Research Article

Microstructure Integration Upon Heating Temperatures in Low Carbon Mn Steel

Shahid Hussain Abro[1*], Mohammed N. Alghamdi[2], Muhammad Sohail Hanif[3], Hazim Moria[2] and Hamza Suharwardi[1]

[1]Department of Metallurgical Engineering, NED University of Engineering and Technology, Pakistan; [2]Department of Mechanical Engineering Technology, Yanbu Industrial College, Kingdom Saudi Arabia; [3]Department of Materials Engineering, NED University of Engineering and Technology, Pakistan.

Abstract: Continuous heating phenomena performed at lead bath-quenching in which austenitic development morphology investigated. The CHQ steel analyzed in the context of Advanced Optical Microscope of Olympus GX51, SEM and Thin-film X-ray Diffracto-meter, with high-intensity mode have been deployed in order to examine the kinetics behavior of austenitic development at CHQ steel. On several quenching experiments the austenite formed at different temperatures and time 10s, 15s, 30s, and 60sec and 800°C 710°C, 740°C, 770°C respectively. Initial microstructure for both the steel is ferrite and pearlite. AC_1 temp: is assumed to be 740°C and AC_3 temperature 800°C has been examined methodically. The soaking time and holding temp: play an important role in developing of gamma-austenite. Mostly ferrite and cementite morphology exist at nucleation sites. At ferrite-ferrite grain interface the austenitic nucleation is not found. At high temperatures, the development of austenite at pearlitic nearby areas are highly noticed. At 800°C growth is about finger-type morphology. The fingers are parallel to pearlite so it is strongly believed that within this area the bainite structure is to be formed. This bainite is assumed to be austenite before cooling.

Received: August 21, 2020; **Accepted:** November 24, 2020; **Published:** December 19, 2020
***Correspondence:** Shahid Hussain Abro, Department of Metallurgical Engineering, NED University of Engineering and Technology, Pakistan; **Email:** engrabro@neduet.edu.pk
Citation: Abro, S.H., M.N. Alghamdi, M.S. Hanif, H. Moria and H. Suharwardi. 2021. Microstructure integration upon heating temperatures in low carbon Mn steel. *Journal of Engineering and Applied Sciences,* 39(2): 164-169.
DOI: http://dx.doi.org/10.17582/journal.jeas/39.2.164.169
Keywords: Up-quenching, CHQ steel, Austenite, Phase transformation, Microstructure, Lead-Bath, Heating rate

Introduction

Cold heading quality (CHQ) steel is a kind of raw material and mostly manufactured from pure ore of iron and appropriate steel scrap within controlled process conditions, which ensures minimum content of metal residuals, uniform chemical composition and clean steel. CHQ steel found its attention in Automotive and different machine parts as well, for instance shaft, gear screw, fasteners, studs, spline socket, connecting rod and rivets, etc. (Chandio and Abro, 2018).

Rapid austenizing, (Up-quenching) refines the grain size of austenite; it avoids distortion produced in components and particularly in micro-alloy grained martensitic homogenously distribute the tiny carbide particles matrix (Abro *et al*., 2019, 2020). It reduces other heat treatment parameters i-e tempering, soft annealing etc. (Abro *et al*., 2019). Uniform temperature produces adequate heat treatment as resultant steel becomes ultrafine grained martensitic matrix (Ghaferi *et al*., 2019). Vast researchers examine CHQ steel but no one explained the austenitic phase transformation applying up-quenching technique (Abro, 2016). Moreover, lots of researcher demonstrates various

Links Researchers

models on phase transformation by past half century, but there is some lacking under the kinetic behavior of phase transformation from ferrite-pearlite to austenite. The development of austenite in CHQ steel gets negligence from steel researchers and manufacturers. Researchers worked up to the examination of compositions, microstructures, and mechanical properties of (spherodized) annealing; they improved the feed stock quality of CHQ steel wires to get homogenized microstructure and enhanced tool life.

Xiaoyu MA working on CHQ steel (1036M) grade microstructural consequences. Six different individual heat treatments analysis they get the different microstructure. They focused only on the calculation volume fraction of pearlite in each sample. As reducing the perlitic phase, it improves the ducility.

EN 10263 CHQ steel and his coauthors studied loss or gain of heat deformation without changes in thermodynamics. They explained elasto-viscoplastic response developed under CHQ steel a on dealing pearlite and ferrite structure (Abro *et al*., 2020).

Professor LI Zhuang at calculate the rolling and cooling effect on mechanical properties and microstructure of CHQ steels of various grades. They examined that CHQ steels mechanical properties increased by the refinement of ferrite-pearlite grains. They applied the fast cooling rate which prevents gamma-alpha phase transformation (Abro *et al*., 2020, 2020). In case of steels, there are so many grades and standards that are usually used for cold heading operations in steel industry (Abro *et al*., 2020). Although austenitic stainless steels non-magnetic in nature then proceeds towards cold working after annealing temperature (Ishteyaque *et al*., 2019), moreover martensitic phase are magnetic in nature hardened by precipitation (Kelly, 1963), ferritic stainless steels are magnetic in nature but no change in hardness observed slightly deviate by cold working, contrary, stainless steels only hardened through age hardening and solution heat treatment (Shah *et al*. 2020). In order to know the cold heading response of these steels used in CHQ process, the austenitic forming ability is necessary to be studied (Abro, 2019). There is no investigation on MA-CHQ steel reported on austenite formation behavior yet. This work is fully focused on the study of development of austenitic formation in CHQ steel; furthermore, this technique also applicable for other grades as well under the limit of CHQ steels.

Materials ad Methods

The experimental process as shown in Figure 1. The experimental steel was obtained in as received condition and then 1200°C heated up to and soaking time is about 120 min as solution treatment.

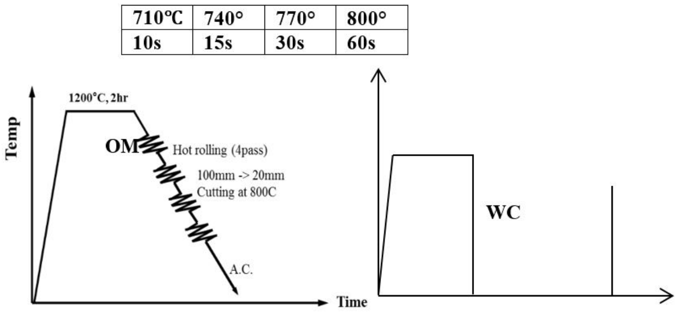

Figure 1: *UP-quenching heat treatment cycle.*

After solution process the steel in 4- passes under hot rolling operation 80 % thickness is reduced and cut at 800°C then normalized. Thermocouple attached with lead-bath furnace as showing the cycles Figure 1.

Table 1: *Chemical composition of the both is listed.*

Composition wt%	Si	C	N	Mn
Experimental steel	0.241	0.463	0.0049	0.872

From ASM metals the austenizing temp: for up-quenching heat treatment (Heat Treatment of Metals Volume 4). From austenitic temperature sample must be quenched under water then perpendicularly cut in rolling direction, mount then polished check the microstructure after etching by Picric Acid and Nital at optical microscope as globally accepted.

Microstructural features

The qualitative and enhanced features of fundamental microstructure (which is a basic tool for a metallurgist), requires the improvements in metallographic dexterity (Abro *et al*., 2019). In this CHQ steel consecutive etching Nital followed by picric acid solution was employed, after etching the optical micrographs were achieved and then followed by SEM microscopy (Ghaferi *et al*., 2019; Ishteyaque *et al*., 2019; Abro *et al*., 2020). For better observation of microstructure used SEM in which secondary electrons requires the formulation of topographic contrast between the distinct phases. Nital is suitable, that it etches the ferritic phase and counter austenite and cementite intact phase (Abro *et al*., 2019; Chandio *et al*., 2019). To reveal the austenite phase 4 % picric diluted in 100grm ethyl alcohol (ASTM E407 Designation) was used consecutively after etching in 2% nital solution. Formation of austenite in any steel has pronounced effect on its mechanical properties (Abro *et al*., 2018).

Microstructural features at T_1

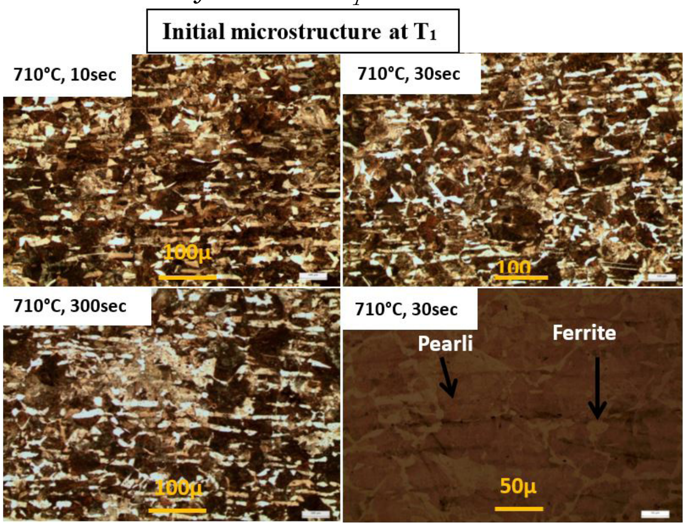

Figure 2: *Initial microstructure is ferrite and pearlite.*

The X-ray diffraction investigation confirms that marten site has been formed.as shown in Figure 5 (Channa *et al*., 2019). The initial microstructure of experimental CHQ steel was ferrite and pearlite at 710°C as shown Figure 2, at holding time of 10, 30, 300 sec. no phase transformation take place except coarsening of Ferrite at 300 sec. (Abro *et al*. 2019). The XRD analysis was performed to ensure the initial microstructure.

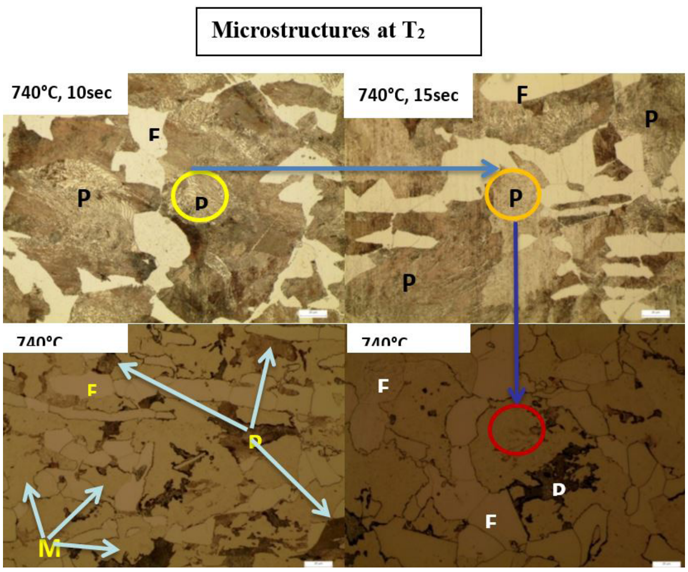

Figure 3: *Microstrucrutural features at 740 °C.*

Microstructural features at T_2

As above the AC_1, the ferrite + pearlite phase mixture is stable, so as increasing temperature the mixture becomes unstable in Figure 6 explaining the transition difference between Gibbs free energy and states (Abro *et al*., 2018). As shown nucleation of austenite can be possible in two steps at ferrite-ferrite grain interfaces or ferrite pearlite interface. Attraction of Austenite nucleation in this experimental steel is possible in Pearlite Island only. as going towards iron carbide boundaries of γ-phase field just solubility difference in α- γ iron rejects carbon particle.

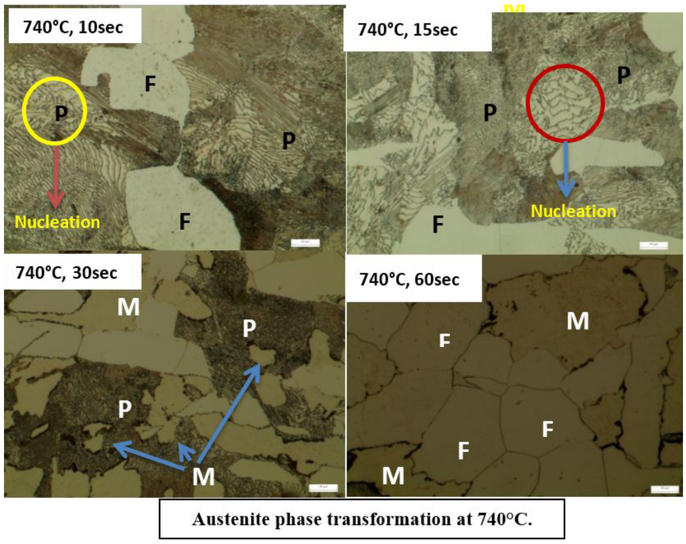

Figure 4: *Nucleation sites for austenite and austenite become marten site upon cooling.*

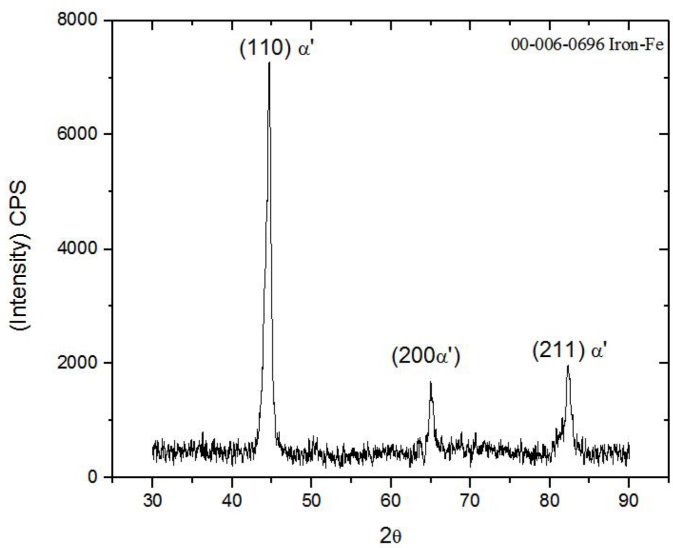

Figure 5: *X-ray diffraction pattern for CHQ Steel at 800°C.*

As cooling rate increases on ferrite-ferritic grain boundaries the presence of carbide particles increase level of austenitic nucleation is doubtful (Abro *et al*., 2019). The holding time plays an important role to nucleate the new austenite grain formation. nearby pearlitic colony nucleation grains takes place broadly. At 740°C, holding time of 10 and

15 sec respectively there is no change or negligible change in microstructure. The Aus. nucleation and growth were observed at the holding time of 30 and 60sec, with increasing holding time, ferrite packet size increases a little, but pearlite phase slowly and gradually decreases to give rise to Aus. phase nucleate. In the pearlite phase cementite plates provide carbon source to nucleate the Aus. grain at the interface of ferrite-pearlite and also it is shorter distance to help for Aus. nucleation and growth. A homologous microstructural behaviour was observed in reference (Savran *et al*., 2007) at ferrite-cementite interfaces, nucleation of austenite starts at carbon colonies, for instance, in pearlite.

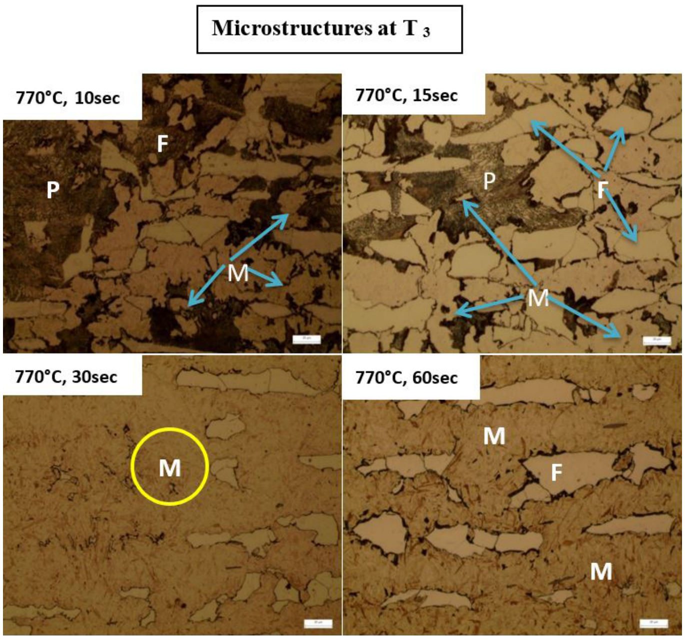

Figure 6: *Austenite nucleation and growth phenome neon at 770°C. Austenite becomes marten site up on cooling.*

Microstructural features at T_3

The Aus. nucleation and growth were observed at the holding time of 10 and 15sec there was a very slow phase transformation process occurs. However, with increasing holding time from 30 and 60sec respectively Aus. grows by disappearing pearlite phase. The nucleation and growth sites are mostly pearlite island with increasing time ferrite packet size decreases. The holding time 10sec and 15 sec on 770°C, the microstructure is highly hetero-genus and Pearlite (black), ferrite (white), and marten site matrix (gray) (Channa *et al*., 2019). At holding time of 60sec pearlite areas disappeared and ferrite a ferrite and marten site appears.

Microstructural features at T_4

During the forming of Austenite high and low temp: At elevated temp: into the austenite region its initial microstructure, is pearlite and ferrite). Transformation driving force for enhanced to change energy of the product phase, the mobility of atoms increases as temperature increasing. Both the frequency of nucleation and growth instantaneously increases with increasing temperature. The effects of up-quenching heating exhibit through micrographs at various soaking intervals as shown at 800°C. The black spots at high temperature accumulate and developed the network and representation of standard grain size. Along black spots the ferritic phase is present, apparently at former grain boundaries.

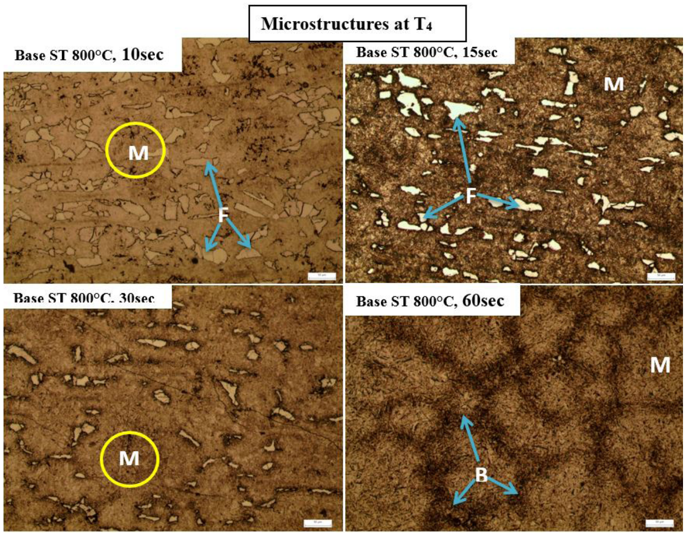

Figure 7: *Austenite growth morphology at 800°C. Austenite becomes marten site upon cooling.*

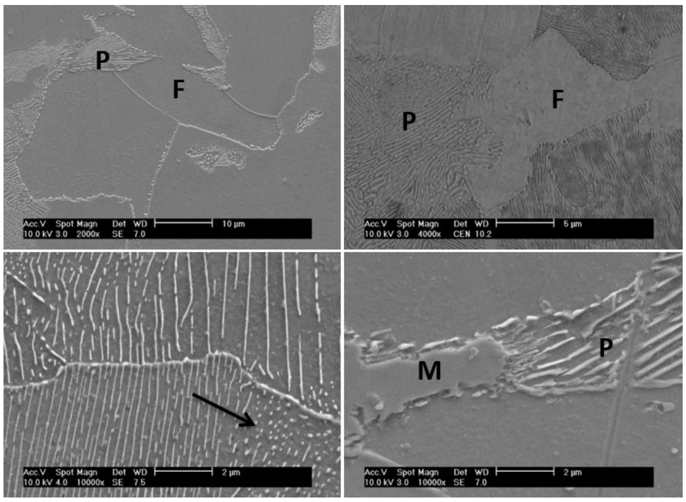

Figure 8: *SEM micrograph at 740°C, 10, 15, 30 and 60sec, showing the austenite formation. Arrow indicating the partially dissolved pearlite.*

Fresh gamma-austenite parts nucleate within pearlite microstructure and grow in alpha-ferrite. Bainite microstructure (black spots) is able to seen with in the zone of former pearlite grains. Pro-eutectois ferrite is surrounded by these black spots which resembles the bainite formation.

Links Researchers

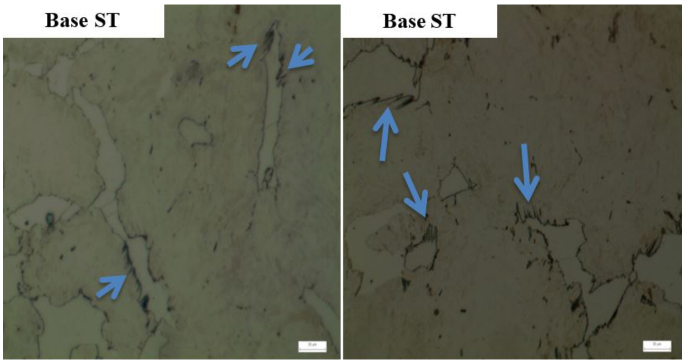

Figure 9: *(a) and (b). Acicular (finger) type growth is spotted on the pearlite-ferrite grain boundaries.*

With increasing holding time up to 30sec the structure tends to homogenize and decreases ferritic phase and slowly disappeared as increased holding time to 60sec. A similar behavior of microstructures was observed by V.I. SAVRAN and his co-authors in their research work.

Results and Discussion

The austenite formation including nucleation and growth of a CHQ steel in up-quenching experiments using lead-bath, has been studied in detail and it is found that: Formation of Austenite only in pearlite phase and no chance at nearby eutectoid ferrite Cementite plates are liable source to develop carbon on ferrite-ferrite grain interface.

Conclusions and Recommendations

- Without additional alloying and heat treatment there is a probability to get fine microstructure (altering the grain size) by adopting up-quenching technique.
- Elongation rate (coldheability) increased by homogenous distribution of microstructure in CHQ steel.
- At higher temperatures amount of nucleation and growth increases which develop austenitic phase majorly. At 800°C with soaking time 60sec, the pearlitic phase slowly dissolves in austenite as soaking time increases.
- At ferrite-ferrite interface carbides is not present due to up–quenching rapidy , if carbide present before phase transformation, upon cooling it disperse in carbon that could be martensitic and austenitic phase. Parallel increase in temperature and holding time decrease the size of pearlite phase and upon cooling it converts to martensite.
- At higher temperature network of Pro-eutectoid α phase slowly towards vanish.
- At 800°C finger type morphology was detected in fig 9(a) and 9(b)
- Ferrite - pearlite grain, finger (Acicular) type growth is achieved. Same morphology also observed In Savran (Savran, Van Leeuwen *et al.* 2007)

Novelty Statement

The srudy is novel because it discusses the development of microstructure as a function of temperatures.

Author's Contribution

Shahid Hussain Abro: Supervised the research.
Mohammed N. Alghamdi: Some part of ex-perimental work (SEM).
Muhammad Sohail Hanif: Provide support in discussion part.
Hazim Moria: Interpretation of results.
Hamza Suharwardi: Translation and writeup.

Conflict of interest
The authors have declared no conflict of interest.

References

Abro, K.A., *et al.*, 2019. Enhancement of heat transfer rate of solar energy via rotating Jeffrey nanofluids using Caputo–Fabrizio fractional operator: An application to solar energy. Energy Rep., 5: 41-49. https://doi.org/10.1016/j.egyr.2018.09.009

Abro, S.H., 2019. Role of Mn Atoms on tensile properties of light weight CHQ steel. J. Eng. appl. Sci., 38(1): 69-74.

Abro, S.H., *et al.*, 2018. Effect of heating rate on microstructural developments in cold heading quality steel used for automotive applications. Mehran Univ. Res. J. Eng. Technol., 37(3): 461-466. https://doi.org/10.22581/muet1982.1803.02

Abro, S.H., *et al.*, 2018. Influence of austenite phase transformation on existing Microstructure of low C-Mn steel. Eng. Technol. Appl. Sci. Res., 8(6): 3525-3529. https://doi.org/10.48084/etasr.2324

Abro, S.H., *et al.*, 2019. Aluminum and aluminum nitrides effect on nucleation sites in micro-alloyed steel. Proc. Pak. Acad. Sci.: A. Phys.

Comput. Sci., 56(3): 17-26.
Abro, S.H., *et al.*, 2019. Findings of grain coarsening temperature and grain growth of light weight steel used in automotive industry. Pak. J. Eng. Appl. Sci., 24(1): 14-17.
Abro, S.H., *et al.*, 2020. Ageing analysis of power cable used in nuclear power plant. Mehran Univ. Res. J. Eng. Technol., 39(1): 195-204. https://doi.org/10.22581/muet1982.2001.18
Abro, S.H., *et al.*, 2020. On the effect of austenite formation kinetics on microstructural features of cold heading quality CHQ steel. NUST J. Eng. Sci., 11: 2. https://doi.org/10.24949/njes.v11i2.399
Abro, S.H., *et al.*, 2020. Impact of nano sized aluminum nitride second phase particles on gamma and alpha phase transformation in less carbon added manganese steel. Pak. J. Eng. Appl. Sci., 27(2): 85-92.
Abro, S.H., *et al.*, 2020. Understanding the effect of aluminum addition on forming the second phase particles on grain growth of micro-alloyed steel, ng. Technol. Appl. Sci. Res., 10(1): 5153-5156. https://doi.org/10.48084/etasr.3243
Abro, S., *et al.*, 2019. Effect of Al, Ni, Mo, Ti, Nb and temperature on grain size number in low carbon high alloyed steel. Sindh Univ. Res. J. SURJ (Sci. Ser.), 51(1): 59-64. https://doi.org/10.26692/sujo/2019.01.11
Chandio, A.D., *et al.*, 2019. Silicon carbide effect as reinforcement on aluminium metal matrix composite. J. Chem. Soc. Pak., 41(4): 650-654.
Chandio, I.A. and S.H. Abro. 2018. Effect of temperature and time on nickel aluminide coating deposition. Mehran Univ. Res. J. Eng. Technol., 37(4): 491-496. https://doi.org/10.22581/muet1982.1803.02
Channa, I.A., *et al.*, 2019. Effect of tempering temperature on the properties of martensitic stainless steel AISI-420. Sukkur IBA J. Emerg. Technol., 2(1): 51-56. https://doi.org/10.30537/sjet.v2i1.430
Ghaferi, M., *et al.*, 2019. Evaluation of different heat treatment cycles on improving single point incremental forming of AA6061 aluminum alloy. Int. J. Adv. Manuf. Technol., 105(1): 83-100. https://doi.org/10.1007/s00170-019-04167-2
Ishteyaque, S., *et al.*, 2019. Hazard and operability study of gas exploration field located in Pakistan. Sindh Univ. Res. J., 51 (2): 41-49.
Kelly, A., 1963. Precipitation hardening. Prog. Mater. Sci., 10: 151-391. https://doi.org/10.1016/0079-6425(63)90010-0
Savran, V., *et al.*, 2007. Microstructural features of austenite formation in C35 and C45 alloys. Metall. Mater. Trans. A., 38(5): 946-955. https://doi.org/10.1007/s11661-007-9128-3