Experimental Analysis of Effect of Roller Burnishing Tool on Surface Integrity Enhancement of Aluminium Alloy 7075

Harish[1] , D. Shivalingappaa[1] , Raghavendra N[1], Udaya Devadiga[2]

[1]Department of Mechanical Engineering, B. N. M. Institute of Technology, Bengaluru, India

[2]Department of Mechanical Engineering, Nitte(Deemed to be University), NMAMIT, Nitte 574110, India

Abstract:

Roller burnishing tool is used for the experimental work of the present study on specially fabricated Aluminium 7075. In roller burnishing, a hard roller is pressed against a rotating cylindrical work piece and parallel to the axis of the work piece. Burnishing is essentially a cold forming process, in which the metal near a machined surface is displaced from protrusions to fill the depressions. The results show significant improvement in the surface roughness and surface hardness of aluminium alloy 7075 were achieved by the application of the roller burnishing process. In the present work, various experiments are conducted to investigate the effect of burnishing force and number of passes on the surface hardness and surface roughness of the aluminium alloy 7075.

Keywords: Burnishing, Hardness, Roughness, Aluminium alloy

1. Introduction

Burnishing is a method of finishing metal surfaces by plastic deformation under cold working conditions by application of pressure through either a hard steel ball or roller. Burnishing causes work hardening and creation of beneficial compressive stresses in the surface layers which, in turn, increase the micro hardness, wear resistance and fatigue strength of the surface layer of the component. Hardened and highly polished steel rollers are brought into pressure contact with a softer work piece. As the pressure exceeds the yield point of the work piece material, the surface is plastically deformed by cold-flowing of subsurface material. Roller burnishing is a metal displacement process. Microscopic "peaks" on the machined surface are caused to cold flow into the "valleys", creating a plateau-like profile in which sharpness is reduced or eliminated in the contact plane. The burnished surface will therefore resist wear better than the abraded surface in the metal-to-metal contact, as when a shaft is rotating in a bushing.

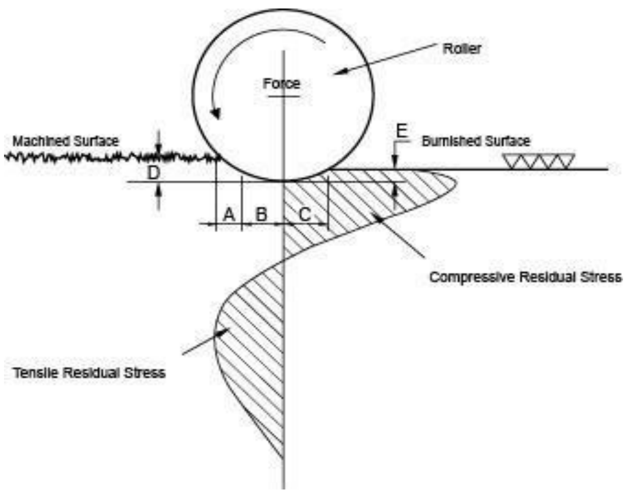


Figure 1 Stress distributions in roller burnishing process [1].

Rodrı´guez. *et al.* [1] carried out studies on the effect of roller burnishing on surface hardness and surface roughness on specially fabricated mild steel specimen. In roller burnishing, a hard roller is pressed against a rotating cylindrical work piece and parallel to the axis of the work piece. Burnishing is essentially a cold working process, in which the metal near a machined surface is displaced from protrusions to fill the depressions. Avile´*et al.* [2] studied about improving surface finish and hardness for M S cylinder using roller burnishing. High surface finish is required for proper working of the machine parts with long life. To get high surface finish lapping and honing processes are in use. These processes are costlier and time consuming. So there is a demand of time for a process which gives good surface finish economically. Harish *et al*. [3] carried out studies on effect of roller burnishing on the mechanical behavior and surface quality of O1 alloy steel which enhances the mechanical properties and micro hardness of the surface of O1 steel using the roller burnishing process. Widely used methods of finishing treatment that create necessary parts with the given roughness usually do not provide optimum quality of the surface. Therefore, methods of Surface Plastic Deformation (SPD) are used. One of the most effective representatives is the roller burnishing. This can simply achieved by pressing a hard and highly polished ball or roller against the surface of metallic work pieces. Harish *et al.*[4] carried out studies on effect of roller burnishing on fatigue properties of the hot-rolled Mg–12Gd–3Y magnesium alloy and found the influence of RB on the high cycle fatigue properties of the Mg–12Gd–3Yalloy was investigated because it is a substitute of aluminum so consider a fatigue property and find conclusions can be drawn: RB improved fatigue strength of the Mg–Gd–Y alloy significantly After RB, the fatigue strengths increased from 150 and 155 MPa, to 225 and 210MPa in the as-rolled alloy and the T5 heat-treated alloy. Y. Zhang *et al.* [5] investigated on single roller burnishing tool by modifying and controlling the burnishing force. Review of previous work carried out on burnishing provided an insight to understand the various mechanisms associated with burnishing and various burnishing methods. The key finding of this literature review are listed as follows:

- The effect of number of passes for the optimum surface finishes of components.
- Surface integrity enhancement of material by roller burnishing process.
- The enhancement of surface quality and tribological properties using roller burnishing process.

2. Methodology

The above defined objectives were accomplished by adopting a methodology for Experimental analysis. Brief description of the methodology followed during the course of this study is as follows;

i. Carry out the Literature regarding the effect of roller burnishing and on surface enhancement by referring journals, books and related documents.

ii. Carry out the design calculation for roller diameter and thickness.

iii. Carry out modeling using solid edge software.

iv. Carry out fabrication of burnishing tool and hydraulic cylinder with hand pump arrangement.

v. Carry out fabrication of fixture for the tool to fit to the lathe specification.\

vi. Carry out testing on surface hardness and surface roughness.

vii. Carry out microstructure testing of aluminium alloy 7075 by scanning electron microscope.

viii. To analyze effect of burnishing on the aluminium alloy 7075 specimen using roller burnishing tool.

3. Specimen preparation.

Specimen taken is aluminium alloy 7075 of length 159mm and diameter 25mm. First, the work piece is held in 3-jaw chuck of the lathe and facing operation is completed on both sides and centre drilling is completed on both faces. Then, the work piece is held in between centers of lathe. A high speed steel single point cutting tool is fixed in the tool post of the lathe and work piece is turned to have 3 step sand groove in between them. It was divided into three parts (1, 2, and 3) of length 50mm with a gap of 3mm. Three tests are to be conducted. Specimen one is without burnishing, specimen two and three are burnished specimen where the load applied is 20kg/cm² and 30kg/cm² respectively for three passes. Figure 2 explains the geometry details of work piece for burnishing.

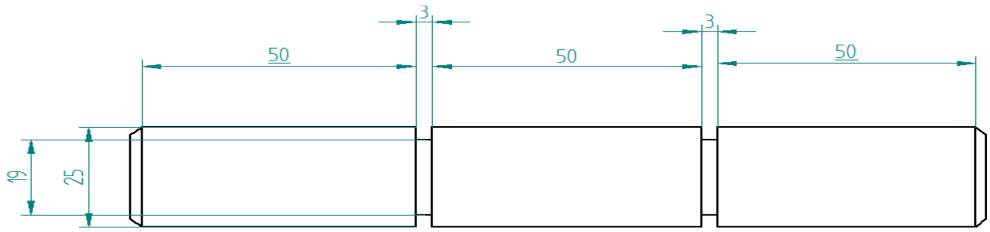


Figure 2 Work piece geometry (All dimensions in mm)

4. Conduction of Experiment.

Here the specimen prepared is fixed to lathe and burnishing tool is to be fixed to the tool post, so a fixture (clamp) has be fabricated in order to hold the tool in the tool post. The fixture has been fabricated in such a way that the tool can be fixed to any lathe. Once the tool is fixed to the fixture, the roller is bought into contact with the specimen. Lathe is switched on and speed is set to prescribed value, then the pressure is applied from the hand pump assembly through roller to the specimen. Different trials are conducted for change in pressure keeping speed and number of pass constant. The burnishing of the specimen is done for 3 passes. Figure 3 shows the experimental setup on the tool post of the lathe.

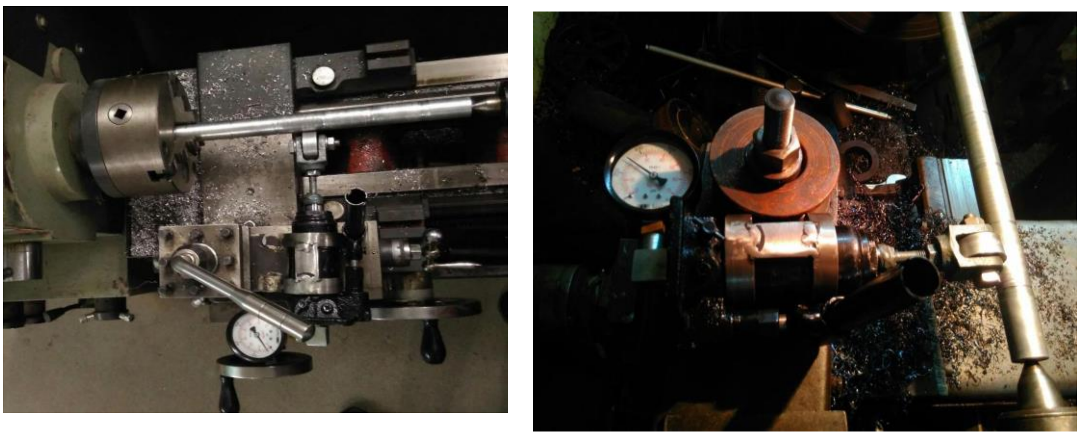


Figure 3 Experimental setup

5. Results and Discussion

In this chapter the results obtained from basic experimental tests namely Surface Hardness from Micro Vickers Hardness tester, Surface Roughness test from Tally Surf meter, and micro structure comparison by Scanning Electron Microscope on all the considered specimens are tabulated, compared and discussed carefully in the following sections.

5.1 Results.

In this section the results obtained from various experimental tests are tabulated. The roughness, hardness, and microstructure of three given specimens before and after burnishing process are tabulated and compared as follows.

5.1.1 Effect of Burnishing on Surface Hardness.

Burnishing is carried out for the specimen keeping passes constant. The pressure is varied once for 20kg/cm² and another one for 30 kg/cm² force, hardness of the material; before and after burnishing is tabulated below in the table 1.

Table 1 Experimental results of surface hardness of the specimen before and after burnishing process

Sl. no.	Specimen	MVHN			Average (Hv)
		1	2	3	
1	Without Burnishing	98.8	101.4	101.3	100.8
2	20kg/cm² 3 passes.	102.0	102.8	104.2	103.0
3	30kg/cm² 3 passes.	108.6	111.5	110.8	110.3

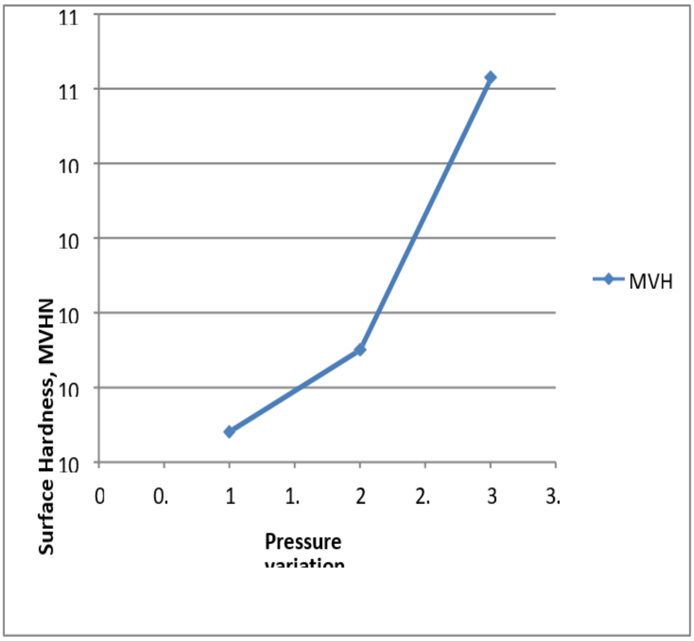


Figure 4 MVHN for 3 passes

5.1.2 Effect of burnishing on surface roughness.

Burnishing is carried out for the specimen keeping passes constant. The pressure is varied once for 20kg/cm² and another one for 30 kg/cm² force, Roughness of the material before and after burnishing is tabulated below.

Table 2 Experimental results of surface of the roughness specimen before and after burnishing process

Sl. no.	Specimen	Surface Roughness(µm)		
		Ra	Rq	Rz
1	Without Burnishing	6.28	8.24	15.67

2	20kg/cm² 3 passes.	2.692	3.23	13.3
3	30kg/cm² 3 passes.	1.910	2.39	10.68

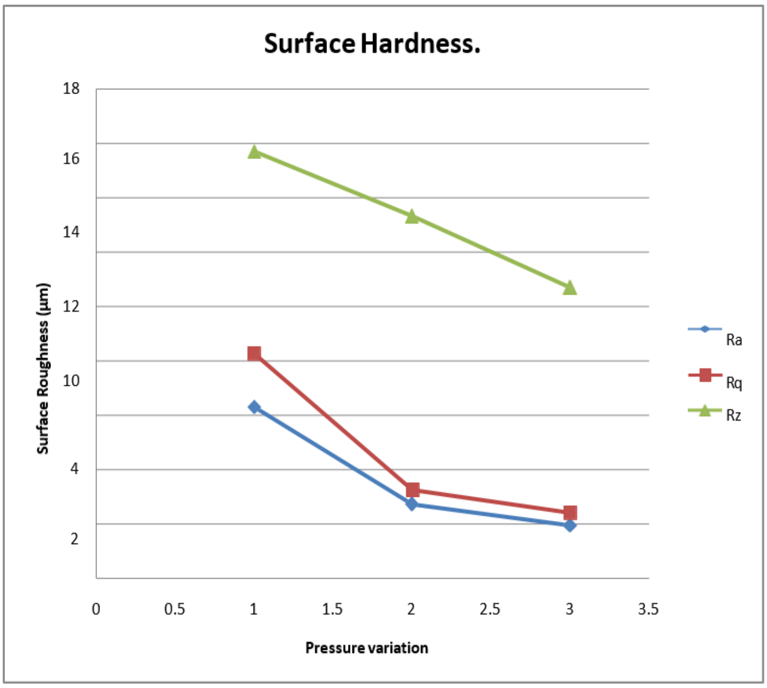


Figure 5 Surface roughness for 3 passes.

5.1.3 Discussion.

The obtained results of all the specimens were tabulated. It is observed that (from table 6.1) the hardness of the specimen has increased constantly with the increase in pressure. When 20kg/cm² has applied hardness is increased from 100.8 HV to 103 HV and when 30kg/cm² is applied hardness has increased from 100.8 HV to 110.3 HV.

From the table 6.2 results of all the specimens were tabulated. It is observed that the roughness of the specimen has decreased constantly with the increase in pressure. When 20kg/cm² is applied roughness (Ra) has decreased from 6.28µm to 2.692µm and when 30kg/cm² is applied hardness has increased from 6.28µm to 1.910µm.

5.2 Study on of Scanning Electron Microscope Images.

5.2.1 Sample preparation.

All samples must be of an appropriate size to fit in the specimen chamber and are generally mounted rigidly on a specimen holder called a specimen stub. Several models of SEM can examine any part of a 6-inch (15 cm) semiconductor wafer, and some can tilt an object of that size to 45°. For conventional imaging in the SEM, specimens must be electrically conductive, at least at the surface, and electrically grounded to prevent the accumulation of electrostatic charge at the surface. Metal objects require little special preparation for SEM except for cleaning and mounting on a specimen stub.

Nonconductive specimens tend to charge when scanned by the electron beam, and especially in secondary electron imaging mode, this causes scanning faults and other image artifacts. They are therefore usually coated with an ultrathin coating of electrically conducting material, deposited on the sample either by low- vacuum sputter coating or by high-vacuum evaporation. Conductive materials in current use for specimen coating include gold, gold/palladium alloy, platinum, osmium, iridium, tungsten, chromium , and graphite. Additionally, coating with heavy metals may increase signal/noise ratio for samples of low atomic (Z). The improvement arises because secondary electron emission for high-Z materials is enhanced.

5.2.2 Detection of backscattered electrons.

Backscattered electrons (BSE) consist of high-energy electrons originating in the electron beam, that are reflected or back-scattered out of the specimen interaction volume by elastic scattering interactions with specimen atoms. Since heavy elements (high atomic number) backscatter electrons more strongly than light elements (low atomic number), and thus appear brighter in the image, BSE are used to detect contrast between areas with different chemical compositions [6,7]. The present work investigated in detail, the microstructure of different specimen by using Scanning electron microscope (SEM). Images shown below for 200X and 500X magnification comparison of without burnishing and with burnishing for 20kg/cm² and 30kg/cm² for 3 passes.

5.2.3 SEM images of 200x magnification comparison.

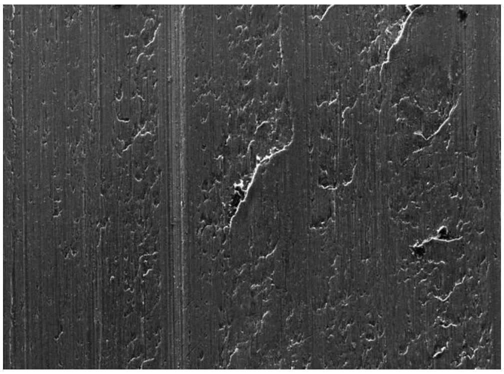


Figure 6 Microstructure image of surface without burnishing

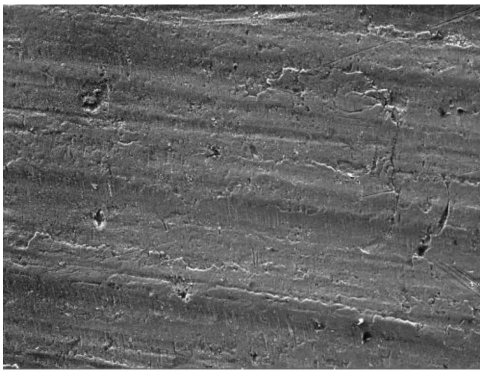


Figure 7 Microstructure image of surface with burnishing for 20kg/cm² with 3 passes

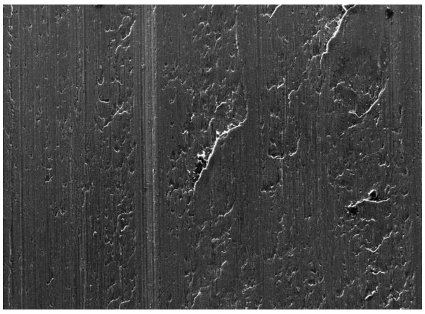


Figure 8 Microstructure image of surface without burnishing

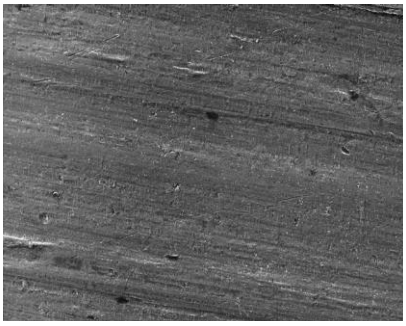


Figure 9 Microstructure image of surface with burnishing for 20kg/cm² with 3 passes

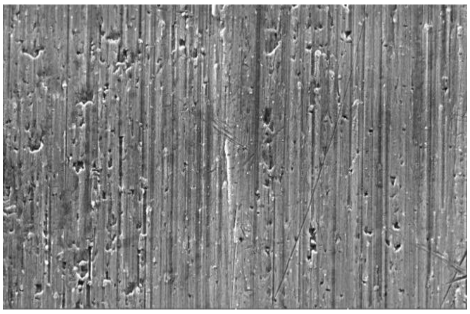


Figure 10 Microstructure image without burnishing.

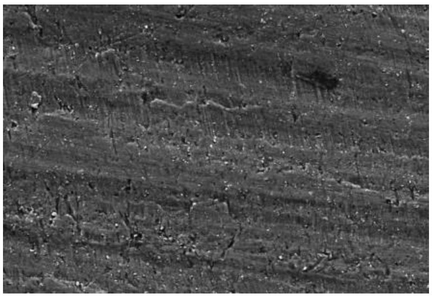


Figure 11 Microstructure image of surface with burnishing for 20kg/cm² with 3 passes.

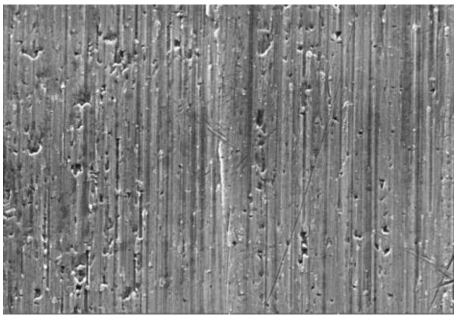
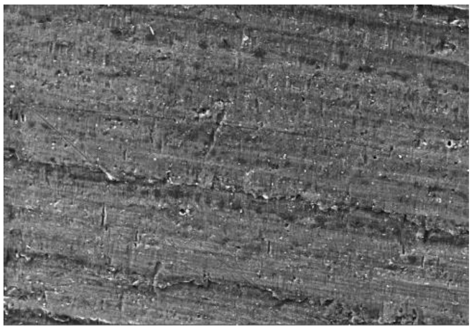


Figure 12 Microstructure image of surface without burnishing



Microstructure image of surface with burnishing for 30kg/cm² with 3 passes.

6. Conlusions and scope for future work

Conclusions.

Conclusions are drawn based on the results obtained from experimental methods are summarized as follows:-

1) Roller burnishing method which is employed for surface modification of aluminium alloy 7075. This allows the high spots to be flattened out and the valleys filled in. It is a new concept in finishing Components. This process eliminates Grinding and honing which are costlier processes while improving the surface finish, surface hardness, wear-resistance etc.

2) After burnishing the surface of aluminium 7075 alloy, the hardness test was conducted by using micro Vickers hardness tester to measure hardness and compared with the hardness value of al 7075 alloy without burnishing. The results show significant improvement in the surface hardness after burnishing process.

3) After burnishing the surface of aluminium 7075 alloy, the test was conducted by using tally surf meter to measure surface roughness and compared with the hardness value of aluminium 7075 alloy without burnishing. The results show significant improvement in the surface roughness after burnishing process.

Scope for future work

Scope for future work: This research work can be extended further in many directions, which are enumerated here.

1. Study the effect of burnishing on improving the corrosion resistance, wear resistance under different condition.

2. Thermal analysis of burnishing process can be taken up to study the effect of heat treatment, if any, on the surface characteristics.

3. Effect of induced compressive stress on stress corrosion cracking and fatigue strength can be analyzed.

4. The effect of burnishing on improving the thermal conductivity of materials can be investigated.

References

1. A. Rodrı´guez, L.N. Lo ´pez de Lacalle, A. Celaya, A. Lamikiz, J. Albizuri, Surface improvement of shafts by the deep ball-bur nishing technique. Surf. Coat. Technol. 206(11–12), 2817–2824 (2012). https://doi.org/10.1016/j.surfcoat.2011.11.045

2. R. Avile´s, J. Albizuri, A. Rodrı´guez, L.N. Lo ´pez de Lacalle, On the fatigue strength of ball burnished mechanical elements. Mech. Mach. Sci. 17, 365–373 (2014). https://doi.org/10.1007/978-94 007-7485-8_45

3. Harish, D. Shivalingappa, P. Vishnu, and Sampath Kumaran, Impact of Ball burnishing process parameters on surface Integrity of an Aluminium 2024 Alloy, in IOP Conference Series: Mate rials Science and Engineering, Jun. 2018, vol. 376, no. 1, https:// doi.org/10.1088/1757-899x/376/1/012099

4. A. Harish, D. Shivalingappa, The influence of ball and roller burnishing process parameters on surface integrity of Al 2024 alloy. Materials Today: Proceedings 27, 1337–1340 (2020). https://doi.org/10.1016/j.matpr.2020.02.614

5. Y. Zhang, J.C. Outeiro, T. Mabrouki, On the selection of Johnson Cook constitutive model parameters for Ti-6Al-4V using three types of numerical models of orthogonal cutting. Procedia CIRP 31, 112–117 (2015). https://doi.org/10.1016/j.procir.2015.03.052

6. Chandrakala B M and S. C. Linga Reddy, "Proxy Re-Encryption using MLBC (Modified Lattice Based Cryptography)," 2019 International Conference on Recent Advances in Energy-efficient Computing and Communication (ICRAECC), Nagercoil, India, 2019, pp. 1-5, doi: 10.1109/ICRAECC43874.2019.8995071.

7. Rashmi S, Chandrakala B M, Divya M. Ramani, Megha S. Harsur, CNN based multi-view classification and ROI segmentation: A survey,Global Transitions Proceedings,Volume 3, Issue 1,2022,Pages 86-90, ISSN 2666-285X,https://doi.org/10.1016/j.gltp.2022.04.019. https://www.sciencedirect.com/science/article/pii/S2666285X22000553).