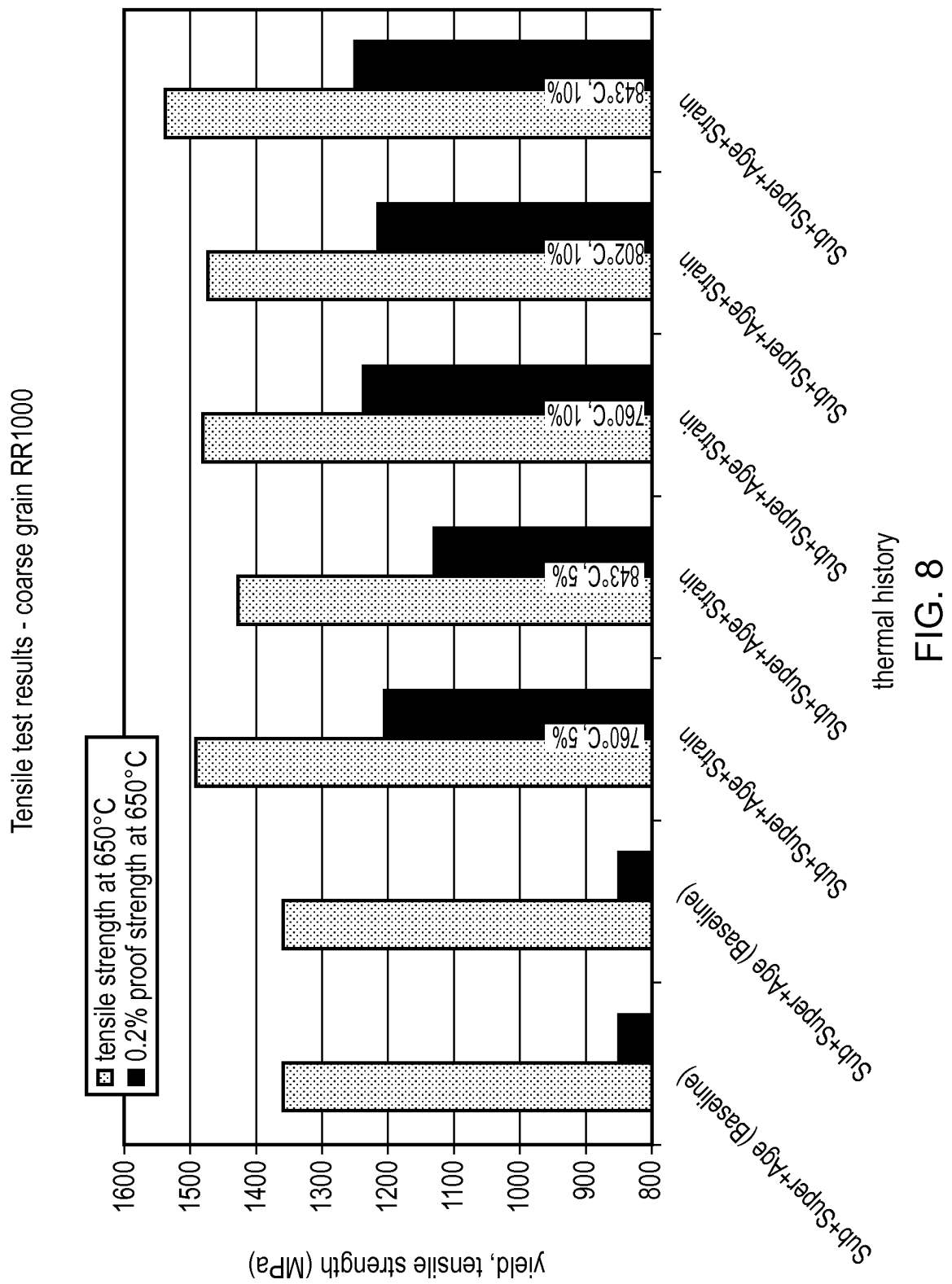


FIG. 7



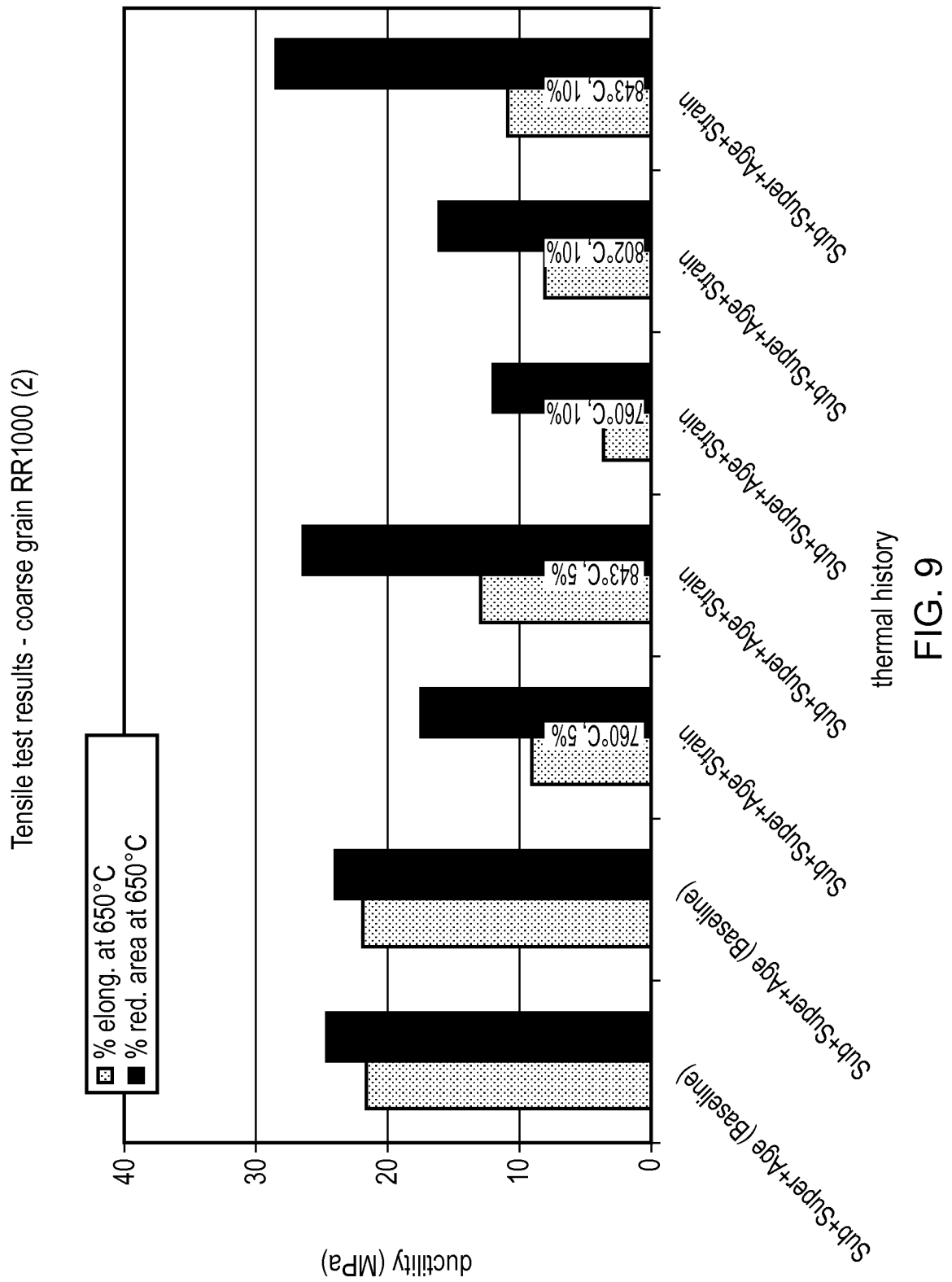


FIG. 10A

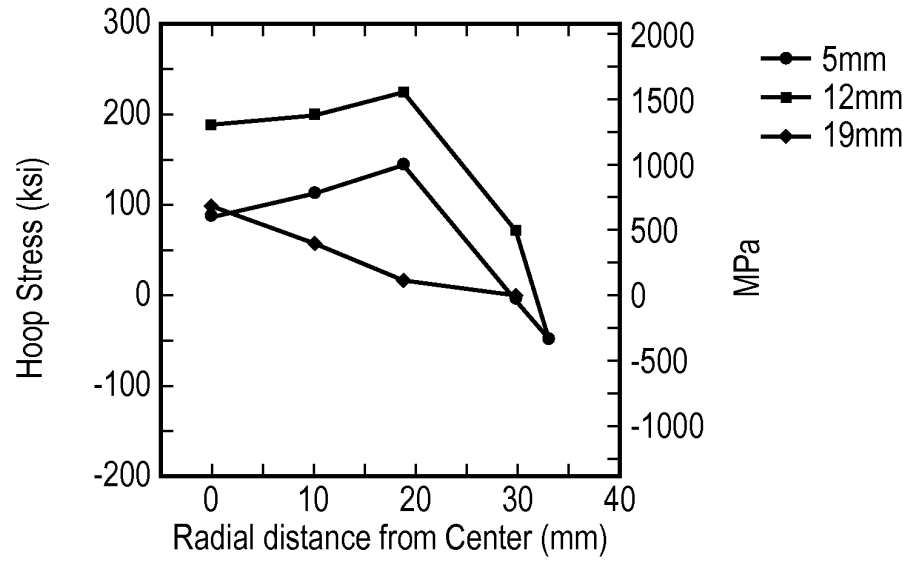


FIG. 10B

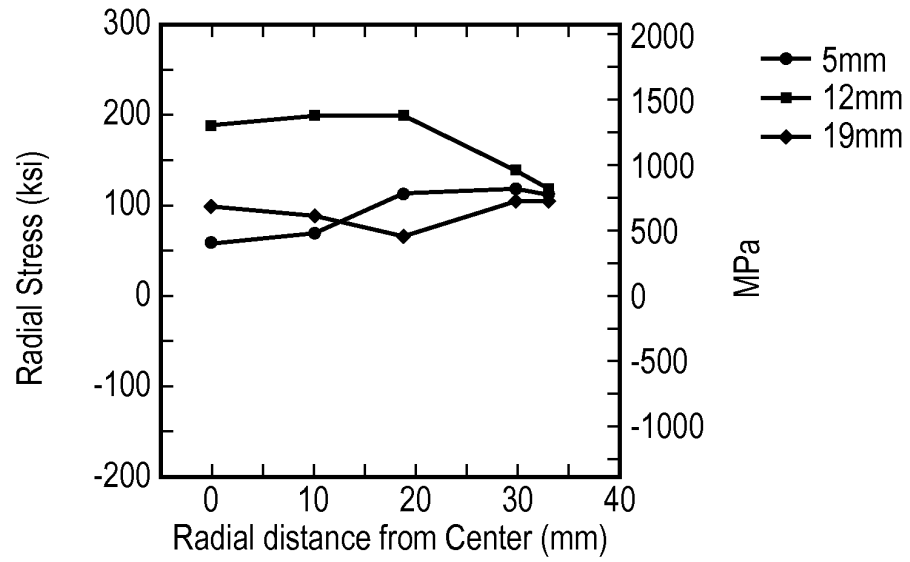


FIG. 10C

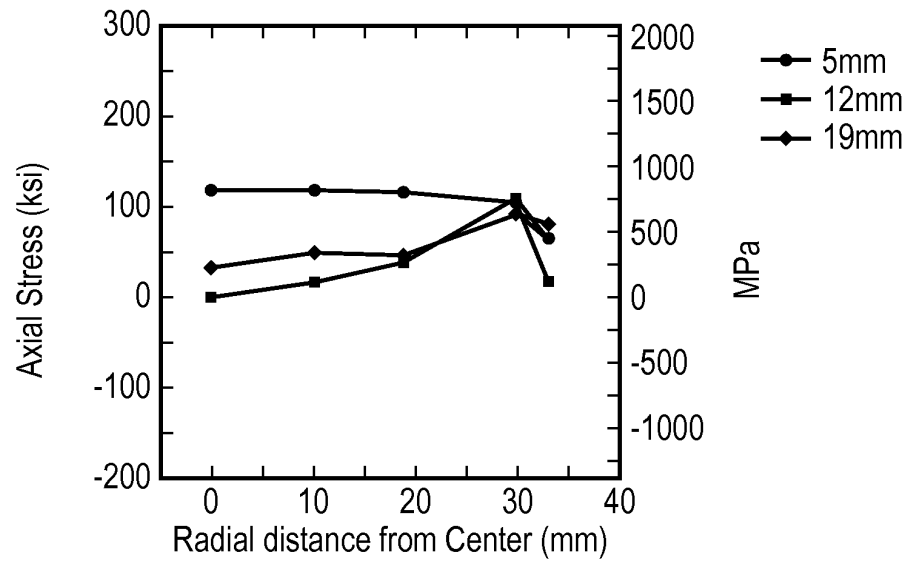


FIG. 11A

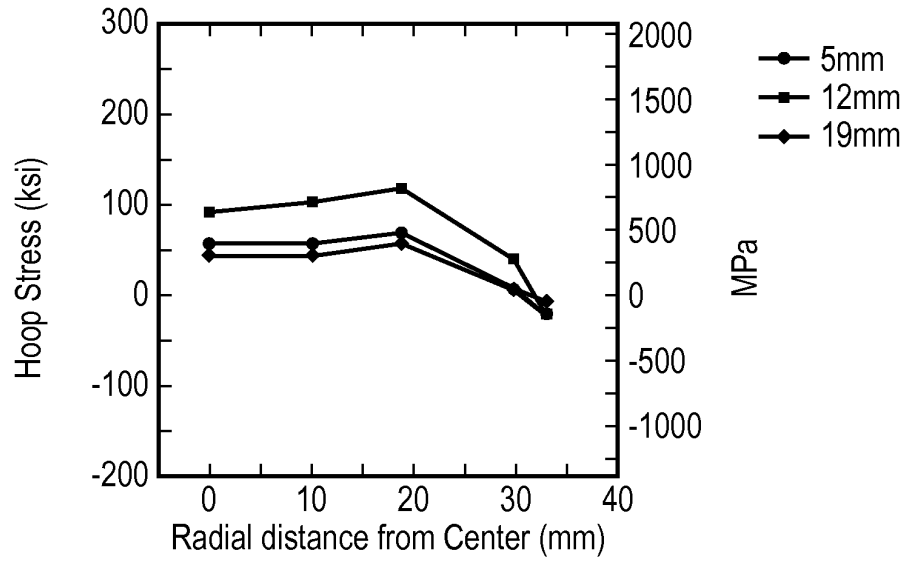


FIG. 11B

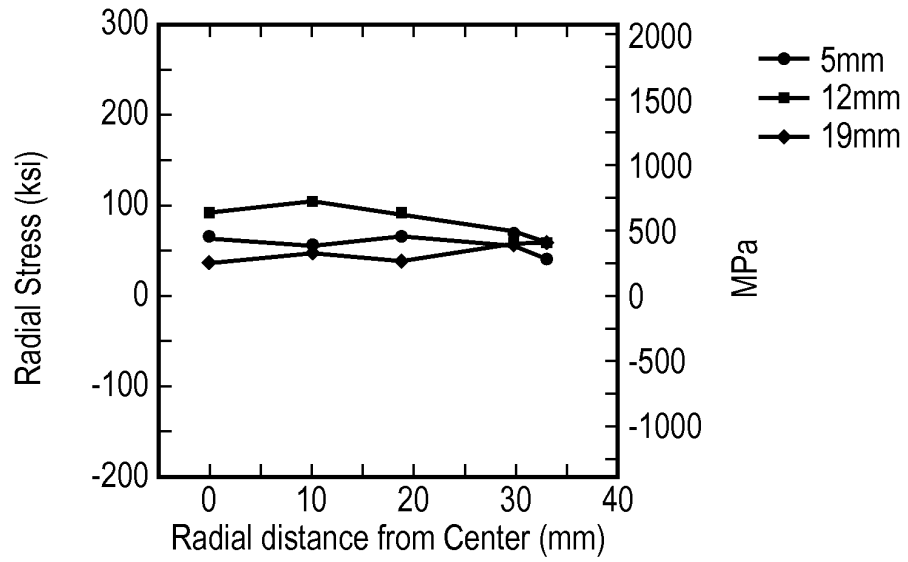


FIG. 11C

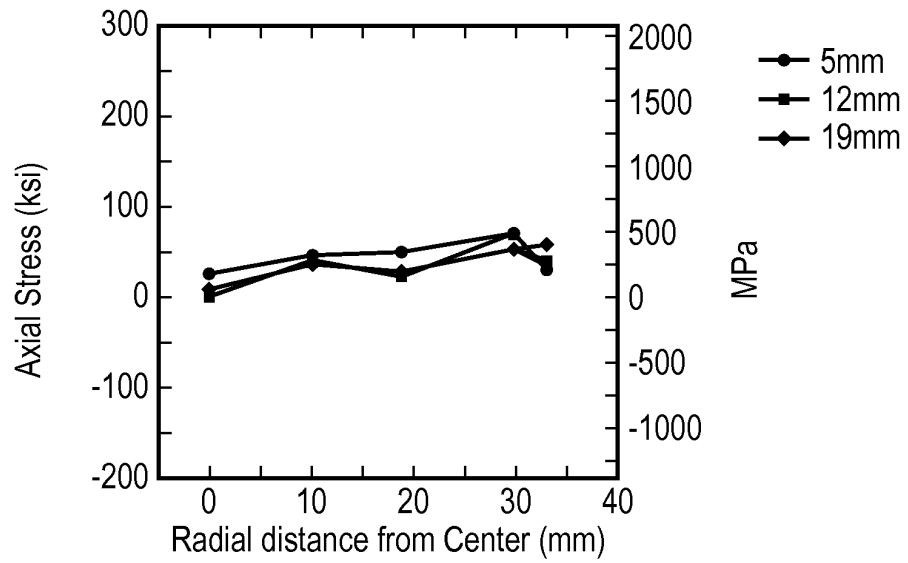


FIG. 12A

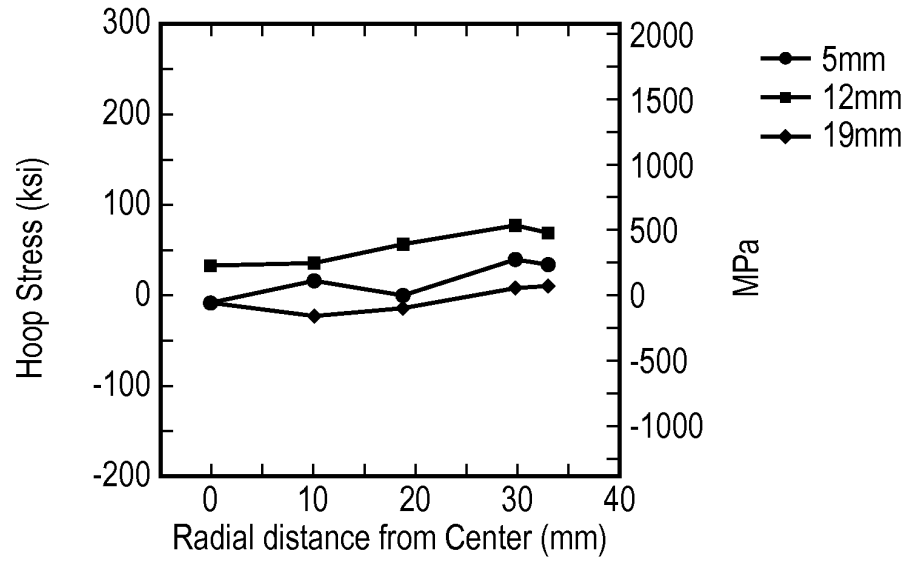


FIG. 12B

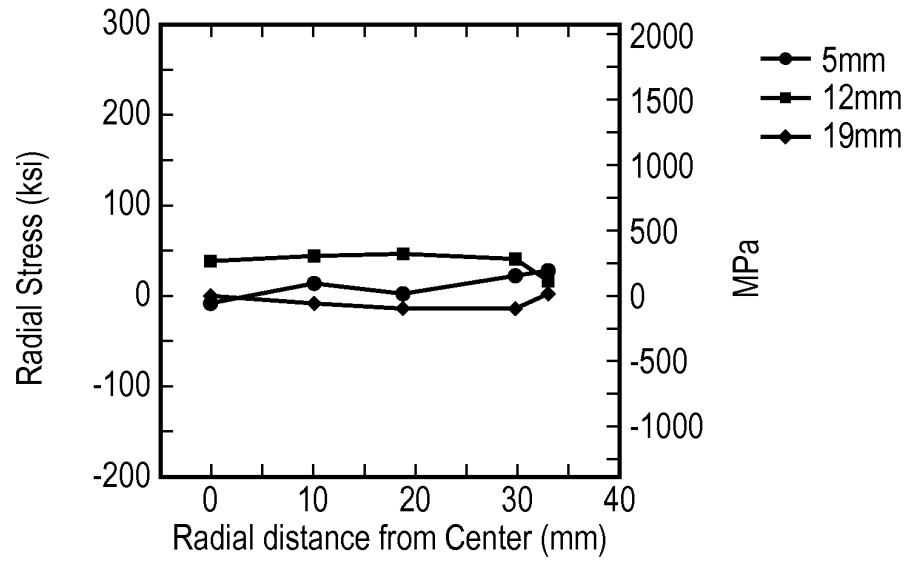


FIG. 12C

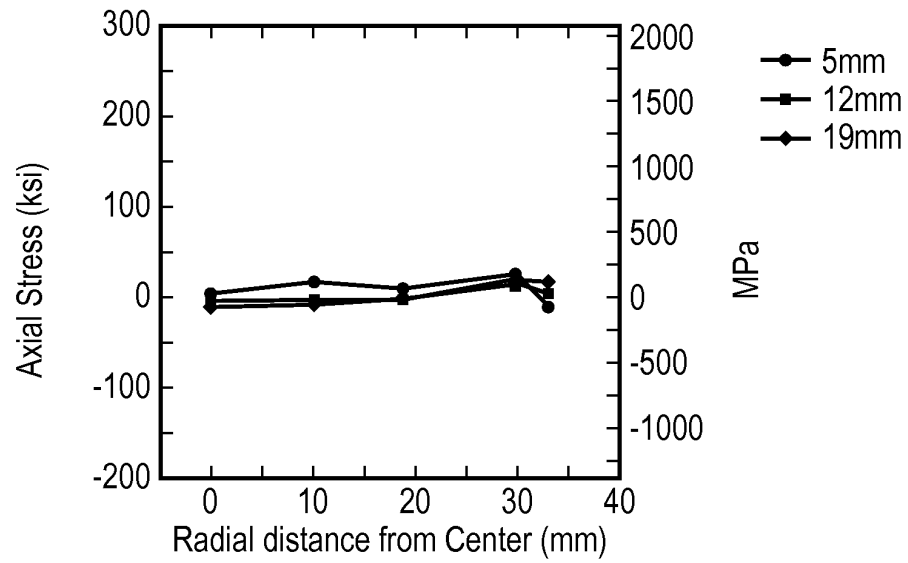


FIG. 13A

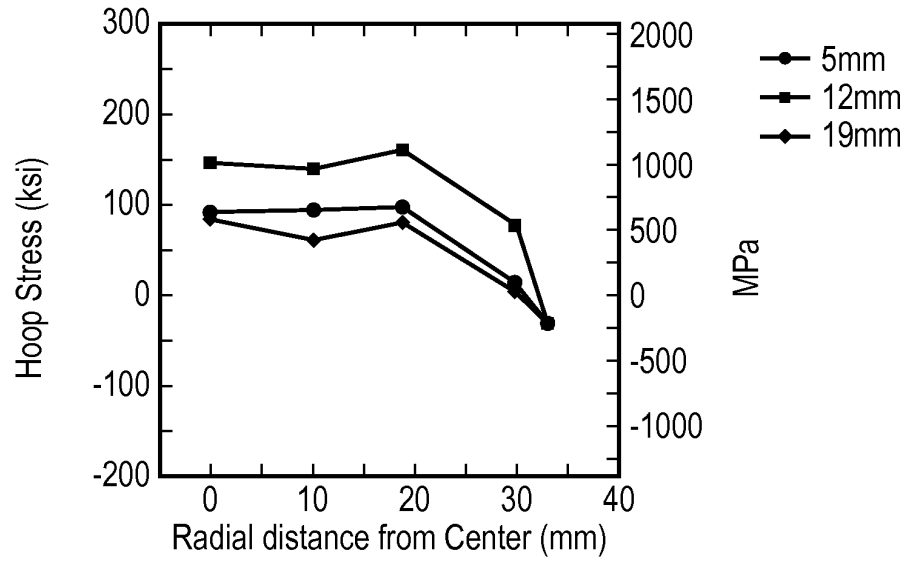


FIG. 13B

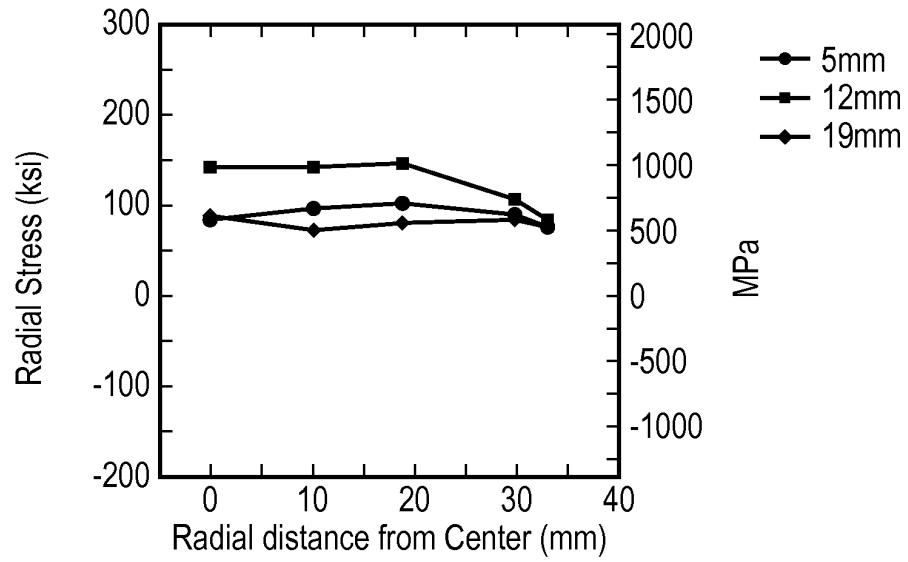


FIG. 13C

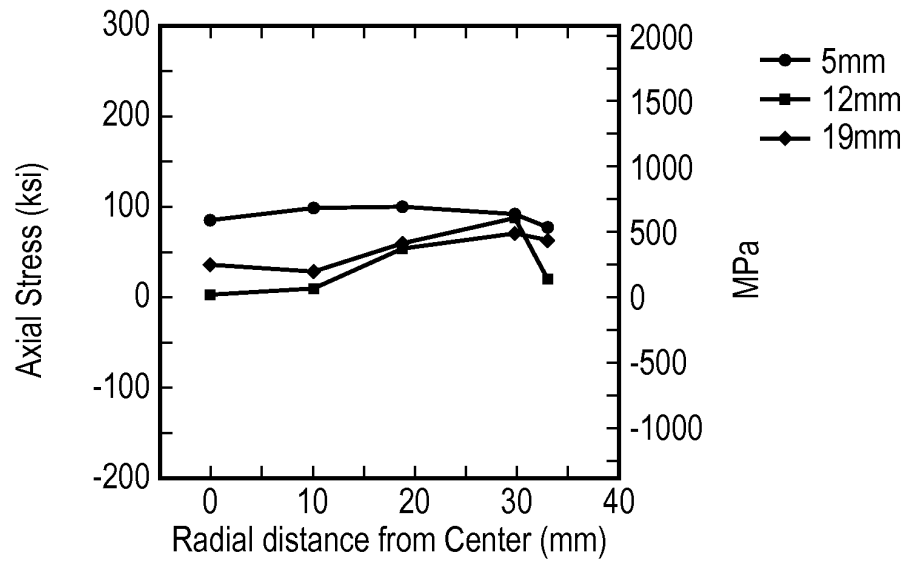


FIG. 14A

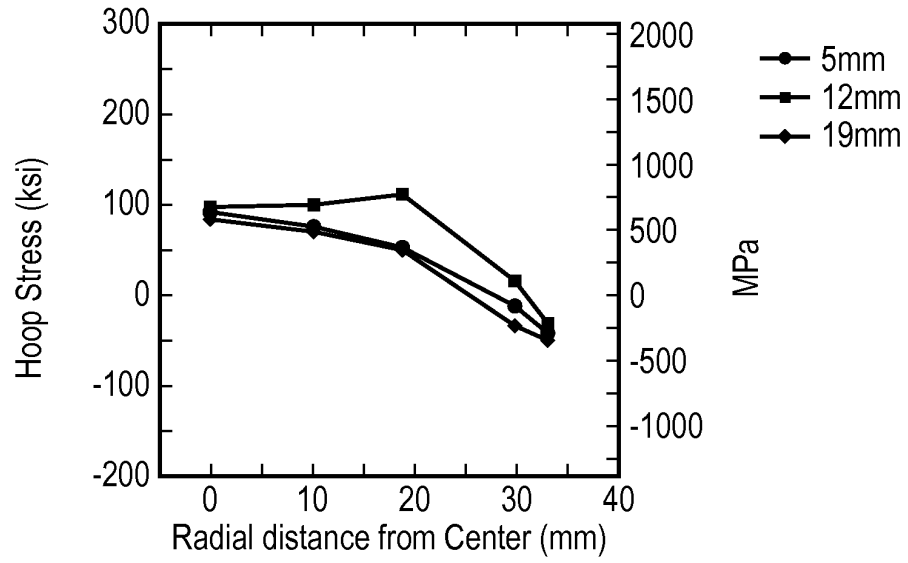


FIG. 14B

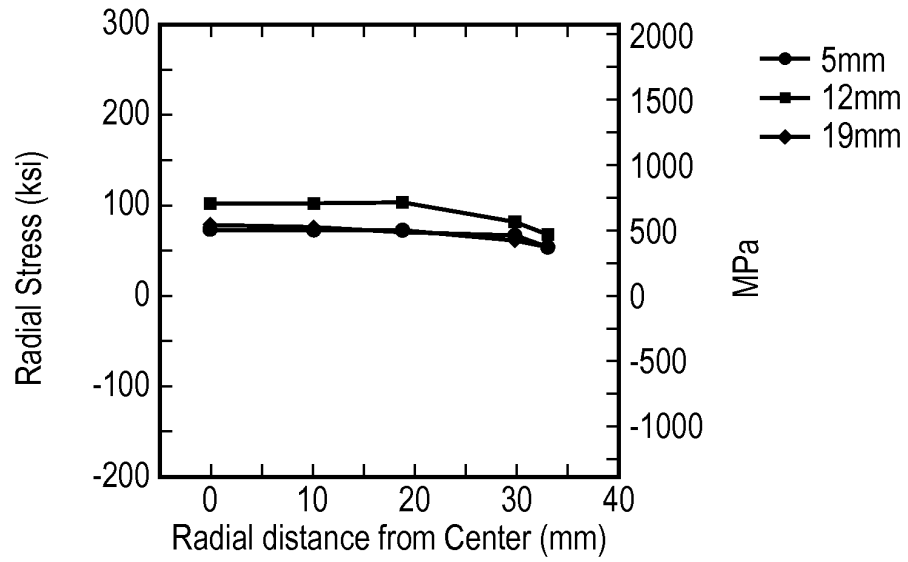


FIG. 14C

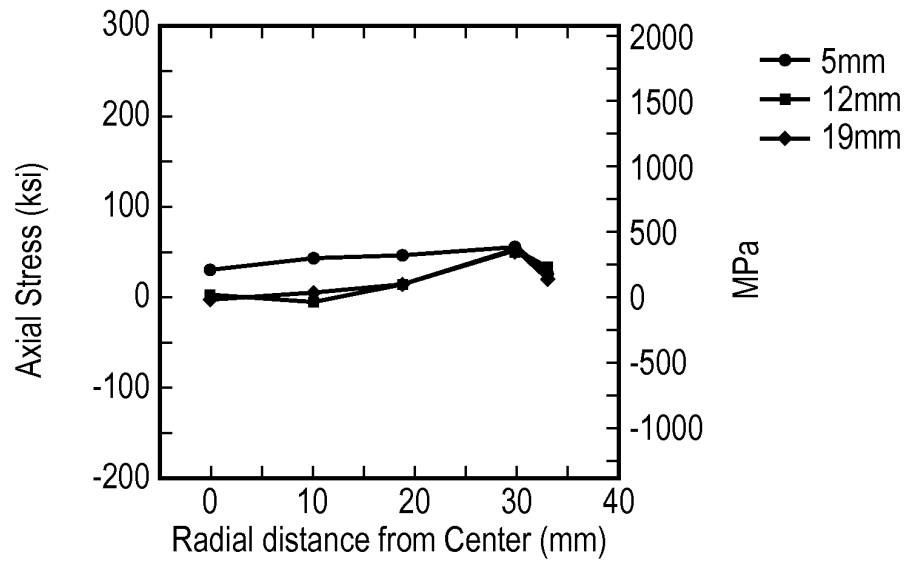


FIG. 15A

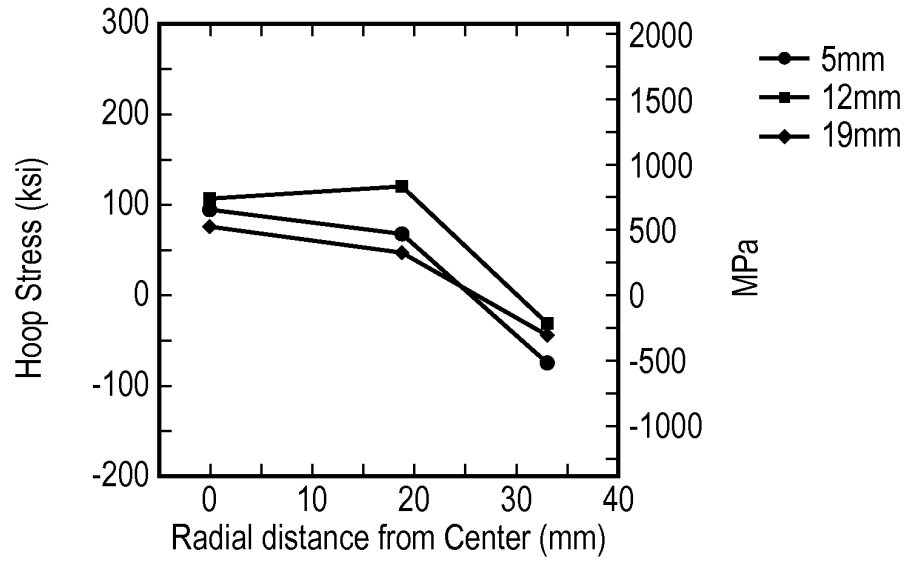


FIG. 15B

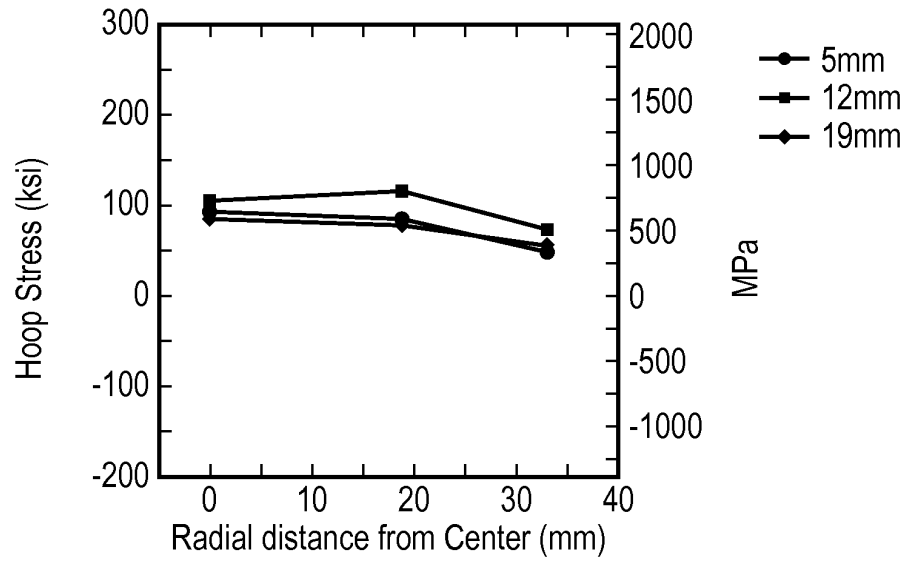
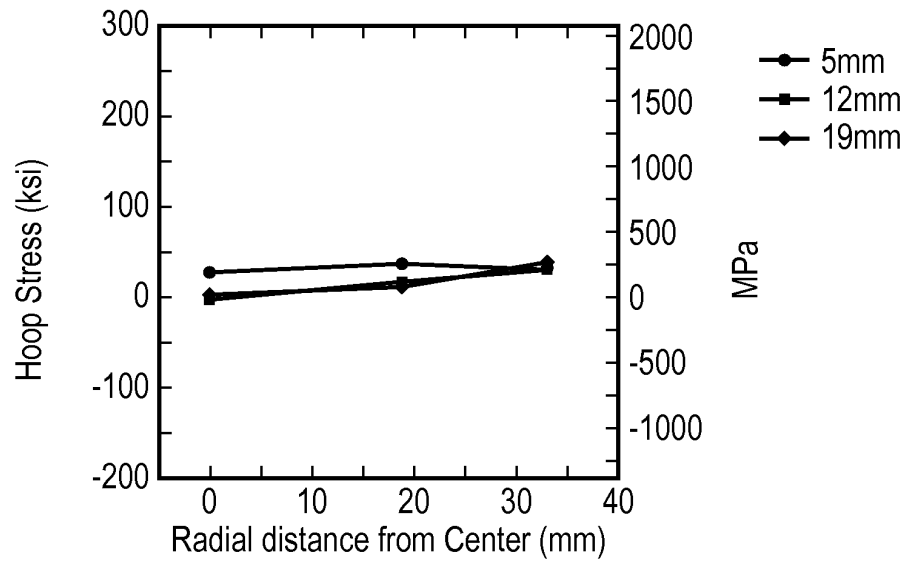


FIG. 15C





EUROPEAN SEARCH REPORT

Application Number
EP 11 17 0184

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The present search report has been drawn up for all claims			
Place of search The Hague		Date of completion of the search 23 November 2011	Examiner Chebeleu, Alice
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	

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The members are as contained in the European Patent Office EDP file on
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