Dispersion analysis of factors affecting parameters of threaded connection "buttress" of oil-and-gas pipelines

I K Tsybryi¹, I L Vyalikov¹, N S Koval¹², and V I Ignatenko¹

¹Don State Technical University, Gagarin sq., 1, Rostov on Don, 344003, Russia
E-mail: ²koval-nc@mail.ru

Abstract. In the context of increasing volumes of oil-and-gas production, quality and tightness assurance of oil-and-gas pipes has become a very urgent problem. The most common methods of pipe connecting are coupling and streamline joints with application of conic, trapezoidal and triangular threads, including buttress ones. The accuracy of thread profile production has a significant impact on interchangeability of items during assembly and their connection reliability, including tightness. In the process of production of items under consideration, various factors, such as technological heredity, rigidity of the processing equipment, its adjustment and installation and others, influence the thread production process. The given article introduces the results of carried-out studies on the impact of the duration of threaded machine operation and the lot of pipe blanks on the main parameters of the thread, such as thread tension by threaded gauge, thread length from the end without black crested threads, etc. The degree of each factor influencing the corresponding parameter was established on the basis of dispersion analysis.

1. Introduction
Analysis of works [1-16] shows an insufficient level of research into the influence of various factors on the process of obtaining a high-quality threaded connection of the "battress" type of oil-and-gas pipelines. For example, in [1], the results of studies of the effect of preload in a threaded joint on its tightness by means of finite element analysis are presented. In [2], the use of promising threaded connections is proposed, the use of which will, according to the authors, reduce the likelihood of damage to pipes and casing strings. For the most part, the considered research results were carried out in order to establish the possibility of increasing the service life of oil-gas pipe joints or are associated with issues of leakage of their connection under various operating conditions. Considering the widespread use of the "battress" threaded connection, an urgent task is to establish, on the basis of analysis of variance, the factors that influence the formation of its quality parameters.

2. Characteristics of oil-and-gas pipelines connections by “buttress” thread, identification of factors affecting the analyzed parameters
The most common methods of connecting pipes of oil-and-gas pipelines are coupling and streamline joints with application of conic, trapezoidal and triangular threads. However, the connection with application of Buttress (Figure 1) threads is considered to be the most reliable one, as it is used in the construction and operation of vertical wells of oil-and-gas and gas condensate deposits.
The structural feature of boring casing with Buttress threads is the high resistance of the threaded connection to tension loads. The profile of the “Buttress” thread has the shape of a non-isosceles trapezoid with a pitch of 5.08 mm and a cone ratio of 1:16. The spectrum of produced thin-walled boring casing pipes with streamline joints for capital workover operations allows to restore casing column of practically all oil deposits. The stab flank, which receives the load factor at the moment of fitting the pipe into the coupling element, as well as working for compression, is made at an angle of 10°, which provides easy fitting of the pipe into the coupling element and reduces thread jamming. The load flank of the profile, which receives the tension load, has an angle of 3°, which reduces the risk of the pipe thread disengaging from the coupling element at significant tension and bending. Tightness is ensured by pressure of threaded-sealing lubricant in constructional gaps of threaded connection profile. Installation with fluoroplastic sealing ring in coupling element is possible. One of the main conditions for reliable operation of oil pipe schedule is strict compliance with the requirements for the quality characteristics of threaded joints of pipes and coupling elements of oil pipe schedule and methods of their control established by the current GOSTs (state all-union standard). Nowadays, the characteristics of threaded connections of boring casing are regulated by GOST 632-80 and the international standard API 5B.

In order to identify factors significantly affecting the parameters characterizing the Buttress thread, 58 pipes of ø168.28 mm were measured. As the parameters of the thread the following were considered: thread tension on a threaded gauge, thread output on the last turn, thread length from the end without black crested threads, thread profile height, thread taper on 5 threads of screw with incomplete and complete profile. Among the main factors that can influence the accuracy of thread formation the following were considered: the duration of the operational period of thread-cutting machine and the lot of pipe blanks melting. The measuring instruments used were: digital pitch gauge, digital depth gauge, the indicative device for measuring thread run-out, digital conical gauge, special indicative device for measuring the diameter and conicity of the seal band.

3. Findings on influence of factors on the parameters of “buttress” thread
Dispersion analysis of data on the parameter “thread tension” has been carried out. The results are described in Table 1.

![Figure 1. Buttress Trapezoidal Thread Coupling.](image-url)
Table 1. Dispersion analysis of the parameter “thread tension”.

| Factor                | SS Effect | df Effect | MS Effect | SS Error | df Error | MS Error | F       | P       |
|-----------------------|-----------|-----------|-----------|----------|----------|----------|---------|---------|
| Lot of melting        | 0.244     | 1         | 0.244     | 21.919   | 56       | 0.391    | 0.625   | 0.432   |
| Duration of machine operation | 14.400 | 5         | 2.880     | 7.764    | 52       | 0.149    | 19.28   | 0       |

Analysis of the table data shows that the duration of machine operation has an impact on thread tension. In order to obtain more complete information about given dependence Table 2 was compiled, which represents information on the average values, standard deviations and dispersion of the studied parameter, depending upon the time group.

Table 2. Descriptive statistics for “thread tension” parameter grouped according to the influential factor “duration of machine operation”.

| Duration of machine operation | Means | N  | Std.Dev. |
|-------------------------------|-------|----|---------|
| 1                             | 1.315 | 10 | 0.277   |
| 2                             | 1.45  | 10 | 0.178   |
| 3                             | 1.08  | 10 | 0.531   |
| 4                             | 0.24  | 10 | 0.196   |
| 5                             | 0.23  | 10 | 0.221   |
| 6                             | 0.58  | 8  | 0.704   |
| All Grps                      | 0.824 | 58 | 0.624   |

Clustering into time groups was performed in the following manner: the entire sequence of pipes under examination was divided into 6 groups – the lots of 10 pipes in the first 5 groups and 8 pipes in the last group. Respectively, the dispersion analysis of the data on the parameter “thread output on the last turn” was carried out. The results are given in Table 3.

Table 3. Dispersion analysis of the parameter “thread output on the last turn”.

| Factor                | SS Effect | df Effect | MS Effect | SS Error | df Error | MS Error | F       | P       |
|-----------------------|-----------|-----------|-----------|----------|----------|----------|---------|---------|
| Lot of melting        | 0.00028   | 1         | 0.00028   | 0.0078   | 56       | 0.0001   | 2.04    | 0.158   |
| Duration of machine operation | 0.00310 | 5         | 0.00062   | 0.0050   | 52       | 0.0001   | 6.447   | 0.00009 |

Analysis of the table data shows that the duration of machine operation has an impact on the thread output on the last turn. To provide more complete information on the given dependency Table 4 was compiled. It reflects information on average values, standard deviations and dispersions of the studied parameter, depending upon the time group.
Table 4. Descriptive statistics for “thread output on the last turn parameter grouped according to the influential factor “duration of machine operation”.

| Duration of machine operation | Means | N  | Std.Dev. |
|-------------------------------|-------|----|----------|
| 1                             | 0.039 | 10 | 0.003    |
| 2                             | 0.04  | 10 | 0.005    |
| 3                             | 0.033 | 10 | 0.014    |
| 4                             | 0.023 | 10 | 0.013    |
| 5                             | 0.023 | 10 | 0.011    |
| 6                             | 0.039 | 8  | 0.006    |
| All Grps                      | 0.033 | 58 | 0.012    |

Dispersion analysis of data on the parameter “thread length from the end without black crested threads” has been carried out. Its results are represented in Table 5.

Table 5. Dispersion analysis of “thread length without black crested threads” parameter.

| Factor                        | SS Effect | df Effect | MS Effect | SS Error | df Error | MS Error | F    | P     |
|-------------------------------|-----------|-----------|-----------|----------|----------|----------|------|-------|
| Lot of melting                | 202.169   | 1         | 202.169   | 2395.21  | 56       | 42.772   | 4.726| 0.034 |
| Duration of machine operation | 942.279   | 5         | 188.455   | 1655.1   | 52       | 31.829   | 5.92 | 0.0002|

Analysis of the table data shows that both factors influence the thread length without black crested threads. To provide more complete information on the given dependencies Tables 6 and 7 were compiled. They reflect information on average values, standard deviations and dispersions of the studied parameter, depending upon the melting (Table 6) and upon the time group (Table 7).

Table 6. Descriptive statistics for “thread length from the end without black crested threads” parameter grouped according to the influential factor “lot of melting”.

| Lot of melting | Means | N  | Std.Dev. |
|----------------|-------|----|----------|
| 112            | 68.142| 7  | 6.618    |
| 5153           | 62.411| 51 | 6.53     |
| All Grps       | 63.103| 58 | 6.75     |

Table 7. Descriptive statistics for “thread length from the end without black crested threads” parameter grouped according to the influential factor “duration of machine operation”.

| Duration of machine operation | Means | N  | Std.Dev. |
|-------------------------------|-------|----|----------|
| 1                             | 58.9  | 10 | 6.045    |
| 2                             | 61.1  | 10 | 6.19     |
| 3                             | 61.9  | 10 | 5.3      |
| 4                             | 69.1  | 10 | 3.695    |
| 5                             | 60    | 10 | 5.981    |
| 6                             | 68.75 | 8  | 6.363    |
| All Grps                      | 63.103| 58 | 6.75     |
Dispersion analysis of data on the parameter “thread height” has been carried out. Its results are represented in Table 8. Analysis of the table data shows that both factors influence the thread height. To provide more complete information on the given dependencies Tables 9 and 10 were compiled. They reflect information on average values, standard deviations and dispersions of the studied parameter, depending upon the melting (Table 9) and upon the time group (Table 10).

**Table 8.** Dispersion analysis of “thread height” parameter.

| Factor                   | SS Effect | df Effect | MS Effect | SS Error | df Error | MS Error | F          | P          |
|--------------------------|-----------|-----------|-----------|----------|----------|----------|------------|------------|
| Lot of melting           | 0.0004    | 1         | 0.0004    | 0.004    | 56       | 0.00006  | 6.197      | 0.0158     |
| Duration of machine operation | 0.003     | 5         | 0.0006    | 0.001    | 52       | 0.00002  | 20.348     | 0          |

**Table 9.** Descriptive statistics for “thread height” parameter grouped according to the influential factor “lot of melting”.

| Lot of melting | Means | N  | Std.Dev. |
|----------------|-------|----|----------|
| 112            | 1.578 | 7  | 0.003    |
| 5153           | 1.569 | 51 | 0.009    |
| All Grps       | 1.571 | 58 | 0.009    |

**Table 10.** Descriptive statistics for “thread height” parameter grouped according to the influential factor “duration of machine operation”.

| Duration of machine operation | Means | N  | Std.Dev. |
|-------------------------------|-------|----|----------|
| 1                             | 1.575 | 10 | 0        |
| 2                             | 1.579 | 10 | 0.005    |
| 3                             | 1.572 | 10 | 0.009    |
| 4                             | 1.561 | 10 | 0.003    |
| 5                             | 1.562 | 10 | 0.004    |
| 6                             | 1.576 | 8  | 0.007    |
| All Grps                      | 1.571 | 58 | 0.009    |

4. Conclusion

According to the data of dispersion analysis, it has been found that the lot of melting has an influence on such thread parameters as its length without black crested threads and the height of thread profile, and the duration of machine operation affects all thread parameters except the pitch of the thread. The standard deviation of the thread output parameter on the last turn (Std. Dev = 0.01) is comparable to the index error of measuring devices (± 0.02); therefore, it is impossible to judge about the influence of the duration of machine operation on this parameter. In order to improve the reliability of control measuring operations and the future determination of the factors influencing the formation of geometric parameters of the thread, it is necessary to use more accurate measuring tools. The presumptive nature of the influence of the melting lot on the studied thread parameters is as follows: the material of pipes from different melts can differ in composition and graininess. Since the machine
cutter is configured to certain parameters of the pipe material, in different lots of melting the parameters of the obtained thread can vary.

The length of threads without black crested threads is affected by heterogeneity of pipe sizes and materials of different lots of melts. Thread tension and the height of thread profile are affected by the duration of machine operation in the following way: in the course of sewing up of cutting tool, the given thread parameters grow (as the pipe diameter increases). On analyzing the data from Table 2, one can come to a conclusion that in the first (pipes No. 0-10) and second (pipes No. 11-20) time groups the machine works properly and the average value of thread tension increases. Afterwards, in the third time group (pipes No. 21-30), the machine state, achieved during its initial adjustment changes, and the average value of thread tension gradually begins to decrease and drops sharply in the fourth (pipes No. 31-40) and fifth (pipes No. 41-50) time groups. The adjustment of the machine was carried out after the treatment of the fifth group, and in the sixth time group (pipes No. 51-58) the average value of thread tension began to grow, which corresponds to the normal machine operating conditions. Revealed regularity can also be observed when considering the influence of duration of machine operation on the height of thread profile (Table 10).

References
[1] Wei Chen, Qinfeng Di, He Zhang, Feng Chen, Wenchang Wang 2018 Journal of Petroleum Science and Engineering, Vol 171, 724-730 doi.org/10.1016/j.petrol.2018.07.079.
[2] Cui F, Li W, Wang G, Gu Z, Wang Z 2015 Journal of Petroleum Science and Engineering, Vol 133, 208-217 doi.org/10.1016/j.petrol.2015.06.007.
[3] Cirimello P G, Otegui J L, Carfi G, Morris W 2017 Failure and integrity analysis of casings used for oil well drilling, Vol 75, 1-14 doi.org/10.1016/j.engfailanal.2016.11.008.
[4] Xu J, Guo R 2012 Procedia Engineering, Vol 31, 381-388 doi.org/10.1016/j.proeng.2012.01.1040.
[5] Li Y, Cao Y, Dou Y, Yu Y 2019 Procedia Structural Integrity, Vol 22, pp 43-50 doi.org/10.1016/j.prostr.2020.01.006
[6] Patel D, Thakar V, Pandian S 2019 Petroleum, Vol 5, pp 1-12 doi.org/10.1016/j.petlm.2018.12.003.
[7] Cirimello P, Otegui J L, Aguirre A, Carfi G 2019 Engineering Failure Analysis, Vol 104, pp 203-215 doi.org/10.1016/j.engfailanal.2019.05.026.
[8] Wang N, Liu C, Jiang D, Behdinan K 2019 Mechanical Systems and Signal Processing, Vol 118, pp 61-77 doi.org/10.1016/j.ymssp.2018.08.029.
[9] Yin F, Han L, Yang S, Deng Y 2018 Journal of Petroleum Science and Engineering, Vol 166, pp 235-241 doi.org/10.1016/j.petrol.2018.03.010.
[10] Guo X, Li J, Liu G, Xi Y 2019 Journal of Petroleum Science and Engineering, Vol 172, pp 731-742 doi.org/10.1016/j.petrol.2018.08.067.
[11] Yang S, Han L, Feng C 2018 Journal of Petroleum Science and Engineering, Vol 168, pp 32-38 doi.org/10.1016/j.petrol.2018.04.068.
[12] Yang M, Zhao X, Meng Y 2017 Applied Thermal Engineering, Vol 118, pp 299-314 doi.org/10.1016/j.applthermaleng.2017.02.070.
[13] Liu Y, Lian Z 2019 Pengfei Sang, Engineering Failure Analysis, Vol 97, pp 589-604 doi.org/10.1016/j.engfailanal.2019.01.058.
[14] Kaldal G S, Jonsson M T 2016 Halldor Palsson, Sigrun N, Karlsdottir, Geothermics, Vol 62, pp 1-11 doi.org/10.1016/j.geothermics.2016.02.002.
[15] Chen G 2016 Journal of Sound and Vibration, Vol 361, pp 190-209 doi.org/10.1016/j.jsv.2015.09.041.
[16] Kaldal G S, Jonsson M T 2015 Karlsdottir, Geothermics, Vol 55, pp 126-137 doi.org/10.1016/j.geothermics.2015.02.003.