Improve Carbon-Sulfur Detection Level to Adapt to the Development of Aero-engine

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***Abstract*—The paper introduces the technical essentials of high level detection of carbon-sulfur in aero-engine materials by using high frequency induction combustion-infrared absorption method. Meanwhile, in order to adapt to the development of aero-engine, the paper proposes and elaborates ten major relations to be properly handled for improving carbon-sulfur detection level so as to meet the demand on more precise, accurate, and fast carbon-sulfur detection.**

***Keywords*—aero-engine materials; high frequency induction combustion-infrared absorption method; carbon-sulfur detection; ten major relations**

I. INTRODUCTION

Aero-engine materials refer to in-service traditional materials such as high temperature alloys, titanium alloy, etc. Among them, high temperature alloys include solidified high temperature alloys, powder metallurgy super alloy, single-crystal super alloy, etc. In addition, in order to reduce the weight of aero-engines, and even the weight of aircrafts, and improve the thrust-weight ratio of engines, more and more materials with high quality and light weight have been using on aero-engines, such as resin matrix composite, titanium matrix composite, titanium aluminide intermetallic, carbon/carbon composites, ceramic matrix composite, fiber reinforced high temperature alloy, graphene reinforced high temperature alloy, etc.; In-service traditional materials are also developing towards more resistant to high temperature. For example, heat-resistant capacity of materials such as high temperature alloy, titanium alloy, and resins base has been constantly improving.

In 2016, two “major special programs” of aero-engines and gas turbines were listed on the top of 100 projects and programs to be implemented in the “13th Five-Year Plan” of China, and the AERO Engine Corporation of China was established. Under the guidance of the development ideas of the Corporation of “Focusing on the major business of aero-engine”, the business of aero-engine materials of Beijing Institute of Aeronautical Materials has been constantly increasing. Accordingly, it is urgent to reinforce the management and control of time nodes. Along with the development of the situation, it has raised higher demand on the detection of carbon and sulfur elements in aero-engine materials, and it is urgent to improve the carbon-sulfur detection level.

II. CARBON-SULFUR DETECTION TECHNOLOGY FOR AERO-ENGINE MATERIALS

A. *Working Principles of Carbon-sulfur Detectors*

A carbon-sulfur detector is required to conduct carbon-sulfur detection by employing high frequency induction combustion-infrared absorption method, and it is a high-tech product integrated with mechanical, optical, electric, computer, heating and analytical technologies, which can quickly and accurately measure the carbon-sulfur mass fraction in many materials such as metals and alloys. Carbon-sulfur detectors have been produced in a large scale and there are over dozens of carbon-sulfur detector manufactures at home and abroad. The working principles of the detectors produced by different manufacturers are almost same.

Put the sample and fluxing agent into the crucible. When the sample is heated and fused in the oxygen flow with high frequency induction heating, the carbon is oxidized into CO2 and the sulphur is oxidized into SO2, both of which are sent into an infrared analyzer. Since CO2 and SO2 can absorb the infrared with a specific wavelength, which leads to attenuation of infrared intensity. There is a function relationship between the attenuation of infrared intensity and the change of CO2 and SO2 concentration. The analytical result of carbon and sulfur contents can be directly displayed on a numerical control table in a form of percentage composition.

There is a common sense problem. The carbon and sulfur are not released at the “birth” of the samples of aero-engine materials, namely, during the process of smelting process, but they are released in a carbon and sulfur detector. The reason for this involves the role of fluxing agent. Proper fluxing agent is an important condition for the total release of carbon and sulphur.

The working principle of using high frequency induction combustion-infrared absorption method to conduct carbon-sulfur detection shows that, total release of carbon and sulphur in samples is the precondition for accurate detection, and the matrix composition of samples has limited impact on the detection.

III. COMMONLY USED METHODS FOR CARBON-SULFUR DETECTION FOR ENGINE MATERIALS

Currently, the commonly used methods for carbon-sulfur detection for engine materials include:

Methods for chemical analysis of super alloys Part 3: Determination of carbon content by high frequency induction combustion-infrared absorption method (HB 5220.3-2008);

Methods for chemical analysis of super alloys Part 6: Determination of sulfur content by high frequency induction combustion-infrared absorption method (HB 5220.6-2008);

Methods for chemical analysis of titanium alloy. Determination of carbon content by high frequency induction combustion-infrared absorption method (HB 5297.22-2001);

Standard Test Method for Determination of Carbon in Refractory and Reactive Metals and Their Alloys by Combustion Analysis [ASTM E1941-2010(2016)].

All standard methods released can not cover all contents of carbon-sulfur detection for engine materials. The reasons for this include constant development of new materials, development of detection technologies, limitation of the length of the paper, or the limitation of the original standards.

A. High Level Carbon-sulfur Detection Technologies

High level carbon-sulfur detection technologies include optimized coordination of human, machine, materials and methods. Technical essentials include the following contents:

Optimization of operating mode (human): it includes detection process optimization and process monitoring reinforcement.

During the operation process of carbon-sulfur detectors, the state of detectors is changing constantly. Operators must observe and monitor the state of detectors in real-time. The observation shall focus on the following aspects:

Carrier gas flow rate shall be maintained at a fixed level, allowing slight fluctuation. If the fluctuation is too high, the detection shall be immediately terminated to eliminate the fault of the detector.

The induced current shall be at the normal range. If the induced current is too low, it indicates that the combustion power is too low, and it is necessary to increase the board-current and add fluxing agent. If the board-current is too high, it might be caused by having too much fluxing agent or by other reasons.

Release curve is an ideal single-peak release curve [1], as illustrated in the Fig. 1.

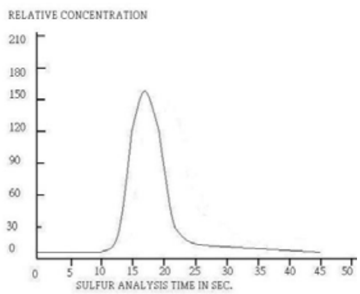

FIGURE I. IDEAL RELEASE CURVE

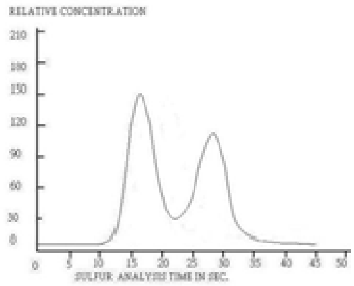

FIGURE II. MULTIPLE RELEASE CURVES

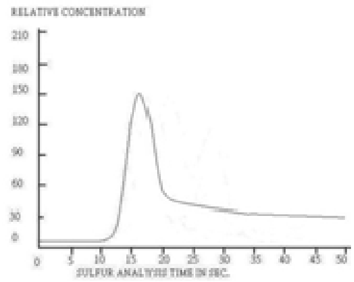

FIGURE III. TAILING RELEASE CURVE

If the analysis conditions are not correct, the following situation may appear which will affect the accuracy:

Incorrect selection of fluxing agent may lead to inconsistency or instability of gas release, and multiple peaks may appear, as illustrated in the Fig.2;

Burning temperature do not match with fluxing agent, poor heating condition, or severe instrument adsorption problems may lead to tailing curve, as illustrated in the Fig.3.

When conducting continuous measurement with multiple materials, it is necessary to consider sequence of the materials to be detected.

(2) Machine optimization (machine): The parameters of detectors are optimized, and it is maintained at the best standby or operating state.

The indications of the best standby or operating state are illustrated as follows.

Release cure is an ideal release curve, as shown in the Fig.1.

Molten mass in the bottom of crucible pot is smooth after meltdown of sample materials, as shown in the Fig.4.

FIGURE IV. MOLTEN MASS IN SMOOTH BOTTOM OF CRUCIBLE POT

Break the molten mass into pieces, and observe them. If they are completely molten mass, the texture shall be homogeneous; if some sample materials are not melting, then the release is not complete.

(3) Sample material optimization (material): Processing method of sample materials to be detected is optimized, to make the sample materials the real representatives of alloy ingot for carbon and sulfur content detection.

(4) Application of standard methods. Corresponding standard methods are flexibly used for different sample materials.

Detection quality accidents caused by low-level mistakes must be eliminated. For example, burning damage of lower brush wheels may cause sudden rise of detection results. It is necessary to carefully treat the doubtful detection data. When necessary, the times of detections shall be increased or re-sampling is made before detection.

The result of high level carbon-sulfur detection with the optimizing coordination of human, machine, materials, and method is very perfect.

Example 1, a type of cast super alloy with its carbon content range controlled at C: 0.11% ~ 0.18%. The products of the same lot of 10 packs were sent for detection. Detection result is illustrated in the Table 1.

TABLE I. CARBON DETECTION RESULT OF A TYPE OF CAST SUPER ALLOY

Sample No.	C %
01	0.162,0.162
02	0.165,0.164
03	0.158,0.160
04	0.162,0.163
05	0.162,0.161
06	0.163,0.164
07	0.159,0.158
08	0.159,0.160
09	0.162,0.164
10	0.160,0.160

Table 1 shows that, the result of the high level carbon detection can be judged by the third valid digital number, and its parallelism is also very good. In fact, usually, clients only need to report two valid digits.

Example 2, a type of cast super alloy with its sulfur content range controlled at: S≤0.0012%. The products of the same lot of 10 packs were sent for detection. Detection result is illustrated in the Table 2.

TABLE II. SULFUR DETECTION RESULT OF A TYPE OF CAST SUPER ALLOY

Sample No.	S %
01	0.0005,0.0006
02	0.0004,0.0005
03	0.0004,0.0003
04	0.0001,0.0002
05	0.0005,0.0005
06	0.0004,0.0005
07	0.0006,0.0005
08	0.0002,0.0003
09	0.0003,0.0004
10	0.0005,0.0004

Table 2 shows that, the result of the high level sulfur detection can be judged by ppm content level, and its parallelism is also very good. In fact, usually, the client only needs to report S≤0.0010%.

IV. Properly Handle ten Major Relationships Related to Carbon-sulfur Detection

In order to adapt to the development of aero-engines, carbon-sulfur detection level shall be upgraded to achieve more precise, accurate, and quick carbon-sulfur detection. By properly handling the following ten major relations, the carbon-sulfur detection level has been improved and the expected goal has been reached.

A. Relation between Detection and Client Communication

Usually, client sends the sample materials to a control center, and the control center establishes the working relation with the client. In fact, it means that, the control center coordinate to establish the working relation between the client and the detection staff. Therefore, the detection staff actively establish the working relation with its client.

Many years ago, the sample materials of titanium alloy show a shape of a fluff of hair, as shown in the Fig.5, and they are likely to be stained with oil. It takes 5 minutes to take 0.50g of the sample material and it may have uneven results, which may seriously affect the progress of detection and the validity of the detection result. For many years, after communicating with clients for many times, the problem has not been solved even today.

Finally, after talking with the business director of the client, we went to the site of titanium alloy sampling, to communicate with sampling staff to improve the sampling process.

In addition to titanium alloy, other alloys also have the problem of oil contamination. The reason is that, the samplers usually use cooling oil in order to protect cutting edge. Usually, these oils are the liquid containing carbon, and the contamination of samples is unavoidable. Clients may ask us to clean those sample materials with oil contamination before detection. Clients shall clean the samples by themselves. Otherwise, oil contamination will be more serious, and violate the basic idea of taking responsibility for sample detection.

Currently, the titanium alloy samples are regular cuttings shapes without oil contamination, as shown in the Fig.6. It only takes a dozen of seconds to weight 0.50g of samples, with two times of parallel measurements to complete the detection. The detection efficiency is improved by 10 times.

FIGURE V. SAMPLE MATERIALS WITH A SHAPE OF A FLUFF OF HAIR

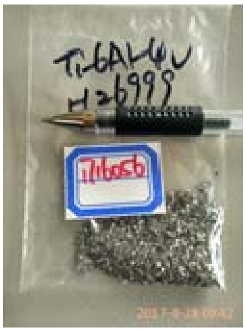

FIGURE VI. NORMATIVE CUTTINGS SHAPE OF SAMPLES

For those unqualified samples, we have been informing clients by phone call in advance. For unqualified results, clients take the following measures: to accept the unqualified result, to make special treatment on the original samples (e.g. cleaning) and then to make re-measurement and re-sampling. No matter what measures are taken, clients show active responses towards notice in advance.

For many years, we have not only established working relation with our clients but also established good friendship with some clients. Therefore, it is more easy and natural for us to carry out the detection. When having new detection tasks, we can always receive the support and help from them, and naturally we can accomplish the work task successfully.

If our detection staff can see things from the client's perspective and take them as their friends, it will be an important step for successful accomplishing the detection work. We shall provide real benefit to our clients and build their loyalty to our service. When they need detection service, they will immediately think of us and finally become our loyal customers.

Behind each pack of samples there is a corresponding alloy ingot and behind each client, there is a huge market. Therefore, at the same time of providing service, we might as well establish friendship with our clients, which will be conductive to our detection service.

B. Relation between Detection Quality and Detection Effect

An important principle of detection is the "Quality first", and this principle shall not be changed. However, clients usually feel "anxious". Once samples are sent to the control center, they eagerly wait and urge the result, and show efficient "Anxiety disorders".

It takes about 1.5 minutes for a carbon-sulfur detector to finish detection, and this time can not be changed. To improve detection efficiency and meet the demand of clients, the only way is to start with the standby state of the detector.

The detector is always maintained at the standby state and it will not have additional costs. It is only the preparation work for the detection. These works include: daily maintenance of detectors; timely supplement of oxygen and nitrogen; inspection and necessary replacement of drying agent; timely cleaning combustion furnace; preparation of standard substances, fluxing agent, quick-wear part, etc. Weight standard substances and add fluxing agent in advance for the detection.

Detection of carbon and sulfur of powder metallurgy super alloy FGH96 is a great challenge. The control range of carbon is very narrow, and the sulfur content is very low, less than 10ppm, which will be a challenge for detection accuracy; meanwhile, clients require conducting carbon-sulfur detection first, and then conducting the follow-up process, which may pose a challenge to the detection efficiency.

At the beginning, we start to conduct the detection after clients send FGH96 samples. We have to take a whole busy day to accomplish the task. Since clients have a lot of follow-up processes, they constantly urge us by telephone, which impose huge pressure on detection quality and efficiency.

After adequate communication with clients, we have established a FGH96 detection group. Once a client has intention to conduct FGH96 detection, he/she may leave a message in the group.

After seeing the message, we start to make preparation, until the detector can conduct the detection at any time.

So far, we are able to report the detection result within one hour after a client sends the FGH96 samples. Sometime we are even able to report the result in a very short time.

C. Relation between Detection and Work Safety

During the process of carbon-sulfur detection, it is necessary to carry out the concept of "Safety first", which embodies as: personal safety of operators, instrument safety, and safety inspection.

Personal safety mainly involves high pressure vessel operation, electricity usage, toxic substances detection, operation process safety, personal dustproof, etc.

Carbon-sulfur detection by using carbon-sulfur detectors involves high pressure oxygen and nitrogen, and it is necessary to have pressure vessel operation certificate to conduct the operation. Only after serious study, an operator can acquire the skill for operating high pressure vessels so as to ensure the work safety.

It also involves the usage of high voltage power and flame furnace, so it is necessary to pay attention to the safe use of electricity, and to maintain the safe distance between a flame furnace and a gas cylinder.

Toxic substances include radioactive elements and materials containing Beryllium. During the development of materials, these toxic substances are likely to be added. The ingredients of typical materials are known. For those research materials, it is necessary to communicate with clients to confirm that the materials do not contain any toxic component.

Burning crucibles containing metal molten state materials with the temperature as high as one thousand degrees is not allowed dropping out on human bodies. Usually, a drawer is installed below to prevent dropping out, as shown in the Fig.7.

FIGURE VII. DRAWER IS INSTALLED BELOW TO PREVENT CRUCIBLE FROM DROPPING OUT

During the working process of carbon-sulfur detectors, some dust is produced. Operators shall wear masks.

Instrument safety mainly involves prevention of serious damage of detector during the detection process. Burning crucibles with high temperature shall not fall into inside of a carbon-sulfur detector. Otherwise, it may cause serious damage of the detector. It is not allowed to detect the explosive materials.

It is necessary to receive safety inspection, keep safety records, and make efforts to get support from safety staff, so as to form a well established safety protection network. Safety functional departments and staff have a well established management standard on safety work. For example, regularly checking the accuracy of pressure gage and safety inspection of gas supply companies can not be accomplished by the people other than carbon-sulfur detection operators. Only with active cooperation with safety work, can we build a well established safety protection network.

D. Relation between Detection Technologies and Quality Control

Detection technology is a precondition, but the quality control is still very important. Quality control includes: quality inspection of quality functional departments and quality control personnel, quality qualification certification, comparison of different laboratories, on-site supervision of important clients, etc.

Quality management and inspection of quality functional departments and quality control personnel is quite essential and one of the means to promote detection quality. It is necessary to consciously receive quality inspection, and keep quality records, and make efforts to get support from quality staff, so as to form a well established quality system. It usually includes complete inspection records and related information, as well as proper preservation of such records and information. On request, the original records and related information can be traced at any time.

Quality qualification certification usually refers to the certification on our detection capacity by major clients (large companies). Major clients send representatives or third parties representatives to conduct certification on carbon-sulfur detection process, results, etc. Such certification usually has a strict requirement on its procedures. As long as the operation follows the procedures, it usually can get the qualification.

Data comparison among different laboratories both at home and abroad is made. The same samples are detected by different laboratory, and the requirement on procedures is wide. Requirement on the detection is high accuracy. Therefore, it requires utilizing super high detection technology to conduct the detection so as to get perfect data.

Technical personnel of clients conduct supervision on the sites. Requirements on such form of quality control are the strictest.

For example, engine materials of a brand have a requirement on carbon: C≥0.045%. In the development process, the carbon value fluctuates around 0.045%. Technical directors of clients and technical experts supervise the carbon-sulfur detection process on sites. We conduct the detection according to the sequence designated by clients on site, and the results are described in the following Table3.

On-site carbon detection results show that, the carbon detection results fluctuate around 0.045%, without regular pattern. Clients satisfied the detection and went back. After sorting the results, the clients sent back the sorted data, as shown in the Table4.

Table 4 shows that, the accuracy of the detection results after cleaning are 0.001~0.002% lower than that of uncleaned, and the detection precision after cleaning is notably improved. According to the feedback from clients, third part report only with three valid digits can not to make a precise judgment around C: 0.045%; Therefore, the detection results from the third party are eliminated although the third party is also a famous detection service provider both at home and abroad.

Through this detection, we have established a close dependency relationship with our client.

TABLE III. RESULTS OF ON-SITE CARBON DETECTION

Detection series number assigned by clients	Client number	C %	Detection series number assigned by clients	Client number	C %
01	-	0.0455, 0.0457	12	-	0.0454, 0.0449
02	-	0.0458, 0.0454	13	-	0.0460, 0.0473
03	-	0.0466, 0.0463	14	-	0.0465, 0.0457
04	-	0.0453, 0.0455	15	-	0.0454, 0.0466
05	-	0.0436, 0.0442	16	-	0.0462, 0.0460
06	-	0.04499, 0.0440	17	-	0.0441, 0.0441
07	-	0.0435, 0.0435	18	-	0.0443, 0.0438
08	-	0.0462, 0.0462	19	-	0.0472, 0.0490
09	-	0.0462, 0.0455	20	-	0.04354, 0.04502
10	-	0.0454, 0.0455	21	-	0.0478, 0.0475
11	-	0.04505, 0.04561			

TABLE IV. CARBON DETECTION RESULTS AFTER SORTING

Client number	Cleaned	Uncleaned	Third party detection
*	0.0455, 0.0457	0.0460, 0.0473	0.046
*	0.0458, 0.0454	0.0465, 0.0457	0.046
*	0.0466, 0.0463	0.0454, 0.0466	0.045
*	0.0453, 0.0455	0.0462, 0.0460	0.045
*	0.0436, 0.0442	0.0441, 0.0441	0.043
*	0.04499, 0.04405	0.0443, 0.0438	0.044
*	0.0435, 0.0435	0.0472, 0.0490	0.046
*	0.0435, 0.0450	0.0478, 0.0475	0.045

E. Detection Trial and Instrument Maintenance

Along with the constant increase of engine material business volume, it is an urgent job to manage and control time nodes. Almost everyday detectors are tested. The frequency of using detectors is increasing, and their workload is also increasing. Workload record of carbon-sulfur detector CS-444 shows: continuous operation of 12 hours, detection of 200packs of sample materials, and consumption of 500 crucibles.

In facing such intensive work, the operators must have certain maintenance skills. Such skills may include: flexible adjustment and application of detector's parameters, safeguard measurement of gas tightness, furnace head cleaning, replacement of quick-wear parts, replacement of reagents, adjustment of mechanical arm, operation of printers, etc. It avoids the problem of outage waiting for maintenance in case of occurrence of breakdown.

F. Detection Standard and Technology Innovation (Innovation of Scientific Research Projects)

Only by constantly paying attention to the development of aero-engine materials, and understanding the inherent difference of materials and their application and development, can we identify the requirements of clients on carbon-sulfur detection, and identify the innovation point by utilizing high level carbon-sulfur detection technologies. Advanced research on carbon-sulfur detection innovation point can be conducted, such as detection technology of S≤1.0ppm for some brands of materials. We may also actively coordinate the current research of material development departments.

Here, we make a brief discussion on technical innovation directions.

Major technical innovations have three directions: the first one is strictly required carbon-sulfur detection; the second one is the evaluation of materials uniformity; the third one is the carbon-sulfur detection of new materials.

Firstly, strictly required carbon-sulfur detection directions

Along with the improvement of smelting technique, the carbon contents in the materials shall be controlled within a more narrow range. For example, carbon contents of certain brand of engine materials is controlled at C≥0.045%, while the actual smelting results is about 0.045%; the carbon contents of another brand of engine material is in the range of 0.012~0.014%. Current method "HB 5220.3-2008 Methods for chemical analysis of super alloys-part 3: Determination of carbon content by high frequency induction combustion-infrared absorption method: Carbon content detection" requires the carbon range:＞0.010~0.050%, with admissible error of 0.005%, which can not meet the detection requirement. It requires developing a new method with admissible error less than 0.002%.

Sulfur usually has even lower detection limits. It requires detection accuracy of S≈0.0001% Along with the advancement of smelting technique, smelting sectors are able to reduce the sulfur contents to 1ppm. To achieve this, it is necessary to make innovative research on detection methods.

Secondly, the evaluation direction of material uniformity

Due to the improvement of alloying degree of engine materials, problems of segregation and uneven texture of alloy occur, which attracts the attention on evaluation of material uniformity. Uniformity of material texture is in nature a uniformity problem of chemical components. Uniformity is a representation of accurate quantitative measurement. Its contents include: determination of element contents (data) of multiple parts of an ingot, to calculate its range, average value, standard deviation, and relative standard deviation. The data of a ingot can be evaluated on its uniformity; the data of different ingots can be compared. Continuous detection of multiple ingots can form data flow so as to establish a database.

Thirdly, new material carbon-sulfur detection direction

Along with the emergence of new materials, many brands involve carbon-sulfur detection. For example, detection of fiber-reinforced high temperature alloy, graphene-reinforced high temperature alloy, carbide ceramics, and carbon-doped titanium alloy containing carbons. graphene involves sulfur detection.

G. Relation between Detection Level and Standard Substance

Content value of standard substance, namely nominal value, shall be clearly and accuracy written on standard substance certificate and user's manual, and its accuracy shall be ensured. However, the nominal values of some specific standard substance may not be correct due to various reasons.

High frequency induction combustion-infrared absorption method for carbon-sulfur detection is a relative measurement method, and it is essentially the measurement of nominal values relative to standard substances. Therefore, the nominal values of carbon and sulphur contents in standard substances directly affect the accuracy of the measurement. Once the following situations occur, it is necessary to confirm the nominal values of standard substances: The laboratory has not confirmed the truthfulness and validity of the nominal values of standard substances, but found that the measurement results of different standard substances exceed the admissible error range of the nominal values. Therefore, a certain standard substance is used to make long term measurement so as to achieve reference values between data before and after.

H. Relation between Detection Work and Intellectual Property

High level detection work must be accompanied with high level ability and wisdom. By summarizing and analyzing detection work, we can constantly improve carbon-sulfur detection level and at the same time generate huge amount of intellectual property. Forms of intellectual property include: patents, papers, standards, know-how, monographs, technical summaries, etc.

Currently, the intellectual properties on carbon-sulfur detection we have now include: one patent, a couple of papers, high temperature alloy carbon-sulfur detection industrial standard, and enterprise standards, technical summaries, etc.

I. Relation between Detection Work and Computer Technologies

It is an urgent job to intensify informatization construction. Major contents of carbon-sulfur detection include: network connection between carbon-sulfur detectors and computers, which can improve the detection efficiency and quality.

In recent years, our lab has established a LIMS system, and carbon-sulfur detection also enters into the LIMS system. Application of LIMS has improved the speed of producing detection reports, and reduced the error rate of reports. At the same time, it provides convenience for the query, analysis, and transmission of detection data.

New types of carbon-sulfur detectors usually set aside network port for computer connection. After simple connection, a detector can enter into LIMS system. However, old types of carbon-sulfur detectors can enter into the LIMS system only after professional transformation.

J. Technology Advancement and Peer Communication

Currently, high frequency induction combustion-infrared absorption method is a mainstream method for carbon-sulfur detection. A lot of laboratories at home and abroad have their own carbon-sulfur detection. We can constantly improve our detection level through communication with peers.

Comparison of the data among different laboratories both at home and abroad is a communication method. Meanwhile, it can help to achieve the purpose of making reliable, accurate, truthful verification on the detection data.

Another approach is to ask peers to conduct experimental verification when establishing a new analytical method. In fact, it is also a way for conducting the evaluation on the validity of new methods. This communication method requires paying attention to technical privacy protection.

In short, peer communication involves some competition, but involves more promotion.

V. CONCLUSION

Along with the development of aero-engines, it sets higher requirements on carbon-sulfur detection. Technical personnel of carbon-sulfur detection need to constantly learn new concepts, new ideas, and new technologies, based on their one specialty, to constantly improve application level of new equipment and new methods. We can play a proper role in the development of aero-engine through properly handling various relations, and constantly improving our working method, working concept, and working procedures. We can improve aero-engine material carbon-sulfur detection level through paying attention to the development of the field of carbon-sulfur detection, and the development of material process.

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