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The formation and control of Laves phase in superalloy 718 welds

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Weld heat input/cooling rate (affected by welding process, parameters, technique, tooling, etc.) was found to influence the microstructural characteristics and segregational features in alloy 718 welds, with low heat inputs proving beneficial. Laves phase formed in the interdendritic regions of the weld metals as a result of segregation. The morphology and composition of Laves phase depended strongly on heat input/cooling rate and influenced its response to subsequent homogenization post-weld heat treatment. The various factors affecting the formation and control of Laves phase in alloy 718 welds are highlighted.

1. Introduction

Superalloy 718 (referred to subsequently as 718) is a precipitation-strengthened nickel-base alloy and is one of the "work-horse" materials being extensively used for critical aero-engine and space applications for high-temperature creep-resistant applications up to 650 °C. The alloy is also used for some cryogenic applications. Electron beam welding (EBW) and gas tungsten arc welding (GTAW) are the two important fusion joining processes used for fabrication of these aerospace assemblies in 718.

Segregation is a common problem in solidified structures like castings and welds. It causes chemical inhomogeneity in the structure and hence is detrimental to the mechanical properties [1, 2]. Data available with regard to segregational aspects of 718 pertains mostly to cast materials [3–8]. Although both the castings and weld metals are solidified structures, they differ in their mode of solidification, thermal cycles experienced and the extent of segregation. They also differ in the actual process of solidification, in that the casting process requires heterogeneous nucleation for solidification to initiate, while this condition is not required for welding. Hence the studies available on castings on the aspects of solidification and subsequent segregation cannot be directly applied to welds. The non-equilibrium thermal cycles experienced during welding also make their direct comparison difficult. This necessitates a separate study for welds. Further, in welding, there are different processes like GTAW, EBW, etc., which differ in their weld heat input/cooling rate, etc. As segregation is basically controlled by weld cooling rates, the EB and GTA welds, with their differing thermal characteristics, may also differ in the extent of segregation.

Data available on the aspects of segregation and its detrimental effects in 718 welds in general is very scarce, and there are no studies comparing the GTA and EB welds of 718. Laves phase, which forms as a result of segregation, is an important aspect of 718 welds for aerospace applications, because it affects structural integrity and can lead to premature failure of critical components during service, resulting in loss of human life and money [2]. Therefore, any attempt to reduce the segregation in welds will be highly advantageous. The present work is pursued in this direction and the paper reports various factors that affect the formation and control of Laves phase as a result of segregation in 718 welds, keeping the aerospace applications in view.

2. Experimental procedure

Sheets, 2 mm thick, of superalloy 718 in solution-treated condition, with a nominal chemical composition (wt%)) C 0.04, Cr 18.4, Ni 54.0, Mo 2.9, Ti 0.98, Al 0.45, Nb 5.1, Fe balance, were automatic GTA and EB welded autogenously using the bead-on-run technique. The weld process parameters used are listed in Table I and these resulted in welds with different heat inputs. EB welding was also performed using a circular oscillating beam. The weld samples were subjected to various post-weld heat treatments (PWHTs), namely, (a) as-welded + directly aged at 720 °C/8 h/FC to 620 °C/8 h/AC, (b) as-welded + solution treated at 980 °C/20 min/AC followed by ageing, and (c) as-welded + solution treated at 1090 °C/20 min/FC to 700 °C/AC followed by ageing, AC indicating air cool and FC furnace cool. The as-welded and heat-treated samples were characterized for their microstructural and segregational aspects using optical, scanning electron microscopy (SEM) and quantitative electron probe microanalysis (EPMA).

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TABLE I Details of GTA and EB weld process parameters

Process details	GTAW	EBW
Heat Input	0.6 kJ mm^{-1}	0.05 kJ mm^{-1}
Voltage	20 V	120 kV
Current	100 A	9 mA
Speed	20 cm min^{-1}	150 cm min^{-1}
Shielding	99.99% argon	10^{-5} Torr vacuum[a]
Working distance	2 mm (stand-off)	40 cm (gun-to-work)

3. Results

3.1. Microstructures

The optical microstructure of the as-received base metal solution treated at 980 °C showed typical wrought austenitic matrix with a grain size of ASTM 6. The scanning electron micrograph (Fig. 1) of the same sample revealed the presence of discrete needle-like delta phase and randomly distributed niobium-rich MC-type primary carbide particles (Nb 90%, Ti 6% and C 2.6%). The grain size of the base metal increased to ASTM 2 when solution treated at relatively higher temperature of 1090 °C.

The GTA as-weld metals showed a well-defined dendritic structure with coarser arm spacings and interdendritic regions decorated with a continuous network of bright structure which was identified as Laves phase by microprobe analysis (Fig. 2a). The continuous network of Laves phase in the interdendritic regions present in the as-welded condition is seen to form globules after solution treatment at 980 °C (Fig. 2b). Further, the emergence of needle-like structure was noticed which was found next to the Laves phase, indicating that it had precipitated out from the existing Laves phase after solution treatment. The stringer bead EB as-weld metals have shown a fine dendritic structure with randomly distributed discrete Laves phase particles in the interdendritic regions. The microstructure of circular oscillating beam EB as-weld metal revealed fragmented dendritic structure due to the churning effect of the oscillating beam during weld solidification (Fig. 3a). The microstructure of the stringer bead EB weld metals solution treated at 980 °C showed sparsely distributed Laves phase (Fig. 3b).

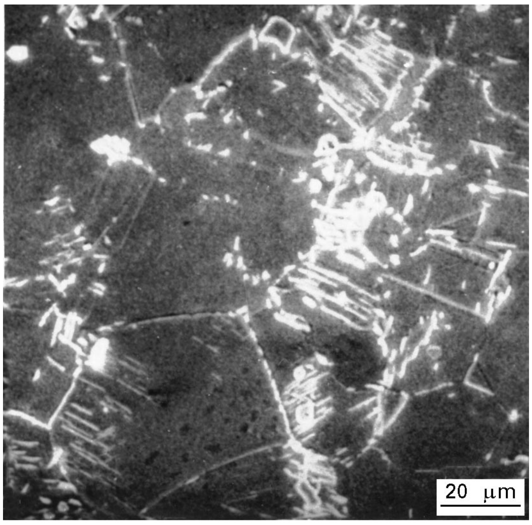

Figure 1 Scanning electron micrograph of the base metal in the solution-treated condition.

3.2. Microprobe analysis results

In order to ascertain the nature of segregation and thereby determine the formation of Laves phase during weld solidification, quantitative elemental distribution in the interdendritic and dendritic regions of the weld metals using scanning electron probe microanalysis (EPMA) was carried out, the results of which are presented below.

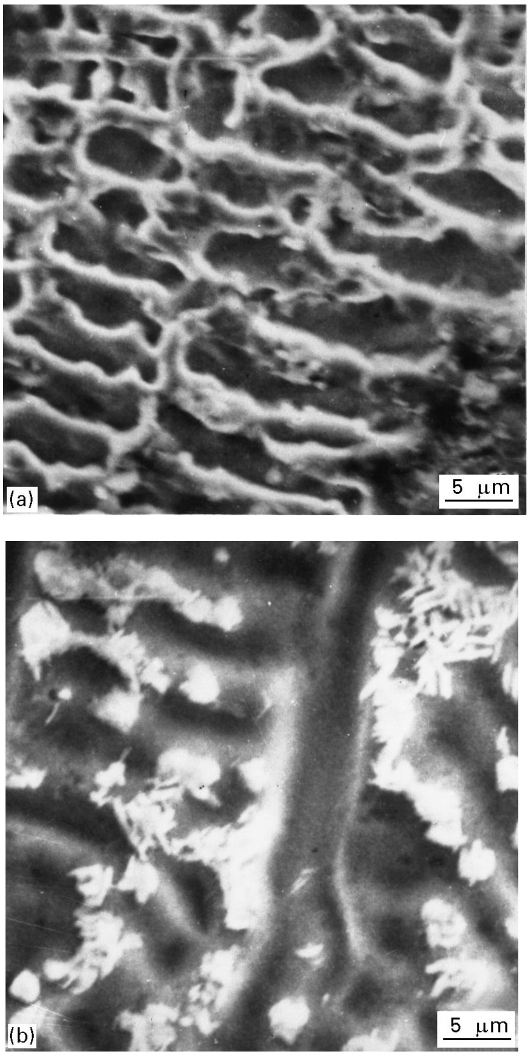

Figure 2 Scanning electron micrographs of the GTA weld metal: (a) as-welded condition, (b) solution-treated (980 °C) condition.

3.2.1. The GTA weld metals

The quantitative values of major elements in various regions of the GTA weldments obtained by microprobe analysis are given in Table II. The niobium content in various regions of the GTA weldments in as-welded and solution-treated (both at 980 and 1090 °C) conditions, is shown in the form of bar chart in Fig. 4. The back-scattered electron (BSE) images and corresponding niobium X-ray mappings of the

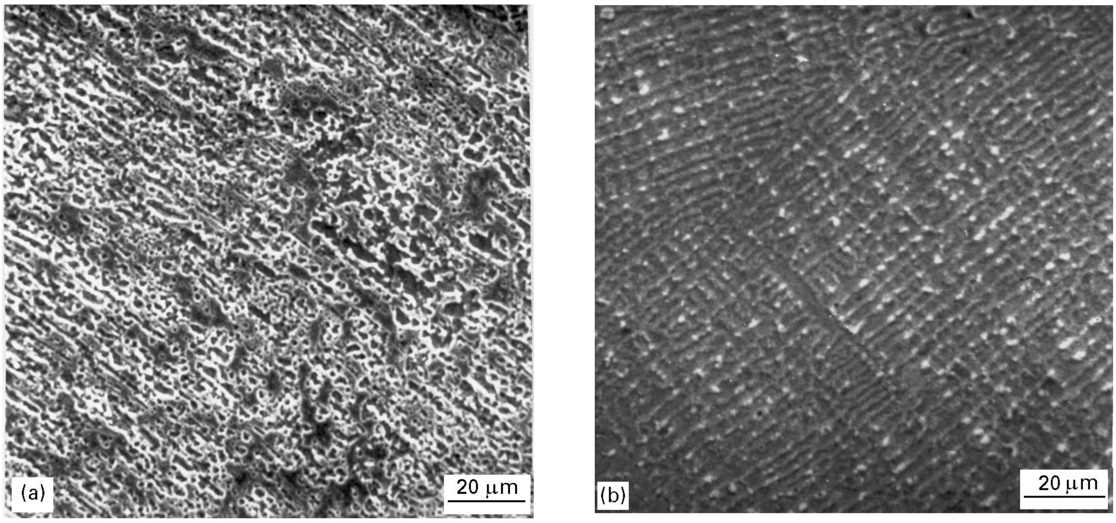

Figure 3 Scanning electron micrographs of the EB weld metals: (a) as-welded (oscillation), (b) solution-treated (980 °C) condition.

TABLE II Microprobe analysis results of the GTA welds

Sample history	Region	Major elements (wt %)					
		Ti	Nb	Ni	Cr	Fe	Mo
Base metal	Matrix	0.85	5.17	52.82	17.89	19.62	2.54
As-weld	Interdendritic	1.426	21.714	45.883	14.298	14.235	3.832
metal	Dendritic core	0.563	2.091	53.609	18.843	20.933	2.270
Solution treated	Interdendritic	1.194	20.710	43.704	15.105	14.686	2.755
(980 °C) weld	Dendritic core	0.624	2.530	53.689	19.206	21.156	2.342
Solution treated	Interdendritic	0.895	4.720	54.068	18.613	19.214	2.638
(1090 °C) weld	Dendritic core	0.807	4.266	51.913	19.345	19.383	2.405

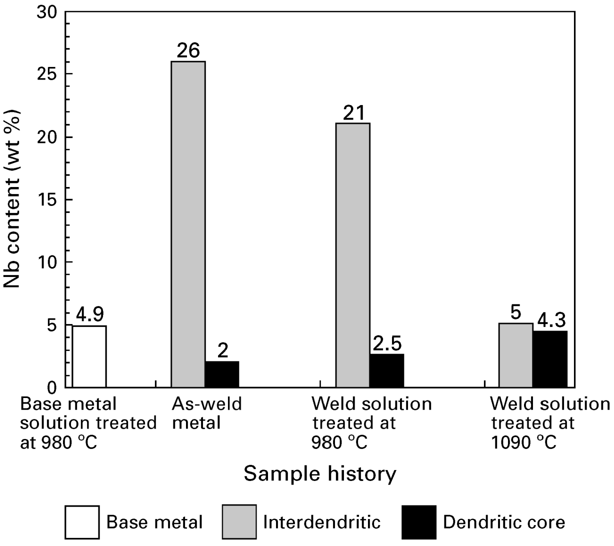

Figure 4 Niobium content in 718 GTA welds.

same, are shown in Fig. 5a–f. The contrast between niobium-rich regions (seen as brighter) and the matrix in BSE images can be clearly seen because of the heavy atomic weight of niobium.

The microprobe analysis results of the GTA as-weld metals have shown that the dendritic core regions of the weld metal are highly depleted of niobium (2%) compared to the base metal (5%). The effective solidification distribution coefficient, *k* value of 0.4 (*k* is the ratio of weight concentration of the element in the weld-metal dendritic core region to that in the base metal) and segregation coefficient (ratio of weight concentration of element in the interdendritic region to that in the dendritic core region, an index of the degree of segregation) value of 12, indicates heavy segregation in the weld metals. This was also reflected in the interdendritic regions of the weld metal where extensive enrichment of niobium to the extent of 20%–26% was observed. A similar trend was observed for molybdenum, silicon and titanium also to a lesser degree, where the enrichment of interdendritic regions was not very extensive, as observed in the case of niobium. While there was an enrichment of niobium, molybdenum, silicon and titanium interdendritic regions of the weld metal, it was depleted of nickel, aluminium, iron and chromium.

Solution treatment of the GTA weld metals at 980 °C did not change the above trend significantly with respect to niobium content, and there was only marginal redistribution of niobium in the dendritic core regions of the weld metal (2.5%). The *k* value of niobium changed from 0.4 in the as-welded condition to 0.5 in the solution-treated condition. The dendritic core regions of the weld metal continued to exhibit significant niobium depletion (2.5% against 5% in the

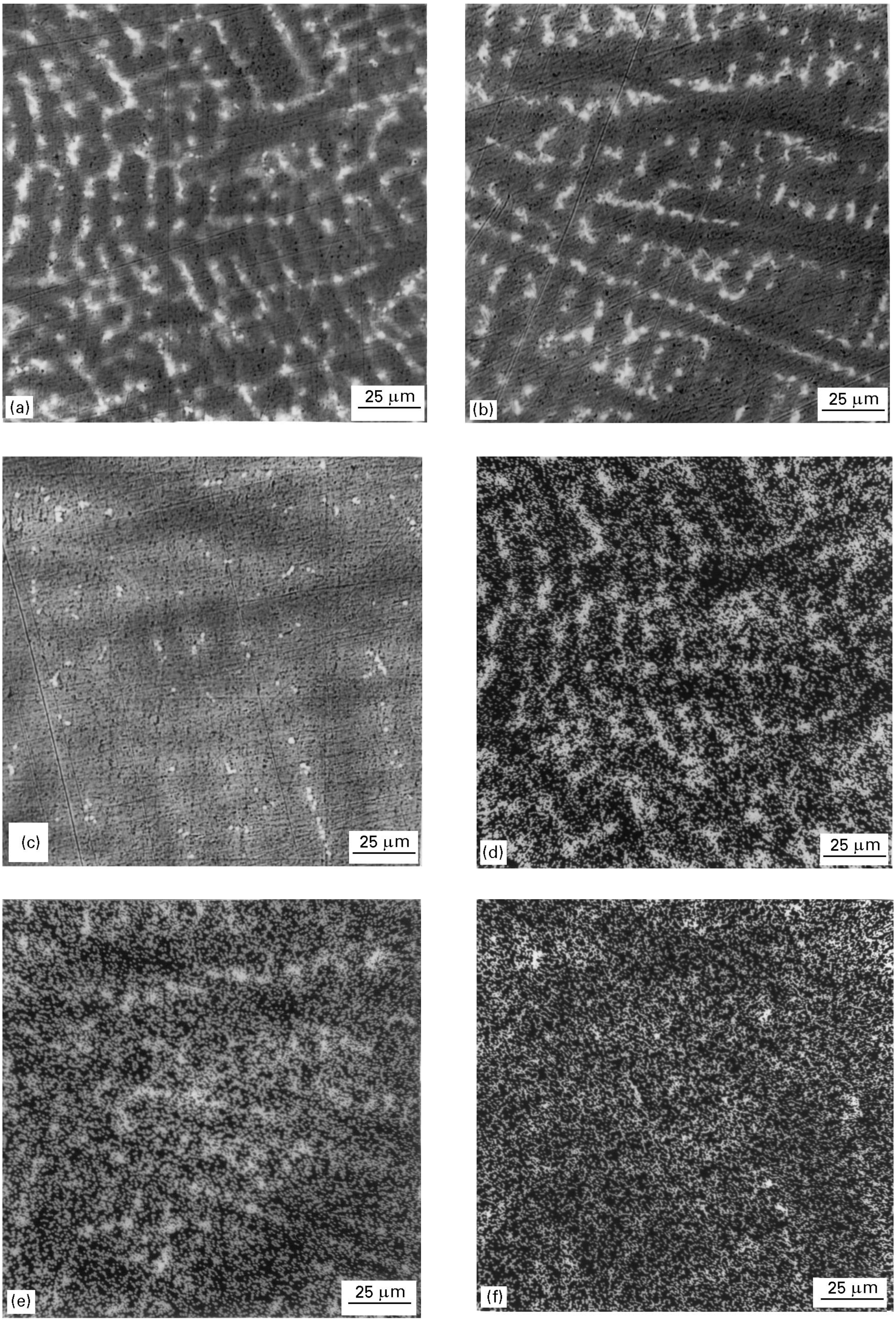

Figure 5 (a–c) Back-scattered electron images and (d–f) niobium X-ray mappings, of the GTA weld metals. (a, d) As-welded, (b, e) solution treated at 980 °C, (c, f) solution treated at 1090 °C.

base metal) and the interdendritic regions continued to exhibit extensive enrichment of niobium even after solution treatment. Although slight enrichment of molybdenum, silicon and titanium was observed in the interdendritic regions, it can be seen that solution treatment evened out the compositional difference of these elements between the base metal and dendritic core regions of the weld metal, by and large. However, iron and chromium continued to exhibit depletion in the interdendritic regions. Solution treatment of the welds at 1090 °C resulted in effective homogenization of the weld structure and, by and large, evened out the compositional difference of all alloying elements in the weld metals.

TABLE III Microprobe analysis results of the EB welds

Sample History	Region	Major elements (wt %)					
		Ti	Nb	Ni	Cr	Fe	Mo
Base metal	Matrix	0.9	4.91	52.71	18.76	19.48	2.45
As-weld metal	Interdendritic	1.266	12.239	50.762	15.57	15.53	3.55
	Dendritic core	0.662	2.486	50.45	19.421	20.94	2.706
Solution-treated (980 °C) weld	Interdendritic	1.28	8.23	51.35	17.501	17.385	2.855
	Dendritic core	0.87	4.51	52.49	19.16	20.343	2.507

3.2.2. The EB weld metals

The quantitative values of elements obtained in various regions of the EB weldments are listed in Table III. It can be observed that the EB as-weld metals also exhibited a similar trend to that of the GTA weld metals, to a relatively lesser degree. The EB as-weld metals responded well to the solution treatment by redistribution of the elements. The uniform composition in the solution-treated weld samples in various regions compared to the as-welded samples, indicates that the usual solution-treatment temperature of 980 °C is sufficient for the EB weld metals (unlike the GTA weld metals) for homogenization of the weld structure.

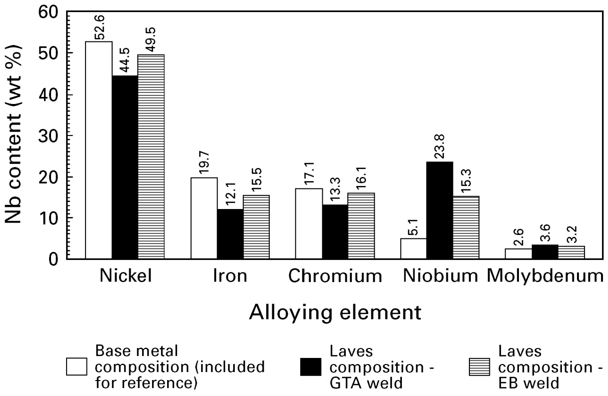

Figure 6 Comparison of Laves composition in 718 GTA and EB welds.

3.3. Identification of phases

In the present study, based on the composition, the niobium-rich areas in the interdendritic regions of the weld metals are identified as Laves phase, which was also confirmed by X-ray diffraction studies. The typical chemical composition of Laves phase formed in the GTA and EB weld metals, as obtained by EPMA, is given in the form of bar chart in Fig. 6. The elemental values of the base-metal composition are also included for comparison. It can be observed that the extent of segregation in the form of Laves phase is more in the GTA welds compared to the EB welds, i.e. the degree of enrichment (niobium, molybdenum, titanium, silicon) and depletion (nickel, aluminium, iron, chromium) of elements with respect to the base-metal composition in the interdendritic regions of the GTA weld metals, is more compared to the EB weld metals.

The needle-like structure that precipitated out from the Laves phase in the GTA weld metals after 980 °C solution treatment has been identified as delta phase from its appearance and microprobe elemental analysis. This is consistent with the literature and similar observations were made by Mills [9, 10] and Lingenfelter [11].

4. Discussion

4.1. The formation of Laves phase in 718 welds

In the case of wrought materials, the ingots prior to thermo-mechanical processing are homogenized at relatively higher temperatures, enough to eliminate the segregation by redistribution of alloying elements and hence segregation is not of major concern. Also, the initial structure is broken-up during thermo-mechanical processing, resulting in typical wrought fine-grained equiaxed structures, unlike in solidified structures as in casting and welding, where segregation is a common problem.

As observed earlier, the weld metals exhibited dendritic structure. Although the bulk weld metal composition was found to be homogeneous, the dendritic structure represents microsegregation (characterized by a composition gradient between the cores and peripheries of individual dendrites) that is developed during non-equilibrium solidification of the weldment. The cores of the dendritic arms have higher solidus temperature and contain less solute than the interdendritic regions (as confirmed by microprobe analysis).

Alloy 718 is precipitation strengthened primarily by γ'' which is based on composition Ni_3Nb. The sluggish ageing kinetics of γ'' precipitation was also found to be beneficial to the material's weldability [5]. However, as niobium is a high concentration refractory element, it tends to segregate into the interdendritic regions during the solidification process, as a result of which some undesirable phases, like Laves, can form in the cast and welded products. This is a serious problem, because the composition inhomogeneity due to segregation remains, even after ageing treatments resulting in degradation of the mechanical properties. This assumes significance in a metallurgically complex alloy like 718 which contains many alloying elements with various size and density differences.

The formation of Laves phase is easier in the weld metals due to microsegregation of alloying elements (especially high atomic diameter elements like niobium, titanium, molybdenum, etc.) because of non-equilibrium solidification conditions that prevail during welding. Laves is a hexagonally close packed phase and is generally accepted [6] to be of the form (Ni, Fe, Cr)$_2$ (Nb, Mo and Ti). This unique chemical composition of the Laves phase, as mentioned above, distinguishes it from the other phases present in the 718 system (especially in terms of high niobium weight concentration). The formation of Laves phase requires a niobium concentration ranging from 10%–30%. The quantitative microprobe analysis results support that the interdendritic regions enriched in niobium, molybdenum, silicon and titanium, consist of Laves phase. Incidentally, these regions are depleted in nickel, iron and chromium contents.

Work on cast solidified structures of 718 indicates that identifying the phases in the niobium-rich regions was done using EPMA or SEM attached with energy dispersive X-ray (EDX) spectroscopy extensively [6, 12–16]. More recently Maguire and Michael [12] used EPMA for characterization of Laves phase in 718, 625 and variants. Radarich *et al.* [6] also used EPMA to confirm the presence of Laves phase in order to study its effect on room and elevated temperature properties of 718 in wrought and cast forms. Richards *et al.* [13] identified the interdendritic light-grey phase enriched in niobium as Laves phase based on the chemical composition which was of A_2B (Fe + Cr + Ni, 64 wt %), (Ti + Nb + Mo, 35 wt %) type. Gordine [14] identified the white phase formed in the interdendritic regions of the 718 weld metals by its appearance and microprobe analysis as Laves phase. Very recently, Chang *et al.* [15] used SEM–EDX, X-ray diffraction (XRD) and differential thermal analysis (DTA) techniques for characterization of Laves phase in niobium-hardened superalloys. The phase has also been identified from the EDX spectrum of extracted precipitates and by selected-area diffraction (SAD) techniques using transmission electron microscopic (TEM) studies [16].

The weld cooling rate/heat input is an important factor in controlling the microsegregation and consequent formation of Laves phase in the weld metals. It should be noted that segregation is a time-dependent phenomenon and hence is strongly affected by the weld cooling rate, as influenced by various factors like heat input, welding process, toolings, welding techniques, etc. Slow weld cooling rates result in relatively large dendritic arm spacings compared to rapidly cooled welds, and these coarse dendritic spacings provide congenial/preferential sites for segregation of alloying elements during weld solidification. Even from this point of view, slowly cooled GTA welds are more prone to segregation.

The relative difference in the solidification substructure and the extent of segregational features exhibited by the GTA and EB weld metals can also be characterized by the combined parameter G/R (G = thermal gradient and R = growth rate or interface velocity). It is shown [17] that a high value of G/R result in less segregation, while a low value of G/R produces a heavily segregated dendritic structure. The EB weld metals with their high G/R value segregated less compared to the relatively low G/R-value GTA welds. The factors G and R also control the amount of supercooling during weld solidification, which determines the extent of segregation. Microsegregation results when solute-rich liquid at the solid/liquid interface solidifies between the dendrites. The high energy density and high welding speed capability of the EB welds with steep temperature gradients and minimal supercooling, resulted in minimal segregation. With low-temperature gradients as experienced by the slowly cooled GTA welds, supercooling becomes very extensive and results in segregation due to well-developed anisotropic dendritic structure.

The EB weld metal responded relatively better to solution treatment by redistributing niobium, compared to the GTA weld metal. The significant depletion of niobium in the GTA weld metal dendritic core regions and extensive enrichment of the same in the interdendritic regions even after solution treatment, indicates that the usual solution-treatment temperature of 980 °C is not effective in homogenization of the weld structure encountered in the present study, and required a solution-treatment temperature higher than 980 °C for redistribution of the alloying elements. This could be attributed to the relatively high immobility of the heavily segregated large-size atoms like niobium in the austenitic matrix. In fact, solution treatment at 1090 °C was found to result in almost complete homogenization of the GTA weld metal structure. The BSE images and corresponding niobium X-ray mappings taken for the GTA weld metals in their as-welded and solution-treated (both 980 and 1090 °C) conditions, clearly supported the trend as discussed above. Almost complete homogenization and redistribution of niobium can be clearly seen in BSE and X-ray mappings (Fig. 5a–f). The sparsely distributed bright spots are niobium-rich Laves particles.

4.2. The control of Laves phase in 718 welds

The formation of Laves phase, particularly in solidified structures is detrimental. The deleterious effects of Laves phase on the properties in wrought and cast materials have been well documented in the literature [4, 6, 9, 10]. Studies have shown that the formation of Laves phase (a) depletes the matrix of principal alloying elements required for hardening, (b) represents a weak-zone microstructure between the Laves phase and the matrix interface, and (c) act as preferential sites for easy crack initiation and propagation because of its inherent brittle nature [6]. The presence of Laves phase in cast base metal was also found to reduce the weldability of the material by causing microfissuring during welding. Studies by Carlson and Radavich [7] have shown that even in solution-treated castings, the elemental segregation diminishes very little, resulting in a microstructure that is optically homogeneous, but almost as segregated as the original casting and prone to formation of low-melting phases and cracks during the weld thermal cycle.

Hence, from the above discussion, it is clear that Laves is a detrimental phase and hence warrants careful control. Because the formation of Laves phase was found to be mainly because of segregation during weld solidification, any effort to minimize the formation of Laves phase for improved weld properties has to be directed towards minimizing segregation, by control of heat input/cooling rate, use of suitable welding techniques, etc. Subsequent PWHTs at proper temperatures also help in reducing segregation through homogenization of the weld structure by redistribution of alloying elements. It is interesting to note that some of the studies to eliminate/reduce the Laves phase in cast structures have been even patented [6]. The methods for control of Laves phase in 718 welds and some suggestions are presented and discussed below.

4.2.1. By control of segregation in the welds

Segregation during weld solidification is strongly influenced by the welding process and parameters that control the weld heat input and subsequent cooling rate. From the point of view of controlling Laves phase in 718 weld metals, one can use the lowest possible heat inputs. In this regard EBW was found to be relatively better. The study has clearly shown that the tendency for formation of Laves phase in the weld metals is greater with relatively lower cooling rates, as in GTAW. Keeping the beneficial effect of relatively fast weld cooling rates in mind, it is suggested that techniques such as extraction of heat quickly from the welded region during solidification to increase weld cooling rates, should be adopted. One practical method in this direction could be resorting to the use of chilling blocks in weld tooling. Use of techniques such as pulsing, which reduce heat build-up, also could be beneficial.

Although not investigated in the present study, the composition of the base metal and filler wire are also important. The essential factor to be controlled in 718 to avoid the formation of intermetallic Laves phase is to maintain the niobium content in the solution. It appears that the problem of Laves phase could be controlled to some extent by modifying the composition of the base and filler metals such as relatively reducing the niobium (iron, chromium, molybdenum, silicon) contents. Here it is pertinent to mention that 718 cast materials with lower niobium contents (4%) were found to be more readily homogenized and those with more niobium (5%) required extended homogenization treatments [7, 8].

It is pertinent to mention here that efforts have been made to produce alloy 718 base metals either "with reduced Laves phase forming tendency" or "free from Laves phase" by carefully tailoring the chemical composition [15, 18, 19, 20]. A low-iron version of 718 was reported to have better stress rupture strength with slightly reduced temperature capability [15]. One effort made to eliminate Laves phase was to reduce chromium (12%) and add more additions of precipitation elements to compensate for the strength loss caused by chromium reduction as is done in PWA 1472 [18]. Snyder and Brown [19] developed a "Laves-free" 718 with comparable mechanical properties by modifying the alloying element contents of 718. Replacement of iron by an optimum amount of cobalt, and niobium by tantalum has been suggested to eliminate the tendency for formation of Laves phase. This new modified version of 718, "free from Laves/HAZ microfissuring problems", developed by General Electric Aircraft Engines (GEAE) is christened Rene 220C. Studies strongly suggested that Laves phase does not form with cobalt alloying and this has also resulted in significantly improved temperature capability over 718 by 50 °C [20].

It also appears from the present results that application of circular beam oscillation in the case of EBW reduces the microsegregation in the weld structure comparatively. Although the weld cooling rates of the beads deposited with the oscillating electron beam technique are expected to be relatively lower than the stringer beads, it is the churning action of the oscillating beam and consequent fragmentation of the dendritic structure of the weld that plays a major role in reducing segregation. Although not tried, similar analogy should also hold good for the GTA welds, and the use of magnetic arc oscillation may be fruitful in reducing the segregation.

To summarize, segregation and thereby the formation of Laves phase in 718 welds can be controlled by the use of (a) fast weld cooling rates, (b) low weld heat inputs, (c) heat extraction techniques such as chilling blocks in tooling, (d) steep thermal gradients, (e) pulsing techniques, (f) low-niobium fillers, and (g) electron beam oscillation techniques, etc.

4.2.2. By homogenization post-weld heat treatments

Needless to say, once Laves phase is formed in the weld metals, the only way to make chemical composition more uniform is to dissolve the detrimental Laves phase and promote sufficient diffusion of niobium into the dendritic regions by subjecting the weldments to solution/homogenization treatments. Therefore, these homogenization treatments are critical. The required homogenization temperature depends on the extent/degree of segregation produced in the weld. Because Laves phases of different morphologies and compositions can form with different solvus temperatures, care must be taken to avoid rapid heating (up to the solvus temperature of Laves) to prevent incipient melting at the grain boundaries which may result in weld cracking during heat treatment. Total homogenization consists of Laves phase dissolution and uniform niobium distribution. While Laves phase can be dissolved, it may not be possible to achieve, economically, the total uniform distribution of niobium.

The Laves phase found in the as-welded condition, should not be present after homogenization treatment. The presence of Laves phase in a homogenized structure indicates incomplete homogenization of the original niobium and subsequently, different precipitation responses will take place in the areas where the Laves phase is present. It may be interesting to note that the segregation that was evident in as-cast condition was unaffected even after 10 000 h ageing at 600 °C [5].

Various authors have suggested different homogenization treatments for wrought and cast materials [7, 9, 10]. Modified heat treatments (at about 1100 °C) are suggested for better Laves and delta dissolution compared to conventional dissolution at 980 °C [9,10]. Studies revealed that more uniform distribution of elements (especially niobium) requires 100 h or more at 1150 °C [7]. However, one should also keep in mind the limitations of using higher solution-treatment temperatures. Total homogenization with shorter durations is not possible, nor economical. Solution treatment above 1040 °C results in grain coarsening, because delta phase, which is responsible for grain-size control by a grain-boundary pinning mechanism, goes into solution at these temperatures. Higher solution treatment temperatures above 1063 °C were found to increase the HAZ cracking susceptibility of EB welded cast 718 due to segregation of boron at grain boundaries [21–23].

The present study indicated that solution treatment at 980 °C is ineffective in homogenization of the GTA weld structure and dissolution of its niobium-enriched Laves phase (while it was sufficient for EB welds) and required higher solution-treatment temperatures of the order of 1100 °C. It was already shown in the previous discussion that low heat input EBW is advantageous from the point of view of lower segregation. Even from the point of view of solution treatment, use of low heat input EBW is advantageous compared to high heat input GTAW because of the ease with which homogenization can be achieved even at lower solution-treatment temperatures.

Overall, it can be said that Laves phase in 718 weld metals is an important aspect of 718 welding metallurgy and warrants careful control to avoid premature failure of high-performance welded components during service. It should be noted that although the Laves phase evaluated in the present investigation cannot be considered to be typical in fabrication of aerospace components by the GTAW process, it is possible to produce welds segregated much worse than in the present work, if welding conditions are not properly controlled and carefully monitored. Hence, formation of Laves phase is of major concern and poses a significant challenge in welding of 718, especially when using high heat input processes like GTAW, which are more prone to segregation due to their slow cooling rate characteristics. In view of the criticality of the aerospace components, it is suggested that extreme precautions are required to be taken during welding of this alloy, especially while using GTAW process.

5. Conclusions

The detrimental Laves phase formed in the interdendritic regions of 718 weld metals, basically due to microsegregation of alloying elements during weld solidification. The morphology and composition of the Laves phase in the weld metals strongly depended on weld cooling rate and influenced its subsequent response to homogenization post-weld heat treatment. While fast weld cooling rates were found to be beneficial, slow weld cooling rates were not.

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