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CORRESPONDENCE and COMMUNICATION:

Istanbul Gelisim University Faculty of Engineering and Architecture
Cihangir Mah. Şehit P. Onb. Murat Şengöz Sk. No: 8
34315 Avcilar / Istanbul / TÜRKİYE
Phone: +90 212 4227000
Fax: +90 212 4227401
e-Mail: ijet@gelisim.edu.tr
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From the Editor

Dear Colleagues,

On behalf of the editorial board of International Journal of Engineering Technologies (IJET), I would like to share our happiness to publish the 32nd issue of IJET. My special thanks are for members of Editorial Board, Publication Board, Editorial Team, Referees, Authors and other technical staff.

Please find the 32nd issue of International Journal of Engineering Technologies at http://ijet.gelisim.edu.tr or https://dergipark.org.tr/en/pub/ijet. We invite you to review the Table of Contents by visiting our web site and review articles and items of interest. IJET will continue to publish high level scientific research papers in the field of Engineering Technologies as an international peer-reviewed scientific and academic journal of Istanbul Gelisim University.

Thanks for your continuing interest in our work,

Prof. Dr. Necmettin MARAŞLI
Istanbul Gelisim University
nmarasli@gelisim.edu.tr
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Table of Contents

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A Performance Analysis of a Two Way Stop Control (TWSC) Intersection under Mixed Traffic Conditions

Joseph Femi Odesanya*

* Department of Logistics and Transport Technology, The Federal University of Technology, Akure, Ondo State, Nigeria. E-mail: jfodesanya@futa.edu.ng

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Abstract- Intersections are road traffic infrastructure on highways installed to help settle directional movement that could result in conflict while vehicular trips are made. Evaluation of the challenges faced by different automobile users at the Araromi junction (A three Leg at-grade Intersection) located in Akure is the main objective of this paper. To achieve this objective, traffic flow data were collected on the spot by video recording and then the data were manually counted. While, the highway Capacity manual 2010 methodology was adopted to analyse The entry flow rates, Potential Capacities, Movement Capacities, Movement Control Delay, Approach Intersection Control and 95th Percentile Quene Length of the intersection. Findings shows that an average entry flow rate of 357 pc/h occurs for all the legs of the intersection, the North bound left turning movement of the intersection was not within the allowable limit, the average potential capacity by lane for the intersection is 445 pc/h, and the average movement capacity by lane 473 Pc/h, the various legs of the intersection has a level of service of ‘A’ and ‘C’ except the left turning minor street movement that has an ‘F’ LOS. Due to the influence of high traffic flow around the intersection, the analysis of the real-time traffic flow results reveals the need to diverge the high right turning movement into other route to cater for low left turning movement causing delay and poor LOS and a need to introduce Signal on the intersection in other to improve on her functionality.

Keywords: Entry Flow Rate, Turning Movement, Potential Capacity, Movement Capacity

1. Introduction

Congestion on the road network is a situation that occurs on a road transport system as a result of increased traffic, which in effect causes slow speed, increase queues, longer travel time and increased automobile fuel consumption and environmental pollution [1, 2]. As peak hourly demand on the road network increases this causes capacity to reduce thereby bottleneck are formed around intersections, these hourly demand affects driving operations around road traffic intersections causing a delay when the level of service of the intersection becomes poor [3]. An increase in commuters’ delays at intersections reduces the level of service of the road user’. In Nigeria, some intersections are known to be very busy with several mixed traffic, the delay witnessed at these intersections at peak periods differs one from another, for multilane roads, at peak periods, lane discipline is a big problem causing the left turn movement to be hindered. This further creates a bottleneck on the road and subsequently reduces the road traffic capacity. Some previous studies had considered different variables such as delay, traffic density, queue length and volume to capacity ratio (V/C) for studying the performance of an Intersection. The measure of service quality that highlights the operational traffic characteristics and their perception by road users is known as the Level of Service (LOS). Measurement of this in Akure, Nigeria for various intersections has been carried out in the past by [4, 5, 6], however, most of the research cited has not worked on the analysis of a three-leg Two Way Stop Control (TWSC) intersection located at the heart of the city of Akure. The entry flow rate, existing flow rate, the Level of Service (LOS), and Capacity of this Araromi junction using the Highway Capacity Manual 2010 (HCM) method was the major objective of this research work. Intersection study is mostly appreciated in appraising the competence and efficiency of the control measure used in the distribution of traffic in an intersection.

2. Literature Review

Most prior research had considered different variable quantities to appraise the performance of a traffic intersection such as the waiting time of the vehicle in queue per vehicle to be serviced by the intersection [7], the minimum response time of vehicles in Queue at an urban signalized intersection [8], vehicle to the capacity analysis of an un-signalized junction with mixed traffic circumstances [9] estimation of capacity within an un-signalized junction under mixed traffic flow conditions [10] comparison based on the capacity of both a signalized and an un-signalized intersection under a mixed traffic stream network [11] critical flow analysis of intersection in a mixed traffic condition at a roundabout intersection [6], Microscopic detailed analysis of un-signalized intersections in multiple Traffic flow conditions [12] are various research outputs that had been carried out to study flow at intersections around the world.

2.1 Traffic Parameters in a Two-Way Stop (TWSC) Intersection

Knowledge of the traffic parameters, like speed, the composition of traffic, the issue of gap acceptance, and the number of conflicting points at the microscopic level, are important for the development of the performance appraisal of the TWSC models. The appraised parameters will help to assess the facilities concerning safety. Several studies have focus mainly on microscopic traffic level characteristics in different types of intersection facilities in more developed countries [12]. Some authors have been able to share few related works on various urban roads having both signalized and un-signalized intersections like in a work carried out by [13] in which they focused on road segments based on the drivers' speed choice and his interactions with other road user's. In a related work by [14] a stronger relationship has been observed between speed reported by drivers and the observed speed taken by the use of Rader, this study also find out that the speed of drivers is sometimes based on the behaviour of other drivers, although the drivers been knowledgeable about their speed in a particular place at a time, they seem to have an unfair awareness of the level of speed generally around them. Wolferman, Alhajyaseen, & Nakamura, (2011) find out that speed profiles on vehicular entry point area (i.e Intersection) and position of the vehicle and vehicle speed are sensitive to the driver at the beginning and end of manoeuvre, their work went further to use empirical data of automobile routes that were obtained at a signalized intersection in a city in Japan which produce a stochastic profile of speed from left-and-right turning, free-flowing movement. Doecke, Wolley, & MacKenzie, (2011) developed a guideline for transport authorities after studying the sequence a vehicle takes when it is in collision part with a another vehicle at a road intersection in a rural community. Viti, Hoogendoorn, Van Zuylen, Wilmink, & Van Arem, (2008) realized that vehicle trajectories are few meters away from where the stop sign normally occurs . Xu & Tian, (2008) worked on microscopic data which looked into the turning effect and gap acceptance behaviours of drivers. They observed that the presence of pedestrians in and around intersections has a great impact on the left turning movement of vehicles. Other studies that have worked on the traffic parameters in a two way stop intersection includes [15, 16]. Some other studies have looked into a different type of traffic parameters such as conflicting points, pedestrian trajectories, vehicle trajectories, acceptability of gap in bad weather condition [17] and lane usage in developing countries. The importance of these parameters for geometric design and evaluation of an un-signalized intersection cannot be overemphasis.

2.2 Flow Rate and the Influence on Level of Service (LOS) and Capacity

Traffic Flow occurs mostly at intersections, with many road users including drivers and passengers moving from one place to another and using the intersection as a connecting point for them to manoeuvre from one directional axis to another. Flows are generated from automobile movement from streets and along highways. Flows can also be generated from bicycles' movement on a corridor, it can also be generated due to pedestrians' movement in stations, parks, shopping malls, and traffic flows are generated close to intersections due to pedestrian crossings, these flows occur any time of day, and flows are normally at its peak during the rush hour of the day [18]. Different kinds of flow exist in engineering practices but Traffic flows are typically different from other flows in various engineering areas like pipe flow and flow of electrons. Human decisions are the basics for Traffic flows to occur and to navigate through an intersection. There are guided rules/laws that are influenced by human behaviours to avoid vehicular crashes. Flow rates are expressed and measured in units per unit of time [18]. These units are units of cars, pedestrians, vessels, containers, and aircraft, depending on the flow rate of the transportation mode being considered. Flow rate is measured in units of vehicles per hour. Traffic movement is very intricate and complex and requires sound analysis to be able to determine information about vehicular movement in road traffic facilities. Measurements, modelling, and analysis of traffic flow phenomena are essential when estimating the capacities of transportation facilities and in making decisions for additional development and expansion of transport amenities [19]. When flow measurements and analysis are properly carried out then, the prediction and proper planning of transport facilities for upcoming queues at highways, and a better understanding of traffic flow circulation in space and time are well articulated [20]. Well-analysed flow measurements will help in proper estimation that can help solve problems associated with queue lengths, traffic density, level-of-service, capacity, and accomplishing activities which will help mitigate traffic congestion [21].

The Concept of Gap-Acceptance

Unsignalised intersections are of two (2) sorts, the Two-Way Stop-Controlled (TWSC) and All-Way Stop-Controlled (AWSC) and their operation are almost similar. Unsignalized intersection functions without any form of input or control by the driver except a positive gap or control is available for the drive to utilize (Troutbeck and Brilon, 1992). The behaviour of the drive to accept a gap created for him to enter and continue his movement is known as gap acceptance. For most instances, the oncoming vehicle approaching from the minor road waits for those in the major road to pass before navigating into the major street. The drive will reject small gaps that will cause a crash if accepted. This method, gives the assumptions that the drivers gives precedence to the right-of-way of the vehicle in the traffic flow to those on the major street in the traffic stream. Nevertheless, Brilon and Wu (2002) posited that gap-acceptance system possesses some shortcomings. One of such setback is that it did not consider the drivers behaviour, as touching priority rules. For instance, forced gap can be drivers who drives aggressively, while well-mannered behaved drivers, that intentionally offers gaps distinctively are not captured based on the priority rules. Prasetijo, (2007) observed that mixed traffic situations worsen traffic movement especially when the movement is one formed as a result heterogeneous movement of both vehicular and non-vehicular means of movement. Hence, another method known as the conflict technique is established to cater for short fall due to the gap-acceptance method, this method is recognised as the Additive Conflict Flow (ACF) method. Likewise, Wu (2000) detailed that some of the major parameters used when designing the intersections are the spread of number of lanes, the traffic flow rates, and the number of pedestrian which will use the intersection, and the flaring of the lane that cater for more vehicles. This conflict method helps in the intersection capacity study. It has been shown that it enhances the dependability of the unsignalized intersection processes used to measure the situation surrounding the intersection. Major factors considered when analysing the conflict technique is the occupation time, (tQ,b) which amounts for the time used by a vehicle when it occupy an area with conflict. Brilon and Wu (2002) describe the term (tQ,b,m) and (tQ,b,I) in an alternative manner to mean the time a vehicle occupies the area when known for conflict. Additional considered parameter in conflict technique is known as blocking time of the conflict area as a result of an oncoming vehicle, (tB,a). Some other researchers like Eisenman , Josselyn, & List, (2004); Vaiana, Gallelli, & Capiluppi, (2007); Joewono & Halimshah, (2012) have worked on gap accepatnce theory.

3. Methodology

Operational analysis for intersections based on the National Cooperative Highway Research Program (2010) was adopted. The process involves the capturing of projected peak turning movement of vehicles going through the intersection. It also considered the traffic peak data (i.e peak hour at 15-minute intervals) for measuring results. The collected traffic data should, to the greatest extent possible, reflect the current peak hour traffic conditions. Data for this work were collected 7.00 a.m. to 9.00 a.m. for peak morning time, 11.00 a.m. to 1.00 a.m. for afternoon time, and 3.00 p.m. to 5.00 p.m. for evening peak time. This data collection represents the start of official duty and the close of working hours in the city of Akure, where the data were sourced. On a conventional intersection, traffic volume data were collected by collection systems using field observatory and video footage recording method of traffic movement at each of the traffic leg.

Video footage courage methodology and Field Observation Methodology

For two weeks, real-time video recordings of the entire intersection were made. This was accomplished by mounting the camera on the story building directly opposite the understudied two way stop intersection and photographing all of the intersection legs from an elevated height of about 20 meters, this exercises was proceeded by measuring the traffic flow. The entry flow was measured first, leg after leg of each of the connecting route to the intersection than, booking of captured traffic flow was carried out in a sequential manner for each leg of the connecting road to the intersection this data were obtained from the pre-recorded videotape, after which the turning movement of the decisions of the automobile user's was also booked. The pre-recorded tape was played repeatedly so as to extract data for each leg differently. The inflow movement were extracted leg after leg and then, the existing flow and wavering pattern of decision of the automobile as they were served was booked. Eight trained field observers were paid to collect data at the intersection. Two (2) individuals were placed to collect data per leg, First person was in charge of entry flow and another collects data on the drivers' circulation/weaving decisions within the roundabout. Manually, the result was entered for bicycles, motorcycles, tricycles, passenger car, and articulated automobile into a real-time datasheet. In line with [18],

Flow (Qe) is expressed in pc/h,

Qe = Entry Flow

Pc/h = Passenger Car Unit Per Hour.

A technique used to regulate the inconsistency for demand flow rate during when peak hourly volume is measured is the Peak Hour Factor (PHF) this demand flow rate is what is adopted in analysing the performance of the intersection. Nicholas and Lester, (2002) defined it as flow when the highest peak of traffic occurs against peak flow rate throughout a certain period around the peak hour.

$$PHF = \frac{Hourly\ volume}{peak\ flow\ rate\ (within\ the\ peak\ hour)} \quad 1$$

$$PHF = \frac{V}{4\ .\ V15} \quad 2$$

Thus: PHF = peak-hour factor, V = Hourly Volume (vph) and, V_{15} = Volume during the Peak 15 min of the peak hour (veh/15 min).

Heavy vehicle adjustment factor, (FHV) is another very important factor considered when analysing traffic performance at intersections. This factor connects the fraction of heavy vehicles in the lane waiting to be served. The factor adjusts for delays due to decrease in saturation flow as a result of availability of heavy vehicle in the steam of traffic flow. This further interruption in over-saturation are due mainly as a result of the inconsistences generated by the operational capabilities of the heavy vehicle such as slow movement, time of response from such saturated passenger car equivalent and vehicle occupancy of the passenger's car. Heavy vehicle can be seen as automobile that has more wheels, i.e above four of its tires having contact with the surface of the road surface. Two (2) is the Passenger Car Equivalent (PCE) attached for various weighty vehicle [18]. To achieve demand flow, equation 3 is used:

$$up = \frac{V}{PHF.\ N.\ fHv.\ fp} \quad 3$$

Thus: up is the demand flow centred on equivalent base condition (pc/h/In); while, *V* is demand volume (veh/h); while, *PHF* is Peak Hour Factor; while, *N* number of lane; while, *fHV* is an adjustment factor of heavy vehicle; and finally, *fp* is an modification factor of unexperienced driver population.

Based on the HCM 2010 the heavy modification factor is thus given:

$$fHV = \frac{1}{1+PT.(ET-1)+PR(ER-1)} \quad 4$$

f_{HV} is the heavy vehicle adjustment factor; while P_T is the proportion of trucks and buses; while, P_R is the proportion of recreational vehicles; while, E_T is passenger car equivalent for trucks and buses in the traffic stream; and finally, E_R is PCE for recreational vehicles in the traffic stream.

4. Result and Discussion

The analysis of the two way stop control intersection based on Highway Capacity Manure methodology follows a process or better still, a set laid down rules after which the result for the entry flow rates, existing flow rates, Level of Service (LOS), control delay and capacity obtained where presented and informed discussion made.

Entry flow for each leg for a period of two hours subdivided into 15 minute periods in the morning, afternoon and evening before conversion into traffic flow rate of the TWSC intersection are presented in table 1, for the mixed traffic that made the approach of the intersection in the morning, afternoon and evening. It was observed that the morning flow rate were more than those of the afternoon and evening flow rate.

Table 1. *Vehicle flow from Araromi axis Left Turn (WB)*

	Morning Session				Afternoon Session				Evening Session			
Time	**Bikes**	**Cars**	**Buses**	**Truck**	**Bikes**	**Cars**	**Buses**	**Truck**	**Bikes**	**Cars**	**Buses**	**Truck**
00-14	55	46	4	0	24	28	0	0	40	30	2	0
15-29	70	69	2	0	30	18	0	1	47	48	2	1
30-44	88	70	3	0	19	22	1	0	21	33	2	0
45-00	114	87	7	0	30	18	2	0	44	33	2	1
00-14	89	80	3	1	29	25	1	0	41	34	3	0
15-29	67	76	2	0	44	21	1	0	51	26	2	1
30-44	63	61	3	1	51	19	2	0	45	33	1	2
45-00	59	43	1	1	73	37	0	0	41	30	0	1
	605	532	25	3	300	188	7	1	330	267	14	6

It was observed that the maximum flow occurs in the orning peak period for all the legs of the TWSC studied for this work. The figure 1 presents, average aggregate flow rate of the traffic that occurs at the intersection during one hour period. In order to verify the variability of the data set for the entry flow decision of the drivers via the TWSC intersection, the entry flow was plotted against the existing flow, this gives a strong R^2 of 0.9333 after the plot the graph in figure 2 shows this.

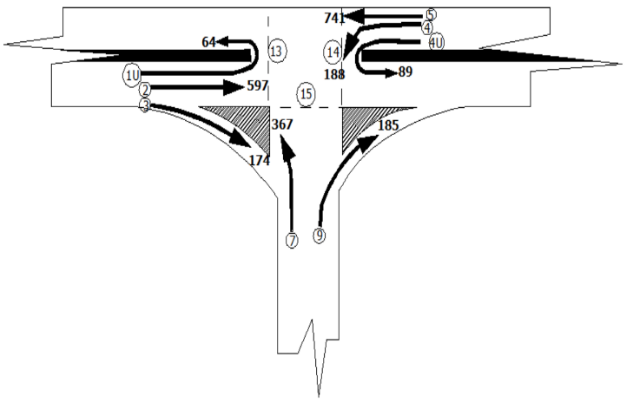

Fig 1. *Flow rate of the traffic at Araromi Intersection.*

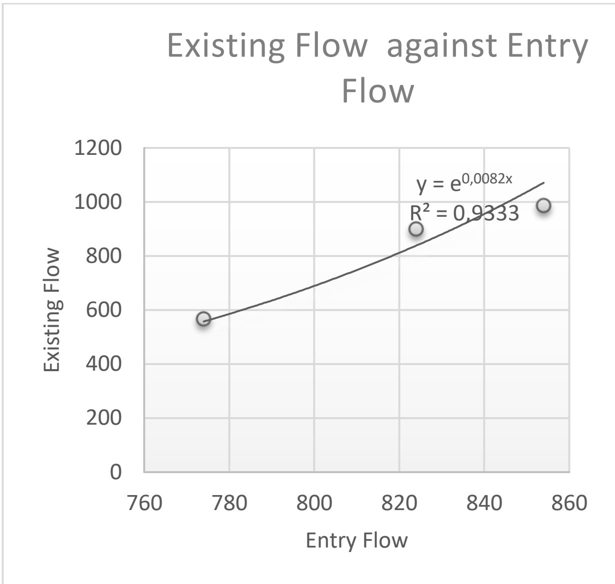

Fig 2. *Existing flow against Entry flow.*

It was likewise observed that the rate for Conflicting flow (V_c), Potential capacity (C_p), Movement capacity (C_m), Movement control delay (d), Approach intersection control (da) and 95th percentile queen length (Q_{95}) for the TWSC analysed are presented in table 2. From the result obtained, V_c, 7 which represent the northbound left turning has the highest conflicting flow, it also has the lowest potential capacity and movement capacity. The level of service of the turning is 'F' signifying poor movement control delay, its 95th percentile queen length is the highest, meaning that road user's trying to make movement through that turning are delayed more than it is necessary and the lane is operating at a very weak capacity. While it was observed that the V_c, 1u has the best conflicting flow of 541, potential capacity of 798, movement capacity of (Cm) 798, level of service 'A' with a good movement control delay of 9.9, it has the best approach intersection control of 0.76, and a Q_{95} percentile quene length of 0.3, which happens to be the best operating in the TWSC intersection considered for this analysis. Generally, the outcomes show that, although most minor movement are functioning at a very low to a restrained delays conditions, the minor movement towards the right turning movement to the Northbound (9) operates at a LOS C while the minor turning in the Left-turning movement (7) experiences high delays and operates at LOS F.

Table 2. *Tabular form of the Araromi TWSC intersection analysis.*

s/ no	Nom	Conflicting flow rate	Nom	Potential Capacities	Nom	Movement Capacities	Nom	Movement Control Delay	Nom	Approach Intersection Control	Nom	95th Percentile Queue Length
1	V_c, 4	771	C_p, 4	511	C_m,4	500	d1u	9.9 A	d_a, EB	0.76	Q_{95},1u	0.3
2	V_c, 9	386	C_p, 9	528	C_m,9	517	d4+4	17.09 C	d_a, WB	4.65	Q_{95},4+4u	2.63
3	V_c, 1u	541	C_p, 1u	798	C_m,1u	798	d9	15.79 C	d_a, NB	599.67	Q_{95}, 9	1.6
4	V_c, 4u	438	C_p, 4u	910	C_m,4u	821	d7	893.92 F			Q_{95}, 7	33.7
5	V_c,i,7	809	C_p,i,7	320	C_m,4+4u	571						
6	V_c,ii,7	851	C_p,ii,7	348	C_m,7	70						
7	V_c, 7	1660	C_p, 7	145	C_m,i, 7	159						
8				445	C_m,ii, 7	342						
9					C_T	130						

Nom= Nomenclature, V_c=Conflicting flow, C_p = Potential Capacities, C_m= Movement Capacity, d = Movement Control Delay, d_a = Approach Intersection Control, Q_{95} = 95th Percentile Queue Length

5. Conclusion and Recommendations

The main focus of this work is aimed at the analysing a Two Way Stop Control (TWSC) Intersection under Mixed Traffic Conditions without the negative impeding forces of pedestrian, the study has shown that although two of the legs of the intersections is still functioning well, one of them had futile servicing output due to over-saturations. It is however, observed that the minor movement of northbound traffic right turn has been flowing well due to less impediment on the through movement of the west bound and the u-turning of the east bound movement. To improve on the quality of traffic flow on the minor leg impeded movement caused as a result of high flow from the major east bound movement, alternative junction should be created through which the heavy traffic on the minor lag can be eased. Such junctions as the stadium junctions in the metropolis which can help in its linkage can be improved on to cater for this excessive movement. The reasons why these junction is not utilised is because of the narrow nature of the linking route toward that junction. Another thing that could ease the over loaded traffic is by the provision of a functional signal in which the right calculations would have been assign to the waiting time from both the major and minor intersection. Although, this will increases the service time of the very good and functional legs but will also increase the service delay for the movement in the left turn direction of the minor leg. The Constraint faced by this work is in the area of using computerised tools for data collections because they are the recent tools/equipment best for traffic data collections. Example is the automated traffic count equipment. Traffic flow congestion and analysis prediction is the future for simulating traffic congestion with the help of Artificial Neural Network (ANN).

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Conflict of Interest

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References

[1] S. Sakar and M. Anil, "Performance Improvement of a Signalized Intersection. (A Case Study of New Baneshwor Intersection).," in *Proceedings of IOE Graduate Conference*, Pulchowk, 2017.

[2] Odesanya, J. F., E. E. Okoko and M. S. Stephens, "The Effect of Road Transport Emission and its Related Human Health Damages along Traffic Corridor in Ikara, Akoko North East, Ondo State.," *Nigerian Journal of Logistics and Transport,* pp. 31-44, 2019.

[3] Y. V. Navandar, A. Dhamaniya and D. A. Patel, "A Quick Method for Estimation of Level of Service at Manually Operated Tollbooths under Mixed Traffic Conditions," *Transportation Research Procedia,* pp. 307-3120, 2020.

[4] A. A. Laoye, A. O. Owolabi and S. A. Ajayi, "Indices of Traffic Congestion on Major Roads in Akure, a Developing City in Nigeria.," *International Journal of Scientific & Engineering Research,* pp. 434-443, 2016.

[5] O. O. Aderinlewo, "Performance Assessment of Selected Intersection in Akure, Nigeria," *ProQuest,* pp. 337-353, 2020.

[6] J. F. Odesanya, "Level of service (LOS) determination for a selected round about in Akure metropolis using HCM methodology and critical lane flow analysis.," *Discovery,* pp. 1-10, 2020.

[7] S. Wanisubut, "A Toll Plaza Simulation Model and Level-of-Service Criteria.," Doctoral dissertation, Polytechnic University, Michigan, USA, Michigan, 1989.

[8] S. Yang and E. Chung, "Driver Response Time of Queuing Vehicles at Urban Signalized Intersections," *Procedia-Social and Behavioral Sciences,* pp. 169-177, 2012.

[9] J. Prasetijo and H. Ahmad, "Capacity Analysis of Unsignalized Intersection Under Mixed Traffic Conditions," *Procedia - Social and Behavioral Sciences,* pp. 135-147, 2012.

[10] R. Surisetty and S. G. Prasad, "Estimation of Capacity at Un-Signalized Intersections under Mixed Traffic Flow Conditions," *American Journal of Engineering Research,* pp. 213-221, 2014.

[11] P. Basil and N. H. Pitale, "Comparison of Capacity at Signalised and Unsignalised Intersection," *International Journal of Science Technology & Engineering,* pp. 108-111, 2017.

[12] S. A. Haji, R. S. Mathai, M. Kumar, R. Anand and N. Kumar, "Microscopic Analysis of Unsignalized Intersections in Heterogenous Traffic Conditions.," *International Journal of Research in Engineering and Science,* pp. 1-12, 2021.

[13] I. Banerjee, S. E. Shladover, J. A. Misener, C. Y. Chan and D. R. Ragland, "Impact of pedestrian presence on movement of left-turning vehicles:method, preliminary results & possible use in intersection decision support.," India Road congress, Boombey, 2004.

[14] M. Haglund and L. Aberg, "Stability in drivers' speed choice,," *Transportation Research Part F Traffic Psychology and Behaviour,* p. 177–188, 2002.

[15] S. Chandra, A. Agrawal and A. Rajamma, "Microscopic analysis of service delay at uncontrolled intersections in mixed traffic conditions," *Journal of Transportation Engineering,* p. 323–329, 2009.

[16] G. R. Patil and D. S. Pawar, "Temporal and spatial gap acceptance for minor road at uncontrolled intersections in India," *Transportation Research Record: Journal of the Transportation Research Board,* p. 129–136, 2014.

[17] S. C. Hwang, C. Lee and D. M. Lee, "Development of Gap Acceptance models for Permitted Left Turn Intersections during Rainfall," *International Journal of Highway Engineering,* pp. 61-68, 2017.

[18] T. Dusˇan and J. Milan, Transportation Engineering, Theory, Practice, and Modeling, New York: Elsevier, 2017.

[19] B. S. Kerner, Introduction to Modern Traffic Flow Theory and Control: The Long Road to Three-Phase Traffic Theory, New York: Springer, 2009.

[20] I. Odesanya and J. F. Odesanya, "Performance Analysis of Traffic Congestion Using Designated Neural Network Training Algorithms," *International Journal of Engineering and Technologies,* pp. 23-33, 2021.

[21] L. Elefteriadou, An Introduction to Traffic Flow Theory, New York: Springer, 2014.

[22] A. Wolferman, W. K. Alhajyaseen and H. Nakamura, "Modelling speed profiles of turning vehicles at signalized intersections," in *3rd International Conference on Road Safety and Simulation RSS2011*, Indianapolis, 2011.

[23] S. D. Doecke, J. E. Wolley and J. R. MacKenzie, "Post impact trajectory of vehicles at rural intersections," in *Australasian College of Road Safety Conference*, Melbourne, Australia, 2011.

[24] F. Viti, S. P. Hoogendoorn, H. J. Van Zuylen, I. R. Wilmink and B. Van Arem, "Speed and acceleration distributions at a traffic signal analysed from microscopic real and simulated data," in *11th International IEEE Conference on Intelligent Transportation Systems (ITSC 2008), 651–656;* , Beijing, 2008.

[25] F. Xu and Z. Z. Tian, "Driver behaviour and gap-acceptance characteristics at roundabouts in California,," *Transportation Research Record: Journal of the Transportation Research Board*, p. 117–124, 2008.

[26] S. Eisenman, J. Josselyn and G. List, "Operational and Safety Performance of Modern Roundabouts and Other Intersection Types," New York State Department of Transportation, Albany, 2004.

[27] R. Vaiana, V. Gallelli and G. F. Capiluppi, "Roundabout intersections: analysis for scenarios by micro-simulation.," in *4th International SIIV Congress-Advances in Transport Infrastructures and Stakeholder Expectations*, Palermo, 2007.

[28] R. Akc¸elik, "A review of gap-acceptance capacity models," in *In 29th Conference of Australian Institutes of Transport Research*, Adelaide, 2007.

[29] P. Joewono and A. Halimshah, "Capacity Analysis of Unsignalized Intersection Under Mixed Traffic Conditions," in *8th International Conference on Traffic and Transportation Studies Changsha, China, August 1–3, 2012*, Changsha, China, 2012.

The Influence of Deep Rolling Process on Fatigue Durability for Vehicle Tie-Rod Component

Emre Azim Hasanoğlu*, Sinan Dayı**, Abdülmecit Harun Sayı***

* Department of Mechanical Engineering, MSc., Izmir Katip Celebi University, Balatcık Mahallesi Havaalanı Sosesi No:33/2 Balatcık 35620, Cigli, Izmir, Türkiye, emreazim@gmail.com ORCID: 0000-0003-4504-4026

** Department of Mechanical Engineering, MSc., Izmir Katip Celebi University, Balatcık Mahallesi Havaalanı Sosesi No:33/2 Balatcık 35620 Cigli, Izmir, Türkiye, sinan.dayi@gmail.com ORCID: 0000-0002-2740-3008

*** Department of Mechanical Engineering, MSc., Izmir Institute of Technology, Gulbahce, 35433 Urla, Izmir, Türkiye, abdulmecitsayi@iyte.edu.tr ORCID: 0000-0002-4319-4058

*** Corresponding Author; Third Author, abdulmecitsayi@iyte.edu.tr, harunumber@gmail.com (preference)

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Abstract - In the automotive industry, most of the components are consistently subjected to the dynamic loading due to the randomly observed situations from road inputs and periodic vibration from IC engine working during the operation. Such loadings cause the durability problem which may result in failure or cracking at stresses that are well below the yield strength of the material. Therefore, along with the development of new processing techniques, different surface treatment processes are applied to enhance the fatigue behavior of components. Being one of the mechanical surface treatment methods, deep rolling is an efficient way for improvement of fatigue performance by strengthening the critical section and providing compressive type of residual stresses. In this paper, the effect of the deep rolling process on fatigue behavior of steel stud in tie-rod used as steering system component was investigated. Force-Number of cycles curves (F-N graph) for the fatigue test have been obtained from the tests. Evaluation of the fatigue endurance limits of the stud at un-rolled condition and rolled conditions at three different loads were performed. Test data was analyzed with a regression line to account for the scatter using probability density functions. The results indicate a significant enhancement in the endurance limit following the implementation of the rolling process, as compared to the unrolled state. Furthermore, it was observed that the endurance limit proportionally increased in line with the rolling load. These findings underscore the crucial role of the deep rolling process in determining the optimal rolling load for the specific stud design and material conditions.

Keywords: Deep Rolling, Tie-Rod, Steering Components, Fatigue Life, Surface Treatment Process

1. Introduction

Tie-rod is one of the most critical parts of the steering mechanism in a vehicle which has the duty of transmitting the force from the steering system to the knuckle, causing the wheels to turn, which plays a significant role on steering system performance, and noise level as well as driver and passenger's safety. Any defect of tie rod ball joint end may cause acoustics and stability problems in the vehicle during driving. Therefore, it is important that the tie rod operates reliably and under severe working condition being one of the factors to need suitable design and proper conditions during manufacturing.

Tie rod consists of two components, which are outer tie rod (OTR) and inner tie rod (ITR). An adjustable threaded connection is the way to connect these two main parts of the tie rod. OTR should have enough inner or outer thread permitting the length of tie rod to be arrangeable. It is important that this adjustment is used to set a vehicle's alignment toe angle on both steered wheels. The joint type of the OTR is an angular ball stud made by steel alloys. It has perpendicular orientation against to general axis of the tie rod. Figure 1 shows a systematic assembly of the sub-components building the OTR. This component consists of a forged or cold-forged housing with a place for the radial ball joint and inner threads at the shaft end to meet axial ball joint of ITR. Another main component of outer ball joint is sealing boot protecting the joint against the ingress of water and dirt, plastic ball race and endcap. Here, grease is used for lubrication which covers inside and outside of the ball race to contact joint ball. Only the ball surface, neck region of the ball joint, and thread connection in housing are machined which gives ready to go shape to OTR. In order to meet and connect end cap with the bottom of OTR housing joint area, rolling operation is applied to the bottom of housing. By having plastically deformed back, end cap seats and perfectly sealed with the bottom of housing [6].

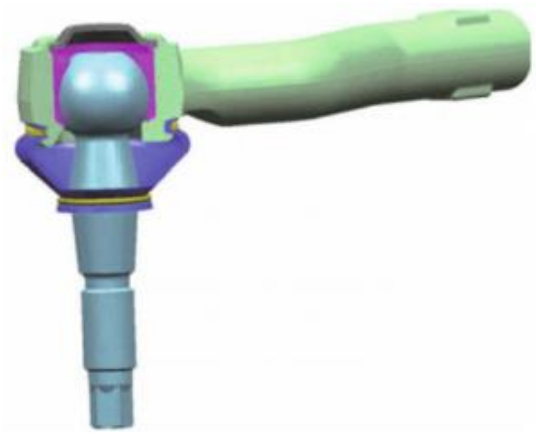

Figure 1. Outer tie rod assembly [6]

In chassis of components, the design of a tie rod is classified as simplest if the centerline of ball joints are in the same axis with ITR and OTR axes. External clamping parts such as steering rack from ITR side and knuckle from OTR side must be in same axis with the ball studs to prevent bending type of loadings in tie rod. This enables a rigid connection by reducing required cross-sectional area. This simplest design cannot be used in every situation because of space restriction of vehicle which requires more complex designs. In order to have fit tie rod to available volume, a calculated offset is given to OTR by moving its center in required axis directions and/or re-design its housing shaft such as presenting initial bend in design (Figure 2). During service life, tie-rods are subjected to static, bearing and dynamic loads under numerous cyclic loadings, similar to those experienced in the random excitations from road inputs, namely the curb steer force which occurs when the vehicle is steered while parked against a curb. The most percentage of forces acting on tie rod is generally compressive type of forces during service [6].

Figure 2. Outer tie rod housing variations [6]

In the automotive industry, mechanical failure is frequently encountered, with fatigue being one of the primary failure modes in various components. In this regard, the durability analysis is the most important step for components subjected to cyclic loading while in design phase. The improvement of time and cost, failure analysis and also optimization of the parts are severe targets in the event of durability analysis through development cycle. It can be said that determination of component and vehicle life is one of the most significant tasks during development. In this regard, numerous research has investigated fatigue failures of outer tie rod. In OTRs, taper region of radial ball studs are the most susceptible areas against fatigue type of failures. Because this region is the interface between OTR and knuckle which has the location of concentrated stress due to excessive dynamic and static loadings. Other critical region for crack initiation is the neck diameter on ball stud. In the literature, it can be found a significant number of examples explaining the fatigue failure on ball stud.

A study about failed SUV tie rod has been published [1]. According to the measurements based on spectrum and hardness results, failed region was on AISI 8620 steel. Failure analysis showed that required composition and hardness were not respected according to the reference standard. Later on, the fatigue type of failure has been found as the main reason after fractographic features inspection. The crack initiation point as well as beach marks have been clearly identified at thread part of the rod. As a conclusion, study observed the main failure reason due to material deficiency which crack initiation and propagation with rupture end supported this outcome. The accident which was taken place was the result of incompatible mechanical part.

Shinde et al. [4] detailed the analysis and investigation of the factors leading to the abrupt failure of an outer ball joint. Without showing any crack initiation, ball stud neck was identified as fracture region. In their study, the finite element analysis is performed to predict the structural responses. The design of ball stud is modified in terms of fatigue and static behavior within safety limit. Sener [3] determined the steering tie-rod fatigue life by collecting the force from roads in Turkey. After processing different signals fatigue characteristics of Turkey’s roads, finite element analysis is executed with the collecting force. This analysis has led to the determination of critical load and stress ranges in the ball stud neck region of the tie-rod. Ozsoy and Pehlivan [8] investigated the maximum stress on the outer tie rod by using finite element method. Different articulation angles were considered as parameters in the analysis. Based on the static analysis results, maximum stress for outer tie rod occurs on ball stud during articulation.

It is well known that the fatigue strength as well as fatigue life strongly depend on the surface integrity. The fatigue behavior of the ball stud can be enhanced through various surface treatment processes, such as deep rolling, nitriding, and induction hardening. In automotive industry, deep rolling process is one of the most common methods to achieve improved fatigue behavior for components especially if there is a critical region to be rolled over. The process is highly effective method to generate compressive type of residual stresses in aimed region of the component. Thus, hardness measurements generally increase thanks to this localized compressive type of loading. Large amount of plastic deformation with low strain rates elevates the dislocation densities in material’s surface having suitable cell structures.

In service, ball studs encounter mostly tensile type of loadings. The incorporation of deep rolling during the manufacturing process of the ball stud results in the introduction of compressive residual stress, effectively counteracting the tensile stress induced by service conditions. This interplay leads to a notable extension in the fatigue life of the component. In addition, improved surface hardness also contributes to fatigue behavior. Deep rolling is also efficient way to create smooth and clean surface finish. During the process, ball or roller type of skater is pushed against surface with a certain number of longitudinal and rotational passes in order to create plastic deformation. Materials having high modulus of elasticity and wear resistance are generally preferred such as hardened steels but also tungsten carbide and ceramics for better mechanical properties to perform deep rolling. Deep rolling process has variety of parameters such as ball rolling speed, feed, number of passes, pressure, lubrication, tool dimension and material which directly affect the finished product’s surface finish [2]. Illustration for deep rolling can be seen in Figure 3.

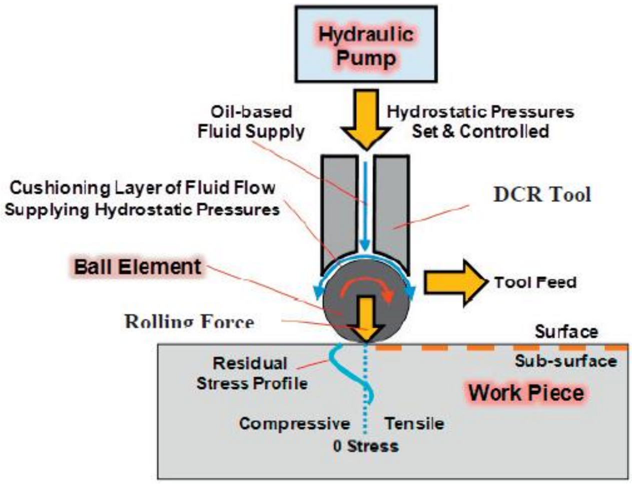

Figure 3. Working principles of deep rolling process

The present study aims to examine the impact of the deep rolling process on the fatigue behavior of a steel stud utilized in a tie-rod for steering system components. To achieve this target, fatigue tests are conducted as part of an experimental investigation to generate S-N curves. These tests aim to assess the fatigue endurance limits of the stud under two distinct conditions: the unrolled state and the rolled state at three different loads.

By analyzing load amplitude versus the number of cycles to failure curves at these three loading conditions, the study calculates the endurance limits by employing regression lines to account for any scatter using probability density functions. Furthermore, the research endeavors to compare these endurance limits with those of the unrolled condition. Additionally, the study assesses the improvement in the endurance limit in relation to the different rolling loads applied.

2. Materials and Methods

The ball stud, composed of 41CrS4 grade steel, is initially formed via the forging process, known for its applicability in producing essential automotive components like transmission shafts, gear shafts, and crankshafts. After the forging phase, the ball stud is subjected to a quenching and tempering treatment, a pivotal procedure for enhancing the strength and hardness of steel and iron-based alloys.

Quenching, a thermal process, involves elevating the material's temperature followed by rapid cooling using diverse mediums such as water, oil, forced air, or inert gases like nitrogen. This controlled process demands rigor regulation by the operator, who precisely manipulates critical parameters, including heating temperature, cooling technique, and speed. These parameters are meticulously tailored in accordance with the material's specific properties, ensuring the achievement of designated material characteristics such as hardness and strength. At room temperature, the initial sample exhibits a tensile strength of 950 MPa and a yield strength of 660 MPa. Subsequently, spectrometric analysis is conducted on the steel ball stud specimens, with the resulting chemical composition presented in Table 1.

Table 1. Chemical composition of 41CrS4 forged steel [11]

Chemical Composition, wt %						
Material	**C**	**Si**	**Mn**	**Cr**	**S**	**P**
41CrS4	0.42	0.25	0.70	1.05	0.020 - 0.035	0.025

In this study, the focus is placed on investigating ball studs subjected to three distinct fillet rolling conditions to establish a relationship between fatigue strength and the applied rolling load. Specifically, the examination encompasses ball studs exhibiting the un-rolled condition, as well as those subject to fillet rolling at 70%, 100%, and 170% of the standard rolling load (%70 F, %100 F, and %170 F, respectively) in the taper region. Figure 4 presents the critical region of the ball stud, as identified from the literature, along with the assembly conditions connecting the ball stud to the knuckle.

It's important to note that the deep rolling process, as an integral part of this investigation, is solely implemented within the taper area of the ball stud.

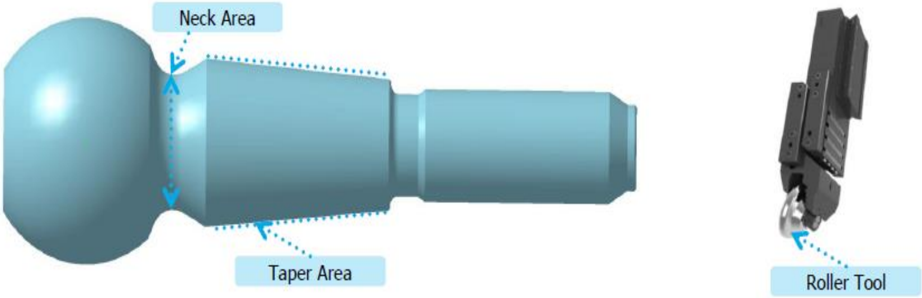

Figure 4. Schematic representation of the ball stud and roller tool

The application of deep rolling on the taper area of the outer tie rod ball stud is performed using a hydraulic rolling apparatus. This rolling apparatus incorporates a primary roller that induces deformation in the taper region of the ball stud simultaneously during the rolling operation. The rollers exert force on the ball stud's taper area at a specific angle to the radial axis, as illustrated in Figure 4.

The deep rolling tool is compatible with both conventional and CNC-controlled machines, seamlessly integrating into the existing process chain. To ensure efficiency, a ball stud undergoes the deep rolling process in a single setting immediately following the neck and ball surface machining process. The deep rolling process is performed at room temperature. Figure 5 demonstrates the rolling operation of the ball stud taper area.

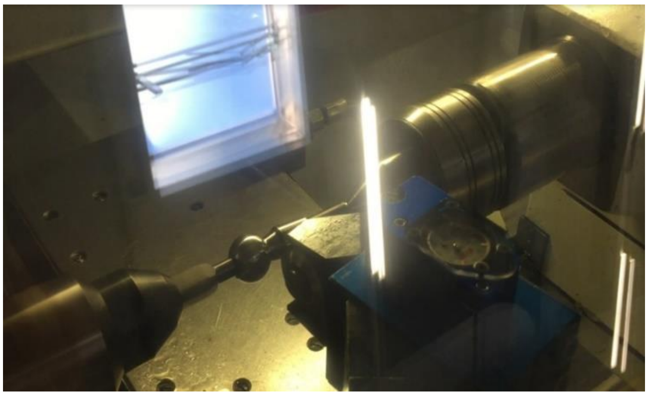

Figure 5. Application of deep rolling process

2.1. Experimental Procedure

In order to comprehensively understand the implications of the deep rolling process on the ball stud of the tie rod component across varying loading parameters, an experimental approach has been devised. Fatigue testing is employed as the primary methodology for evaluating the load versus cycles to failure curve data of the ball stud under three distinct rolled conditions, facilitated by a servo-hydraulic testing machine.

The specimen is precisely secured from the taper area using an adaptor designed to replicate the dimensions of the original knuckle. Subsequently, it is mounted onto the fatigue test rig, where a nut is fastened to the original torque value. A cyclic radial force is then systematically applied to the taper region of the ball stud, identified as the critical point within the outer tie rod under operational conditions. Notably, the tests were conducted under completely reversed constant amplitude cyclic loads. For visual reference, Figure 6 provides tangible insights into the configuration of the test specimen and the experimental setup.

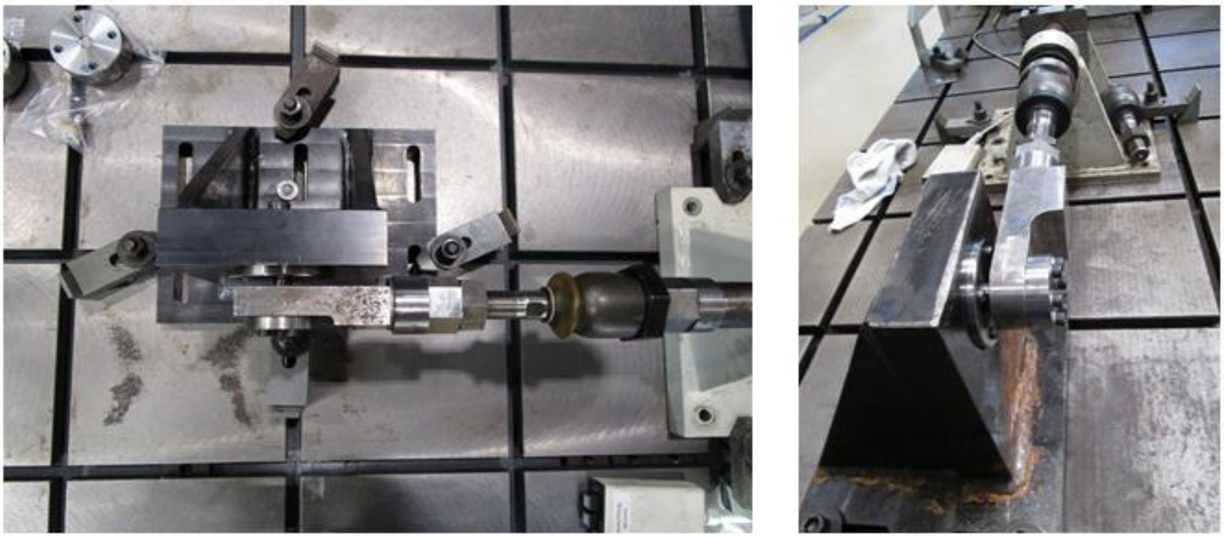

Figure 6. Experimental set-up of ball stud fatigue test

Throughout the testing process, the operating frequency was consistently noted to be in the range of approximately 8-10 Hertz. To adequately encompass both the crack initiation and propagation stages on the test specimens, a relatively substantial frequency limit of ±1 Hertz, equivalent to 10% of the operating frequency, was employed. The number of cycles to failure is recorded for the applied radial loads to establish the load amplitude versus the number of cycles to failure (F-N) curves for the ball stud under three distinct rolling conditions. The rolling force is adjusted by regulating the depth of penetration. Moreover, a test run-out criterion is implemented, set at 10 million cycles. Consequently, the fatigue strength values incorporated in this study represent the fatigue strengths observed at the 10 million cycle mark.

A staircase test methodology is adopted for the selection of the load amplitude in the fatigue tests. With this approach, the first specimen is subjected to testing at a pre-established load amplitude level, guided by prior experience. Should the specimen fail, the subsequent test utilizes a reduced load amplitude level. Conversely, if the specimen endures without failure, the subsequent test incorporates an increased load amplitude level. This sequential process is reiterated until a substantial dataset is acquired, enabling the construction of the F-N curve and facilitating the calculation of the endurance limit.

3. Results and Discussion

In order to compare the deep rolling process effect, un-rolled ball stud specimen testing is firstly carried out on tension – compression fatigue test machine. During test, the number of cycles until failures is recorded against applied radial load amplitude throughout the tests. Fatigue test results of ball stud in un-rolled condition are presented in Table 2. It can be seen that the fatigue results of the ball stud without rolling process have a high spread of the reached load cycle when the fracture location is changing from neck to the taper area within load level. At the loads higher ±8 kN, results showed that there is an acceptable spread. The fracture location is found as always in ball stud neck area.

Table 2. Fatigue results of ball stud in un-rolled condition.

Load [kN]	**Frequency [Hz]**	**Load Cycles [-]**	**Fracture Region**
±3.5	8	2.000.000	-
±5	8	382.600	-
±5	10	508.600	Taper
±5	10	438.800	Taper
±5	10	490.400	Neck
±6.5	10	175.600	Neck
±6.5	10	134.400	Neck
±6.5	10	104.500	Neck
±6.5	10	149.700	Neck
±8	10	56.000	Neck
±8	10	64.700	Neck
±8	10	63.200	Neck
±8	10	63.700	Neck
±12	10	6.400	Neck
±12	10	8.500	Neck
±12	10	7.100	Neck
±12	10	9.100	Neck
±14	10	5.300	Neck
±14	10	5.600	Neck
±16	10	2.000	Neck

The ball stud is subjected to extremely high cycle fatigue load in service conditions, requiring the stresses to be elastic. In cases where stresses are primarily elastic and high cycle fatigue is predominant, F-N approach is frequently employed. This approach utilizes the nominal stress rather than the localized stress at the root of the notch. In this regard, F-N curve in Figure 7 shows the fatigue life determined by using experimental method with the scatter probability density for un-rolled ball stud. The staircase test data are demonstrated as the applied load in N versus number of cycles to failure curves on a semi-logarithmic scale. Results are analyzed with a regression line to account for the scatter using probability density functions. It is observed from graph that the tension-compression endurance limit for the un- rolled ball stud is around 3.5 kN.

As explained in material and methods section, 3 different rolling force levels are considered during ball stud sample production and fatigue test has been performed on those samples to investigate the effect of different rolling forces. Due to a small amount of rolled ball studs including different rolling parameter, the test with rolled ball studs is performed only on load level ±10 kN and ±12 kN to compare the reached load levels with the former basic wöhler test that is created for un-rolled ball studs (Figure.7).

The achieved load cycles for ball stud produced with different rolling forces can be seen in Table 3 as follows.

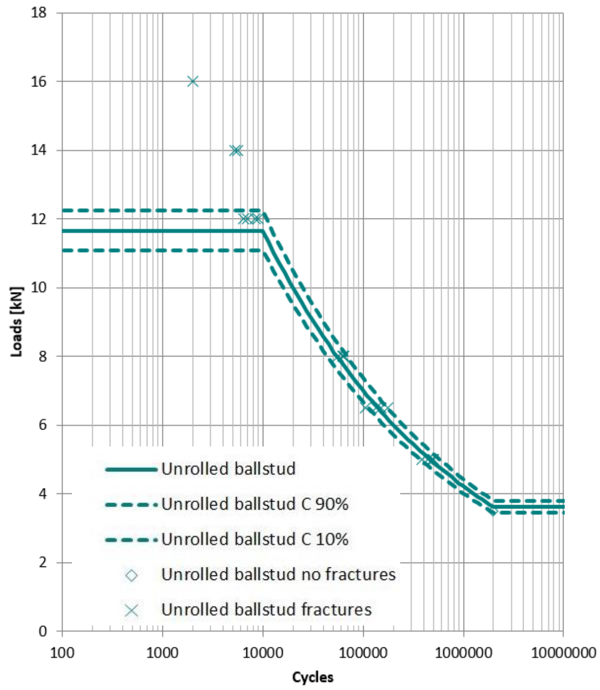

Figure 7. F-N curve of ball stud in un-rolled condition.

Part No.	Load [kN]	Frequency [Hz]	Load cycles [-]	Remark	Rolling Force
1	±10	10	309.100	ball stud neck fracture	%70 F
4	±10	10	480.800	gauge line fracture	%100 F
5	±10	10	369.700	gauge line fracture	
6	±10	10	399.600	gauge line fracture	
7	±10	10	451.600	gauge line fracture	%170 F
8	±10	10	483.200	gauge line fracture	
9	±12	10	56.600	ball stud neck fracture	
10	±12	10	46.700	ball stud neck fracture	%170 F
11	±10	10	456.000	gauge line fracture	
12	±10	10	452.000	gauge line fracture	

Figure 8. Fatigue results of rolled ball studs in different rolling force.

On load level ±10 kN the fracture is in ball stud gauge line and even including the part no. 1 with lowest rolling parameter, the spread of the reached load cycles is ok. Nevertheless, part no. 1 with lowest rolling parameter reaches lowest load cycles of all rolled hardened ball studs. The reached load cycles exceed the results of non-rolled ball studs by about 3 times.

On load level ±12 kN fracture is located in ball stud neck and the reached load cycles exceed the results of non-rolled ball studs just about 1,5 times. Since rolling force increase the achieved cycles and failure locations become more stable, fatigue test is performed on ball stud specimen that is deeply rolled under %170 F loading conditions to compare the effect of rolling process. Test results of ball stud in rolled condition are presented in Table 4. It is understood from results that the fatigue limit for the deep rolled ball stud is around 23.000 cycles at ±12 kN whereas the fatigue limit for the unrolled ball stud is around 7.000 cycles. Hence, the deep rolled ball stud's fatigue limit is enhanced by three times as compared to that of the un- rolled ball stud. It can be also observed from graph that the tension-compression endurance limit is increased to approximately 6 kN for the rolled ball stud.

Table 4. Fatigue results of ball stud in %170 F rolled condition.

Load [kN]	Rolling Load [N]	Frequency [Hz]	Load Cycles [-]	Fracture Region
±6.5	%170 F	10	2.000.000	-
±6.5	%170 F	10	2.000.000	-
±8	%170 F	10	284.500	Neck
±10	%170 F	10	64.000	Neck
±10	%170 F	10	63.700	Neck
±10	%170 F	10	57.000	Neck
±12	%170 F	10	24.700	Neck
±12	%170 F	10	21.500	Neck
±12	%170 F	10	23.500	Neck
±14	%170 F	10	7.300	Neck
±14	%170 F	10	7.400	Neck
±14	%170 F	10	9.700	Neck

The difference in results between deep rolled and un-rolled ball stud is shown in Figure 8 below.

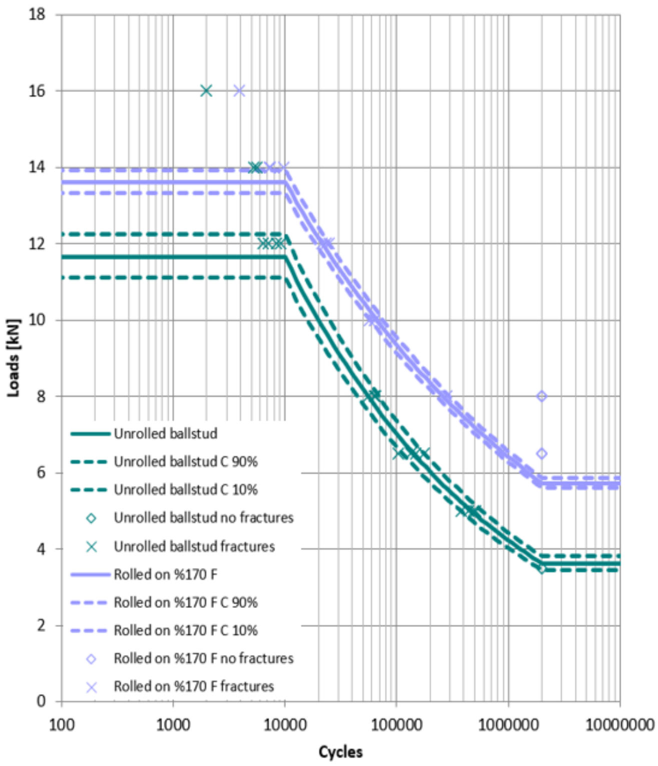

Figure 8. F-N curve comparison of ball stud in rolled at %170 F and un-rolled condition.

4. Conclusions

In this study, the effect of the deep rolling process on fatigue behavior of ball stud made of steel 41CrS4+QT material is investigated. For this purpose, fatigue life predictions by using the F-N approaches are carried out on un-rolled and rolled ball stud at three different loads, which are %70 F, %100 F and %170 F, and then fatigue endurance limits are compared with each other. Regression line to account for the scatter using probability density functions is used for test results. Based on the comprehensive analysis of the experimental results, the following conclusions can be drawn:

The fatigue limit for the un-rolled ball stud is 7.000 cycles whereas the fatigue limit for the rolled ball stud is 23.000 cycle at the same load. The fatigue test of the deep rolled parts proved that the application is successful. Results have shown that the endurance limit of steel are enhanced by four times as compared to those of the un-rolled. This fact describes that the deep rolling is an effective process to improve the fatigue strength of ball stud significantly by a convenient local deformation and hardening process.

With regards to gaining a better understanding on deep cold rolling process variables, rolling load is chosen as the parameter. It can be understood from results that as the rolling loads of ball stud increase, fatigue values for deep rolling indicate the improvement. As expected, the deep rolling results in a residual stress state strongly depend on the rolling force.

Similarly, as the rolling loads of ball stud increase, mechanical surface treatments regarding the maximum residual stresses and the penetration depth increase. Surface strengthening is a major portion of the fatigue limit for ball stud and measuring the residual stress in the near-surface zone showed that certain amount of the surface zone is subjected to high compressive residual stresses. Compressive residual stresses compensate the tensile components of the service loads and local hardness increase can retard the crack initiation which both improves the fatigue strength.

References

[1] Falah, A.H., Alfares, M.A., Elkholy, A.H., (2007), Failure investigation of a tie rod end of an automobile steering system, Elsevier, Engineering Failure Analysis 14,895–902.

[2] Schulze, V., (2006). Modern Mechanical Surface Treatment. Wiley-VHC Verlag GmbH& Co. KGaA, Weinheim, pp. 25–134.

[3] Sener, A. S., (2016), Steering Wheel Tie Rod Fatigue Life Determination According to Turkish Mission Profiles, International journal of engineering technologies p. 56-63.

[4] Shindre, S. Kadam, A. Patil, S. Pandit, (2016), Design Modification and Analysis of Suspension Ball Joint Using Finite Element Analysis, International journal of innovative research in sicence, engineering and technology, p. 1297.

[5] Patil, M. A., Chavan. D.S, Kavade, M.V., Ghorpade U.S., (2013). FEA of tie rod of steering system of car, I. J. Application or Innovation in Engineering 2, 5, 222-227.

[6] Heißing, B., Ersoy, M., (2011), Chassis Handbook, Vieweg & Teubner Verlag, Springer Fachmedien Wiesbaden GmbH, 1st edition.

[7] El-Axir, M.H., (2000). An investigation into roller burnishing. Int. J. Mach. Tools Manuf.40, 1603–1617.

[8] Pehlivan, M.K., Ozsoy, M., (2014), Computer aided structural analysis of rot head. Bilecik Şeyh Edebali Universitesi Fen Bilimleri Dergisi. 1(1): p. 45-51.

[9] Altenberger, I., (2005), Deep rolling - the past, the present and the future, 9th International conference on shot peening. September 6-9, Paris, Marnela Vallee, France.

[10] Kloos, K. H., Fuchsbauer, B., Adelmann, J., (1987), Fatigue properties of specimens similar to components deep rolled under optimized conditions, international journal of fatigue 9, No. 1, pp 35-42.

[11] Web-based source, saarstahl.com.

Beyond Functionality: Morphological Design Tools for Users' Satisfaction in Housing*

Halise Betül Bulut**, Jamel Akbar***

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** Corresponding Author, PhD Student, Department of Architecture, Fatih Sultan Mehmet Vakıf University, Sütlüce Mah. Halıcıoğlu Kavşağı No: 12 Beyoğlu, Istanbul, Türkiye. E-mail: halisebetulbulut@gmail.com ORCID: 0009-0002-1227-0641

*** Prof., Department of Architecture, Fatih Sultan Mehmet Vakıf University, Sütlüce Mah. Halıcıoğlu Kavşağı No: 12 Beyoğlu, Istanbul, Türkiye. E:mail: jamelakbar@alum.mit.edu ORCID: 0000-0003-0685-0500

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Abstract - Various factors can affect an individual's satisfaction level. While studying residential satisfaction and assessing it, subjective perceptions have the most significant influence. An essential element in ensuring satisfaction in housing is to consider the design of spaces that cater to individuals' specific desires and needs that change over time. Housing was frequently constructed considering the specific subjective needs of individuals, before the era of industrialization. As industrialization rises, housing gradually transformed into a commodity. Certain researchers propose that studying traditional built environments and harnessing the data gained from such analyses can be advantageous for contemporary housing production. Notably, Habraken is a prominent researcher who sought to ensure users' satisfaction in housing by devising the "Support System" rooted in his analysis of Dutch houses. Traditional house plans in Türkiye exhibit resemblances to the morphological arrangements observed by Habraken in Dutch houses, yet with some distinctive characteristics. In modern times, designers often prioritize function as the primary consideration. However, there have been attempts, such as Habraken's, to shift towards prioritizing morphology instead. This paper will explain links between users' satisfaction and their ability to change their immediate environments through morphologies that accommodate diverse functions.

Keywords: Sectors; Potentiality; Users' Satisfaction in Housing; Traditional Houses in Türkiye; Morphology.

1. Introduction

The satisfaction of users with the built environment is heavily influenced by their preferences and choices, which are in turn influenced by their ability, capacity, and willingness to alter the environment to suit their needs and desires. As a result, it is crucial for the built environment to be able to accommodate changes. The traditional built environment represents the culture and values of a particular community, and it consists of people's experiences and interactions within their built surroundings in which occupants had maximum control as the case of Muslims' built environment. Traditional buildings in the Muslim world in general [11], and in Türkiye in particular, are built with sectors that are capable of accommodating various functions and can adapt to changing needs. However, modern approaches to design focuses on function; yet an alternative morphological approach can maximize the potential of the built environment and improve users' satisfaction. Designers can create a more satisfying environment with a morphology-based approach that accommodates change.

2. Satisfaction (in general) – Life Satisfaction

The study of ‘satisfaction’ has its roots in the 1940s and is currently used in various fields including housing, marketing, landscape architecture and medicine. However, it is dominated by social psychology scholars [5].

Veenhoven [15] mentions that satisfaction is an evaluation of something that pertains to both contentment and enjoyment, and it is a state of mind that covers both cognitive and affective appraisals. This evaluation can be both temporary and long-lasting over time.

Parker & Mathews (2001) assert that satisfaction is commonly defined as a process of evaluation between what was received and what was expected. This description stands as one of the most widely adopted in current literature [5].

Satisfaction has been examined in a variety of distinct subcategories over the years. Life satisfaction stands out as the most all-encompassing subcategory, with the greatest degree of interaction with other domains.

Life satisfaction is the extent to which an individual positively assesses the overall quality of their life-as-a-whole. In essence, it gauges the individual's contentment with the life they are leading [15].

Life satisfaction involves an evaluative process where individuals assess the quality of their lives based on their own distinct set of criteria [1].

An individual presumably engages in a comparison between their perceived life circumstances and a self-imposed standard or set of standards. The extent to which these conditions align with the established standards determines the reported level of high life satisfaction. Therefore, life satisfaction is a conscious cognitive judgment of one’s life in which the criteria for judgment are up to the person [1].

In the literature, related terms to life satisfaction encompass happiness (occasionally used interchangeably), quality of life, and subjective or psychological well-being (a more comprehensive term than life satisfaction). The research on life satisfaction and associated concepts is extensive, with ongoing theoretical debates surrounding the nature and stability of life satisfaction [13].

Achieving a sense of satisfaction with one's life is an essential aspect of an individual's well-being and can greatly affect their quality of life over time. Given its importance, it is a matter that should be regarded with great significance and addressed accordingly.

During the 1960s, there was a growing interest in studying life satisfaction, and one of the primary areas of focus was how to measure it. Despite the fact that life satisfaction is highly subjective, researchers attempted to quantify it using numerical values. Veenhoven [15] noted that for a long time, measurements of life satisfaction were conducted in a similar manner to doctors measuring blood pressure, using an “objective” and “external” evaluation. However, it was later realized that this could not be done in the same manner.

Sousa and Lyubomirsky (2001) declare that a significant portion of the research has concentrated on the "objective" determinants of life satisfaction. This involves exploring the correlation between satisfaction and various environmental factors, including both imposed elements such as culture and relatively controllable factors such as income, occupation, education, and marriage, as well as specific aspects of persons (e.g., gender, age). [3].

Day (1980) claims that while everyone knows broadly what satisfaction means, it clearly does not mean the same thing to everyone [5].

Certain factors can be categorized as having an impact on an individual's level of satisfaction, but their effects can vary widely from person to person, and even time to time. This complexity makes it difficult to measure satisfaction accurately.

2.1. Users’ Satisfaction in Housing

Housing is perceived as an investment, a commodity, a component of the federal tax system, a design challenge, a building, a set of buildings, a community asset, and more. However, all housing is ultimately viewed by someone as a place for home. As a “place” for home, it represents the core of the physical portion of the social-physical environment that is home [4].

Having a place to live that can be considered home is a fundamental requirement and desire for people in their lives. For this reason, a house plays a significant role in ensuring life satisfaction. Research studies that investigate the level of contentment with one's living arrangements are categorized as residential satisfaction studies.

Residential satisfaction is not a static, uniform experience or state: it is an outcome that perceived by an individual or household, indicating their current housing status aligns with their needs and desires. Because residential satisfaction is based upon perception, the determinant factors essential to attain satisfaction will certainly be different in each case. Given that residential satisfaction is rooted in perception, the determinants crucial for achieving satisfaction will inevitably vary for each case. Factors shaping this perception include expectations, historical context, demographic characteristics, employment status, and other pertinent influences [5].

Balestra and Sultan (2013) assert that the notion of satisfactory housing conditions encompasses not only the physical, architectural, and engineering components of the house but also those of the surrounding environment. Residential satisfaction, according to their perspective, is further influenced by the social, behavioral, cultural, and demographic characteristics of the household [12].

Studying existing satisfaction models guides to the conclusion that crucial variables that have an impact on residential satisfaction are contained within the following four main domains [5]:

- characteristics of individuals (socio-economic variables)
- dwelling unit
- neighborhood
- community services

Recognizing and acknowledging these factors is a vital step in comprehending the current state of people's satisfaction. However, it's important to bear in mind that these factors are not static and can change over time as people's situations and perspective shift. Although it's a common desire for people to inhabit a prosperous neighborhood, the importance of certain factors can vary greatly from person to person. While some factors are universally sought after and remain unchanged, others can be highly subjective and differ significantly among individuals.

Studies related to residential satisfaction and its assessment are primarily influenced by subjective perceptions. The most crucial aspect of ensuring satisfaction in housing is to take into account designing places that accommodate individuals' specific desires and needs that change in time.

There are two key elements that require consideration: firstly, the unique needs and desires of different individuals, and secondly, the fact that individuals and their needs and desires are not static, but rather evolve and change over time (Fig. 1).

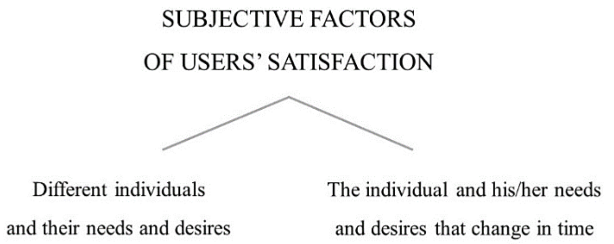

Fig.1: Subjective factors of users' satisfaction (Halise Betül Bulut, 2023)

One of the most significant factors in determining users' satisfaction is recognizing the distinct needs and preferences of each individual. However, it is equally important to acknowledge that these needs and preferences can evolve over time. The passage of time can hold distinct meanings for different individuals, which can also impact their requirements and preferences. Therefore, in situations involving users' satisfaction, it is crucial to account for the fact that individuals' needs and desires are subject to change over time, just as it is essential to consider the distinct needs and desires of various people.

It's not unexpected that personal preferences play a crucial role in achieving residential satisfaction. Historically, housing has often been built with the individual's subjective needs in mind, before the industrialization. However, with the rise of industrialization, housing has become a commodity, subject to market forces. As a result, the impact of political and economic factors on housing is considerable.

3. Traditional Built Environment

Before industrialization, individuals were in a position to create their own built environment as they are in control especially in the Muslim world as according to the Islamic legal system was invested in the hands of occupants [11]. Within the conditions they had, they built their homes according to their own desires and needs, and during the time they lived there, they were able to modify their homes to suit their changing desires and needs.

The most efficient solutions were of course those arrived at by the people who lived on a site and knew what its constraints and advantages were. Each had his own unique situation to deal with. As a result the urban environment became a huge laboratory for trying out a vast variety of solutions. When others saw that a solution worked, they adopted it too and in the process improved on it. In this way, the accretion of decisions that came to govern each property became the generator of affordable innovative solutions [11].

When examining traditional environment, it becomes apparent that typologies developed over time in response to local conditions, culture, and characteristics of the region. People passed down their knowledge and experience to shape these typologies, which changed and progressed to reach their present-day form. Indeed, the term "convention" as many demonstrated reflects the accumulations of environmental knowledge [6].

Housing is a complex matter involving issues such as financial, sociological, or political. However, here we will limit its focus to the design aspect of housing. In this regard, typology is a promising tool that can aid in designing effective solutions to accommodate change.

According to Petruccioli [2], studying typological processes can serve a dual purpose. Firstly, it allows us to identify the essential characteristics of a building that enable its continuity during changes over time. Secondly, it highlights the unique characteristics that differ from the norm and add value to the experimentation of building design. In other words, analyzing typological processes gives insight into both the regular and exceptional features of a building.

Habraken [14] argues that historical urban areas were not structured solely by function, but rather by the type and location of buildings. The arrangement of the house had a degree of autonomy. Across cultures, there have been significant variations in house design, but upon closer inspection, there is a consistency in the way spaces are classified according to size.

When we talk about a type or about a convention that generated a type, we are not talking about function but only about spaces that are arranged according to certain rules. The functions can always change; function is the variable within the form [11].

3.1. Support System

Some researchers believe that analyzing traditional built environment and utilizing the knowledge gained from such analysis could be beneficial for modern housing production. An important researcher is Habraken [10], who aimed to ensure users' satisfaction in housing by developing the support system based on his analysis of Dutch houses.

In designing a support, the objective is to find a solution that allows for all the desired variations while using as few detachable units as possible. The design of a support is a matter of optimization. How can the greatest variety in lifestyle and personal idiosyncrasies be accommodated using as few detachable units as possible?

Why people change their houses [7]:

- The need for identification
- Changes in lifestyle
- New technological possibilities
- The changing family

Individuals make changes to their houses when they have the chance. In spite of all the technical, legal and financial restrictions, they try to change their living environments. They take the opportunity when it arises, when they have control.

Three principles for the design of supports follow [7]:

- First, each dwelling unit in a "Support System" must allow for a number of different layouts
- Secondly, it must be possible to change the floor area, either by additional construction or by changing the boundaries of the units within the support
- In the third place, supports or parts of a support have to be adaptable to non-residential functions

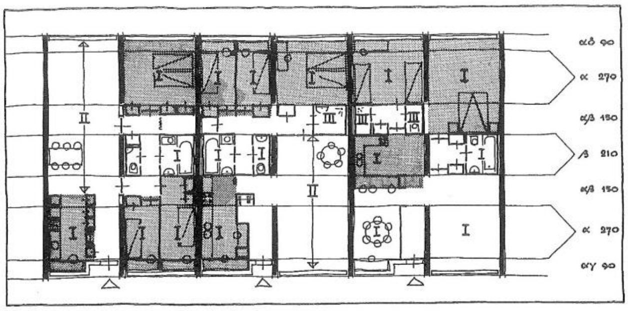

Fig.2. Zones and sectors [7]

According to Habraken, traditional houses in the Netherlands are made up of components called 'zone' and 'sector' and he noticed that these houses were designed based on morphology (Fig. 2). Similarly, when examining traditional buildings in Türkiye, it can be seen that there are same approaches in their house plan patterns.

3.2. Traditional Houses in Türkiye

As a concept, The Turkish House is a subject on which there has been much debate and contains too many different examples to provide a clear definition. The aim of this study is to benefit from the logic of typologies of traditional houses in Türkiye in general terms, not specific examples.

It has been suggested that the origin of the concept of the traditional houses in Türkiye goes back to the nomadic period and, indeed, the whole Turkish way of life prior to their migration and settlement in Anatolia bore all the characteristics of the nomadic way of life [9].

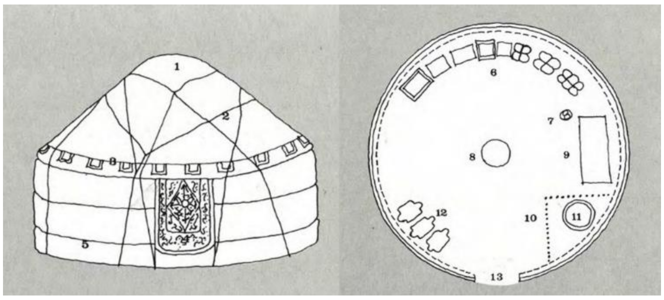

Fig. 3. The tent [9]

The tent, the dwelling unit of the nomad, was used either communally or in a cluster or adjacent units and now became transformed into the rooms inside the house. But as with the tents, there is negligeable communication between the rooms, each one having a single door opening onto the courtyard or the sofa (hall). This goes to show that the rooms were conceived and used as independent units [9].

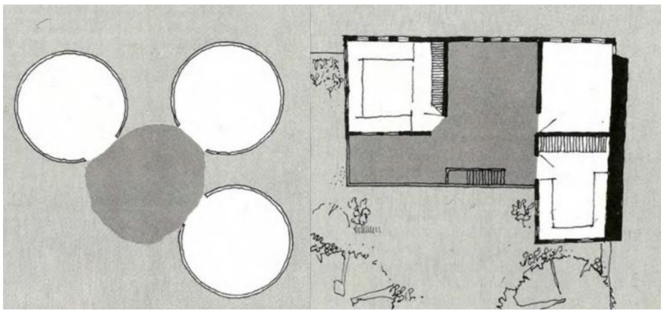

Fig. 4. Comparison of a tent and a house [9]

Comparison of life in a tent and a house [9]: Similarities exist in how living units and communal spaces are organized in both. The connection between the rooms and the sofa in a house mirrors the relationship between individual tents and their shared communal space.

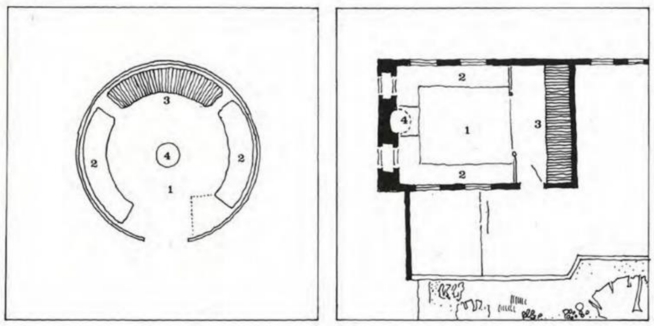

Fig. 5. Comparison of a tent and a room [9]

Comparison of the general arrangement and use of the room and the tent [9]: The importance resides in the akin functionality, use of space and the relationship between them.

1. Multi-purpose central area

2. Periphery used for seating

3. Closed utility areas, cupboards, chests, bedding

4. Heating; the central hearth in the tent is moved to aside wall in the house

Traditional houses consist of sofa and rooms which serve multiple functions. The sofa is an area providing access between the various rooms and has a varied technical terminology in Turkish "sergah, sergi, sayvan, çardak, divanhane, hayat" etc. In addition to providing an interior passage, it also serves as a gathering space, with the surrounding area adjusted to accomodate seating. In time, various sections became distinct features and concepts like the "eyvan, sekilik, taht, köşk" came into being. Thus the "sofa" became the most important element of the form of the traditional houses in Türkiye and influenced its whole shape [9].

The key feature of a room in a traditional houses in Türkiye is its versatility, as it serves multiple functions within the household. Similar to a nomadic tent, each room serves as a space for sitting, eating, working, and sleeping. The formation and function of the rooms may be summarized as follows [9]:

- They are independent units serving specific functions
- The interior arrangement is limited by definite principles
- These principles are created by social characteristics
- The rooms are arranged around a single comman utility area
- The position and state of the comman area varies according to several factors

Traditional houses in Türkiye have a unique feature that is able to accommodate changes for their users' needs and desires over time. This feature ensured that the same typology can be implemented in various places for ages by different generations.

3.3. Sectors within Traditional Houses in Türkiye

The plans in Türkiye have similar morphological arrangements as those observed by Habraken in Dutch Houses.

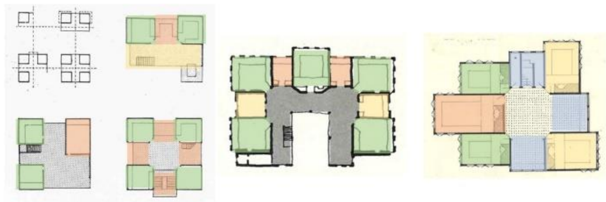

Fig. 6. Sector analysis - traditional houses in Türkiye [8, 9] (coloring by Halise Betül Bulut - colors represent varying space sizes)

Habraken's concept is illustrated in the plans as if they were rooms and sofas. In Fig. 6, the colors don't denote distinct functions; instead, they indicate spaces of equal size within specific plans. These spaces aren't assigned a fixed function but rather evolve morphologically, allowing for versatile use across various functions.

It's evident that there are sectors in traditional house plans in Türkiye. Nonetheless, there exists a significant distinction. It is noticeable that traditional house plans in Türkiye do not have well-defined zones but rather quite clear sectors.

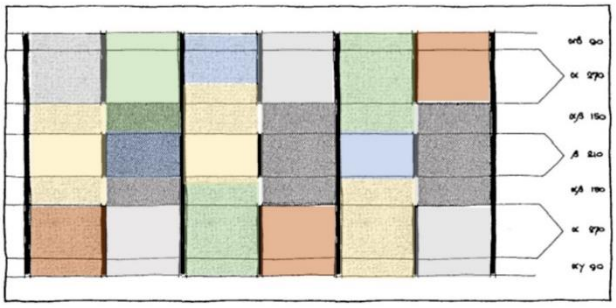

Fig. 7. Sectors with zones [7] (coloring by Halise Betül Bulut - colors represent varying space sizes)

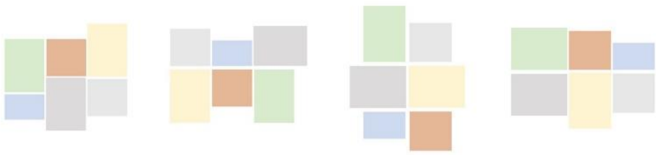

Fig. 8. Sectors without zones (Halise Betül Bulut - colors represent varying space sizes)

Traditional houses in Türkiye are based on sectors which accommodates different functions. Plans with sectors have more potential than contemporary designs to accommodate change and different people's needs and desires (Fig. 8).

4. Conclusion

Several factors influencing individual satisfaction in housing can vary greatly among individuals and personally over time. Subjective perceptions play a significant role in studying residential satisfaction. Designing spaces that adapt to individuals' changing desires and needs is crucial for ensuring satisfaction. Historically, housing prioritized subjective needs but shifted towards commodification with industrialization.

Some researchers propose that exploring traditional built environments and utilizing the knowledge acquired from such investigations can be advantageous for modern housing production. Notably, Habraken aimed to ensure users' satisfaction in housing by developing the support system based on his analysis of Dutch houses. Traditional house plans in Türkiye bear resemblances to the morphological arrangements observed in Dutch houses by Habraken, albeit with distinct characteristics.

A notable feature of traditional houses in Türkiye is their ability to serve multiple functions within a single room. These rooms, as sectors, have the potential to be utilized for various purposes at different times.

Currently, design methodology is heavily focused on functionality, however, there is an alternative approach that prioritizes maximum potential and users' satisfaction by allowing them to adapt the physical environment to their specific needs. This approach is based on morphology, which emphasizes form to better suit the needs of its users through sectors.

A design tool that is developed with considering these issues may have more potential for design and help to ensure more users' satisfaction.

References

[1] E. Diener, "Subjective well-being", Psychological Bulletin. Vol. 95 No:3, pp. 542–575.

[2] A. Petruccioli, "Vernacular architecture and typology", A|Z ITU Journal of The Faculty of Architecture, 13(1), pp. 5–13. doi: 10.5505/itujfa.2016.60252.

[3] L. Sousa, S. Lyubomirsky, "Life satisfaction", Worell, J. (Ed.), Encylopedia of women and gender: Sex similarities and differences and the impact of society on gender. Vol: 2, pp. 667-676.

[4] S. Weidemann, J. R. Anderson, "A Conceptual Framework for Residential Satisfaction", Altman, I. and Werner, C.M. (Ed.), Home Environments (Human Behavior and Environment), Plenum Press, New York and London, pp. 153-182, 1985.

[5] C. Aigbavboa, W. Thwala, Residential Satisfaction and Housing Policy Evolution, Taylor & Francis Group, London: Routledge, 2018.

[6] S. Anderson, On Streets: Streets as Elements of Urban Structure, The MIT Press, 1986.

[7] N. J. Habraken, Variations: The Systematic Design of Supports, Laboratory of Architecture and Planning at MIT, Cambridge, Mass, 1976.

[8] D. Kuban, Türk Ev Geleneği Üzerine Gözlemler, Türk ve İslâm Sanatı Üzerine Denemeler, Arkeoloji ve Sanat Yayınları. İstanbul, 1982.

[9] Ö. Küçükerman, Kendi Mekanının Arayışı İçinde Türk Evi-Turkish House in Search of Spatial Identity, TTOK. İstanbul, 1985.

[10] S.H Kendall, J. R. Dale (Eds.), The Short Works of John Habraken: Ways of Seeing / Ways of Doing (1st ed.). Routledge, 2023, https://doi.org/10.4324/9781003011385

[11] J. Akbar, "Accretion of Decisions: A Design Strategy", Theories and Principles of Design in the Architecture of Islamic Societies, Proceedings of a Symposium held at Harvard U. and the

Massachusetts Institute of Technology, edited by M. B. Sevcenko; Cambridge, Mass., 1988, pp. 107-114.

[12] C. Balestra, J. Sultan, "Home Sweet Home: The Determinants of Residential Satisfaction and its Relation with Well-being", OECD Statistics Working Papers, No. 2013/05, OECD Publishing, Paris.

[13] N. J. Beutell, "Life Satisfaction in Relation to Work and Family", available at: https://www.researchgate.net/publication/259486067_Life_Satisfaction_in_Relation_to_Work_and_Family, 2006 (accessed 16 April 2023)

[14] N. J. Habraken, "Tools of The Trade, Thematic Aspects of Designing", available at: https://www.habraken.com/html/downloads/tools_of_the_trade_final.pdf, 1996 (accessed 16 April 2023)

[15] R. Veenhoven, "Satisfaction and social position: within nation differences compared across nations", available at: https://personal.eur.nl/fsw/research/veenhoven/Pub1990s/96g-full.pdf, 1996 (accessed 16 April 2023).

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[1] J. Clerk Maxwell*, A Treatise on Electricity and Magnetism,* 3rd ed., vol. 2. Oxford:Clarendon Press, 1892, pp.68-73.

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[2] Y. Yorozu, M. Hirano, K. Oka, and Y. Tagawa, “Electron spectroscopy studies on magneto-optical media and plastic substrate interface”, *IEEE Transl. J. Magn. Japan*, vol. 2, pp. 740-741, August 1987.

Conferences

[3] Çolak I., Kabalci E., Bayindir R., and Sagiroglu S, “The design and analysis of a 5-level cascaded voltage source inverter with low THD”, *2nd PowerEng Conference*, Lisbon, pp. 575-580, 18-20 March 2009.

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[4] IEEE Standard 519-1992, Recommended practices and requirements for harmonic control in electrical power systems, *The Institute of Electrical and Electronics Engineers*, 1993.

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‡ Corresponding Author; Second Author, Postal address, Tel: +90 312 123 4567, Fax: +90 312 123 4567,corresponding@affl.edu

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Abstract- Enter an abstract of up to 250 words for all articles. This is a concise summary of the whole paper, not just the conclusions, and is understandable without reference to the rest of the paper. It should contain no citation to other published work. Include up to six keywords that describe your paper for indexing purposes. Define abbreviations and acronyms the first time they are used in the text, even if they have been defined in the abstract. Abbreviations such as IEEE, SI, MKS, CGS, sc, dc, and rms do not have to be defined. Do not use abbreviations in the title unless they are unavoidable.

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2. Introduction

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Authors are requested write equations using either any mathematical equation object inserted to word processor or using independent equation software. Symbols in your equation should be defined before the equation appears or immediately following. Use “Eq. (1)” or “equation (1),” while citing. Number equations consecutively with equation numbers in parentheses flush with the right margin, as in Eq. (1). To make equations more compact, you may use the solidus (/), the exp function, or appropriate exponents. Italicize Roman symbols for quantities and variables, but not Greek symbols. Use an dash (–) rather than a hyphen for a minus sign. Use parentheses to avoid ambiguities in denominators. Punctuate equations with commas or periods when they are part of a sentence, as in

$$C = a + b \quad (1)$$

Section titles should be written in bold style while sub section titles are italic.

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3.1. Figure Properties

All illustrations must be supplied at the correct resolution:

- Black and white and colour photos - 300 dpi
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Figure 1. Engineering technologies.

Table captions should be written in the same format as figure captions; for example, “Table 1. Appearance styles.”. Tables should be referenced in the text unabbreviated as “Table 1.”

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Acknowledgements

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References

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[2] H. Poor, *An Introduction to Signal Detection and Estimation*, New York: Springer-Verlag, 1985, ch. 4. (Book Chapter)

[3] Y. Yorozu, M. Hirano, K. Oka, and Y. Tagawa, "Electron spectroscopy studies on magneto-optical media and plastic substrate interface", *IEEE Transl. J. Magn. Japan*, vol. 2, pp. 740-741, August 1987. (Article)

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[6] IEEE Standard 519-1992, Recommended practices and requirements for harmonic control in electrical power systems, *The Institute of Electrical and Electronics Engineers*, 1993. (Standards and Reports)

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[12] IEEE Standard 519-1992, Recommended practices and requirements for harmonic control in electrical power systems, The Institute of Electrical and Electronics Engineers, 1993. (Standards and Reports)

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