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Tailoring Phase Transformations in SAE 9254 Steel: A Dilatometry-Based Study on Austenitization, Quenching, and Carbon Partitioning Processes

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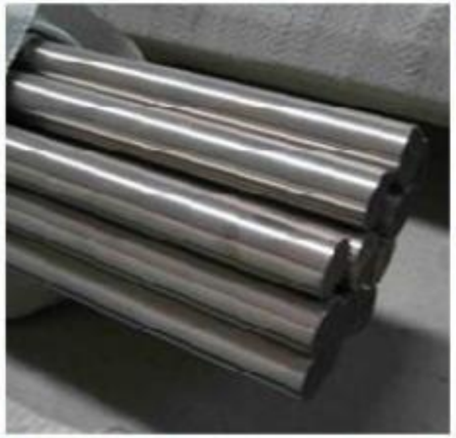
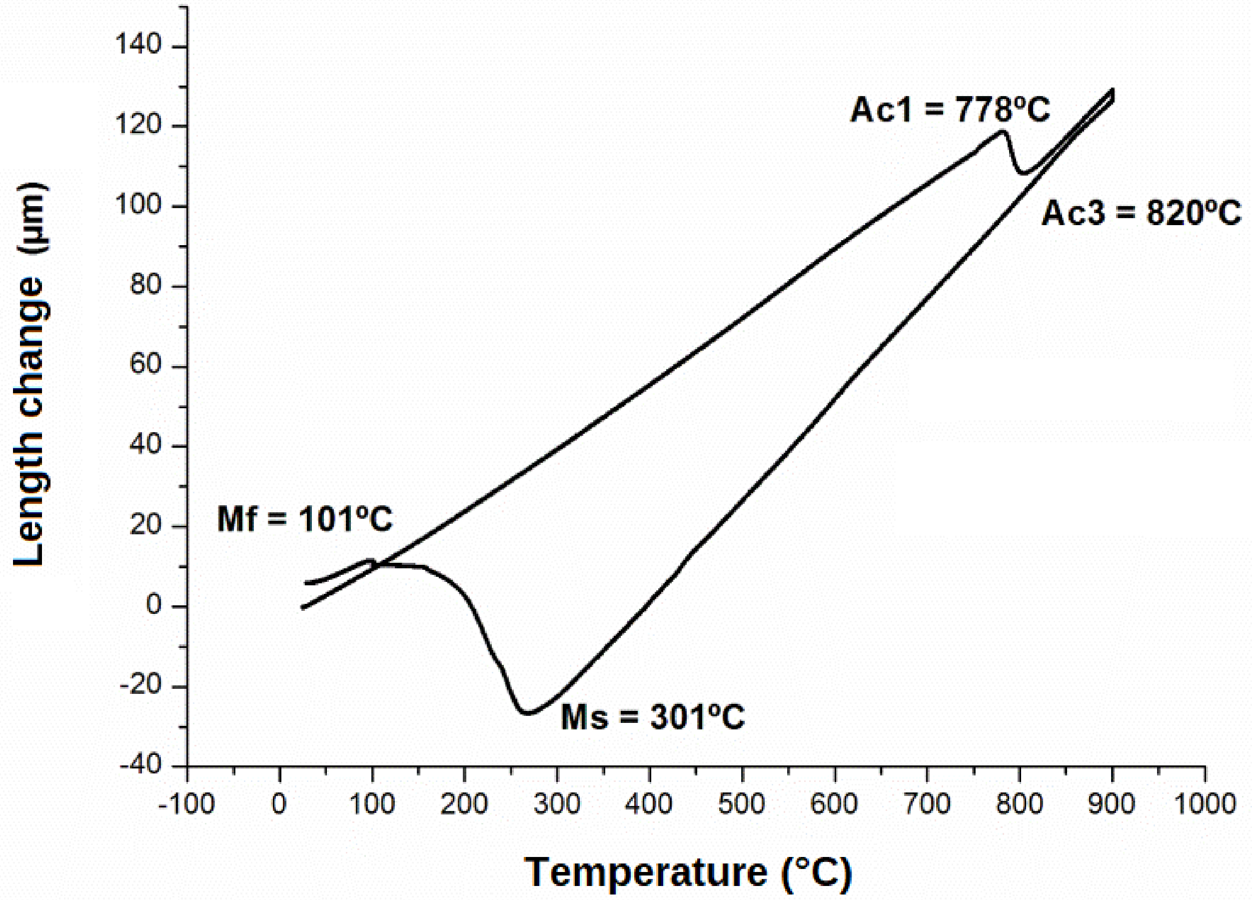
9254 Steel

1, Chromium vanadium type spring steel.
2, Suitable for oil hardening and tempering.
3, Good wear and abrasion resistance;
4, Excellent toughness and shock resistance.



C	0.56-0.64
Si	1.60-2.00
Mn	1.60-2.00
P	≤0.025
S	≤0.025
Cr	≤0.35
Mo	≤0.35
V	≤0.25

Phase Transformations and Austenitization in 9254 Steel: A Dilatometric Study



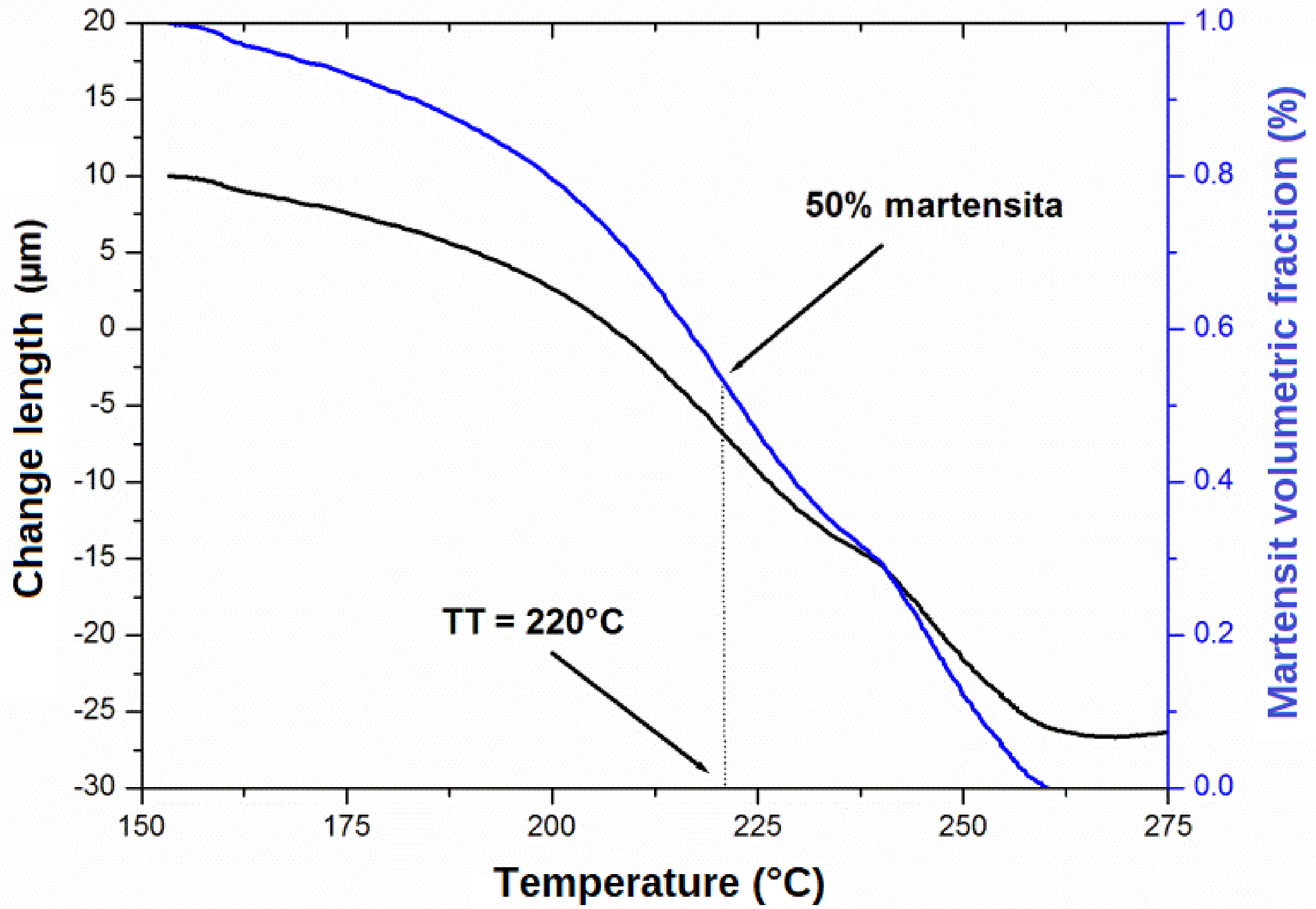
- Use of dilatometer to determine critical austenitization and quenching temperatures for achieving mixed microstructures.

- Observation of gradual linear volumetric expansion at 780°C, marking transformation of BCC ferrite matrix into
- FCC austenite.

- Complete austenitization signified by contraction up to 820°C.

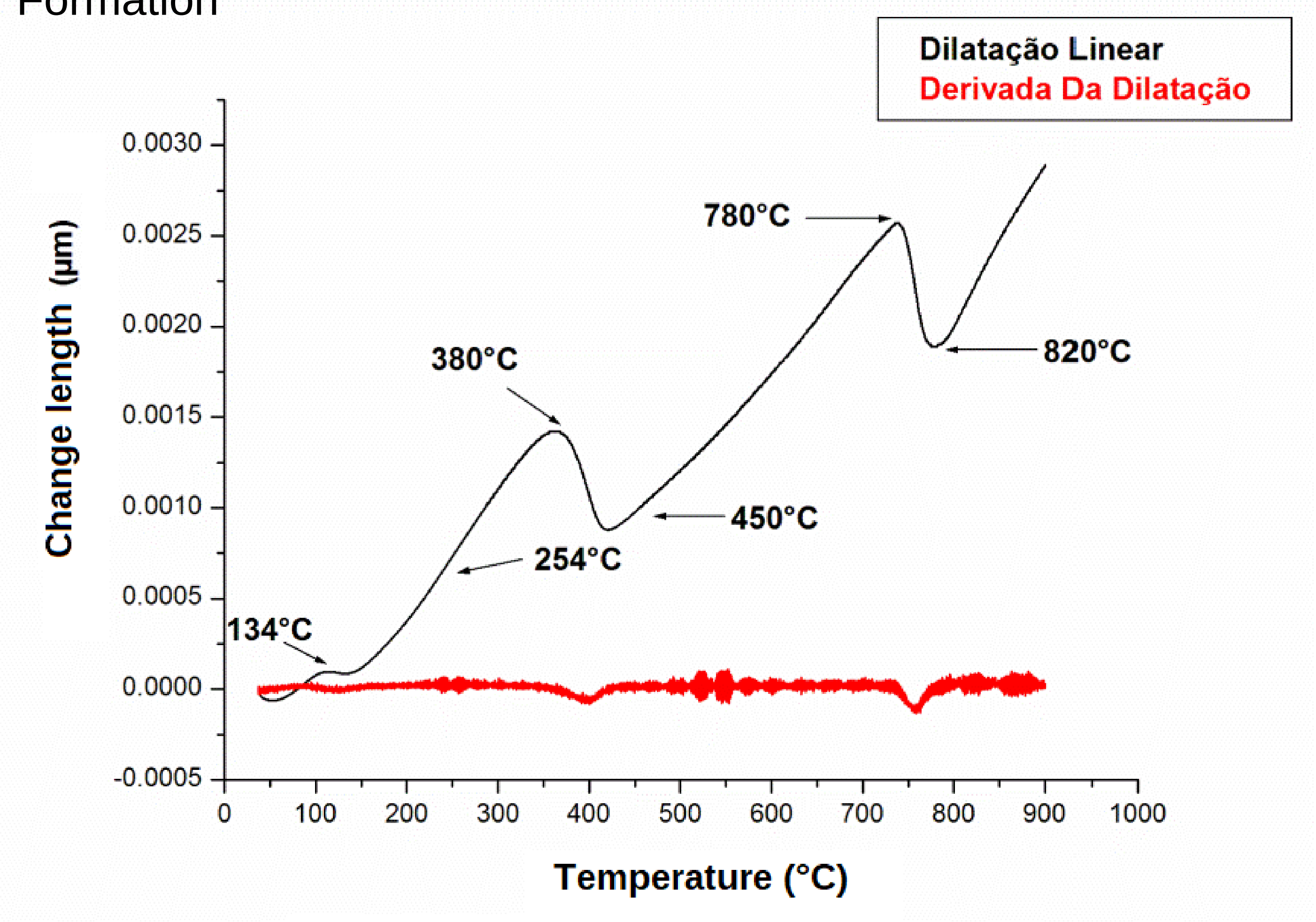
- Quenching post-austenitization led to formation of BCT martensitic phase, with significant volumetric expansion between 301°C and 101°C.

Quenching Parameters for Phase Transformation in Steel



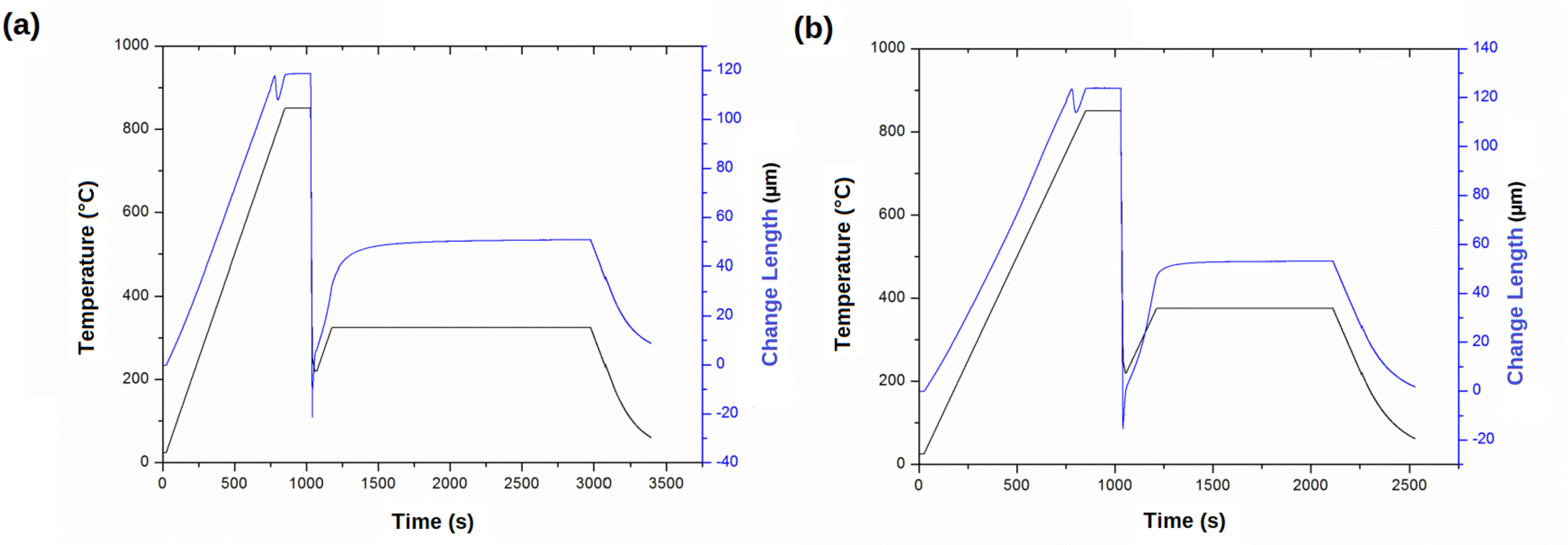
- Quenching temperature determined to be 220°C, necessary to produce 50% martensite post-quenching.
- Volumetric fraction of martensite calculated using lever rule in conjunction with dilatation data.
- Onset and completion of martensitic transformation identified at 301°C and 101°C respectively.

Isothermal Holding Temperatures and Dwell Times for Carbide Formation



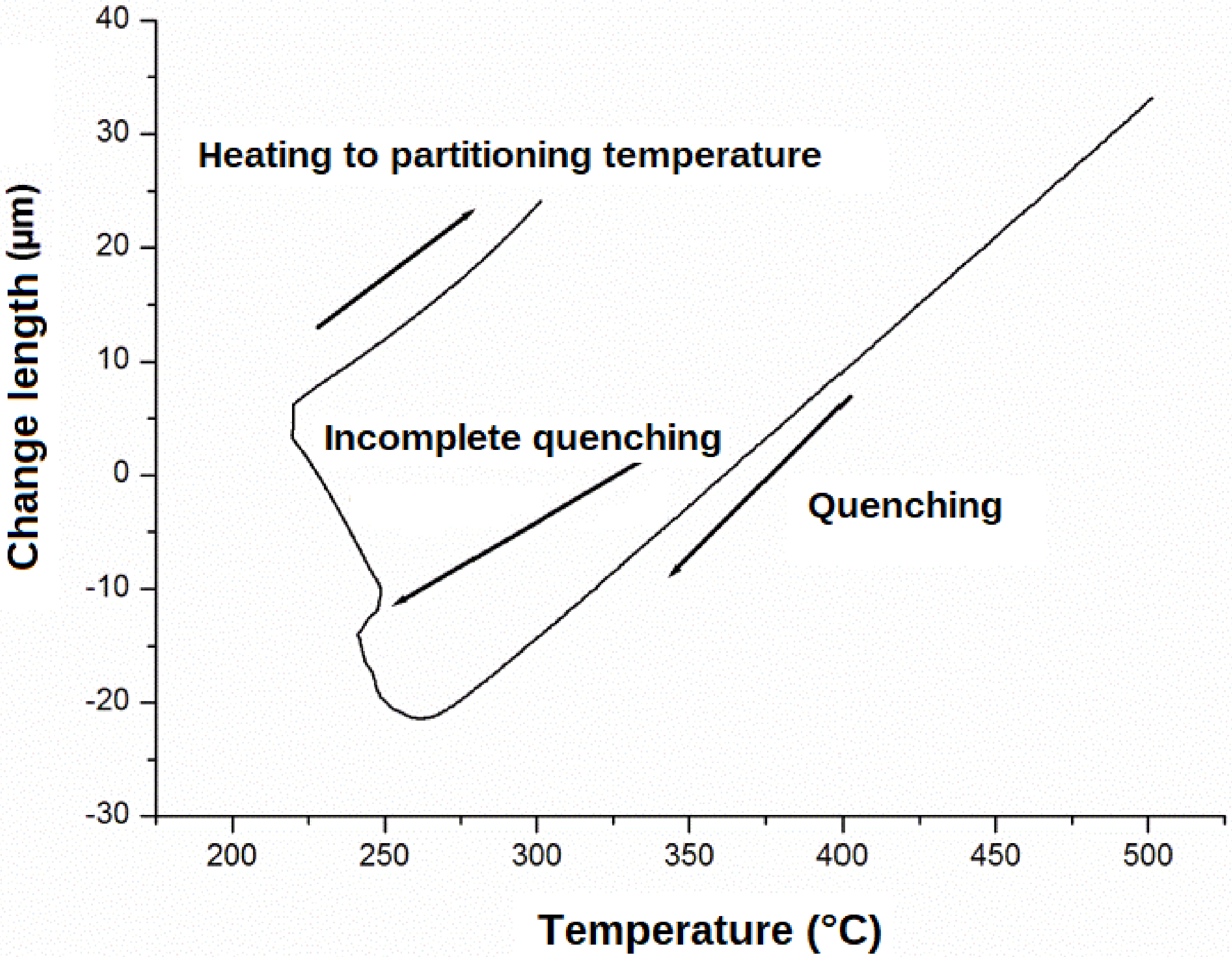
- Change in dilatation between 134°C and 254°C potentially associated with the relaxation of supersaturated martensite.
- Significant contraction between 380°C and 450°C likely due to decomposition of retained austenite into bainitic ferrite and the formation of transition carbides.
- Further contraction suggests commencement of austenitization at around 780°C (Ac1) and completion around 820°C (Ac3).

Establishing Isothermal Holding Temperatures and Phase Transformations During Heat Treatment



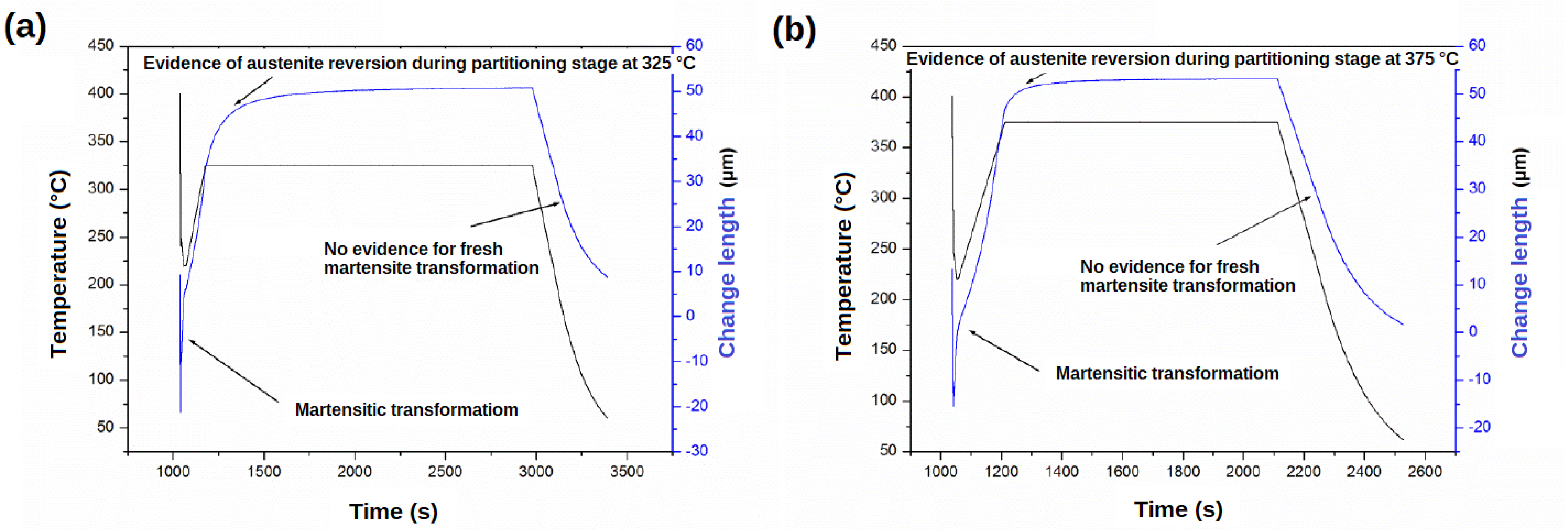
- Isothermal holding temperatures determined to be 325°C and 375°C with holding times of 30 minutes and 15 minutes.
- Phase transformations during proposed heat treatments observed using dilatation variations.
- Austenitization occurs at 850°C, followed by quenching to 220°C, resulting in 50% martensite.
- Partitioning carried out at temperatures of 325°C and 375°C.

Martensitic Transformation Due to Quenching



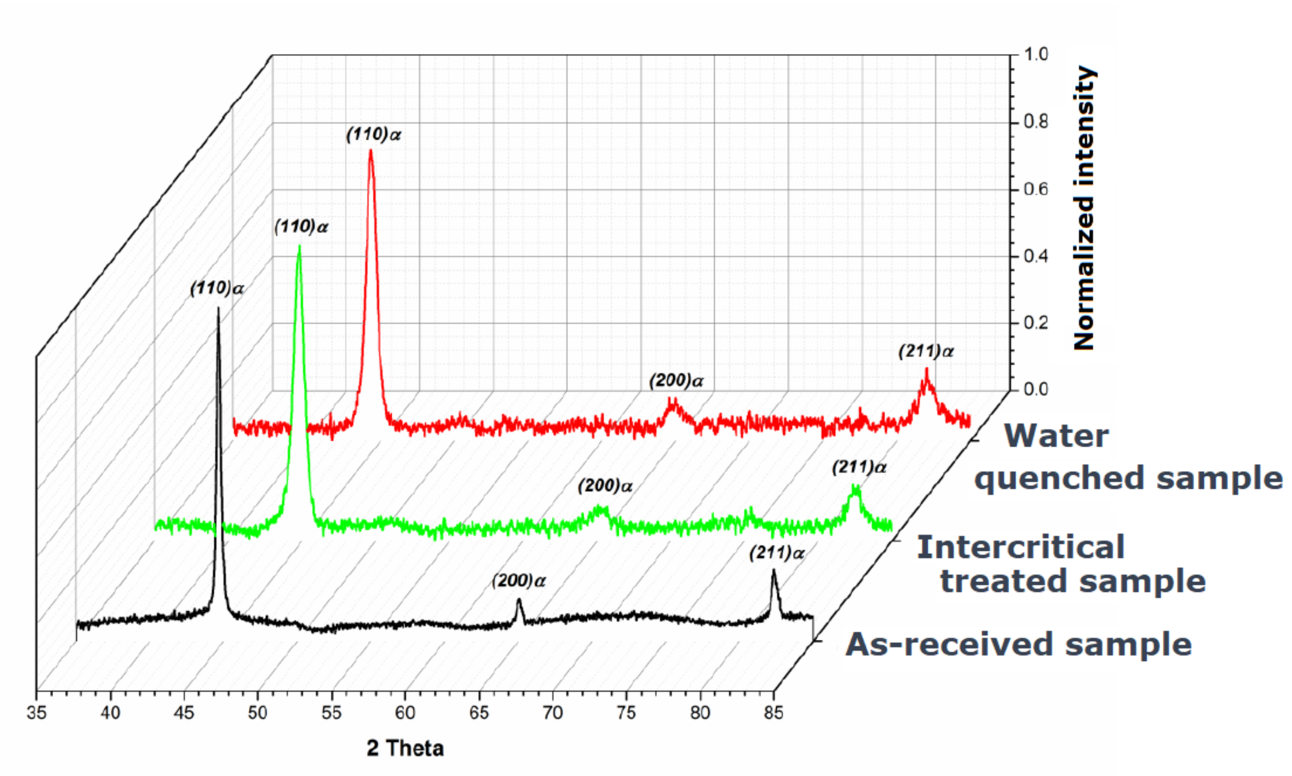
- Lattice expansion observed due to quenching at 220°C, signifying martensitic transformation.
- Quenching aims to transform half of the austenite into martensite.
- Resulting microstructure comprises 50% martensite and 50% untransformed austenite in the QP-220-325 and QP-220-375 samples, along with about 10% ferrite.

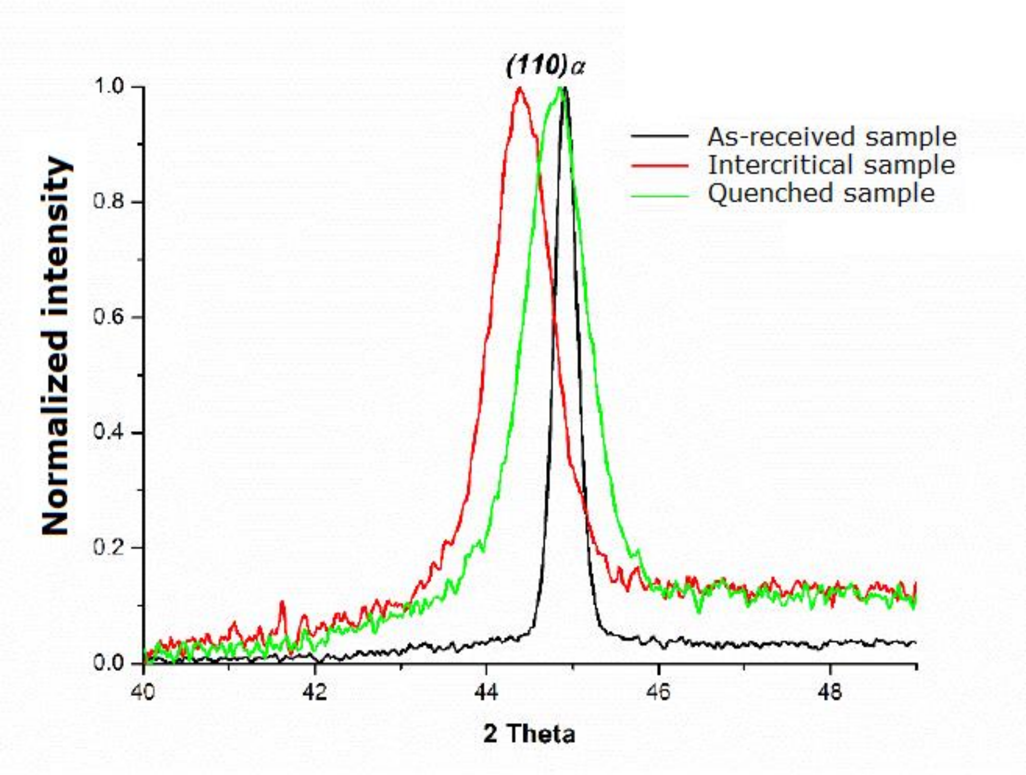
Carbon Partitioning and Bainitic Transformation



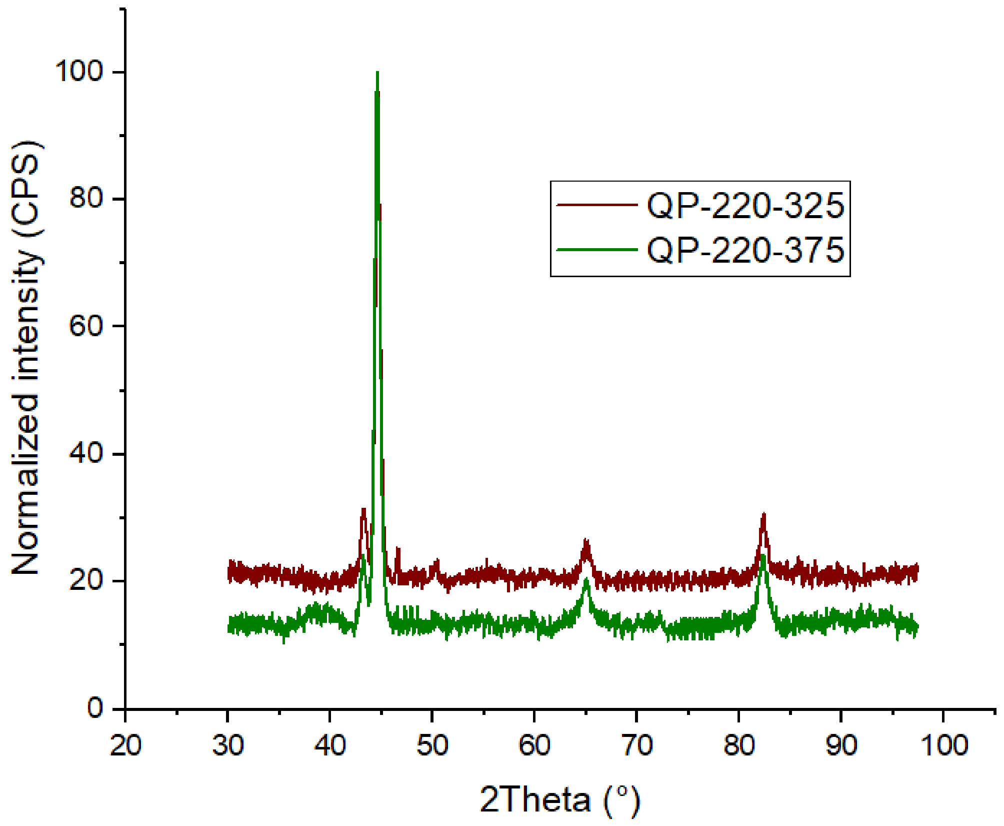
- After quenching, two different temperatures were utilized for carbon partitioning of the untransformed austenite.
- Expansion during isothermal treatments (partitioning stage) likely suggests the decomposition of austenite and bainitic transformation.
- Smooth contraction upon cooling to room temperature indicates the absence of fresh martensite in the final microstructure.
- Post heat-treatment microstructures likely comprise martensite, a fraction of bainite, and stabilized austenite.

Phase Transformation Effects on XRD Patterns





- Water-quenched and intercritical heat-treated samples showed minor peak width variation and shift, attributed to phase transformation.
- Incomplete transformation of austenite to stable phases in rapidly cooled water-quenched samples.
- Peak broadening in quenched samples, indicative of deformed structure, high dislocation density, and high stresses from rapid quenching.
- Notable peak shift and broadening values for the water-quenched sample compared to intercritical heat treatment.



Sample	a (nm)	D (nm)	δ x10-3 (nm-2)	ε x 10-3
As-received sample	0.2852	27.9113	1.2836	0.0033
Water quenched sample	0.2883	10.7031	8.7293	0.0086
Intercritical sample	0.2855	10.2949	9.4355	0.0089
QP-220-325	0.2874	16.0606	3.8768	0.0057
QP-220-375	0.2879	14.9549	4.4713	0.0062

- Carbon partitioning-treated samples exhibited retained austenite peaks due to phase transformations.
- Supersaturated martensite lost excess carbon to untransformed austenite during partitioning, promoting bainitic transformation.
- Heat treatments involving partitioning resulted in lower retained austenite compared to quenched samples.
- Suppression of carbide precipitation attributed to high silicon content in the alloy.
- Provided values for dislocation density, microstrain, lattice parameter, and average grain size under all conditions.

Impact of Intercritical Heat Treatment on Austenite Retention

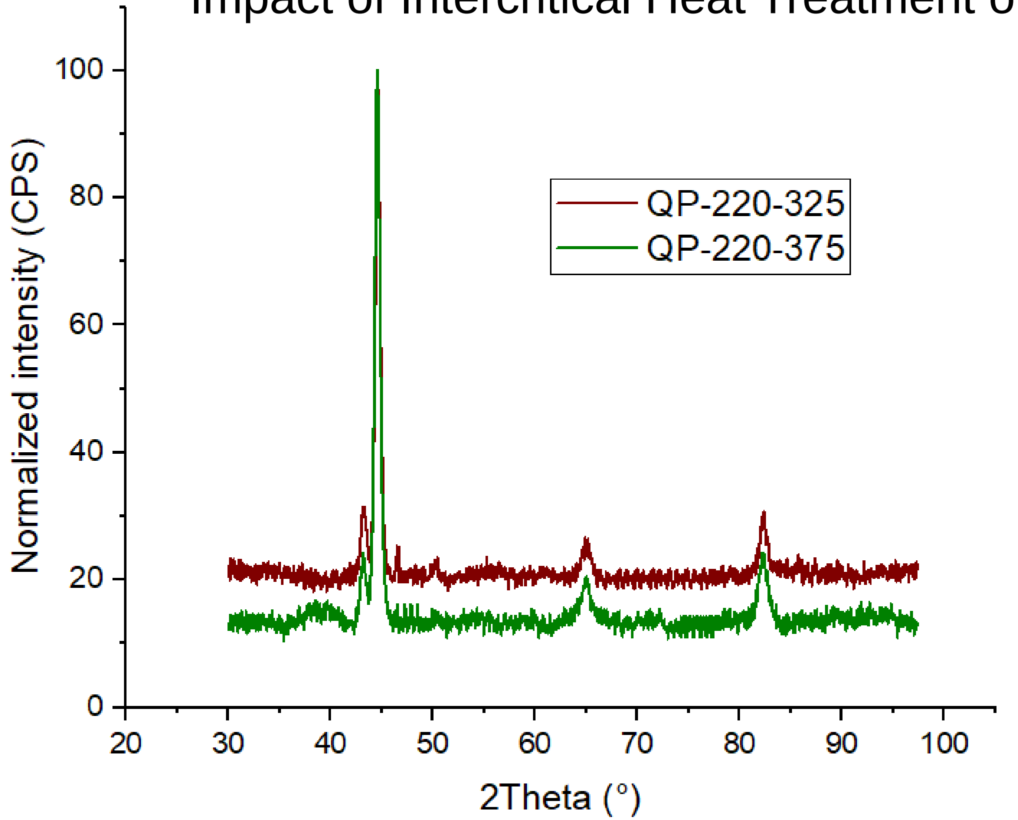
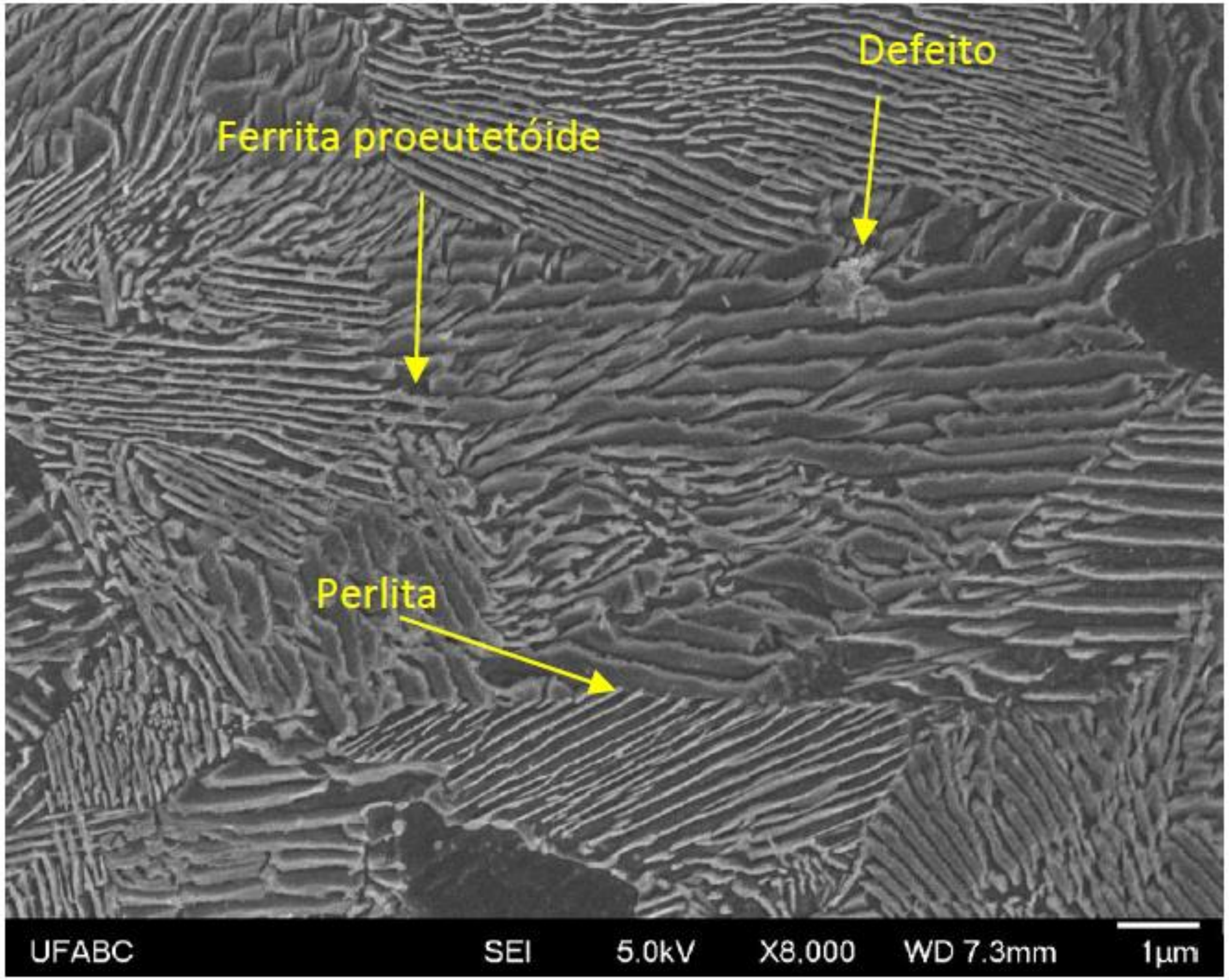


Table 3: Calculated volume of retained austenite after partitioning.

Sample	Volumetric fraction of retained austenite (%)
QP-220-325	16.97
QP-220-375	12.15

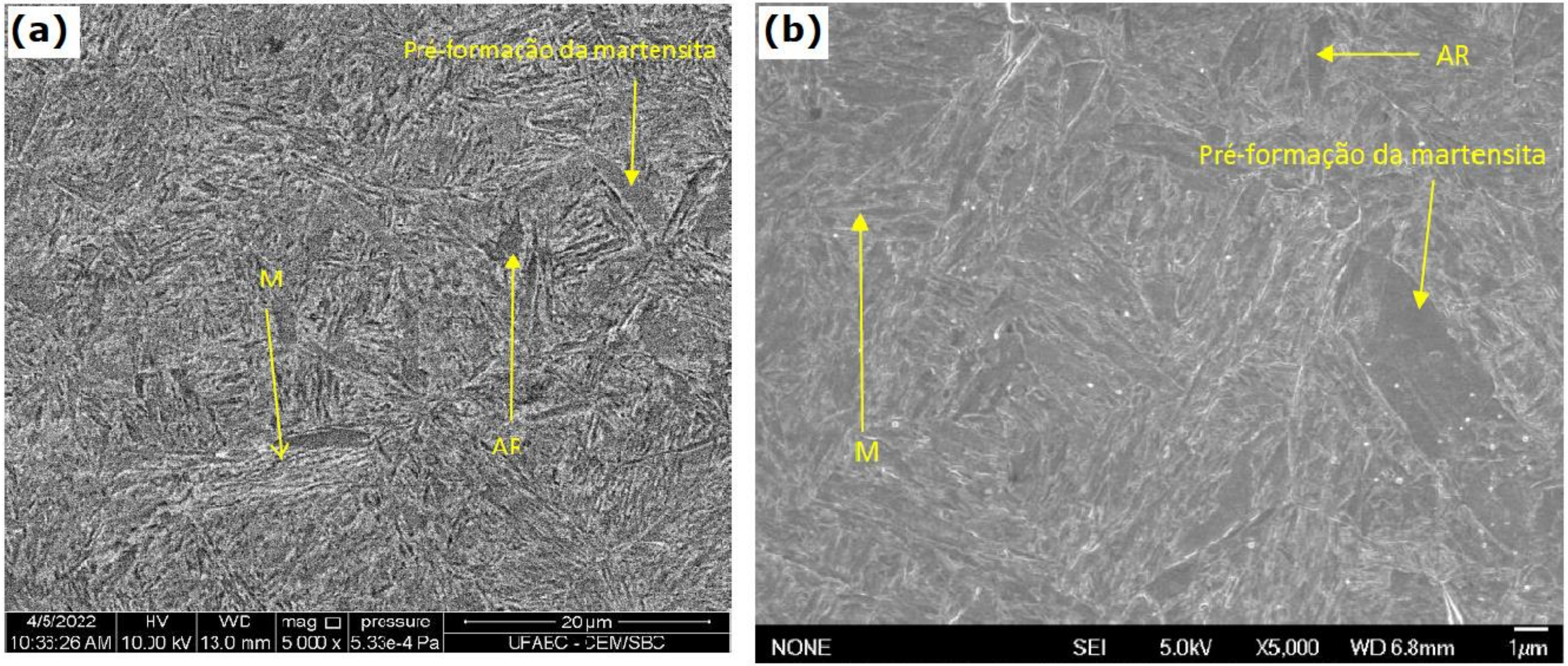
- Intercritical heat treatment results in higher retained austenite due to complete carbon dissolution in austenite prior to quenching.
- High silicon content (1.20 to 1.60 wt% Si) significantly impacts the amount of retained austenite.
-
- Silicon retards the precipitation of carbides like cementite.
- For QP-220-325 and QP-220-375 samples, retained austenite decreases as partitioning temperature increases.
- Retained austenite transforms into more stable structures, such as bainite, when subjected to heating.

Pre-treatment Microstructural Analysis via SEM



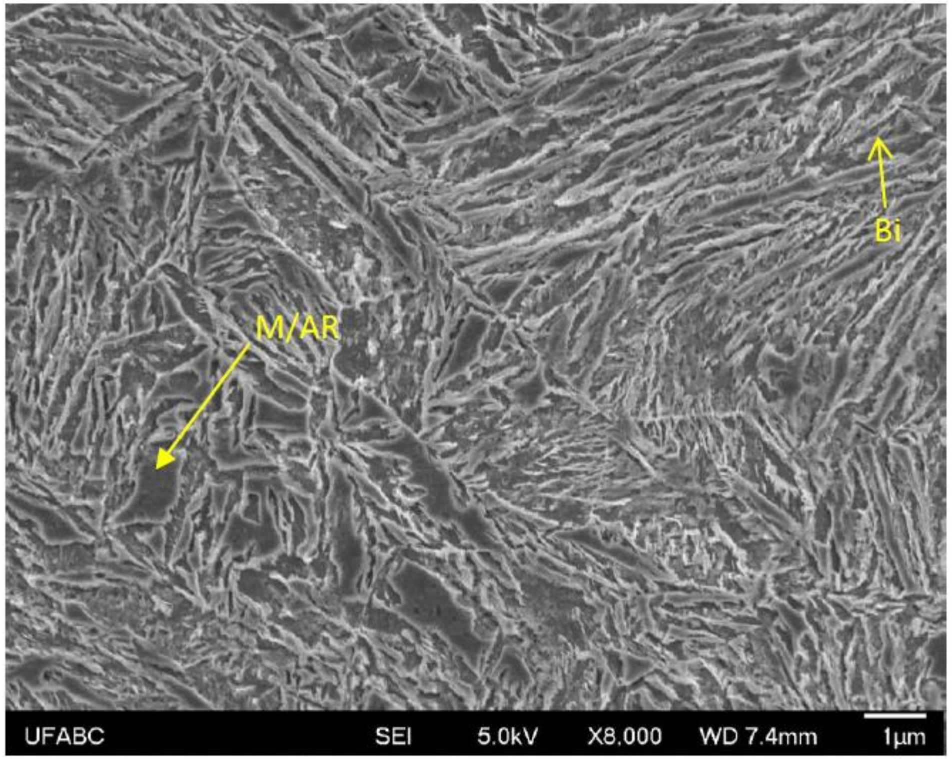
- SEM analysis was conducted on the as-received material to establish a microstructure reference before heat treatments.
- The initial microstructure consisted of proeutectoid ferrite (darker regions) and pearlite (regions with lamellar structures).
- Some defects due to the manufacturing process were observed.

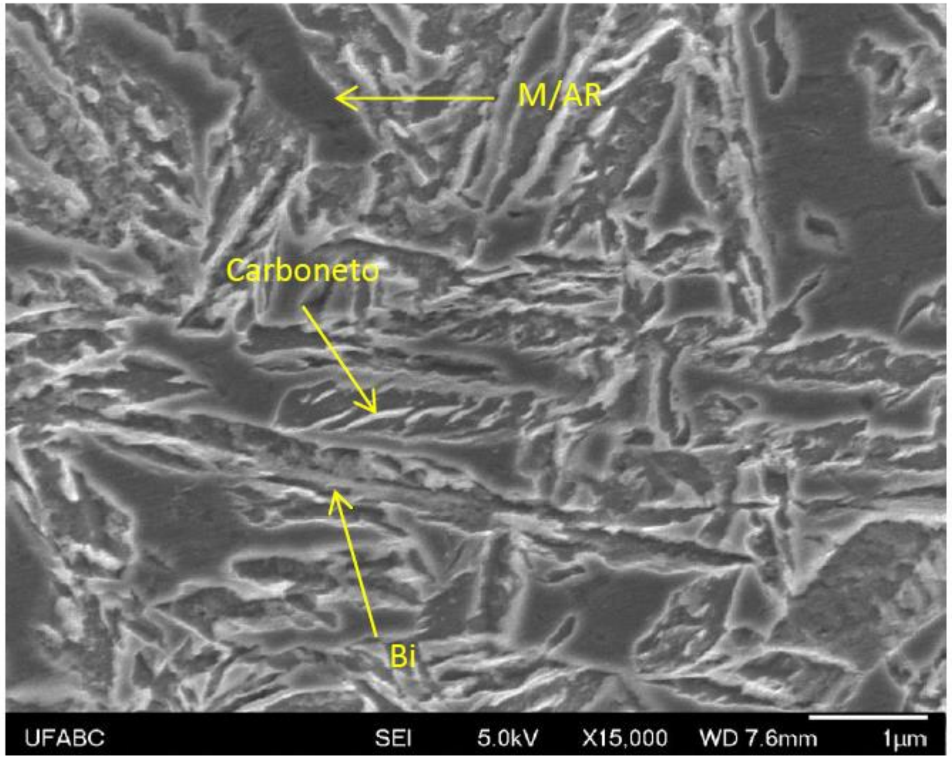
Microstructural Analysis of Two Quenching Processes



- The water-quenched sample primarily consisted of martensitic laths and a substantial amount of retained austenite.
- The sample subjected to intercritical treatment also showed martensite and retained austenite in its microstructure.
- Despite expectations, the presence of ferrite was not detected using this technique.

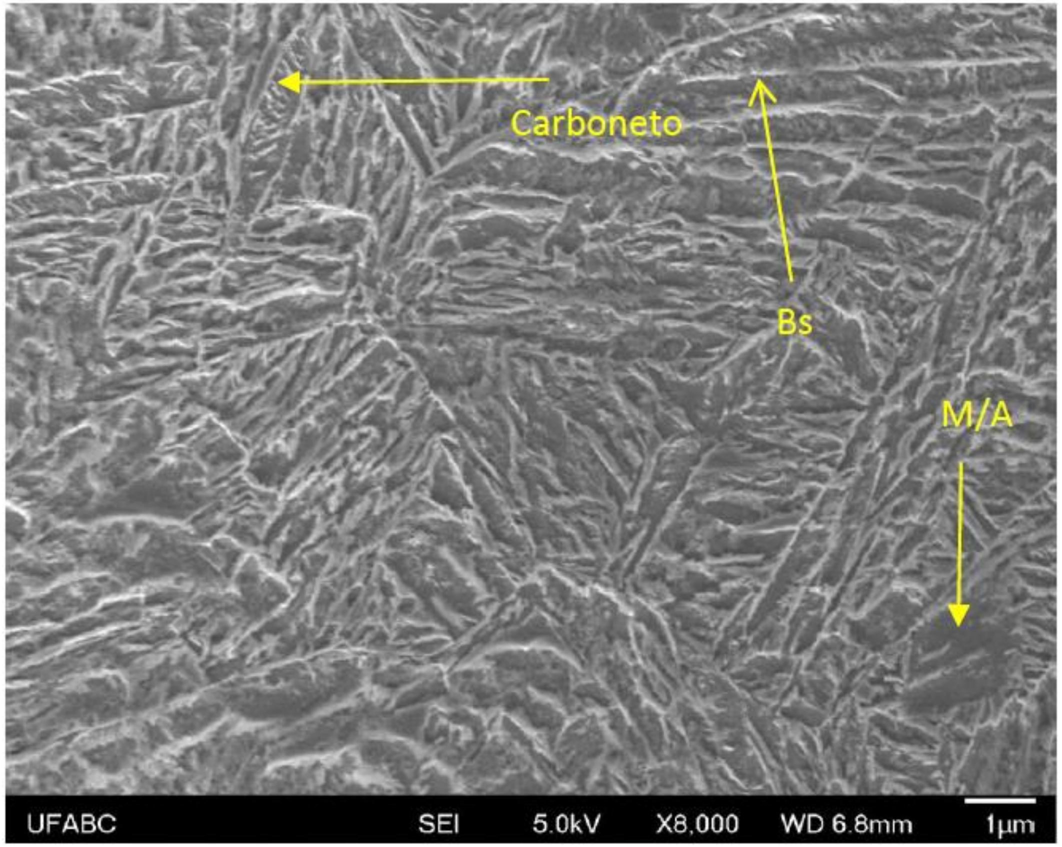
SEM Analysis of Microstructure in QP-220-325 Condition

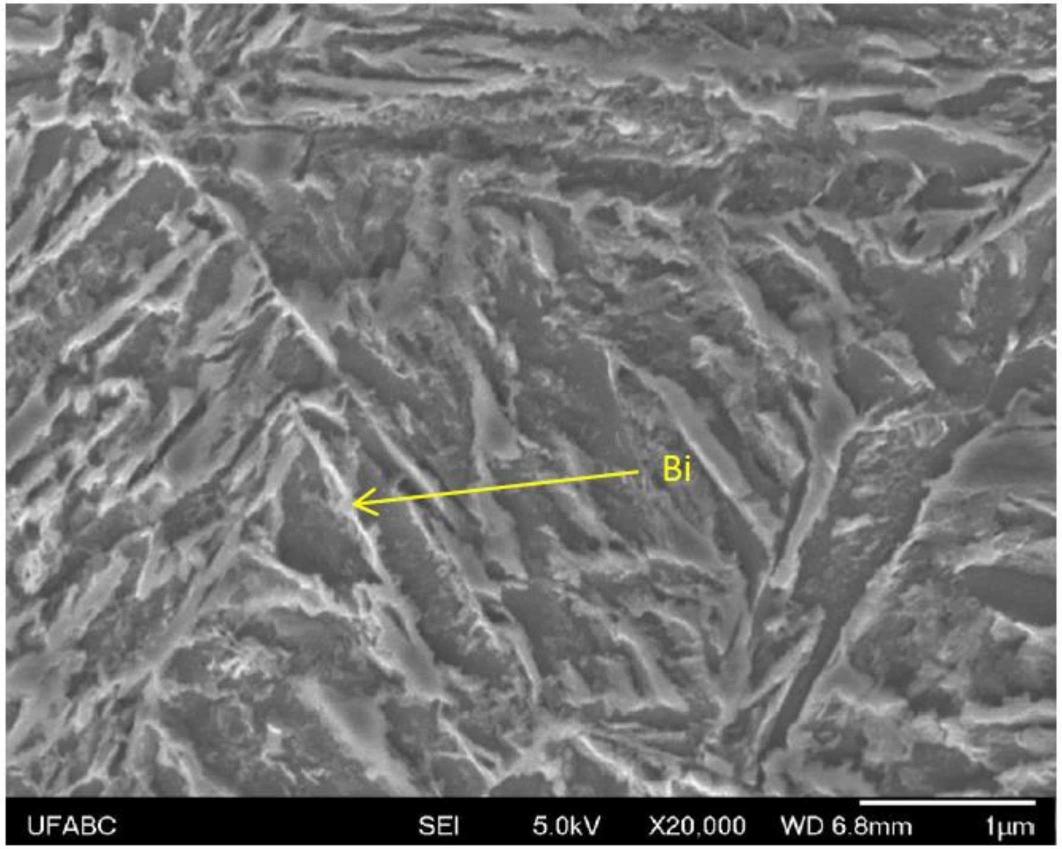




- SEM images reveal a primary microstructure of elongated martensitic laths and distinctive bainitic structures.
- Retained austenite was identified, which can be associated with the selected partitioning temperature and time.
- Unexpectedly, fine carbides were also observed, potentially influenced by factors like alloy composition or local cooling rate variations during quenching.

SEM Analysis of Microstructure in QP-220-375 Condition



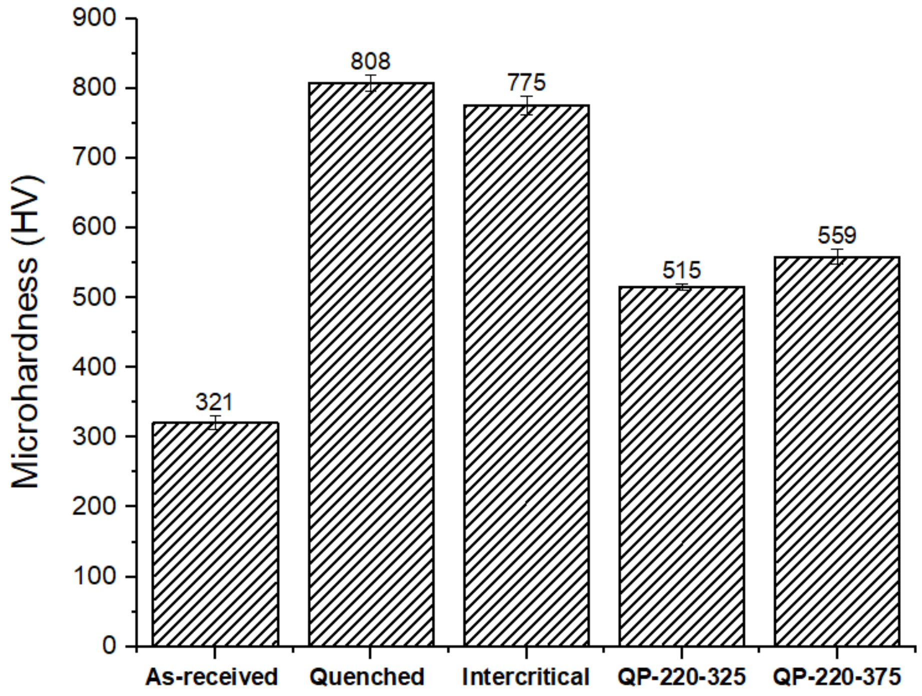


- SEM images reveal a microstructure featuring elongated martensitic laths and distinct bainitic structures, indicating the occurrence of phase transformations during heat treatment.
- Retained austenite is also present in the samples, implying an incomplete transformation possibly due to the selected partitioning temperature and time.
- The micrographs display unexpected fine carbides, whose presence may be ascribed to factors such as alloy composition, quenching cooling rates, or localized variations in carbon content.

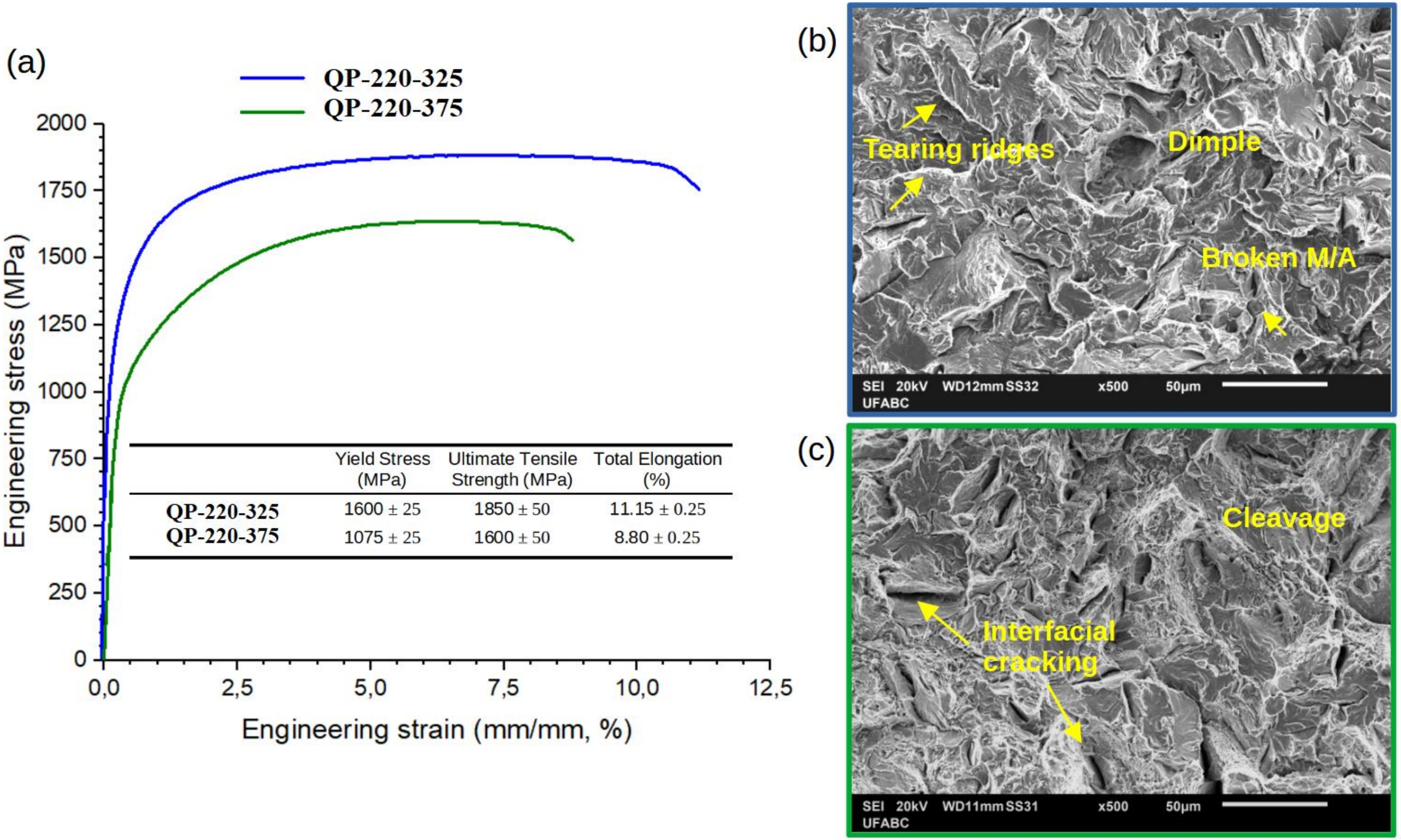
Microhardness Analysis of SAE 9254 Steel

Table 4: Vickers microhardness of SAE 9254 steel resulting from different heat treatments.

Sample	Microhardness (HV)
As-received sample	321 ± 9.5
Quenched sample	808 ± 11.5
Intercritical sample	775 ± 13.2
QP-220-325	515 ± 4.5
QP-220-375	559 ± 10.5



- As-received, water-quenched, and intercritically heat-treated samples display varying hardness: 322 HV, 808.70 HV, and 776.30 HV, respectively.
- Partitioned samples (QP-220-325 and QP-220-375) exhibit increasing hardness with rising partitioning temperature.
- Microhardness outcomes highlight the link between heat treatment processes, microstructure alterations, and mechanical properties.



	Yield Stress (MPa)	Ultimate Tensile Strength (MPa)	Total Elongation (%)
QP-220-325	1600 ± 25	1850 ± 50	11.15 ± 0.25
QP-220-375	1075 ± 25	1600 ± 50	8.80 ± 0.25

An excellent mechanical resistance (YS~1600±25 MPa - UTS ~1850±50 MPa) and elongation (~11.15±0.25%) were obtained by designing the proper microstructural features in the samples.

Conclusion: Multiphase Microstructure of SAE 9254 Steel through Heat Treatment

- Effective austenitization achieved at 850°C for 180 seconds, with quenching at 220°C generating roughly 50% martensite.
- Isothermal holding at 325°C and 375°C for 30 and 15 minutes respectively, triggered austenite-to-bainite transformation and carbide formation.
- XRD and SEM confirmed phase transformations and illustrated detailed microstructures, including unexpected carbide formation.
- Hardness, measured via the Vickers scale, increased in quenched samples and further with higher partitioning temperatures.
- Study supports feasibility of heat treatment for microstructural manipulation in SAE 9254 steel, though more research on carbide formation and impact is needed.
- Future efforts should target in-depth quantitative analysis of microstructures and heat treatment parameter optimization.

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