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Application of taguchi method for optimization of design parameters ın enhancement the robust of "c" type snap-fits

"C" tipi geçmeli bağlantıların sağlamlığının geliştirilmesinde taguchi yöntemi ile tasarım parametrelerinin optimizasyonu

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Application of Taguchi Method for Optimization of Design Parameters in Enhancement The Robust of "C" Type Snap-fits

Highlights

- *Parameter optimization for type C snap-fits.*
- *Analysis of design parameters with Taguchi Method.*
- *Impact analysis with ANOVA for type C snap-fits.*

Graphical Abstract

In the study, parameter optimization was carried out by Taguchi method while designing C type snap-fits. The accuracy of the method was ensured by full factorial analysis. In addition, the effects of parameters for the design were evaluated by performing ANOVA analysis.

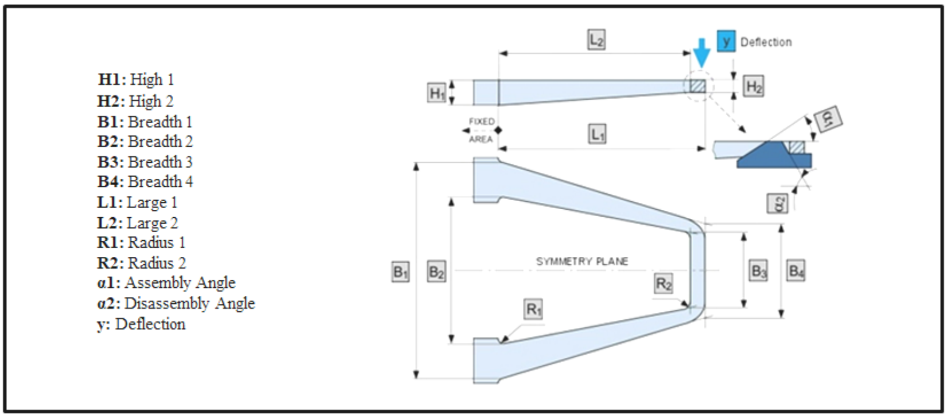

Figure. Parametric dimension of the "C" type snap fits [19].

Aim

Investigation of the suitability of Taguchi method for C type snap-fits design.

Design & Methodology

The designs were parametrically designed in ANSYS software. Taguchi method was used for parameter optimization.

Originality

The Taguchi method was not used for the C type snap-fits design, which was designed parametrically in previous studies.

Findings

In the study, the values obtained by using the Taguchi method and the ANSYS results of C-type snap-fits designs with full factorial analysis are in agreement.

Conclusion

It has been proven that the correct results can be obtained by saving time and labor by using the Taguchi method for experimental design for C type snap-fits designs with parametric design, and it has been proven that this method is suitable for C type snap-fits elements.

Declaration of Ethical Standards

The author(s) of this article declare that the materials and methods used in this study do not require ethical committee permission and/or legal-special permission.

Application of Taguchi Method for Optimization of Design Parameters in Enhancement The Robust of "C" Type Snap-fits

Araştıma Makalesi/Research Article

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ABSTRACT

Using statistical approaches, industrial product designs can be optimized quickly and reliably. The Taguchi method is a statistical approach that helps us to optimize the process parameters and help us to save time in terms of labor and cost. In this study, the optimization of the design parameters by using the Taguchi method for the design of the C-type snap-fit connection, which is one of the flexing fasteners used in many areas of the industry, was investigated. The design and analysis of the study was carried out by using ANSYS software. The design parameters were optimized and the effective parameters were determined. ANOVA analysis was performed to determine the effective parameters. In addition, full factorial analysis was performed to verify the method used. For example, the optimum normal stress value obtained with the Taguchi array was obtained for the combination of H1=0.4;R1=3;α1=40;α2=89;y=6 and material is PLA. When we examine the table in Figure 4, we can see that the result of 328740.27 among 729 test results and the result of the parameters in the Taguchi set match.

Anahtar Kelimeler: C-Type snap fits, finite element analysis (FEA), design of experiment (DOE), taguchi metod, ANOVA.

"C" Tipi Geçmeli Bağlantıların Sağlamlığının Geliştirilmesinde Taguchi Yöntemi ile Tasarım Parametrelerinin Optimizasyonu

ÖZ

İstatistiksel yaklaşımlar kullanılarak endüstriyel ürün tasarımları hızlı ve güvenilir bir şekilde optimize edilebilir. Taguchi yöntemi, süreç parametrelerini optimize etmemize ve işçilik ve maliyet açısından zamandan tasarruf etmemize yardımcı olan istatistiksel bir yaklaşımdır. Bu çalışmada, endüstrinin birçok alanında kullanılan esnek bağlantı elemanlarından biri olan C tipi geçmeli bağlantı tasarımı için Taguchi yöntemi kullanılarak tasarım parametrelerinin optimizasyonu araştırılmıştır. Çalışmanın tasarımı ve analizi ANSYS yazılımı kullanılarak yapılmıştır. Yapılan çaışma ile tasarım parametreleri optimize edilmiş ve etkin parametreler belirlenmiştir. Etkili parametreleri belirlemek için ANOVA analizi yapılmıştır. Ayrıca, kullanılan yöntemi doğrulamak için tam faktöriyel analizi yapılmıştır. Örneğin, Taguchi dizisi ile elde edilen optimum normal gerilme değeri H1=0.4;R1=3;α1=40;α2=89;y=6 ve malzeme PLA'nın kombinasyonu için elde edilmiştir. Şekil 4'teki tabloyu incelediğimizde 729 test sonucu arasından 328740.27 sonucu ile Taguchi setindeki parametrelerin sonucunun eşleştiğini görebiliriz.

Keywords: C Tipi geçmeli bağlantı, sonlu elemanlar analizi, deney tasarımı, taguchi metodu, ANOVA.

1. INTRODUCTION

The optimization of production processes and designs has become popular over the years. Many methods have been developed and implemented in this context. There are a wide range of approaches available from the past to the present, such as Build-Test-Fix, One-Factor at a Time, and Design of Experiments. Design of Experiments is considered one of the most comprehensive statistical approaches in product and process improvements. The Taguchi Method is a sub-branch of this statistical approach and is preferred for product and process improvements in many areas.

A. B. Naik and A. C. Reddy has optimized the welding parameters and stresses of duplex stainless steel 2205 by tungsten inert gas welding. By changing the parameters such as current, time, velocity, oxide flux changes, it has made optimization of these parameters in order to increase the welding hardness, depth and tensile strength. The Taguchi method and variance analysis were performed and an artificial neural network was created to predict errors in the welding process. The orthogonal L9 design experiment set was performed from Taguchi method. Variance analysis and optimum design

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parameters were determined by analysis of variance (ANOVA) [1]. D. Y. Park et al. investigated the effects of material and process conditions on powder injection molding process. For the parameters such as injection temperature, powder size, first powder volume, fractionation and shear rate, test kits were formed using the Taguchi method. At the end of the experiment, additional tests were performed and Taguchi method was confirmed [2]. C. L. Lu et al. CMOS-MEMS microphone stress distribution and malfunction under shock load with finite element method. Parameters of diaphragm, were examined by the Taguchi method. Experimental sets were created and the effects of these parameters were investigated. According to the JEDEC standards, the simulation test was performed according to JESD22-B111 and JESD22-B110B by performing a drop test. Recommendations have been made to improve the design and robustness of the MEMS microphone [3]. J. Long et al. The laser welding technique carried out a joint configuration with the preformed metal powders of the 6016 aluminum alloy to the DC04 steel. In order to optimize the laser power, focus distance, welding speed and shield gas flow parameters for the laser welding, laser welding was carried out. Showed that the tensile properties were significantly improved [4]. E. Teimortashlu et al. used the Taguchi method to design the tertiary mixture self-compression test. The three additives consist of fly ash (FA), slag (S) and Nano silica (NS) (PC) to partially replace Portland cement. It is tried to optimize the 28 day grout by taking certain percentages for the mixture. 16 series experiments were performed using the L16 Taguchi sequence. As a result of the experiments, optimum compressive strength was obtained [5]. Bing-Sheng Yu and Yi-Yu optimized the purity and yield of synthetic smectite using the Liu Taguchi method and discussed the effects of synthesis factors. Efficient values for high quality synthesis were determined by controlling the purity and yield of the synthetic smectite with parameters determined at temperatures of 200 ° C - 220 ° C, 48-96 hours, and 7, 9 and 11pH [6]. P. Adewale et al. In the presence of a commercial lipase catalyst (Eversa Transform), biodiesel production from crude high oil (CTO) was optimized using the Taguchi method. Methanol, reaction time and temperature, and enzyme dose are considered as the process parameters containing the molar ratio of crude high oil. The effects of oil on the in situ esterification were investigated by the Taguchi method [7]. D. B. Niranjan et al. The aluminum alloy 6061 T6 aims to obtain the optimum process parameters by performing Teguchi optimization for turning on the cylinder rods. It has optimized the cutting parameters, such as cutting speed, feedrate and depth of cut, as the process parameter. The surface finishing speed was 429 m / min, the feed rate was 0.05 mm / min and the cutting depth was 1 mm and the surface quality was obtained from the determined parameter ranges [8]. S. K. Kharea et al. It has realized optimization of turning process by using parametric design of Taguchi methodology. L9 examined the effects of cutting speed, feed rate, depth of cut and rake angle parameters using the experimental design. He searched the effect of these parameters on surface roughness [9]. In order to improve the heat transfer in the Ata and Acır air flow solar collector, designs were made using different fin angles, collector slopes and Reynolds numbers. Heat transfer in the study parameters affecting the improvement of Taguchi method was optimized [10]. N. P. Kim et al. It has aimed to ensure that the printing process is at a constant speed by optimizing the factors affecting the 3D printing process with Taguchi. It tried to find the range in which the materials were optimal by using three independent variables (WC), speed per minute (RPM) and nozzle diameter tip (TIP). Using the optimum parameter values, the pot and the pottery have printed various 2.5D and 3D structures and proved the printability of such structures [11]. Günay et al. optimized the Taguchi method for the mechanical properties (printing speed, fill rate and scanning angle) of PLA+ samples [12]. R. Chauhan et al. investigated the effects of different types of air jet geometries causing heat transfer and air friction changes in a solar thermal collector. The experiment-based design is used to optimize basic parameters with Taguchi. The jet diameter ratio was examined in each direction of flow and in the range direction through the heat transfer and liquid friction behavior. The result was obtained by optimizing the optimal design combination of a developing jet solar collector [12]. A. C. Mitra et al. used the Taguchi method for optimization of parameters when designing a durable suspension. It aims to reduce the variability of a vehicle in relation to the mass of the vehicle in Ride comfort using the combination of tire pressure, damping coefficient and spring stiffness. Thus, a robust suspension design process was carried out [13]. T. Sangkharata and S. Dechjarerna explored the effect of spinning process parameters in an effort to obtain large deformation without the failure of wall breakage or wrinkling. In this study, Taguchi method is carried out finite element analysis to decrease the number of numerical simulations. In addition, Taguchi main effect analysis and ANOVA results showed that the spinning depth, mandrel slope, and support roller width were the most important factors affecting the spinning force [14]. R. Goutham et al. study on mechanical properties of recycled Acrylonitrile Butadiene Styrene (ABS) blended with virgin Acrylonitrile Butadiene Styrene (ABS) using Taguchi method has attempted to optimize material mechanical properties by optimizing the properties of Acrylonitrile butadiene styrene (ABS) material, such as filler density. The Taguchi method has been used to recognize a set of parameters that give good results for a number of specific responses. [15]. E. R. Fitzharrisa et al. For the design of material extrusion additive manufacturing (MEAM), the design of a test technique known as the Taguchi method examined the

effects of parameters such as the temperature of the printing, the heat treatment time and the heat treatment temperature. It has been observed that the most effective parameter on all the properties studied is the heat treatment temperature [16]. Yusuf et al. have written a computer program that improves any parameter design problem with one quality characteristic, two quality characteristics, or three quality characteristics [17]. As given in the examples, the Taguchi method is applied in many areas and the desired optimization process is made and the parameter effects can be examined. In this study, the effects of the design parameters will be determined by using the Taguchi method in the design of snapfits and the parameter values will be found for the optimum design process. The accuracy of the data obtained with the Taguchi method is ensured by full factor analysis. With the result obtained, it was evaluated whether this method can be used to optimize the snap fits design.

2. MATERIAL VE METHOD

The Taguchi method uses orthogonal array to examine the entire parameter field by testing fewer combinations instead of testing all combinations between parameters. In this specially designed method, parameter deviations and optimum parameter options are obtained by determining the deviation amounts in the variables. In this study, the design optimization was carried out using the Taguchi method for a C type snap-fits connection. First of all, the parametric dimensions for the planned connection element are determined as shown in Figure 1.

The independent variables for the connection element whose length parameters are shown are determined. This parameters; H1 (high), R1 (radius), α1 (assembly angle), α2 (disassembly angle) and y (deflection) values. PLA (Polylactic acid), ABS (Acrylonitrile Butadiene Styrene) and PETG (Polyethylene terephthalate glycol) materials were compared for the designed connection element. In accordance with the parameters determined for C-type snap-fits, the levels of the parameters are determined as shown in Table 1.

For the parameters whose factors and levels are determined, the design of experiment was created in Minitab software. The appropriate orthogonal array was chosen from the experimental design methods using the Taguchi method. The L27 orthogonal array was found suitable for this study. The generated orthogonal array is given in Table 2.

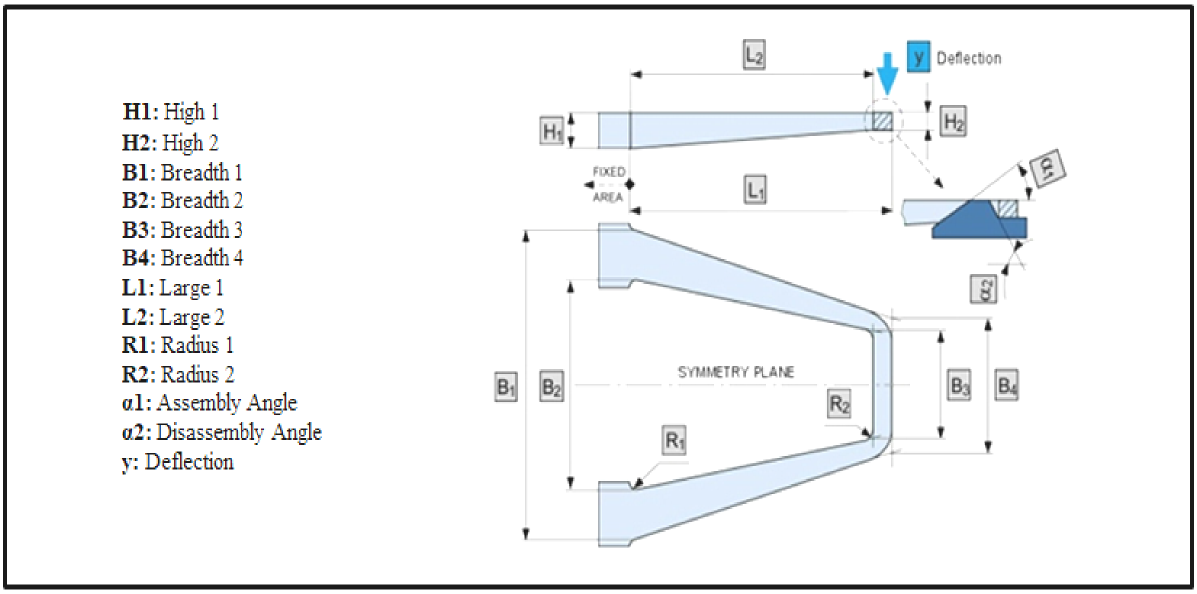


Fig. 1. Parametric dimension of the “C” type snap fits [19].

Table 1. Factor- level of C type snap fits.

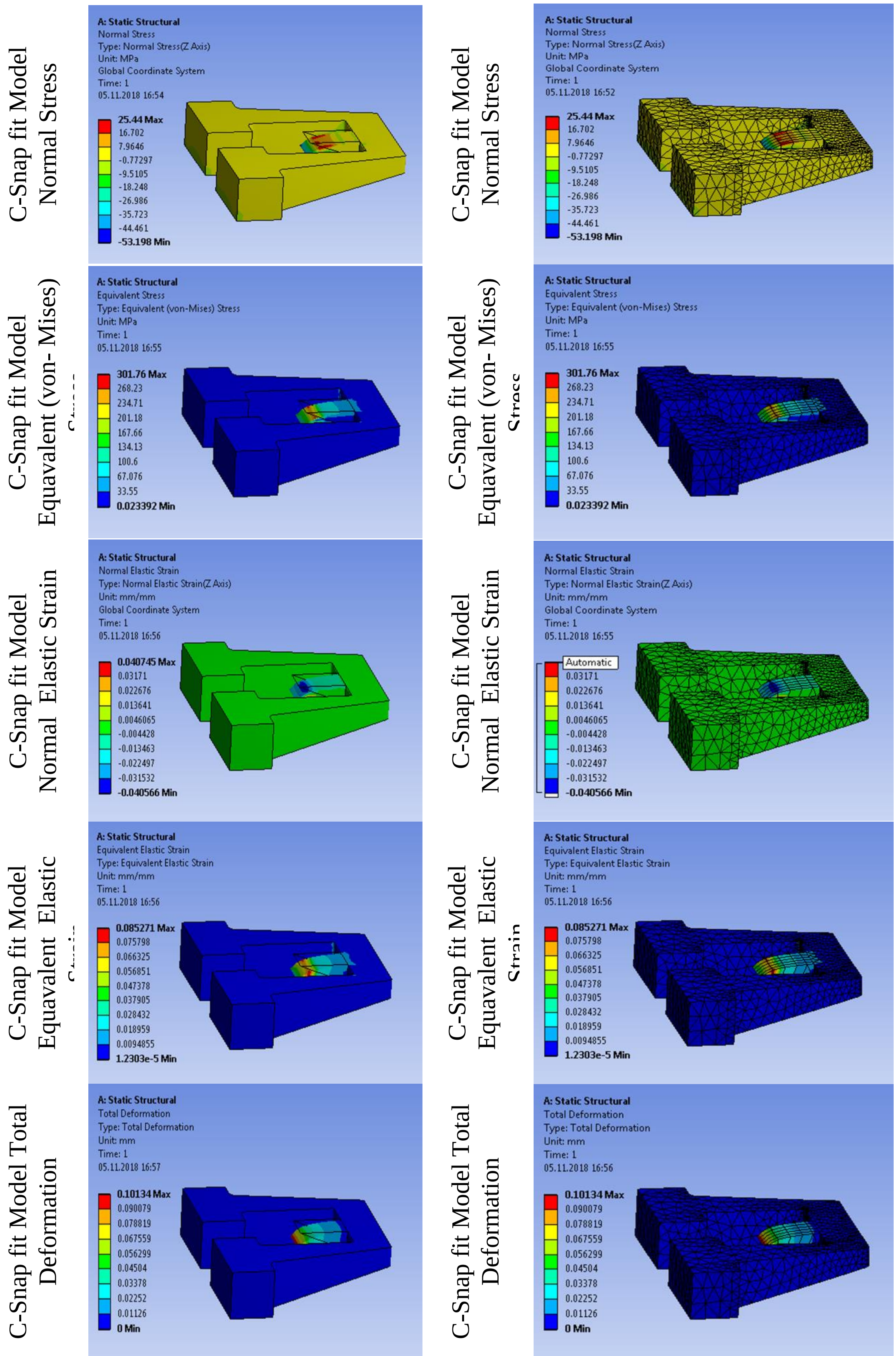
Factors	**Level 1**	**Level 2**	**Level 3**
H1(mm)	0,4	2,4	6
R1(mm)	0,05	1,5	3
α1(mm)	20	40	60
α2(mm)	20	60	89
y(mm)	0,1	3	6
Materials	PLA	ABS	PETG

Table 2. Orthogonal array L27 for C type snap-fits.

Exp. No	Materials	H1(mm)	R1(mm)	α1(mm)	α2(mm)	Y(mm)	A	B	C	D	E	F
1	PLA	0,4	0,05	20	20	0,1	1	1	1	1	1	1
2	PLA	0,4	0,05	20	60	3	1	1	1	1	2	2
3	PLA	0,4	0,05	20	89	6	1	1	1	1	3	3
4	PLA	2,4	1,5	40	20	0,1	1	2	2	2	1	1
5	PLA	2,4	1,5	40	60	3	1	2	2	2	2	2
6	PLA	2,4	1,5	40	89	6	1	2	2	2	3	3
7	PLA	6	3	60	20	0,1	1	3	3	3	1	1
8	PLA	6	3	60	60	3	1	3	3	3	2	2
9	PLA	6	3	60	89	6	1	3	3	3	3	3
10	ABS	0,4	1,5	60	20	3	2	1	2	3	1	2
11	ABS	0,4	1,5	60	60	6	2	1	2	3	2	3
12	ABS	0,4	1,5	60	89	0,1	2	1	2	3	3	1
13	ABS	2,4	3	20	20	3	2	2	3	1	1	2
14	ABS	2,4	3	20	60	6	2	2	3	1	2	3
15	ABS	2,4	3	20	89	0,1	2	2	3	1	3	1
16	ABS	6	0,05	40	20	3	2	3	1	2	1	2
17	ABS	6	0,05	40	60	6	2	3	1	2	2	3
18	ABS	6	0,05	40	89	0,1	2	3	1	2	3	1
19	PETG	0,4	3	40	20	6	3	1	3	2	1	3
20	PETG	0,4	3	40	60	0,1	3	1	3	2	2	1
21	PETG	0,4	3	40	89	3	3	1	3	2	3	2
22	PETG	2,4	0,05	60	20	6	3	2	1	3	1	3
23	PETG	2,4	0,05	60	60	0,1	3	2	1	3	2	1
24	PETG	2,4	0,05	60	89	3	3	2	1	3	3	2
25	PETG	6	1,5	20	20	6	3	3	2	1	1	3
26	PETG	6	1,5	20	60	0,1	3	3	2	1	2	1
27	PETG	6	1,5	20	89	3	3	3	2	1	3	2

5. RESULTS AND DISCUSSION

In the ANSYS software for the C type snap fits, which were set up for the experimental set, the finite element analysis was performed. The stress, strain and deformation results obtained by the dimensional parameters are shown in Figure 2. The results obtained for the sample PLA material. The same process was obtained and presented in other test sets including ABS and PETG materials (Table 3). Taguchi analysis was performed by using the results obtained from ANSYS together with the orthogonal array 27 experimental set. The S / N ratio is calculated for each output by selecting the larger-the-better type of control function. The S / N ratio calculations of the whole experiment are presented in Table 3. The mean S / N ratio was calculated for each factor. As a result of the averages obtained, the optimum parameter values are shown separately for stress, strain and deformation in the graphs shown in Figure 3. When we examine image 3, we see the parameters and the levels defined by 1,2 and 3. The remaining parameter value in the graphs is obtained as parameters which provide the optimum stress, strain or deformation values. These values are presented in Table 4.



Fig, 2. ANSYS results for "C" type snap fits.

Table 3. S/N Ratio for C type snap-fit outputs.

Exp. No	Normal Stress S/N Ratio (dB)	Equivalent Stress S/N Ratio (dB)	Normal Strain S/N Ratio (dB)	Equivalent Strain S/N Ratio (dB)	Deformation S/N Ratio (dB)
1	28,16388453	49,6444582	-27,74742594	-21,33280329	-19,88426306
2	73,74257267	89,20079217	2,054118446	18,0747424	9,586245339
3	109,7231304	123,6358096	31,09927585	52,53433749	15,95991757
4	12,54531956	34,02522409	-43,36691667	-36,95201759	-19,8842401
5	58,05961635	73,61991022	-13,48706079	2,493860185	9,589917015
6	94,22122281	108,1247481	15,48738976	37,02328256	15,85765009
7	4,587438197	26,06769001	-51,32742367	-44,90967437	-19,88445351
8	50,02029721	65,62206719	-21,4417328	-5,503982653	9,58911313
9	86,20688266	100,1068524	7,64855	29,00535236	15,87860677
10	56,29351619	77,34721966	2,478710465	8,259882956	9,659119662
11	78,24934965	93,75150045	8,642228482	24,50354102	15,6201719
12	72,97876092	86,77793133	-3,991821211	17,55360202	-19,81546839
13	40,66433237	61,72286926	-13,14611796	-7,364422798	9,658475863
14	62,30642343	77,90517003	-7,19450781	8,6572101	15,6143642
15	57,01638658	70,80314365	-19,81931667	1,57881389	-19,75149947
16	32,68960352	53,74658438	-21,12218131	-15,34077019	9,657654186
17	54,16128276	69,76979332	-15,24611028	0,521833464	15,60830528
18	48,84760069	62,62793467	-28,4012507	-6,596410208	-19,66549248
19	59,31772084	80,5992421	8,171168769	14,2681353	15,67986418
20	39,93518001	55,50079521	-26,95061756	-10,98485374	-19,93707665
21	99,7309855	113,609412	25,87204549	47,14784385	9,596336879
22	43,67809975	64,95275215	-7,472035655	-1,378443451	15,67832365
23	23,70218122	39,36920241	-42,98109663	-27,11644704	-19,95517173
24	83,44440971	97,2836386	9,502914171	30,82206915	9,878815319
25	35,72062985	56,99681996	-15,42907544	-9,334346831	15,67838097
26	15,76301172	31,44193946	-50,92577597	-35,04370989	-19,95422608
27	75,61786335	89,45897965	1,370931407	22,99738198	9,864034214

Table 4. Optimum value of parameter for each outputs.

Parameter	Optimum Value for Normal Stress	Optimum Value for Equivalent Stress	Optimum Value for Normal Strain	Optimum Value for Equivalent Strain	Optimum Value for Total Deformation
Material	PLA	PLA	PETG	PETG	PLA
H1	0,4	0,4	0,4	0,4	0,4
R1	3	3	3	3	0,05
α1	40	40	60	60	20
α2	89	89	89	89	89
y	6	6	6	6	6

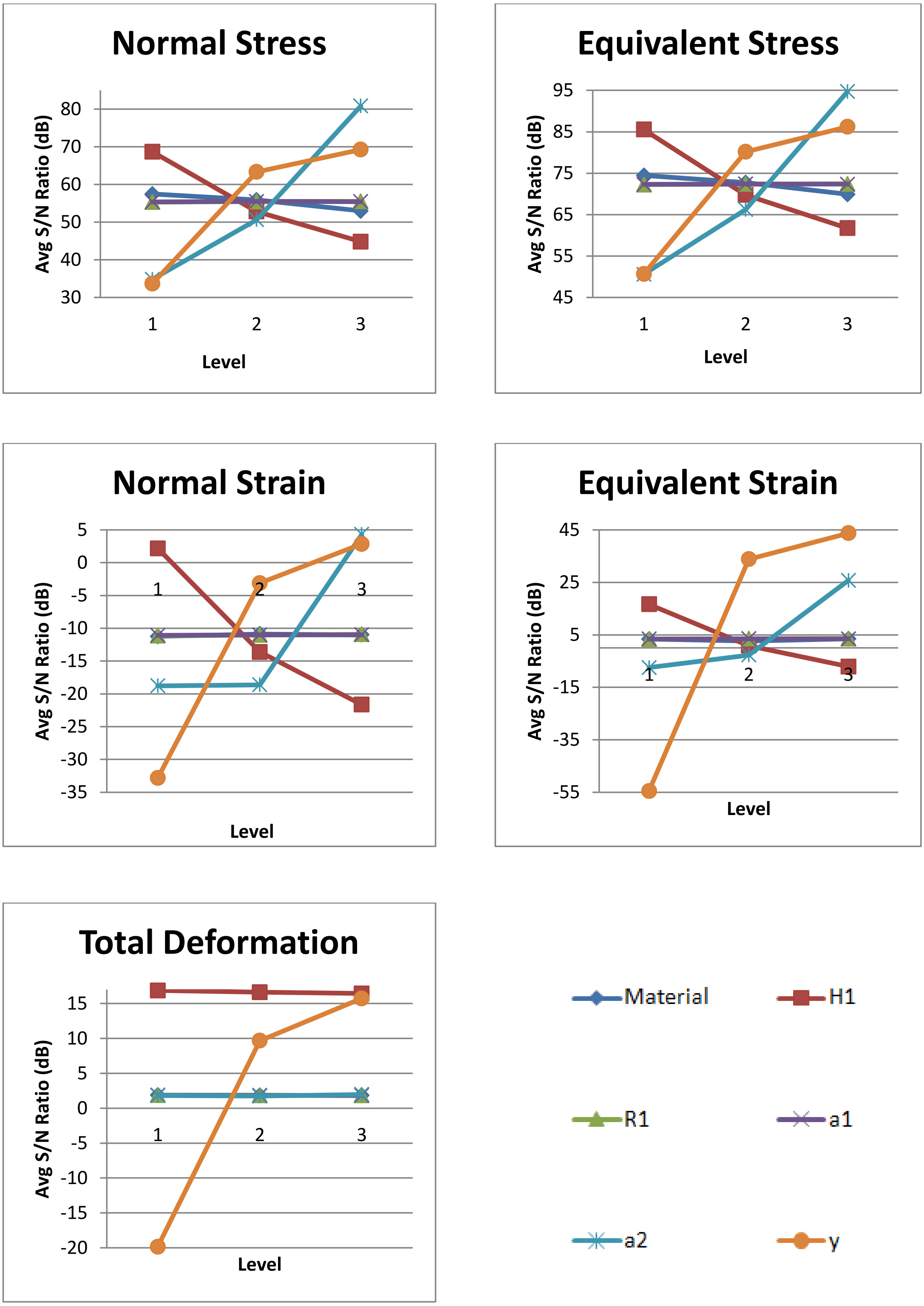


Figure 3: S/N Ratio- Level chart for C type snap-fit parameters.

The accuracy of the optimization data obtained by the Taguchi method was checked with full factorial analysis. The full factorial analysis consists of combining all the parameters of the experiment and performing the experiment. In our problem, all parameter combination test sets were replaced with 729 instead of 27 test sets obtained with Taguchi method for C type snap-fit. Each output is checked and the resulting table is shown in Figure 4. As shown in Figure 4, the values obtained with the Taguchi method were also reached when full factorial analysis was performed. The Taguchi method has been proven to optimize the desired output by installing more experimental sets.

Parameters						Normal Stress	Equivalent Stress	Normal Strain	Equivalent Strain	Total Deformation
PLA	3,6	0,05	20	89	3	16996,13205	84155,5203	2,002226059	23,44294453	3,123388318
PLA	4,8	0,05	20	89	3	12662,78227	62804,95858	1,48443131	17,49522829	3,120546908
PLA	6	0,05	20	89	3	10182,78625	50451,95638	1,187968027	14,05411029	3,121176469
PLA	0,4	0,05	20	89	6	306306,7178	1519814,131	35,88920122	423,3668747	6,280523984
PLA	1,2	0,05	20	89	6	101390,2404	502768,1301	12,04035905	140,0535164	6,24420148
PLA	2,4	0,05	20	89	6	50406,5948	249654,8885	5,997361408	69,54520607	6,240473514
PLA	3,6	0,05	20	89	6	33992,26409	168311,0406	4,004452118	46,88588905	6,246776636
						⋮				
PLA	4,8	3	40	89	3	12974,82626	64347,59898	1,52529852	17,92494631	3,10520358
PLA	6	3	40	89	3	10216,78225	50618,89081	1,2061394	14,10060096	3,111002376
PLA	0,4	3	40	89	6	328740,27	1635306,164	39,48376666	455,5398331	6,040529247
PLA	1,2	3	40	89	6	105582,4668	523006,8101	12,58850421	145,6915741	6,142873661
PLA	2,4	3	40	89	6	52144,51169	258515,2671	6,19982134	72,01321983	6,180783964
						⋮				
ABS	4,8	3	40	89	3	10588,10858	51798,9183	1,47307259	17,91034365	3,102251349
ABS	6	3	40	89	3	8334,812985	40732,30059	1,157959092	14,08385229	3,107925765
ABS	0,4	3	40	89	6	268312,3338	1316742,957	38,98895205	455,2869492	6,034582246
ABS	1,2	3	40	89	6	86131,22471	420795,0847	12,44563173	145,4972725	6,136701152
ABS	2,4	3	40	89	6	42556,95759	208117,4192	6,126118905	71,96013069	6,174137096
						⋮				
PETG	6	3	60	89	3	6024.910125	29654.53322	1.184183013	14.09323478	3.109367366
PETG	0,4	3	60	89	6	193900,6524	958298,0261	39,32169861	455,4305801	6,037356755
PETG	1,2	3	60	89	6	62261,96169	306376,2809	12,54369203	145,6051178	6,139579751
PETG	2,4	3	60	89	6	30756,12853	151480,8867	6,176133672	71,99103928	6,177283836
PETG	3,6	3	60	89	6	20473,97289	100891,8123	4,154795644	47,94913101	6,197892081
						⋮				

Fig. 4. Full factorial analysis result for C type snap-fits.

Analysis of Variance (ANOVA) is used to identify and quantify the sources of different trial results from different trials. ANOVA analysis was performed to determine the effect values of the parameters used in the study. The data obtained are shown in Table 5. In Figure 5, graphically, the status of each parameter relative to each other is explained.

Table 5. ANOVA Analysis results.

		SS (Sum of Square) %				
Parameters	**DOF**	**Normal Stress**	**Equivalent Stress**	**Normal Strain**	**Equivalent Strain**	**Total Def.**
Material	2	15,0495	14,932	10,356	11,701	0,889
H1	2	19,637	20,052	27,949	23,699	0
R1	2	7,668	7,612	5,309	5,951	0,059
α1	2	7,781	7,7301	5,417	6,124	0,118
α2	2	33,762	33,282	35,007	38,854	2,371
y	2	16,102	16,389	15,960	13,669	96,56
Total	12	100	100	100	100	100

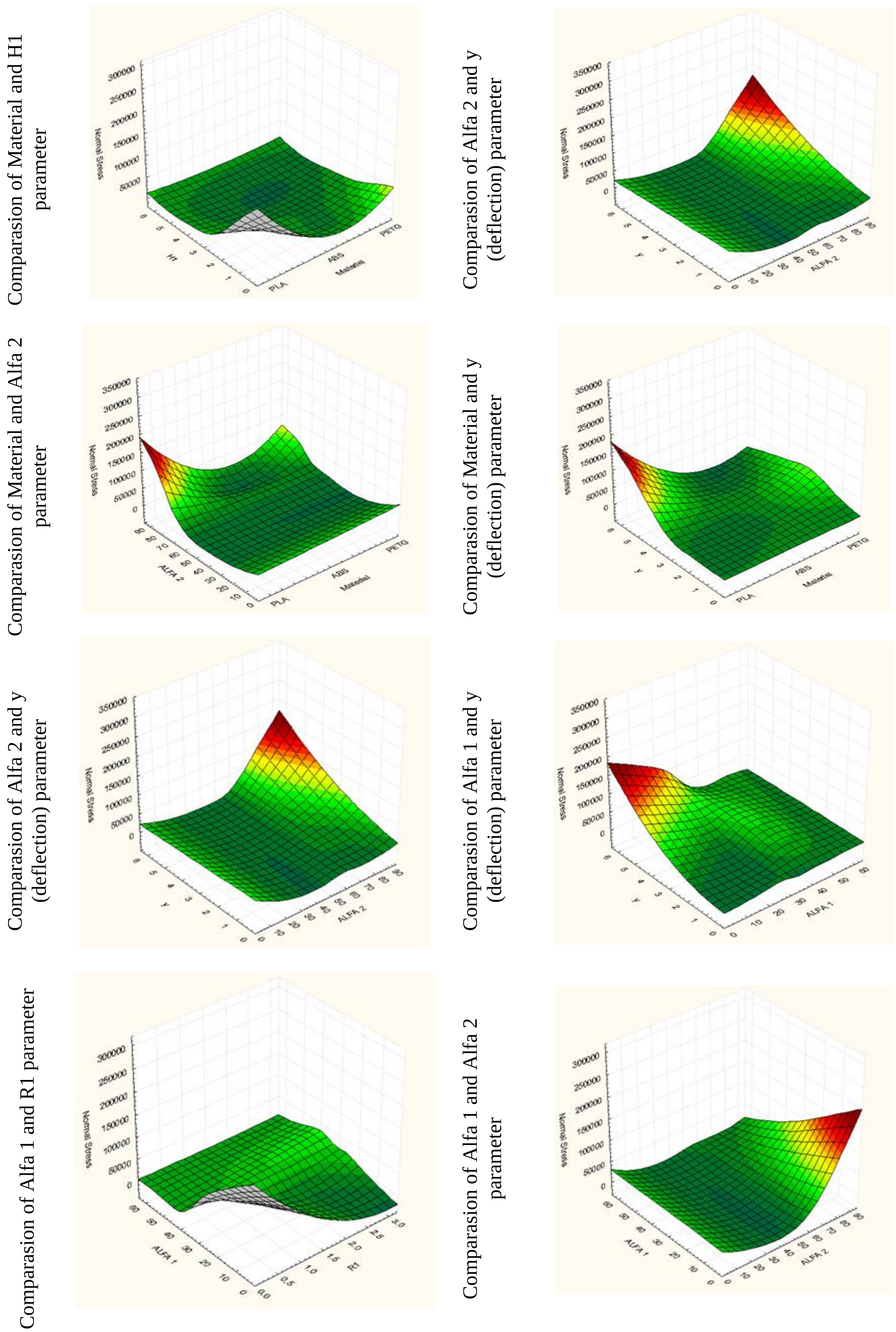


Fig.5. Comparison of the parameters of normal stres with ANOVA

In ANOVA, the sum of all condition parameters and total frames of error components is equal to the sum of SS (sum of squares of deviations).

$$SS = \sum(X - \bar{X})^2 \quad (1)$$

$$SS_T = SS_M + SS_H + SS_R + SS_{\alpha1} + SS_{\alpha2} + SS_Y + SS_E \quad (2)$$

Where, SS_M= sum of squares of deviations for materials, SS_H= sum of squares of deviations for H1parameters, SS_R= sum of squares of deviations for R1parameters, $SS_{\alpha1}$= sum of squares of deviations for α1parameters, $SS_{\alpha2}$= sum of squares of deviations for α2parameters, SS_Y= sum of squares of deviations for Y parameters, SS_E= sum of squares of deviations for error compoents and SS_T= sum of squares of deviations for total parameters.

When Table 5 is examined, it is seen that the input parameters have different values for the normal stress, equivalent stress, normal strain and equivalent stran outputs but in the same direction. For these outputs, the effect value of the α2 parameter is distinguished by a significant difference. This parameter is followed by the parameters H1, y, material respectively. The parameters R1 and a1 have been found to be not very effective parameters for design optimization. The effect of the y (deflection) parameter is clearly seen when the same parameters are evaluated for total deformation output.

6. CONCLUSION

In this study, stress, strain and deformation values of snap-fits connections were investigated. The effects of the generated parametric dimensions on these outputs and the optimum parameter determination were carried out. Taguchi method was used for experimental optimization. The Taguchi method used for full factorial analysis structures has been proven. Anova analysis was performed to determine the parametrical effects. Based on the experimental data obtained, the following inferences can be made.

- ✓ In the experiment set designed using the Taguchi method, 27 experimental sets were created instead of 729 experimental sets and time and cost of the experiment were saved.
- ✓ Full factorial analysis was performed in the ANSYS environment for the applied method. The method used in the analysis is verified and detailed in the article.
- ✓ The Taguchi method described in detail can be applied in many other studies.
- ✓ The Taguchi method has been found to be an efficient method to simplify the process parameters in a simple way.
- ✓ This method, which is a reliable and simple method of validation with full factorial analysis, is undoubtedly used in all other studies.

DECLARATION OF ETHICAL STANDARDS

The authors of this article declare that the materials and methods used in this study do not require ethical committee permission and/or legal-special permission.

AUTHORS' CONTRIBUTIONS

Fulya ERDEMİR: Carrying out the experiments and analyse the results. Wrote the manuscript.

Murat Tolga ÖZKAN: Carrying out the experiments and analyse the results.

CONFLICT OF INTEREST

There is no conflict of interest in this study.

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