alpha phase precipitates. However, in beta titanium alloys, the continuous grain boundary alpha phases, non-uniform alpha precipitation, and the relatively large beta grain sizes persist as problems hampering the improvement of mechanical properties of beta titanium alloys. Particularly if a high strength state is attained, the ductility and fatigue properties of the alloys usually tend to be compromised.

[005] Earlier work detailed in references [1] to [5] listed later herein found that minor addition of carbon to beta titanium alloys can eliminate grain boundary alpha phases, accelerate and refine alpha precipitation and refine beta grain size. These changes were found to result in significant increases in ductility and fatigue properties of the alloys, without resulting in a loss of high strength levels. The beta titanium alloys studied include burning-resistant titanium alloy Ti-35V-15Cr-0.3Si-0.1C, Ti-15-3-3 alloy (a shortened designation for Ti-15V-3Cr-3Al-3Sn) and Ti-13Cr alloy. However, this work did not extend to Beta-C titanium alloy over which the present invention seeks to provide an improved heat treatable composition enabling attainment of enhanced physical properties, specifically enhanced levels of UTS and, where relevant, DSS and fatigue strength in threaded regions.

General Description of the Invention

[006] The present invention provides a meta-stable β titanium alloy that, apart from carbon content, typically corresponds to the composition range for standard Beta-C titanium alloy and, for ease of description, the meta-stable β alloy of the invention is herein distinguished as "modified alloy". Since its development about 50 years ago by RMI Titanium Company, standard Beta-C has found important use where very high strength is required, such as fasteners and components of landing equipment for aircraft.

[007] As with standard Beta-C titanium alloy, the modified alloy of the invention has 7.5 to 8.5 wt.% vanadium, 5.5 to 6.5 wt.% chromium, 3.5 to 4.5 wt.% molybdenum, 3.5 to 4.5 wt.% zirconium, 3 to 4 wt.% aluminium, oxygen up to 0.14 wt.%, a maximum of 0.3 wt.% iron, nitrogen up to 0.03 wt.%, hydrogen up to 0.03 wt.%, a maximum of 50 ppm yttrium, a maximum of other elements ~~(apart from carbon and titanium)~~comprising incidental impurities of 0.15 wt.% each and 0.40 wt.% in

aggregate in excess of 0.05 wt.% up to 0.1 wt.%, with a balance (apart from carbon) of titanium. In the standard Beta-C titanium alloy, carbon is not to exceed 0.05 wt.% and this usually is regarded as meaning less than 0.05 wt.% carbon, and typically as less than 0.02 wt.% carbon. Indeed, there is no minimum requirement for carbon in Beta-C alloy, making clear that in fact carbon is present only as an undesirable impurity that is difficult to avoid. In the modified alloy of the invention carbon is to be at a stable level above in excess of 0.05 wt.%. Also, in further contrast, the present invention allows for or typically requires an intentional addition of carbon beyond the exclusion of "less than 0.05 wt.% carbon", with reference to "total carbon" in relation to the present invention designating the combined value of such residual value carbon, plus the added carbon.

[008] In the modified alloy of the invention, the total carbon is to be sufficiently in excess of 0.05 wt.% as to achieve the required improvement in the mechanical properties of UTS, DSS and threaded fatigue strength or limit. However, the maximum total carbon content is to be controlled so as to preclude carbide formation having a detrimental effect on the level of fatigue strength. As a practical matter, the requirement for a carbon content not exceeding 0.05 wt.% in the standard Beta-C titanium alloy precludes carbon being added, other than incidentally being present in the constituents of which the standard alloy is produced. In contrast, the modified alloy of the invention usually requires an intended addition of carbon, particularly if the modified alloy is to be produced from a quantity of melted standard beta-C alloy. As indicated, total carbon is to be present at a level in excess of 0.05 wt.%, although an acceptable level is such that the total carbon does not exceed a maximum at which carbides can form and have a deleterious effect.

[009] In seeking a stable total carbon content providing the required improvement of the mechanical properties of UTS, DSS and fatigue strength in threaded regions, while avoiding carbides forming and having a detrimental effect on the level of fatigue strength, it is found that the acceptable upper limit for total carbon can vary with the specific overall alloy composition within the lower and upper limits of the ranges for vanadium, chromium, molybdenum, zirconium, aluminium and, hence, titanium indicated for the alloy of the invention. Also, the required mechanical

properties of UTS, DSS and fatigue strength in threaded regions are attained by an appropriate heat treatment regime. Additionally, the propensity for a given alloy within the limits of those ranges to accommodate a given upper limit for total carbon varies from one composition to another. That propensity varies not only with alloy composition, but also with the specific heat treatment and, in particular, with variation in the rate of cooling from a sufficiently elevated temperature. Allowing for these factors, it is found that the carbon can be added to a stable total carbon content of about 0.2 wt.% Total carbon in excess of 0.2 wt.%, increasingly~~such as to about 0.25 wt.%. Carbon in excess of 0.25 wt.%~~ tends to result in the formation of carbides under all cooling conditions following heat treatment for all compositions, at least in the case of precipitation hardening of the β phase enabled by heating providing solution treatment above the respective beta transus temperature for each alloy. Thus, in general, it is appropriate~~necessary~~ not to exceed 0.2 ~~0.25~~ wt.% total carbon ~~in total~~ in order to comply with the small window for the carbon addition and limit the formation of carbides having a detrimental effect on the level of fatigue strength.

[010] As indicated, it generally is required that the total carbon content does not exceed 0.2~~0.25~~ wt.%, to avoid carbides forming at least to an extent having a detrimental effect on the level of fatigue strength of the alloy. However, the total carbon content preferably does not exceed 0.2 wt.% in total for all alloy compositions within the lower and upper limits of the ranges for vanadium, chromium, molybdenum, zirconium, aluminium and, hence, titanium indicated for the alloy of the invention. The total carbon content also needs to be sufficiently above 0.05 wt.% in order to achieve the required improvement in the mechanical properties of UTS, DSS and fatigue strength in threaded regions. The total carbon level above 0.05 wt.% varies to an extent with alloy composition and, to allow sufficiently for this, the total carbon content generally is required to be from about 0.065 wt.% to about 0.2~~0.25~~ wt.% and preferably from about 0.07~~0.70~~ wt.% to about 0.20 wt.%. More preferably the total carbon content, for all alloys of the invention, is from about 0.07~~0.70~~ wt.% to about 0.15 wt.%, such as from about 0.07 wt.% to about 0.1~~0.010~~ wt%, and most preferably about 0.08 wt.%. The possible stable carbon content in the