iJRASET
International Journal For Research in Applied Science and Engineering Technology



INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 10 **Issue:** VI **Month of publication:** June 2022

DOI: https://doi.org/10.22214/ijraset.2022.43096

www.ijraset.com

Call: 08813907089 | E-mail ID: ijraset@gmail.com

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 10 Issue VI June 2022- Available at www.ijraset.com

Design, Modeling and Analysis of Reciprocating Compressor

Hrishikesh Ganesh Jarang[1], Dr. R. S. Deshpande[2]
[1]M.E. Scholar, [2]Associate Professor, P.V.P.I.T. Bavdhan, Pune

Abstract: ***The present day concept of automation has increased the use of compressed air in every field of industrial life. To design double acting gas compressor with an intention to provide the operating pressure required for less time taken by single acting compressor to generate the same pressure of compressor. Basic components of double acting reciprocating gas compressor are designed. In this paper the process of reciprocating gas compressor from raw stage to the analytical stage had been explained. In these process firstly to check the standard data and as per standard data the design calculation is being proceed. The aim of this topic is to know the effect on piston, connecting rod, piston head, and piston rod, guide way and may other components. We have limited standard bore size diameter reciprocating gas compressor cylinder so to get various bore size diameter for various place and for various uses for that reason to develop the compact size reciprocating gas compressor cylinder. So to get the proper results as per standarddata book need many research papers, books, and data so that it can be very helpful for designing and developing compact size reciprocating gas compressor cylinder. While designing the reciprocating cylinder one thing should be considered that is the capacity of gas tank should be measured, the standard cubic meter per hour (SCMH) should be known and to find out the SCMH valve we have to know the stroke length of reciprocating gas compressor. It means that for designing and making compressor firstly know the duty cycle and SCMH of reciprocating compressor.***

Keywords: Reciprocating Compressor, Natural Gas, Square Engine, Positive-displacement, Double-acting, Compressed gas

I. INTRODUCTION

This paper represents the vital role of compressor in various field like oil extraction, gas production, oil purification, gas transmission, refrigeration, chemical industries, etc. To obtain thehigh temperatures required to metal to metal, one needed a steadystream of oxygen to blow into the fire. In general compressors supported the principle of operation, compressors unit classified into positive displacement compressors and non-positive displacement or dynamic compressors. Though the particular demand is under rated capability needs to be modify within the production method and are associated in having to the air source. However the capability of compressor is from time to time regulated by means of avoid flowing ends up with the exceedingly wasted energy. Reciprocating have their sub types like single acting reciprocating compressor, double acting reciprocating compressor, single stage and multistage. They found to be an particularly in application, like within oil and gas, or in industry.

Mainly, piston compressors are very important half in any method which are utilized in. Some of the key components of reciprocating compressor are cylinder which is the main components of compressor the next one is crankshaft which is connected with the connecting rod which is guided with the guideway, the piston in which having suction or inlet and discharge or outlet, the valves is also the important part of compressor there are types of compressor with their ratings. The frame is there wherethe main operation is perform. In the positive displacements compressor a piston is driven through shaft and rod through with electric motor, which reduces the quantity of the cylinder occupied by the gas. In reciprocating compressor the gas intake in the suction manifold, then flows into the compression cylinder everywhere it gets compressed. Reciprocating applications are oil refineries, oil and gas production, gas pipelines, etc. In reciprocating compressor suction gas square measure typically suffered in suction strainers and get separated to rid of entrained particulates. The crank-shaft is fitted with the counterweights to balance the dynamic forces which created by the movement of bearings. The distance piece can be supported through the connecting rod which is placed frame to the cylinder. The distance piece is usually with the foremost material within the system.

In single acting reciprocating compressor the gas can be sort andthat uses just one finish of the piston for the suction and the compression purpose. That means in normally the primary stroke of the piston intake the gas within the compressor whereas the gas compression happens within the second stroke. Therefore, in just one aspect of the piston uses for consumption and the compression functions. As the piston moves in a down ward direction then the gas pressure in the intervals drops down below the pressure of the atmosphere in cylinder.

While in double acting reciprocating compressor cylinder that uses each side of the piston through gets intake/inlet by valves and gets compress the gas is termed as double acting reciprocating compressor cylinder. In double acting the piston gets in both the direction i.e. in straight ward as well as in backward also. As the compression heat is increase the "double acting" reciprocating compressor is cool with the help of air cooled heat exchangers and limit up to the standards value. In reciprocating compressor the cylinder include within the essential double-acting elements. On the little compressor, the cylinder were created directly into the compressor. In the whole process thepiston movement among the cylinder, the fluid or gas should not get leak through the space between the piston and also through the cylinder wall.

II. LITERATURE REVIEW

In these literature reviews it is mainly focus on the positive- displacement compressor and that of reciprocating gas compressor. Reciprocating compressor play a vital role on industrial areas. This literature survey is for too deep study on reciprocating compressor there various types of components, the use of material for casting cylinder, the design calculation of reciprocating compressor of various components, after modeling of compressor static and thermal analysis has been done on reciprocating compressor. While studying on a reciprocating compressor many parameters have been considered like their design parameter, pressure and temperature, their stroke length, etc.

III. METHODOLOGY

- In design consideration I study on the on the design aspects like capacity of tank, size of compressor, compression ratio with respect to high and low pressure.
- In design calculation read the design procedure of reciprocating compressor from various journals, research paper , reference books , etc.
- While doing modeling the applying of all design calculation with design aspects for making a #d CAD modeling tocheck whether the design calculation and design parameters are right as per standards

In analytical section, the static and thermal analysis have been done on 3d CAD modeling of reciprocating compressor

A. Square Engines

Bore-Stroke Ratio is the ratio between the measurements of the bore diameter of engine cylinder to its piston stroke- length. The bore diameter of cylinder is divided by the “stroke- length” gives the “Bore-to-Stroke” ratio.

The ‘Bore-stroke ratio’ is a significant factor which determines engine’s power & torque independently. The bore to stroke (B/S) ratio is an aspect that should be considered primary in the design stage of the engine. As the “bore/stroke” ratio decreases under the same interruption conditions, the cylinder surface/volume ratio at top dead center (TDC) also decreases, which increases engine efficiency due to the cooling reduction effect. Like this, the “Bore to Stroke” ratio is an important factor that directly affects engine efficiency.

Various studies based on the “Bore to Stroke” ratio have been previously conducted. Mainly the studies have been interpreted to compare the turmoil intensity, flame surface and thermal efficiency in the cylinder according to the “Bore to Stroke” ratio. Experimental studies based on B/S ratios were often conducted. However, in the case of engine investigation is based on most Bore to Stroke ratios, the torque and engine power comparison.

IV. CYLINDER CALCULATION

In a reciprocating compressor, the proficiency depends on the degree displaced by the piston throughout its movement. The swept volume of 1 piston may be calculated the subsequent means. Not all the cylinder volume may be used for the compression as there's invariably the clearance at the top of the cylinder that is still with some air within. This development may be quantified by process the meter effectiveness of the mechanical components.

A. Selection of Material

Reciprocating compressor cylinders are made from designated material for explicit pressure and gas handling capacity. Low pressure gas vapor enters the compression chamber through suction port of the positive displacement reciprocating compressor and mechanical work decreases as the inflict vapors to rise. For low and medium pressure cylinders they are fabricated from forged iron and howeverare accessible in nodular iron. In medium to high pressure cylinders the material used as a nodular iron for the medium to air mass cylinder and for the higher pressure cylinders the compressor is made up of steel forging.

TABLE I MATERIAL PROPERTIES

	Properties	**Ductile Cast Iron (ASTM A 536)Gr. 60-40-18**
1	Tensile Strength	460 MPa
2	Yield Strength	310 MPa
3	Allowable Bending Stress	230 MPa
4	Shear Modulus	66 GPa
5	Density	7.1 g/cm^3
6	Coefficient of Thermal Expansion	6.4 X 10^{-6}/^{0}F
7	Thermal Conductivity	36 W/m-K
8	Elongation	22%

B. Experimental Setup

Suction Pressure (Ps): - 4
Bar Temperature (T): - 300
Celsius Stroke length (S): - 73.025 mm
RPM: - 900-1600
R = 461.88 J/Kg. K

Diameter of cylinder (D) = 73.14 mm = 2.875 inchesEquations:
By Ideal Gas EquationPV = mRT
Swept volume is outlined because the volume swept by theengine piston throughout one stroke

Swept Volume (V) = $\pi r^2 S$

Volumetric Efficiency= Effective Swept Volume with respect to swept volume= $\frac{V1-V4}{V1-V3}$

Mass Flow Rate of Gas in (SCMH) = $\frac{m \text{ X Volumetric efficiency}}{\text{Density of gas}}$

Total length of cylinder = Stroke length + Piston length + Clearance length at head end + Clearance length at crank end

Total height of cylinder = Internal Diameter of Cylinder + Thickness of inner shell + Outer shell Thickness and Flange Thickness

V. SIMULATION

For making a 3D CAD model simulation is the earlier step have been done on the basis of design aspects. All the calculated values that are to be used and according to the design standards the 3D CAD model has been done on the basis of design calculation

VI. MESHING

There are different shapes or topologies of element selected while performing meshing. Different types of elements are used depending on the shape of the CAD Model. For complex geometry tetrahedral element fits better than the other elements. The computing time of the tetrahedral element is less as compared to other elements. While doing meshing various things to be consider for better meshing like aspect ratio, skewness, jacobian ratio, element quality and maximum quality angle.

A. Boundary Condition

Boundary conditions can be applied to geometry including faces, edges, points, vertices, nodes, elements or the entire model. Finite element analysis is carried out by static structural and steady state thermal analysis. Static structural analysis is carried out by considering the loads of inside working pressure of cylinder, self-weight, and steady state thermal analysis is carried out by considering the load of design internal temperature of cylinder.

VII. RESULT AND DISCUSSION

For brittle material the maximum principle stress has been calculated and for the ductile material equivalent stress (von-Misses) stress has been calculated. So on these basis I have calculate equivalent stress (von-Misses) stress and the value is in their under limit i.e. in the safe condition i.e. according to the material ductile iron ASTM A536 Gr.60-40-18 maximum allowable stress is 230 MPa and that of calculated maximum allowable stress is 214 MPa according to the ansys software results. The deformation is also the main factor which affects while performing reciprocating compressor in actual condition.

VIII. CONCLUSIONS

The theoretical calculation, simulation and analytically are found to be completely safe and within safe stress limit for reciprocating gas compressor cylinder. As per results and by referring material properties the maximum equivalent (von-Misses) stress is 143.46 MPa and their limit is 230 MPa. The total deformation is 0.42319 mm which is negligible and limit up to 5 mm.

A. Recommendations

Used of ductile iron is more preferable as because of having maximum allowable stress as compared to others.

B. Future Scope

The CNG cylinder demand is increasing and the various modifications had been coming on compressor according to their uses and their limitations. As the size of compressor gets compact then there should be increase in thickness of cylinder results gets heavier while carrying, so research should be done on these basis.

IX. ACKNOWLEDGMENT

It gives us great pleasure to present this paper on Design, Modeling and Analysis of Reciprocating Compressor. In preparing this paper on project work number of hands helped us directly and indirectly. Therefore, it becomes my duty to express gratitude towards them.

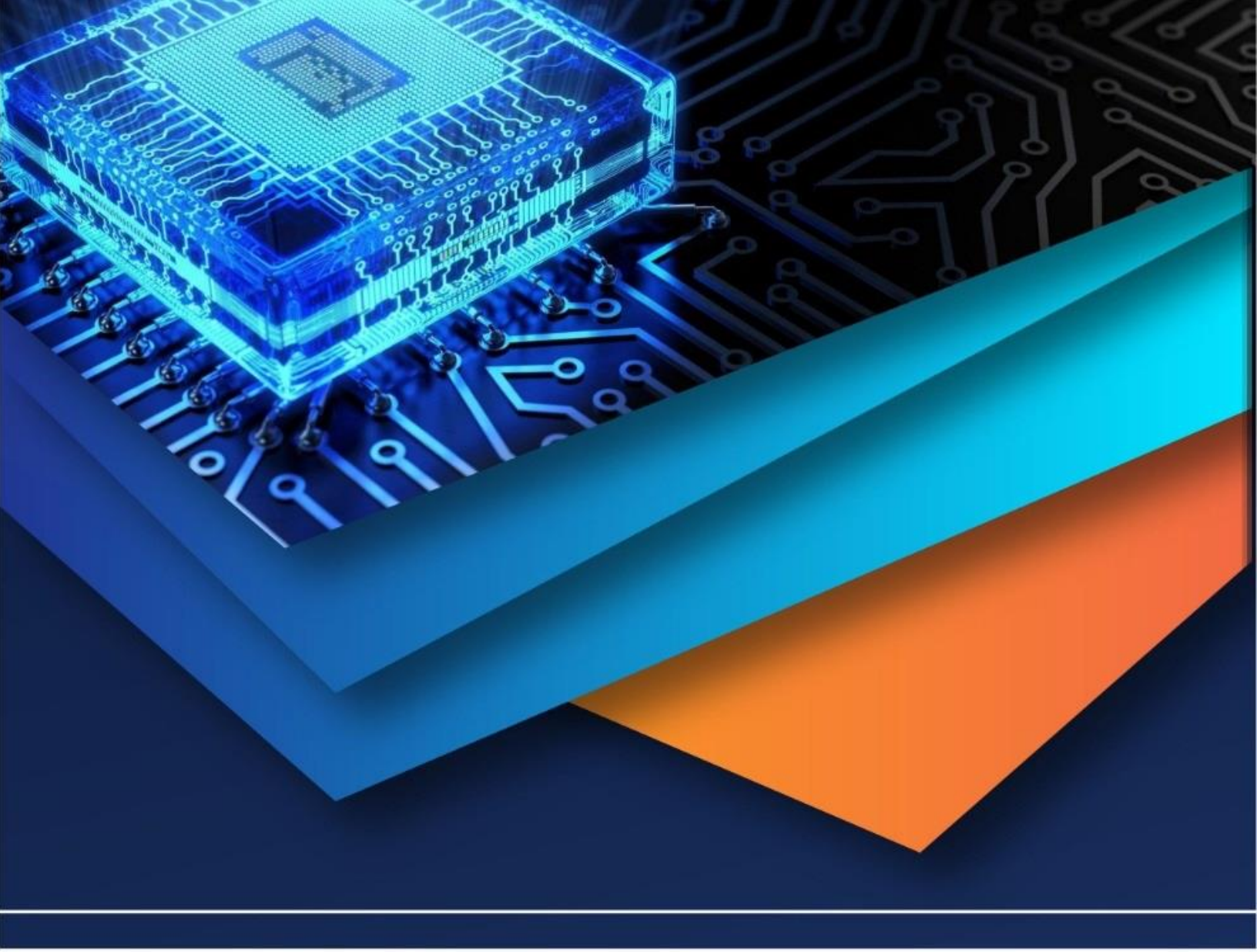
We wish to express sincere thanks to my Guide Pradip T. Kharat and Co-Guide Dr. R. S. Deshpande for his valuable guidance and encouragement throughout the course of the work. His inspiration constantly endeavors co- operation in analyzing the documents, data and helpeda lot to complete the project successfully in time.

REFERENCES

[1] Performance Assessment of a Two-Stage Reciprocating Air Compressor-IkpobariAmueleNwakpang, Barinaadaa Thaddeus Lebele-Alawa, and BarinyimaNkoi - European Journal ofEngineering Research and Science, Vol 4, No.4, April 2019
[2] Performance Analysis of a Single-acting Reciprocating Compressor Using Thermodynamic Concepts- Ekong, Godwin I., Ibibom, Emmanuel N. , Bassey, Isaiah U.- International Journal of Engineering Science Invention (IJESI) ISSN (Online): 2319-6734, ISSN (Print): 2319-6726 www.ijesi.org,Volume 9 Issue 5 Series I , May 2020 , PP 20-31
[3] Optimization of capacity control of reciprocating compressor using multi-system coupling model-Xu Sun, Jinjie Zhang, Yao Wang, Junyan Wang, Zhen Qi.- Applied Thermal Engineering, Volume 195, August 2021, 117175
[4] Design, Modeling and Analysis Of Double Acting Reciprocating Compressor Components– P.K.Jadhao , K.K. Jadhao, S. S. Bhagwat - International Journal of Scientific & Engineering Research Volume 3,
[5] Issue 4, April-2012 ISSN 2229-5518
[6] Design and fabrication of multi engine air compressor- P.Balashanmugam, G.Balasubramanian - International Journal of Scientific and Engineering Research, Volume 3, Issue 4, April 2012
[7] Failure analysis of reciprocating compressor crankshafts-J.A.Becerra, F.J.Jimenez, M.Torres, D.T.Sanchez, E.Carvajal - Engineering failure Analysis, Volume 18, Issue 2, March 2011, Pages 735-746
[8] Improvement of one-dimensional gas dynamic model for pulsation prediction in reciprocating compressor systems-Liu Zhanz, Enle Xu, WenguangJia, Cao Xing - Energy Procedia, Volume 152, October 2018, pages 137-142
[9] Thermodynamic analysis of natural gas reciprocating compressors based on real and ideal gas models- Mahmood Farzaneh-Gord, Amir Niazmand, Mahdi Deymi-Dashtebayaz, Hamid Reza Rahabari - International Journal of Refrigeration, Volume 56, August 2015, Pages 186-197
[10] The Estimation of Thermal Conditions of Highly-cooled Long-stroke Stages in Reciprocating Compressors-Yusha V.L., Den'gin V.G. , Busarov S.S , Nedovenchanyi A.V. , GromovA.Yu.- International Conference on Oil and Gas Engineering, OGE-2015, Procedia Engineering 113 (2015) 264-269
[11] Updating temperature monitoring on reciprocating compressor connecting rods to improve reliability-Jim Townsend, M. Affan Badar, Julie Szekerces - Engineering Science and Technology, an InternationalJournal, Volume 19, Issue 1, March 2016, Pages 566-573
[12] Improving torque performance in reciprocating compressors viaasymmetric stroke characteristics-Ibrahim A. Sultan, Truong H. Phung
[13] Positive Displacement Machines, Modern Design Innovations and Tools, 2019, Pages 145-162
[14] Design of Machine Elements – V.B.Bhandari
[15] Studies on hard chrome plating in reciprocating air compressors - Aadhithiyan Amutha Kulasekaran, Anbarasu Subramanian - Proceedings of the

ASME 2018, International Mechanical Engineering Congress and Exposition IMECE2018, November 9-15, 2018,
[16] Pittsburgh, PA, USA
[17] Analysis of valve-retainer orientation influence on a reciprocating compressor for natural gas vehicle refueling stations – IssacoStiaccini, Giovanni Galoppi, Francesco Balduzzi, Marco Sacco, Sabrina Santoni, Giovanni Ferrara - Journal of Natural Gas Science and Engineering,
[18] Volume 38, February 2017, Pages 516-526
[19] Design considerations for an engine-integral reciprocating natural gas compressor – Mohammad Malakoutirad, Thomas H. Bradley, Chris Hagen - Applied Energy, Volume 156, 15 October 2015, Pages 129- 137
[20] Second law analysis on performance of double stage reciprocating air compressor with inter cooler – C.Subramaniyan, B.Kalidasan,
[21] N.Bhuvanesh, K.B.Prakash, A.Amarkartik
[22] Detection and estimation of valve leakage losses in reciprocating compressor using acoustic emission technique – Hoi Yin Sim, RahizarRamli, Ahmed Saifizul, Ming Foong Soong - Measurement,
[23] Volume 152, February 2020, 107315
[24] The Experimental Research of the Thermal Conditions in Slow Speed Stage of Air Reciprocating Compressor – V.L.Yusha, S.S.Busarov, R.Yu.Ghoshlya, A.V.Nedovenchanyi, B.S.Sazhin, M.A.Chizhikov,
[25] I.S.Busarov - Procedia Engineering, Volume 152, 2016, Pages 297-302
[26] Reliability, Availability, Maintainability (RAM) study, onreciprocating compressors API 618 – Francesco Corvaro, Giancarlo Giacchetta, Barbara Marchetti, Maurilio Recanati - Petroleum, Volume 3, Issue 2, June 2017, Pages 266-272
[27] Comparison of heat transfer models for reciprocating compressor – J. Tuhovcak, J.Hejcik, M.Jicha - Applied Thermal Engineering, Volume 103, 25 June 2016, Pages 607-615
[28] Approximation of the compression process to isothermal in a reciprocating compressor with a liquid piston - V.E.Shcherba, E.A.Pavlyuchenko, E.Yu.Nosov, I.Yu,Bulgakova - Applied Thermal Engineering, Volume 207, 5 May 2022, 118151
[29] Numerical and experimental study on fluid compressibility in a two- stage reciprocating pump-compressor - Andrey Zanin, Evgeniy Pavlyuchenko, Victor Scherba - Applied Thermal Engineering, Volume194, 25 July 2021, 117106
[30] Piston trajectory optimization of a reciprocating compressor - Ernane Silva, Thiago Dhutra - International Journal of Refrigeration, Volume 121, January 2021, Pages 159-167
[31] Towards energy-efficient LNG terminals: Modeling and simulation of reciprocating compressors - Harsha V Reddy, Vikas S Bisen, Harsha N Rao, Arnab Dutta, Sushant S Garud, Iftekhar A Karimi, Shamsuzzaman Farooq - Computers and Chemical Engineering, Volume 128, 2 September 2019, Pages 312-321
[32] Evaluation of ionic liquids as replacements for the solid piston in conventional hydrogen reciprocating compressors: A review - NasrinArjomandKermani, Irina Petrushina, Marvin M. Rokni - International Journal of Hydrogen Energy, Volume 45, Issue 33, 24 June 2020, Pages 16337-16354
[33] Performance characterization of small variable-capacity reciprocatingcompressors using a minimal dataset - Guilherme Z. Santos, Adriano F. Ronzoni, Christian J.L.Hermes - International Journal of Refrigeration, Volume 107, November 2019, Pages 191-201

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 10 Issue VI June 2022- Available at www.ijraset.com



10.22214/IJRASET

45.98

IMPACT FACTOR: 7.129

IMPACT FACTOR: 7.429

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Call : 08813907089 (24*7 Support on Whatsapp)