

The Basic Problems of Breakdown of Oil Refining Equipment

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Abstract. The paper describes typical cases of failure of elements of oil refining equipment, including the destruction of welded joints made by austenitic electrodes, furnace coil pipes cracking, hydrogen cracking, metallurgical cases and corrosion. The causes of destruction and depressurization are classified with the identification of the main problems and the relations between them.

1 Introduction

The modern oil refining industry is characterized by the use of powerful power plants and process fluids with high corrosion activity. Therefore, increasing the reliability and service life of equipment in order to increase safety and optimize economic resources is always an urgent task.

An important step in determining ways to solve this problem is to conduct a comprehensive analysis of the accident rate of oil refining equipment, identifying common types of damage and critical factors that affect it.

2 Methods and materials

To find ways to solve the problem, “VNIKTIneftekhimoborudovanie” JSC (the research institute) conducted an analysis of the data accumulated as a result of studies of more than a thousand cases of failure and depressurization of oil refining equipment of the wide range of steels, used in petrochemical production. Tests of defective fragments included: mechanical tests (tensile tests, long-term strength and creep tests, impact tests, hardness tests), metallographic analysis, determination of the chemical composition of steels and welds, X-ray diffraction analysis (phase composition, stress, products of corrosion), chemical SEM analysis of corrosion deposits.

3 Results and discussion

The main objects of this work (Fig. 1) are coil tubes of tube furnaces, technological pipelines, vessels and apparatuses. Fragments of shut-off and control valves (SCV), parts of pumps and compressors, tubes of heat exchangers, etc. were also studied.

The diagram shows weld joints in a separate group. Formally, they can relate to all other groups, but are presented separately as an important indicator illustrating the existing problems of the design of assemblies, non-

compliance with welding technology or incorrect selection of materials.

Consider a number of typical cases of failure of the objects indicated on the diagram.

One of the regularly arising problems is the destruction of welded joints of pipe fragments of steel 15Cr5Mo (AISI 501 analog) made by austenitic electrodes. The determining conditions for the occurrence of brittle fractures are factors of heterogeneity and deterioration of the properties of certain zones of such welded joints [1, 2].

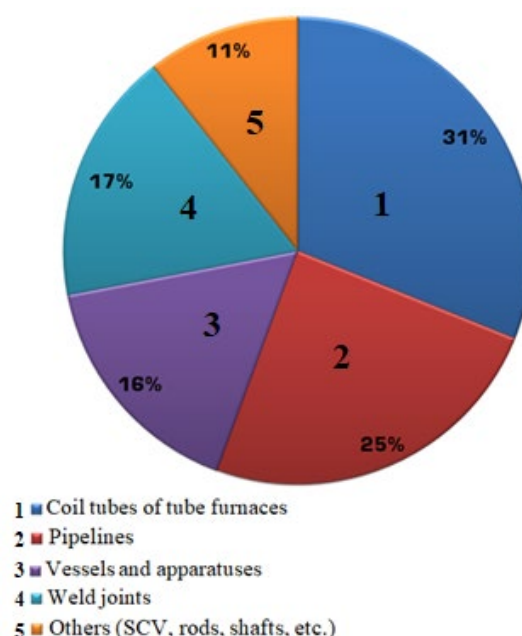


Fig. 1. The main objects of research of “VNIKTIneftekhimoborudovanie” JSC for 1980-2019.

During cooling after welding heat affected zones (HAZ) are hardened (Fig. 2), which, together with the action of internal stresses due to the difference in the linear expansion coefficients of the austenitic weld metal and the base metal, leads to crack formation (Fig. 2). Measures to prevent the destruction of austenitic welded joints [2-4], such as providing heat removal during the

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welding process or regulation of thermal cycles, in most cases are not taken.

According to the results of studies of the metal of coil tubes of tube furnaces, about 50% of the fragments show a mismatch with the required mechanical characteristics. Degradation of metal properties is caused, as a rule, by overheating of parts of pipes facing the flame of the burners. For example, in overheated regions of coils made of austenitic steels, the structure contains multiple accumulations of the σ -phase along the grain boundaries (Fig. 3), which causes severe embrittlement, a decrease in their ductility and strength, and, ultimately, destruction at operating pressures.

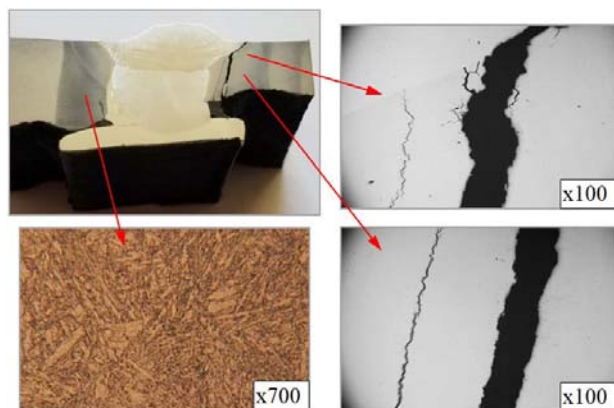


Fig. 2. Cracks in the HAZ during welding of 15Cr5Mo steel with the ANZHR-2 electrode and the hardening structure in HAZ.

The main reason for the failure of technological pipelines is corrosion-erosion wear up to the formation of through holes. Most of the elements of process pipelines are subject to varying degrees of hydrogen sulfide corrosion: high temperature, low temperature, and accelerated local corrosion in the presence of dead ends and other types of irrational constructions.

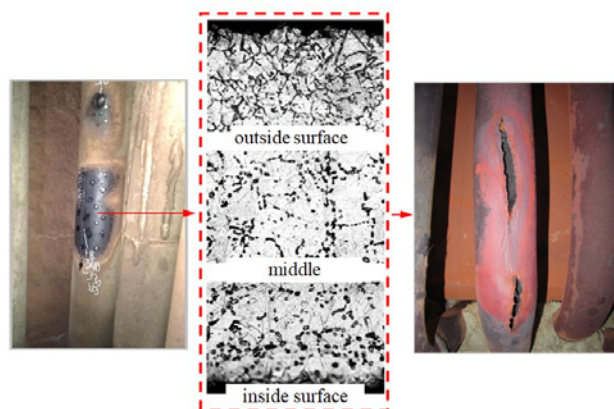


Fig. 3. The area of overheated of the pipe, its microstructure (x320) and possible consequences.

In some cases, steep taps with a small radius of curvature are exposed to increased erosion wear. When a vapor-liquid mixture moves with sufficiently high speeds, the phenomenon of rebound of the liquid phase can occur. With an abrupt change in the direction of flow, the liquid phase as heavier will be discarded by

centrifugal forces to the periphery, i.e. to the outside of the tap. With a large amount of vapor phase, the cross-sectional area for the liquid phase can significantly decrease, which will cause a significant increase in the velocity of the liquid flow and lead to erosive wear of the taps [5]. Often there is an erroneous use of steep taps for parts of coils located outside the furnace furnaces, where conventional taps with an increased radius of curvature can be used. This use of steeply bent taps is not justified.

For vessels and apparatuses in contact with hydrocarbon gases and propane-butane fractions, a characteristic type of destruction is low-temperature hydrogen delamination (Fig. 4). In particular, this is typical for steels 09Mn2Si and 16MnSi (A516, A561 ASTM analogs) which exhibit a high tendency to delamination under the conditions of hydrogenation [6].

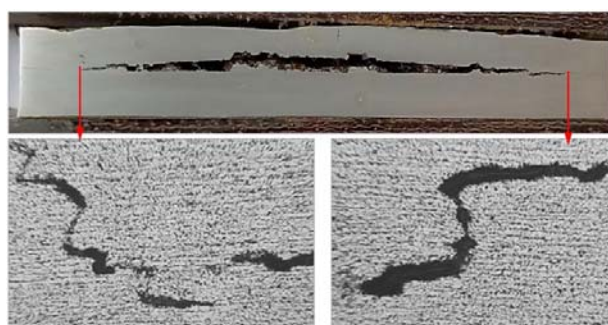


Fig. 4. Hydrogen delamination of the wall of the vessel of the viscosity breaking unit (x100).

One of the typical causes of depressurization (formation of through gaps) in molded cases of shut-off and control valves is metallurgical defects (pores, shrinkage shells, exogenous inclusions) (Fig. 5), which lead to softening and accelerated wear due to thinning of the walls and intensification of corrosion processes.

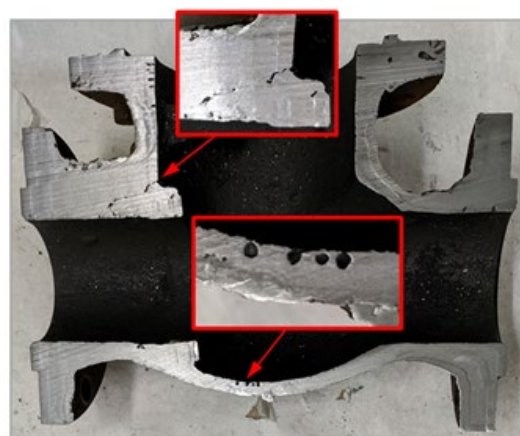


Fig. 5. The longitudinal section of the valve (casting defects).

According to the research results, all the causes of the formation of defects and equipment failures can be divided into two main groups:

- technological (defects of a metallurgical nature and machining, violation of welding technology, inappropriate material use, constructively irrational design decisions);

- operational (fatigue, corrosion, wear, violation of operating and maintenance conditions).

With such differentiation, certain difficulties may arise due to the fact that many reasons are largely interrelated. So, for example, increased corrosive wear can be associated both with the composition of the environment (an increase in its aggressiveness caused by insufficient inhibition, or violation of the operating conditions of the equipment), and with the quality of the metal (which relates to metallurgical reasons), or the improper choice of the material. The main difficulty is in the correct identification of the root causes and the establishment of mechanisms of various destruction processes.

Analysis of the research results, taking into account the foregoing, made it possible to formulate a diagram of the reasons for the failure of oil refining equipment based on the expert activity of the institute (Fig. 6). Cases of the impossibility of identifying the main among the many influential factors have been placed in a separate sector, “cumulative reasons”.

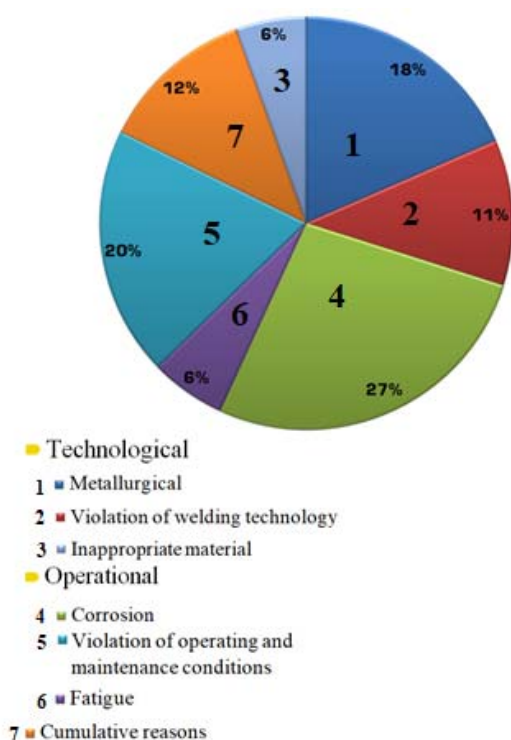


Fig. 6. The main reasons for the failure of petrochemical equipment.

The diagram shows that corrosion is the biggest cause. However, it should be noted that most of the cases of precisely the corrosion damage to equipment elements are associated with natural wear, i.e. appear in objects that have already fulfilled the design operational lifetime. In general, the task of studying the mechanisms of corrosion and methods of dealing with it is one of the priorities in the oil refining industry, and significant scientific resources are directed to its solution. In recent years, the corrosion factor has gained an additional relevance in connection with an increase in the content of sulfur compounds in the technological environment,

as well as in the conditions of the transfer of oil refineries to increased overhaul mileage.

Thus, in addition to corrosion in the diagram, those problems come to the fore that are, in our opinion, not enough attention paid: on the part of operational reasons - violation of operating conditions in conjunction with violations of welding technology as factors that largely depend on the qualifications of the working personnel and methods control in production, and from the technological reasons - the metallurgical factor. It includes casting defects, high contamination of the metal with nonmetallic and exogenous inclusions, defects in machining, mismatch of the required metal structure of the equipment with the operating conditions. At the same time, a significant problem is the lack of normative documentation regarding input control procedures for the purity and structure of the metal and determination of reject parameters.

4 Conclusions

1. As a result of the studies, it was found that the accident rate at oil refineries is determined by two groups of reasons: technological and operational. The determining factor in the first group is metallurgical, associated with the lack of regulatory measures for input and operational control of the purity and structure of the metal, and in the second - violation of the operating conditions and welding technology, which is associated with the qualification of working personnel and the imperfection of control methods in production, as well as the corrosion factor.
2. To solve a number of these problems “VNIKTIneftekhimoborudovanie” JSC is working on scientific projects within the framework of the corrosion management system, emergency monitoring, and also developing IT projects aimed at optimizing and automating control and design processes. The successful implementation of these projects will significantly reduce the accident rate in production, reduce economic damage, and also increase the safety and reliability of equipment.

References

1. R.S. Zajnullin, *Obespechenie rabotosposobnosti oborudovaniya v usloviyah mekhanohimicheskoy povrezhdaemosti* (Ufa, 1997)
2. A.V. Bakiev, *Tekhnologiya apparostroeniya. Uchebnoe posobie* (UGNTU, Ufa, 1995)
3. R.S. Zajnullin, A.V. Bakiev, A.G. Halimov, *Neft' i gaz*, **6** (1978)
4. R.S. Zajnullin, A.V. Bakiev, A.G. Halimov, *Neft' i gaz*, **4** (1978)
5. Yu.A. Bad'in, S.V. Solodnikov, V.A. Feoktistov, “Himicheskaya tekhnika”, **06** (2019)
6. A.M. Sukhotin, *Korroziya i zashchita himicheskoy apparatury. Spravochnoe rukovodstvo* (Himiya, 1974)