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Optimization of surface control mechanism for solid welding wires (Unalloyed and stainless steel)

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AFFIDAVIT

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Preface

I was encouraged and guided by a ton of individuals and groups throughout this timeframe, and I'd like to thank them all:

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Abstract

Every product produced had to be maintained and preserved under specified circumstances to optimize their productivity and after-market application for a very long period. Welding wires are an essential material for companies because they are regularly used. It is crucial to safeguard them against wear and tear caused by varied environmental and supply conditions when welding wires are created. Examples of wear and tear are the quantity of surface coating being lost or the presence of water molecules that weaken the surface. First of all, the analysis is done by Mig-Weld residual analyzer through the smoke detection process. Then the best performance is measured by a computer program, which further refers to the high quantity of coating removed as smoke under specific parameters such as current and pulse duration from that particular location. The major problem is that, first, the manufacturing of this machine had been ceased. Now, no after-sales services are available concerning the issues. Second, whether the smoke is from the drawing agent or the coating cannot be determined.

In this situation, the IR spectroscopy technique was utilized to establish the difference between the calcium stearate and the coating oil. The significant advantages of IR spectroscopy over other forms of analysis are that both the user and the technician using them are simple to comprehend, that they save money and effort. Under certain conditions, they are portable. Two of the most popular oils used for securing wires are Protec and Ballistol® universal oils. Six distinct drawing agents are utilized, such as Traxit 2145, Traxit TNA1680CSB, Traxit Zel 760 AB, Vicafil salvia2, and Vicafil Sumac 2. Apart from the current proof of principles, the method is now implemented to actual drawing agents used in industrial wire manufacturing processes to differentiate pure calcium stearate from the Ballistol® coating oil by infrared (IR) spectroscopy. The IR spectra of selected drawing agents were compared to the IR spectrum of pure Calcium stearate in a first attempt, demonstrating that the proof-of-concept works for real drawing agents utilized in the wire manufacturing sector. However, more research in this part and stream is required for quantification and more dependable and precise results. In an initial attempt to equate the IR spectrum of chosen drawing agents with pure Calcium stearate, the proof of concept worked for actual drawers used in the wire industry.

Kurzfassung

Jedes hergestellte Produkt muss unter bestimmten Bedingungen gewartet und aufbewahrt werden, um seine Produktivität und seine Anwendung nach dem Gebrauch für einen sehr langen Zeitraum zu optimieren. Schweißdrähte sind ein wesentliches Material für Unternehmen, da sie regelmäßig verwendet werden. Es ist daher entscheidend, sie vor Verschleiß zu schützen, der durch unterschiedliche Umwelt- und Versorgungsbedingungen bei ihrer Herstellung verursacht wird. Beispiele für diesen Verschleiß sind der Verlust der Oberflächenbeschichtung oder die Anzahl der vorhandenen Wassermolekülen, die die Oberfläche schwächen. Zunächst erfolgt die Analyse durch den MIG-Weld residual analyzer durch den Raucherkennungsprozess und dann wird die beste Leistung durch ein Computerprogramm gemessen, das sich weiter auf die hohe Menge an Beschichtung bezieht, die als Rauch unter bestimmten Parametern wie Strom und Pulsdauer von dieser spezifischen Stelle entfernt wird. Hauptprobleme sind dabei, erstens, dass die Herstellung dieser Maschine eingestellt wurde, sodass jetzt kein Kundendienst für diese Probleme zur Verfügung steht und zweitens, dass nicht festgestellt werden kann, ob der Rauch vom Ziehmittel oder von der Beschichtung stammt.

In dieser Situation wurde die IR-Spektroskopie-Technik eingesetzt, um den Unterschied zwischen dem Calciumstearat und dem Beschichtungsöl festzustellen. Die großen Vorteile der IR-Spektroskopie gegenüber anderen Analyseformen sind, dass sie sowohl für den Anwender als auch für den Techniker einfach zu verstehen ist, dass sie Geld und Aufwand spart. Ausserdem sind sie unter bestimmten Bedingungen leicht transportierbar ist. Zwei der beliebtesten Öle, die zur Sicherung von Drähten verwendet werden, sind Protec und Ballistol® Universalöle. Es werden sechs verschiedene Ziehmittel verwendet, darunter Traxit 2145, Traxit TNA1680CSB, Traxit Zel 760 AB, Vicafil salvia2 und Vicafil Sumac 2. Neben dem aktuellen Grundsatzbeweis wird die Methode nun auf Ziehmittel, die tatsächlich in der industriellen Drahtherstellung verwendet werden, angewandt, um reines Calciumstearat von dem Ballistol®-Beschichtungsöl mittels Infrarot (IR)-Spektroskopie zu unterscheiden. Die IR-Spektren ausgewählter Ziehmittel wurden in einem ersten Versuch mit dem IR-Spektrum von reinem Calciumstearat verglichen, was zeigt, dass der Proof-of-Concept für reale Ziehmittel, die in der Drahtherstellungsbranche eingesetzt werden, funktioniert. Für eine Quantifizierung und verlässlichere und präzisere Ergebnisse sind jedoch weitere Untersuchungen in diesem Bereich und Strom erforderlich. In einem ersten Versuch, das IR-Spektrum ausgewählter Ziehmittel mit dem von reinem Calciumstearat gleichzusetzen, funktionierte der Proof-of-Concept für reale, in der Drahtindustrie verwendete Ziehmittel.

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1. INTRODUCTION

In England, wire industries began to grow, and then they began to use it for power and transform it into wires as the years passed and human technological evolution [1]. A basic definition of wire is generally a cylindrical, flexible string or metal piece used to convey electric or telecommunications loads or messages. Furthermore, the technologies have been considerably developed to handle various applications such as welding, controllers, springs, automotive applications, aerospace applications, etc.

The steel wires, which were initially developed by the drawing process in the 18th century, are fundamental sorts of cables, such as structures, utilized for welding, industrial, and construction applications [2]. At Voestalpine Böhler Welding GmbH, which usually consists of stainless steel with metallic and mineral-based fillers on the interior, an iron alloy that contains at least 11 percent chromium prevents it from rusting. The procedure starts as the manufacture of stainless steel cables using a big stainless steel plate, heated under the melting point. It then transfers the dimensions to the next sector by increasing the size and lowering the broad spectrum through coils.

As welding consumables, core wire electrodes are highly demanded all over the world. A pliable wire is a wire that begins its production by continually filling in the band material of a not-alloy or high alloy (stainless steel) for the construction of U-shaped fillers using rolling equipment, then scrubbing it into a tube shape using rolling machines. The dimensions are usually large after filling and reduced by drawing and rolling the wire lubrication and are then completed.

The form or procedure used to decrease resistance and interruption in the interaction of contact surfaces is lubrication, such as oil, grease, etc. Lubrication. The Voestalpine Böhler Welding GmbH's uses Ballistol® and Protec coating oils are the most popular to protect wires from rusting through lubrication, penetration, cleaning, shielding, and the preservation of metals through the creation of a protective surface layer. Because of its low surface tension, it may penetrate metallic particles through tiny cracks and pores.

MIG WELD Residual Analyzer is used to inspect the surface conditions of the wire electrodes within a few moments from contamination while storing or even during transportation in a wire feed device which, under realistic conditions, is hardly measurable. During all this procedure, the surfaces of the coated wires are always problematic when Voestalpine Böhler Welding GmbH utilizes the residual analyzing machine MIG Weld to measure them. The smokes generated by the wires do not indicate whether the smoke is from residues or coating, as when the wires are placed between the electrodes and utilized for heating the wire for surface testing. It is also essential to consider that the obsolete system and program, with no improvements, is discontinued and does not give completely dependable results.

The primary purpose of this study is thus to create a new analytical technique or prototype for the solid wire surface control device that can distinguish between coatings and residues in the industrial context and replace the MIG-WELD waste analyzer accurately assess the findings.

2. STATE OF THE ART

2.1 Coating

2.1.1 Theoretical aspects of coating

Because two surfaces are rubbed, the materials from the surface are lost a lot, and therefore a change of one-character form occurs. The coating is used to protect the surface from the processes of wear and tear [3]. The coating is described as the thin film of a layer on the material's surface, which is utilized to improve the surface characteristics. Furthermore, it helps preserve the material from the corrosion process. Surface protection plays an integral part in the coating. It is of higher importance to maintain features such as product usability and product values. The coating has a vital function, for example, in the automobile sector. The manufacturer put the coating ingredient both before and after the painting. A zinc layer is generally placed before painting on the metallic body, which permits the removal and preparation of all disinfectants for the paint, which may be effective. In contrast, the layer termed ceramic protects against large corrosions after the painting and works as a protective layer for the manufacturer's chemical bond paint. [4].

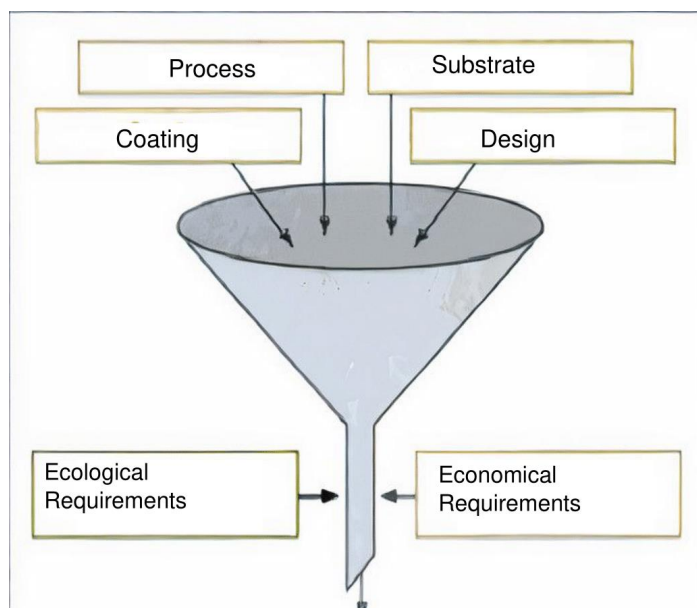


Fig 1: Factors determining the quality of the coating [5]

Figure 1 shows that the quality of the layer depends on many elements, which might affect the overall characteristics of the material. This is sometimes defined by a procedure involving less heating and, in turn, causing the coating fluid not to be deposited correctly. While the design also plays a crucial function, on the other hand, basic techniques with fewer complex shapes leading to a suitable deposition of the coating and vice versa.

In addition, coatings can protect the material from the conditions of the environment by tolerating the physical and chemical impacts. Different ecological factors, such as rain, snow, frost, intense sunlight, heat from the automobile, and pollution, are dangerous [6]. The layer on the surface works as help for these prospects. The coating is also used at home to enhance hold onto the flooring, in addition to industry and other uses, to decrease slippery conditions

[7]. Today, most goods take necessary items such as the external surfaces of the aircraft from little things, such as mobile screen surfaces, and everything requires a coating procedure.

Given the industries that generate steel cables or are used to manufacture metal-related goods, they all need several coating techniques to avoid corrosion.

The clothing is a branch according to its features and uses in the various sectors, and a particular reason for handling and protection is required. For the specific reason these are necessary:

- 1. Organic coatings are employed to decrease noise pollution. For example, acoustic coatings reduce noise from entering from outside in the car sector, which is also utilized in heavy machinery.
- 2. Stripping coatings are applied for protection for or in the storage or transportation of components and patterns. [8]
- 3. The coating is employed mainly in electrical engineering, where it is used for the electrical production of the isolated substrate.
- 4. The coating is used to produce a protection layer and isolate long-lasting pipes, windows, and condensation material when construction is done in a house or building.

No more relevant evaluation of the usage of coatings in numerous sectors is evident and is utilized for valuing, securing, and increased efficient items. These parts are used for several degradation tasks, such as architectural coating, various industrial coating, automobile coating, and ink printing.

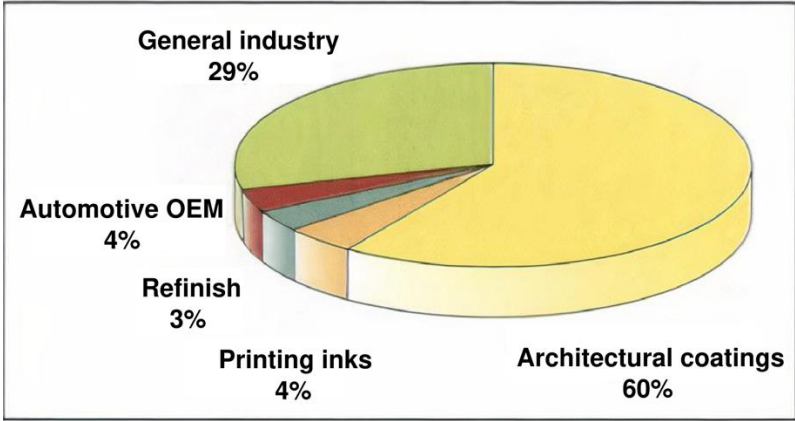


Fig 2: Worldwide coating market in 2000 by segment [9]

Fig 2 shows that slightly over 60% of the global coating market is for architectural applications, for example decorating purposes. The 29 percent of industrial paints employed in various elements, including machine coating, prevent severe heat from painting numerous components in the automobile sector such as bumpers and rails and multiple computers and daily appliances, including mobile phones or laptops. Compared to the 4 and 3 percent utilization for the automotive sector and refinishing, there are typically favorable features to preserve the paint before painting a car. Following an accident or disaster in the surface finish of the painting or vehicle, the cover is utilized to restore it. At 4%, the world market requires inks for printing. [10]

2.1.2 Basic physical chemistry

Physical chemistry is utilized better to understand the development of the coating and its behavior. We can learn more about the free energy and electric potential of processes through thermodynamics [11]. It consists of three kinds, and the following are:

1. Potential electrodes – It is defined as the chemical relation of free energy change dictated by the driving force that acts due to this reaction. The reaction of Vant's Hoff Isochore determines where G is the free energy, and K_p is the constant balance at constant pressure. [12]

This may also be calculated utilizing the Nernst equation, which determines the plot between deposition elements compared to potentially supplying a deposit-inert electrode.[13] This, in turn, defines the deposition curves for electrode surface or solution volume changes. [14]

The electrode potential for various metals is different when univalent ions move the electron more effectively than higher value ions. The table presented in Fig 3 illustrates this:

Principles of Metal Surface Treatment and Protection

TABLE 1.2. STANDARD (REDUCTION) ELECTRODE POTENTIALS (25°C)

| Metal couple | E^0 (volts) | Metal couple | E^0 (volts) |
|----------------------|---------------|--|---------------|
| Li ⁺ /Li | - 3.01 | 2H ⁺ /H ₂ | 0.00 |
| Ca ⁺⁺ /Ca | - 2.87 | Cu ²⁺ /Cu | + 0.337 |
| Na ⁺ /Na | - 2.713 | O ₂ /OH ⁻ | + 0.401 |
| Mg ²⁺ /Mg | - 2.37 | Cu ⁺ /Cu | + 0.52 |
| Be ²⁺ /Be | - 1.85 | Hg ₂ ²⁺ /Hg | + 0.798 |
| U ³⁺ /U | - 1.80 | Ag ⁺ /Ag | + 0.799 |
| Al ³⁺ /Al | - 1.66 | Rh ³⁺ /Rh | + 0.8 |
| Ti ²⁺ /Ti | - 1.63 | Hg ²⁺ /Hg | + 0.854 |
| Zr ⁴⁺ /Zr | - 1.53 | Pt ²⁺ /Pt | + 1.2 |
| Mn ²⁺ /Mn | - 1.18 | Cl ₂ /Cl ⁻ | + 1.358 |
| Zn ²⁺ /Zn | - 0.763 | Au ³⁺ /Au | + 1.50 |
| Cr ³⁺ /Cr | - 0.74 | Au ⁺ /Au | + 1.70 |
| Fe ²⁺ /Fe | - 0.44 | Cr ³⁺ /Cr ²⁺ | - 0.41 |
| Cd ²⁺ /Cd | - 0.403 | Sn ⁴⁺ /Sn ²⁺ | + 0.15 |
| Co ²⁺ /Co | - 0.277 | Cu ²⁺ /Cu ⁺ | + 0.153 |
| Ni ²⁺ /Ni | - 0.25 | Fe ³⁺ /Fe ²⁺ | + 0.77 |
| Sn ²⁺ /Sn | - 0.136 | Cr ₂ O ₇ ²⁻ /Cr ³⁺ | + 1.33 |
| Pb ²⁺ /Pb | - 0.126 | | |

Fig 3: Standard values of electrode potentials for different metals [15]

2.2 Coating methods

Coatings are often utilized to isolate metal surfaces from the corrosive environment by the premise that the anode is employed to sacrifice coatings and reaches the cathode to protect the metal after implementation. [16]

In comparison with sample metal, these coverings are generally divided into two pieces. The following are:

1. Metal base like steel needs zinc, aluminum, or occasionally cadmium coating.
2. While chromium and nickel coating is utilized for the other coating, which is nobler than the substrate, the electrical conductivity and hardness increase aside from its danger in different applications.

To get unique surface characteristics, particularly for steels, surface modification processes are needed. There are several techniques of surface processing, but the most prevalent surface coating is one such approach. A different surface coating is necessary since the coating procedure differs for increasing corrosion and wear resistance with surface hardness. The most frequent and manufacturing processes for surface coating can be defined as follows.

2.2.1 Vapor deposition method

The condensation method for the production of thin layers on the specimen is used. The condensation and evaporation mechanism on the target surface is required. There are two functions in the steam deposition method:

1. Physical deposition of vapor - The atomic deposition process is characterized when the material is evaporated from the solid or fluid in the form of a gaseous state and carried by vapor or low-pressure gas, in the form of condenses, on the substrate [17]. It is utilized mainly to offer the coverage of few nanometers to one thousand nanometers in several layers.

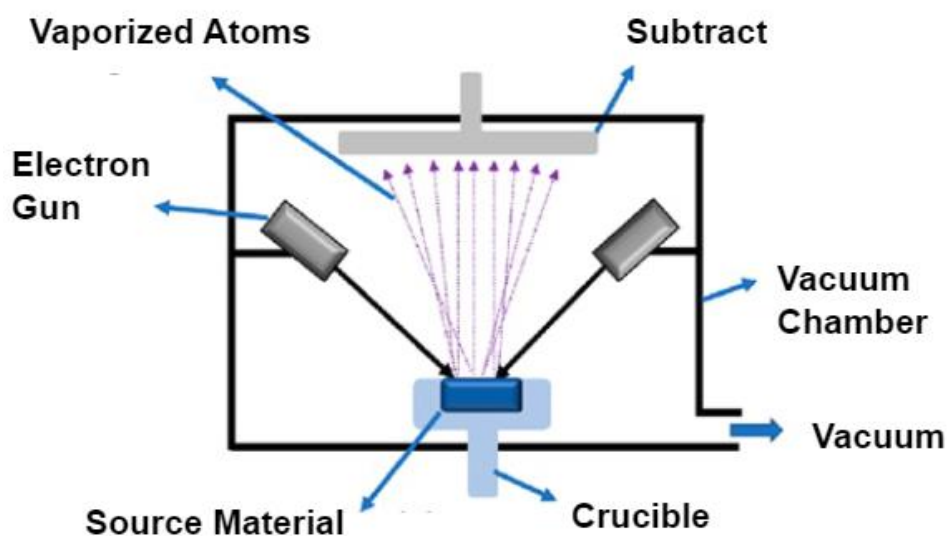


Fig 4: Schematic diagram of PVD [18]

As in figure 4, plasma sputtering is included in the procedure. It needs an ionizing or atomizing process and may be done in two ways: evaporation of physical materials or plasma sputtering. In physical evaporation, the substrate is heated via evaporation by up to 1000 to 2000 degrees centigrade and then condensed. [19]

By accelerating different ions on the surface during plasma sputtering, the surface releases the coating material. In the event of the method, the accelerated ions damage the surface that ejects the desired texture of the coating atoms. It is achieved via the electrostatic process, which also improves surface adhesion under the solid kinetic energy of the material ions.

2. Chemical vapor deposition (CVD) - The method of coating that involves a thermally induced chemical reaction with the delivery of reagents in a gaseous form to a thermodynamically closed chamber surface of the heated substrate is specified.

Figure 5 shows the schematic of the CVD procedure as CVD consists of a room containing one or more hot objects to be coated by the flow of precursor gases. The gases within the chamber conduct chemical interactions with the heated surface that result in a small layer of the surface being deposited by exhausting gas as unreacted gasses, and the chemical by-products are removed from the chamber. Usually, the temperature is 100-2000 degrees centigrade under the hot-chamber walls [20]. CVD has considerable benefits over PVD because CVD enables a thicker layer of coating to be deposited to avoid heat and other characteristics. Secondly, CVD enables the use of the mixed source material, i.e., one coating gas or many gases in the chamber that are imputable. [21]

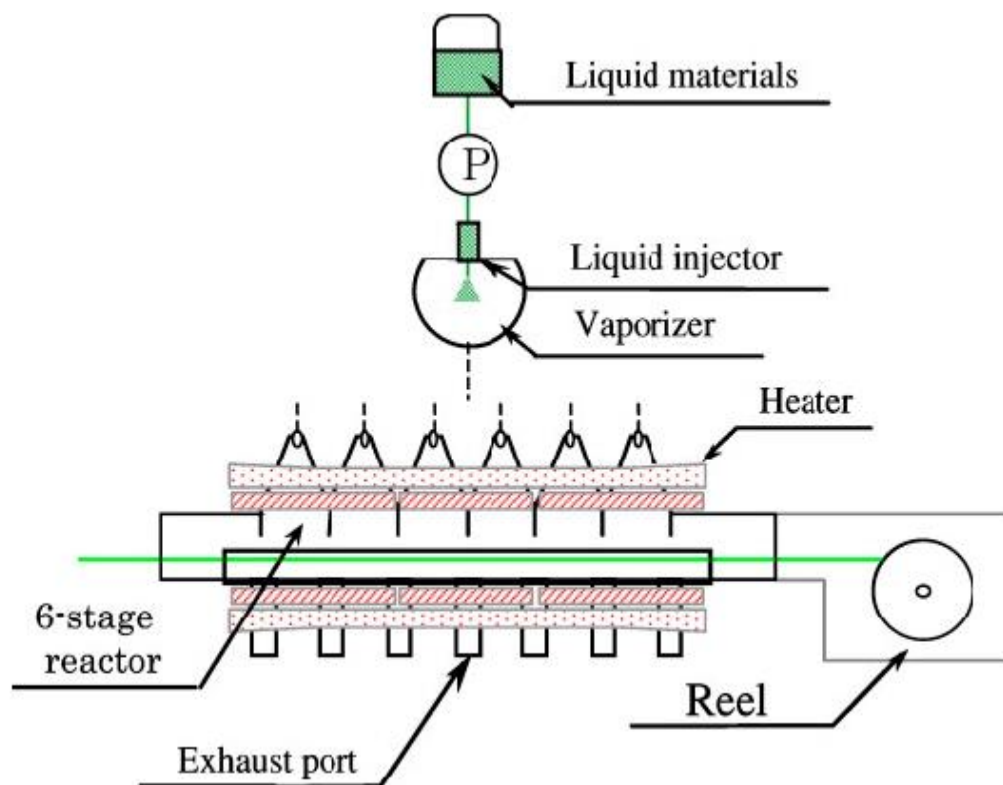


Fig 5: Thermodynamically hot-wall CVD reactor [22]

3. Thermal Spraying - Thermal spraying is described as a surface coating method. The surface is covered by accelerating heated or molten particles to create a laminar surface microstructure [23]. Thermal spraying is advantageous in relative

movements for the interaction of surfaces. Compared with standard engines with gray iron lines, friction reduction after the thermal spray was substantial. [24] [25]

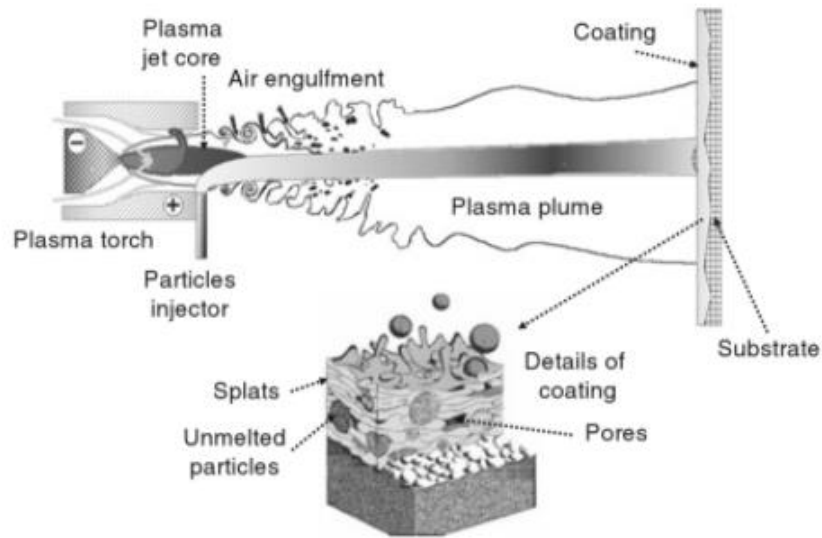


Fig 6: Schematic process of thermal spraying [26]

Figure 6 demonstrates a thermal spray procedure. The method generally involves gas flow to an atmosphere with a torch or weapons or controlled atmosphere. It consists of feeding, heating, acceleration, and guiding the thermal spray flow to the substrate. The molten material is sprayed on the surface of the substrate, heated and heated, accelerated utilizing gas to create a layer of surface-coating. [27]

1. Electrochemical processes – the electrostatic properties of different metals are used by electrochemical coatings, whether ions in the solution or sheet metals. There are two types of approach:
 - Electroplating - Electrodeposition is based on the Faraday Law of Electrolysis employed for coatings and metal extraction reasons and is often referred to as electroplating. The Law of Faraday stipulates that" the amount of element released in the cathode or anode during the electrolysis is proportionate to the amount of current passing through the solution [28]. However, the corresponding weight is likewise

proportional."[29]

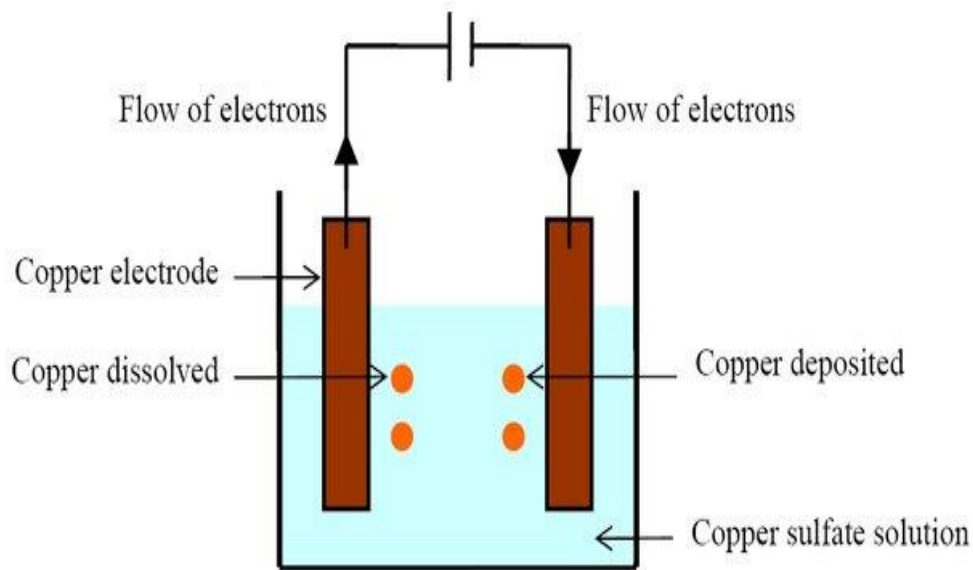


Fig 7: Schematic diagram of the electroplating process [30]

Figure 7 shows the fundamental electroplating process. In the device, the base metal employed as a cathode can be covered by different metal ions. Anodic ally polarizing the impurity metal is an internal direct current force that encourages the emission of the desirable ions [31]. The emitted metal ions are subsequently placed in the solution and are used for a cathode on the base metal. The requested ions remain in the solution and should not be withdrawn from the metal source. In addition, ions have been deposited as cathode material on the surface of the base metals [32].

- Electro less coating method: The significant distinction between electrode and electrode plate is the absence of external power. Surface cleaning and dipping into the solution begin the process. The ions in the solution and ions on the surface are engraved onto the surface. The ideal coating ion is therefore substituted by the difference in potential by the etchant ions.

2.3 MIG-Weld Residual Analyzer

2.3.1 Theory

The source of the gasses and therefore the genesis of porosity are several hypotheses in the same seam: [33]

- On the surface of the workpiece are generally high moisture and organic degradation of the base material and the filler wire (condensation, grease). [34]
- Hydrogen content in the metal basis and the wire filler. [35]
- Insufficient gas protection levels. [36]

The primary material for removing residuals in the surface may be addressed quickly using mechanical and chemical cleaning methods, which cannot be handled with wire-shaped solders (1.0-1.6 mm)[37]. One of the main reasons for the contaminated wire electrodes and TIG rods surface in production mistakes, poor storage, and inadequate wire feeding systems. Due to the current state of the art, hydrogen analysis in production circumstances is difficult. There have been relatively few laboratories in such study internationally, which means not everybody has access to process testing and improvement, as the holes are on the sold metal, and hydrogen is still there. [28=29] About the potential to test wire electrodes from sources to verify or delete them, for the measurement of wire electrodes, the MIG-WELD residual analyzer has been developed by Migalco.

2.3.2 MIG-WELD Residual Analyzer machine

The system consists mainly of the machine used to conduct the test and a program that enables us to see test results with different parameters. Describing the device consists of two electrodes connected internally to the power source to provide the workpiece with a high current. There is a hole just above electrodes that comprises a sensor for recording and analyzing the fumes. To not let the smoke go outside and to achieve the total efficiency by diverting the entire amount of smoke into the sensor, the quadrant-shaped metal covering, which further contains two diagonal strips inside that, allows the optimum fumes to reach the sensor. There's also a toggle on the device's rear side to make the machine turn on or off.

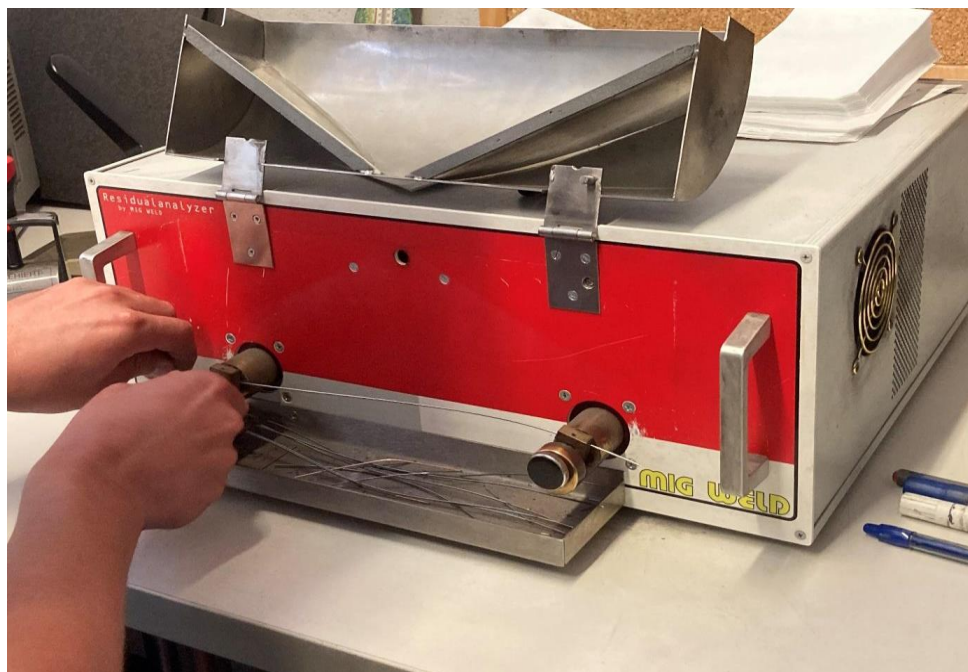


Fig 8: MIG Weld Residual analyzer machine

The second component describes a software system that, with the assistance of embedded graph representation and certain parameter blocks, allows the results of the workpiece calculation to be evaluated by variable parameters for reliable and precise results.

The program consists of a square dialogue block containing a graph reflecting the correlation between the concentration mg/m^3 concerning seconds. Variable parameters such as current and pulse duration are included in the square box, which can be changed according to the properties of the workpiece placed between the electrodes. The maximum and the integral value are also shown in two blocks during the whole process, with a meter below determines the mg/m^3 value recorded by the sensor.

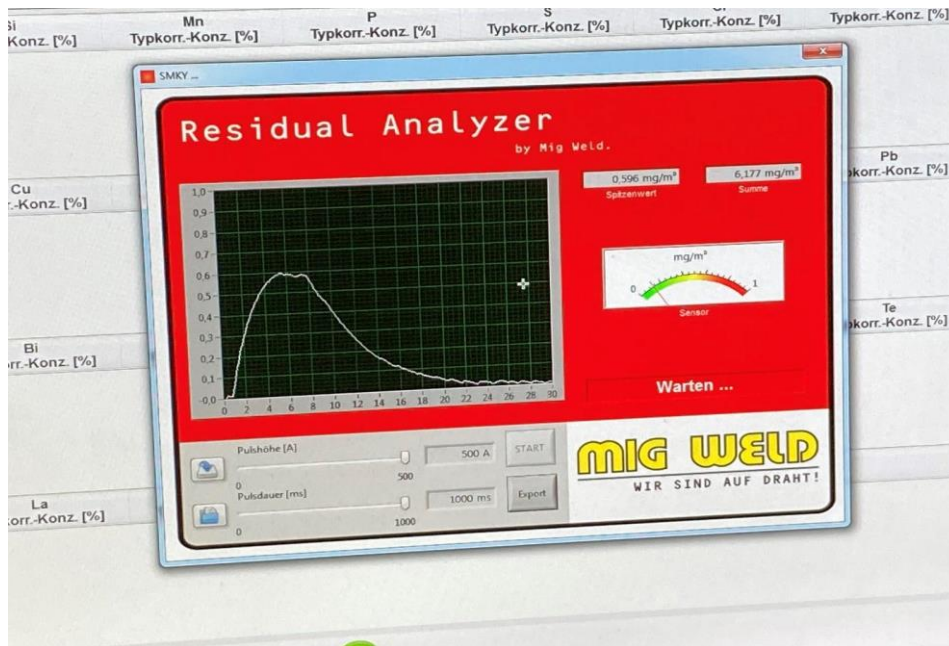


Fig 9: MIG-WELD computer program

2.3.3 Working Principle

A wire electrode of approximately 30 cm is captured and clamped between the two electrodes. When clamping is not to touch the wire where the testing will occur, one thing to take care of is to touch it from the outside of the testing range. After clamping, the quadrant surface must be closed, select the variable at a current pulse of 100-500 amperes and click on start according to the melting temperature conditions within 300-700 milliseconds. The wire electrode is heated to a temperature near the melting point, evaporating the lubricant and other organic impurities from the drawing process on the surface. The generated fumes are accumulated by the sensor and analyzed.



Fig 10: Instantly after the current pulse. The evolution of smoke is evident [38]

It takes 30 mins for one measurement. The output of the sensor is shown as a curve. The maximum value and the integral value are displayed and can provide surface coating information. For the documentation, the measured results can be exported into excel sheets. Manually, the wire batch, diameter, and customer data are entered.

Interpretation of outcomes can be made through the representation of the curve. The relationship determines the characteristics of wire electrode feeding and the porosity, spatter generation, and fumes such as less than 0.1 mg/m^3 , where mg/m^3 determine the number of particles in milligrams removed per m^3 when you burned, choose poor wire feeding. In contrast, porosity is determined above 0.5 mg/m^3 in the wire, whereas the optimum value is determined between 0.1 and 0.5 mg/m^3 for the feeding wire. Since the current depends on the wire diameter, the smaller diameter corresponds to the smaller ampere, as if the ampere is more significant, it will contribute to wire breakage.

2.3.4 Pros and Cons of MIG-WELD Residual analyzer –

- In the case of an incident, the analyzer is portable and may be utilized by the user instantly. Test results are available within a few minutes.
- The findings are both numerically and visually calculated and may be documented for future references by export and in the form of excel sheets.
- The most crucial disadvantage of this analyzer is that you can't buy it, but it's stopped.
- As a removal component, the MIG WELD device may not distinguish between the coating from the residual surface due to uncertainty between the quantity and which of these parts.
- When the amount of residual is too small, this, in turn, means less coating due to the use of more lubricant, leading to less weldability and feed ability.

2.4 Gravimetric method

One of the principal ways to determine the amount of an analyte is through the chemical phase. It is possible to apply the theory and work measurement to decide the results of the particular problem.

2.4.1 Gravimetric analysis principle [39]

A collection of techniques employed during quantitative assessments of the analyte in analytical chemistry, which test the ion based on its mass, focus on the gravimetric method. Based on theoretical analyses, the same calculation may, as long as the relative concentration of the other elements is known, can also be used to calculate the same analyte weight in one combination until the mass of the ion is calculated as a particular compound.

2.4.2 Types of gravimetric analysis

Thermogravimetric analysis – Thermogravimetric analysis is an experimental method for measuring thermal stability and its volatile percentage of components by monitoring weight change when a sample is constantly heated. [40]

These analyses involve understanding physical processes, such as phase changes, absorption, adsorbents, deposition, and chemical phenomena like chemisorption, thermal breakdown, and techniques of solid-gas [41]. Analysis of thermogravimetric (TGA) is conducted in a device called the thermogravimetric analyzer. An analyzer continuously examines mass while the sample's temperature has been changed throughout time [42]. Actual amounts of thermography research are known to be mass, temperature, and time, but from these three baseline measures, numerous other data may be derived. [43]

The following are the two different types:

- Isothermal or Static Thermogravimetric
 - Gravimetric dynamics
1. Physical gravimetric - Includes physical separation and gravitational categorization in environmental samples of substances based on instability and particle size (i.e., total suspended solids). There is a transition of a soluble analyte into an insoluble shape that precipitates from the solution in the natural process. In some instances, particles can be distinct from liquids, solids, and gases in which the chemical reaction does not need the analysis mass. [44]
 2. Precipitative gravimetric analysis is defined by adding a suitable reagent termed precipitation as a conversion of analysis to its precipitation insulation [45]. Gravimetric is referred to as gravimetric precipitation based on the mass reaction connected to the analyte.

A precipitation process is used to isolate one or more components of a solution by integrating them into a solid. Since the analysis starts at the solution stage, the phase shift occurs and responds to a solid residue. The concrete can be separated from fluid components utilizing filtering. The solid mass can be used for the determination of ionic compound volume or concentration in the solution.

2.4.3 Advantages and disadvantages of gravimetric method

- It is precisely when utilizing a modern analytical balance.
 - The probable cause of the error can be easily verified as filtrate for precipitation integrity can be evaluated, and residues can be examined closely and thoroughly for existing impurity.
 - To calculate the atomic mass of different elements, up to six digits can be used.
 - This involves the use of a new analytical balance.
- Analysis of a single element or a small group of elements may be performed at a time may be performed - - This technique has a highly time-consuming function.
 - The method is difficult to perform without mass measurement since it is the base for the entire process.

2.5 Analysis of coating

The amount of coating applied is the density of the coating, an essential part of the substance's usage and price. The calculation of the thickness of the coating is an integral component of its application. There are several testing methodologies, including destructive and non-destructive methods:

2.5.1 Non-destructive techniques

It is characterized as a test, check, or assessment procedure for coating discrepancies or changes in component or assembly properties without compromising part serviceability. In other words, it may be shown that the component can be utilized after the test or evaluation. The most prevalent methods of non-destruction include:

1. Ultrasonic thickness measurement — Ultrasound thickness measurement is one of the most widely used measurement tools for measuring solid element thickness by throwing ultrasonic sound and returning it to the surface via the wave.[46]

The UTM concept is based on the velocity of the sound wave to be used for traveling an unknown distance, which helps to compute the actual length and, therefore, the surface thickness. [47] The UTM process acts as an electrical pulse generator to be used on the transducer. This translates the pulse into the mechanical vibration that is connected to the specimen ahead. Now the mechanical vibration traverses a constant and known speed through the sample, and there is a reflection when it contacts the rear surface, and the waves re-enter the surface. The transducers capture these vibrations, convert them back into electric currents, and measure how long they took

the vibration to move, go, and come. Therefore, the specimen thickness is determined. [48] The major disadvantage of UTM compared to residual measurement techniques is we cannot distinguish between oil and coating.

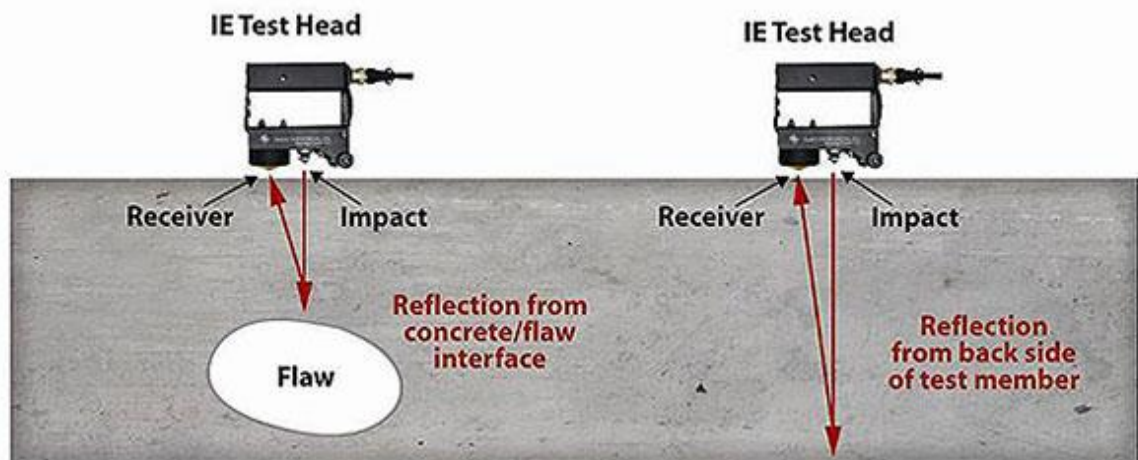


Fig 11: Coating thickness gauge based on ultrasonic thickness measurement [49]

2. Residual Measurement - Some materials have been used regularly in high-temperature cabinets and can tolerate greater temperatures than high-temperature alloys with lower densities. They have been used to store enclosure barrier coatings (EBC) [50] to protect them from enclosure conditions. These circumstances are directly connected to the production of cracks and cause the structural collapse of the layer. There is little residual stress measurement technique on an EBC system, widely employed by x-ray diffraction [51].

XRD analysis is used to discriminate between the crystalline structures of a material, known as x-ray diffraction, and therefore give information on the chemical composition.

XRD is based on the positive interference of the monochromatic X-ray and the crystalline sample as a fundamental principle: Cathode-focusing, filtered ray-emitting radiation is produced by X-rays, collimated to the focus, and directed towards the sample. [52] When the circumstances fit with Bragg's law ($n\lambda = 2d$), the interaction of the occurred rays with the sample generates constructive interference (and diffraction). [53]

Vibrational methods for analyzing coatings and surfaces of wires

Raman Spectroscopy – Raman spectroscopy is one of the two methods used for determining the modes of vibration of the molecules, in addition to IR spectroscopy. It is used to determine the different states of vibrational and virtual energy. [54]

The fundamental concept underlying this is the Raman Effect that concerns the particle polarization of the electrons [55]. It can be an inelastic form of illumination in which a photon

energizes the test. This excitement places the atom in a virtual state of liveliness for a short time; occasionally, the photon is recently emitted [56]. Inelastic scrambling means that the photon's vitality is less or more energy-effective than the photon that occurs. The test is in a unique vibrational or rotational condition following the diffusion event.

The complete Raman spectrograph process, including lasers, detectors (including detectors of dispersive Raman), and filters, may be viewed from Fig 12.

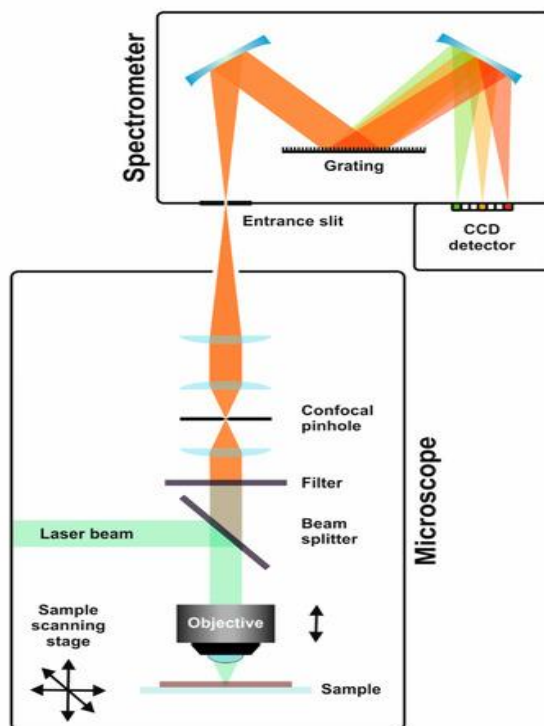


Fig 12: Schematic diagram of one dispersive Raman spectroscopy setup [57]

INFRARED Spectroscopy [58] - It is used to research or identify the chemical material in gaseous, liquid, or solid form. It is characterized by absorption, emission, and reflection to detect infrared radiation. An infrared spectrometer is equipment used to determine this process, and its measurement is termed an infrared spectrum. The diagnosis is made from the transmission (micromole/mole) to the wavenumber ($1/\text{cm}$).

The fundamental definition of infrared spectroscopy is based on the absorption frequencies of the molecule that are the structural features. The absorption happens at a deep, vibrational frequency equivalent level. The molecule is characterized as vibrational frequencies, or vibration mode, which can vibrate in each direction.

In addition, the vibrational frequencies are distributed in three portions depending on the direction of vibration: radial, longitudinal, and latitude. Radial contains symmetric stretches and anti-symmetric stretches, while wagging and twisting are included on the longitudinal, and scissors and rocking are included in the latitudinal. [59]

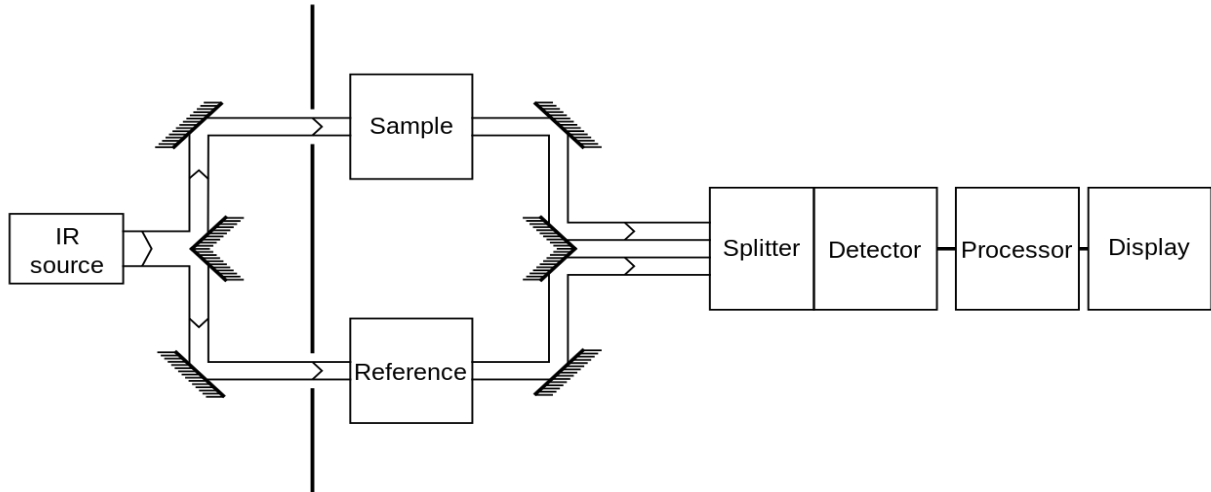


Fig 13: Schematic diagram of IR Spectroscopy [60]

The procedure of IR spectroscopy is shown in picture 13. The approach consists of infrared light transmission through the samples. Monochromators are used in some situations to disperse light to the samples and are referenced in equal quantities. In the case of vibrational frequencies of bonds similar to the infrared frequencies, absorption takes place. This leads to the absorption of energy within this frequency and is mainly employed to examine covalent bonds' materials.

IR spectroscopy is utilized in many applications; however, as far as we know, in wire manufacturing, it has not been used as an indicator to differentiate between coating oil and draining agent.

3. RESULTS AND COMPARISONS

3.1 Infrared Investigations and Comparisons

The goal of the thesis was to develop a novel non-destructive material test for wires for differentiating the drawing oil from the main calcium stearate-based coating agent usable on an industrial level. The main goal should be a process that would be cheap, quickly be done, and the setup should be movable to any location based on the requirement. By considering these significant points, IR (Infrared Spectroscopy) was chosen to determine the differences.

The previous chapter about the brief description of Infrared (IR) Spectroscopy uses the infrared radiation area, which is radiation with a higher wavelength and lower frequency than visible light. It is used to identify and research substances.

3.2 Industrial drawing agents and coating liquids

In this chapter, a brief description of some of the coating liquids used by industry is given, such as Protec WLSO4.3 and Ballistol®, before moving on to the more descriptive and experimental aspects of drawing agents.

3.2.1 Coating Liquids [61] –

For the coating liquids, the two major basic principles required for the coating process in comparison with the liquid flow and interaction between the solid and liquid state are the Rheology and surface chemistry, as this will allow to predict the insight for the use and application of the coating liquids and to deal with the problems coming out of it.

Firstly Rheology is defined as the study of physical behavior under stress. This encompasses changing the shape of the liquid when the pressure is being applied. This includes four significant aspects as viscosity, elasticity, plasticity, and rigidity. Among these, viscosity plays a vital role as it acts directly as a liquid resistance on the surface.

Secondly, Surface Chemistry is defined as the mutual attraction between the molecules of the ink and the attraction between the molecules of liquid and substrate through the phenomena of wetting. This is used to remove many complications and problems that are usually seen in the coating process.

During this coating process for the steel welding wires, the primary use of coating is the oil-based liquids as it plays a vital role as an anti-corrosion (prevention from rust) and prevention of the metal. The oil-based coating is considered a coating that includes drying oils. The prominent ingredient in the drying oil is the fatty vegetable oil that chemically reacts with the oxygen and gradually hardens and dries the oil through the mechanism of autoxidation (addition of oxygen into organic compounds) by injecting oxygen molecules into the carbon and hydrogen bonds, covering the wet film into the dry film.

As a covering foundation for industrial machinery and infrastructures, oil coating is typically used to preserve the adhesion of the surface. The primary oil-based coating liquids used by the Voestalpine BÖHLER welding for the wires are the Protec WLSO4.3 and Ballistol®.

3.2.1.1 Protec [62] –

During the care of the welding wire, multiple surface properties contribute to different situations, requiring a high integration of surface cleanliness, which is also a complicated feeding situation. The substance that is ideal for summarizing and handling all these conditions is, therefore, the Protec WLSO4.3

Protec WLSO4.3 is often used as a surface lubricating oil to protect the wire electrodes and ensure that perhaps the friction values increase. Drawing agent's debris from the surface is eliminated by forming a protective barrier against corrosion and oxidation.

The Major advantages of using Protec are –

- Allows obtaining characteristics of the wire according to the supply conditions, which in turn increases the productivity and quality of the wire.
- It improves surface structure by proper interaction of molecules which results in longer service life.



Fig 14: Lubricating Liquid Protec WLSO4.3

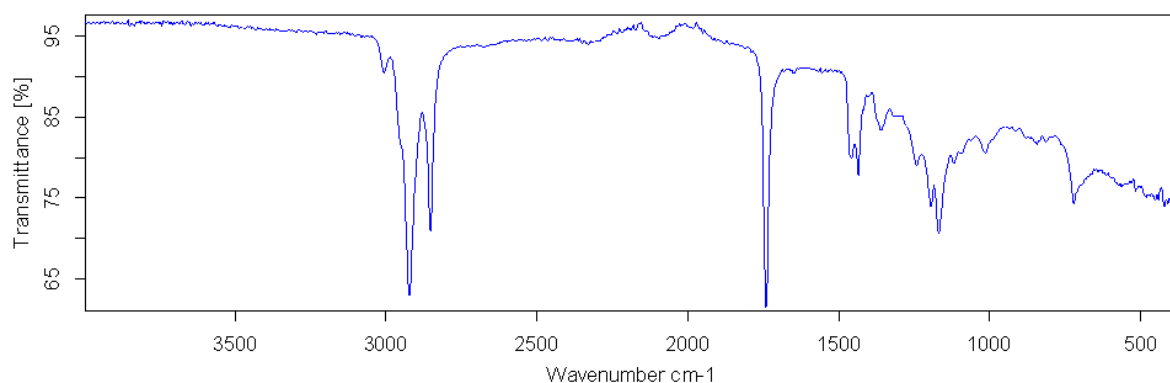


Fig 15: IR spectrum of Protec WLSO 4.3

3.2.1.2 Ballistol® –

As an alkaline, emulsifying oil cleaner and corrosion-resistant lubricant that includes Isobutyl alcohol as the primary ingredient, Ballistol® universal oil is specified [63]. In the tool industry and the production of many other items made of metal, it is commonly used. It creates an alkali barrier coating on the metal surface which neutralizes the corrosive traces of the acid to protect the surface from corrosion. This is because it can crawl through the tiniest cracks and fissures in metal surfaces because of its low surface tension.

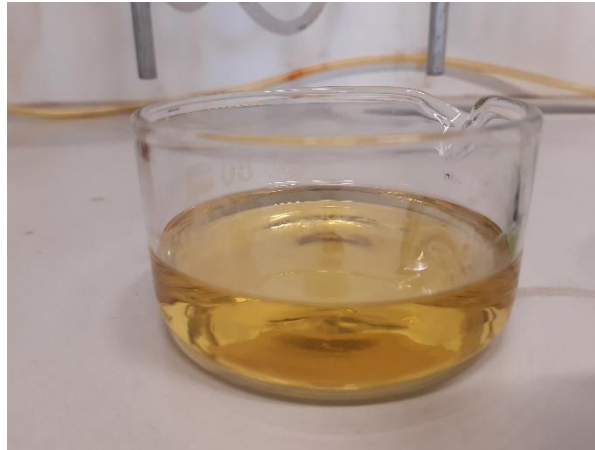


Fig 16: Ballistol® Universal Oil

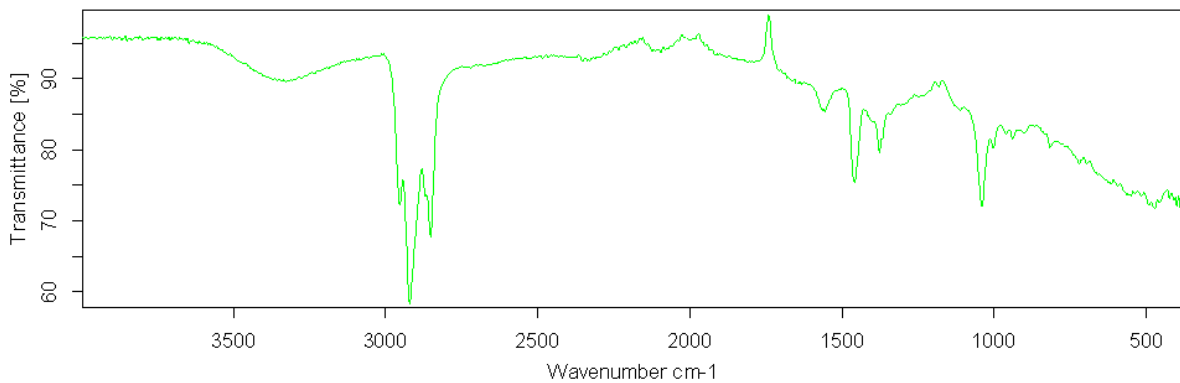


Fig 17: IR spectrum of Ballistol®

A sample of Ballistol® oil with its IR spectrum can be seen in fig 16 and 17, respectively, which is being used at Voestalpine Böhler Welding GmbH. PEL (Permissible Exposure Limit), a mandatory limit on an employee's exposure to a chemical material estimated in time-weighted TWA. It is 100 ppm TWA which is for Ballistol®. As far as physical features are concerned, the boiling point is 128 C (262.4 F). Moderate evaporation levels at 20 C (68 F) as per the protection datasheet. In contrast, it cannot be readily soluble concerning the solubility of liquids.

Several drawing agents have used several mixtures to treat the welding wires to clean before applying oil as a coating. This is based on two types of production lines: high alloyed welding wires and unalloyed welding wires.

In this chapter, a brief description of the chemical composition, some fundamental properties, and the corresponding IR spectra of six different drawing agents are summarized.

3.2.2 Drawing Agents for unalloyed welding wires

1. VICAFIL SALVIA - 2

Condat corp. Introduced Vicafil Salvia 2 as a drawing agent for the manufacture of unalloyed welding wires. The drawing agent comes in a powder form that is light brown and has faint odors.

Chemically Vicafil Salvia 2 consists of a mixture of

| | |
|--|----------|
| Stearates, $\text{CaC}_{36}\text{H}_{70}\text{O}_4$ | >50% |
| Disodium tetra borate pentahydrate, $\text{Na}_2\text{B}_4\text{O}_7 \cdot 5 \text{H}_2\text{O}$ | 10-20% |
| Calcium hydroxide, $\text{Ca}(\text{OH})_2$ | 10-20%, |
| Sodium nitrite, NaNO_2 | 2.5-10%. |

The relative density ranges from 0.7 to 0.8, and the relative density temperature is 68 ° F. It is also partially soluble in water. While it is stable under normal conditions, it must be kept away from fire/spark, and adequate ventilation must be provided to prevent dust dispersal in the air and accumulation and dust generation.

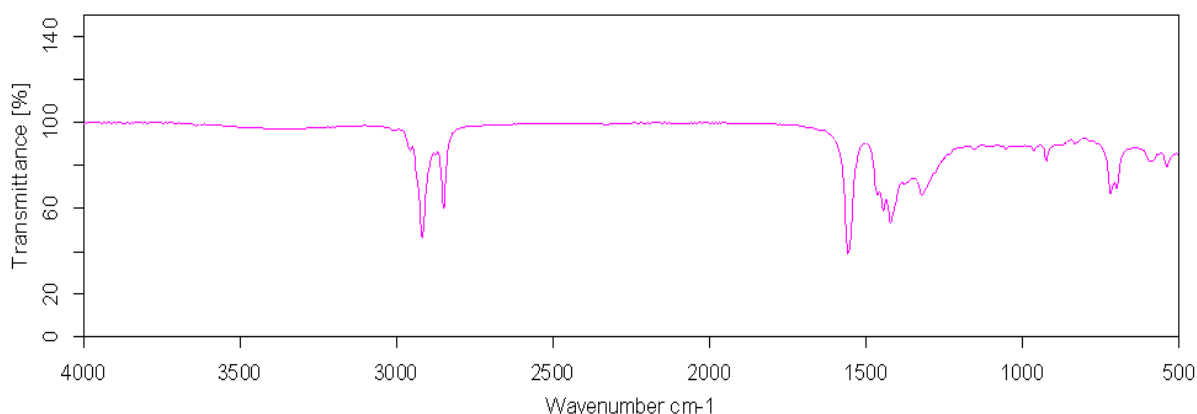


Fig 18: IR Spectrum for VICAFIL SALVIA 2

The figure above displays the IR spectra with the coordinate as transmittance and wavenumbers, directly proportional to frequencies.

VICAFIL SALVIA 2 - It is a drawing agent used for unalloyed welding wires with more than 50% of the content as stearates and with the properties of soluble in water partially. It also contains some other chemicals such as Calcium Hydroxide and Sodium Nitrite.

2. VICAFIL SUMAC – 2

Condat Corporation had introduced Vicafil Sumac 2 as a new drawing agent to treat unalloyed welding cables. The only difference between Vicafil Sumac 2 and Vicafil Salvia 2 is the ingredient, which is Potassium hydroxide instead of Sodium Nitrate. The physical properties include a solid physical state in a powdery form and a white color with slight odors.

Chemically Vicafil Sumac 2 consists of a mixture of -

| | |
|---|-----------|
| Potassium hydroxide (KOH) | 1 - 2.5% |
| Nitric acid sodium salts NaNO_2 | 2.5 - 10% |
| Stearates, $\text{CaC}_{36}\text{H}_{70}\text{O}_4$ | >50% |
| Disodium tetraborate pentahydrate, $\text{Na}_2\text{B}_4\text{O}_7 \cdot 5 \text{H}_2\text{O}$ | 10-20% |

The relative density temperature is 68 ° F, and the relative density varies from 0.7 to 0.8. It is highly soluble at 20 ° C but entirely soluble at 80 ° C. The elimination of igniting sources and the avoidance of dust accumulation and creation are the main issues when making it in normal conditions. Also, remain cautious when moving dry powders because movement produces static electricity charges.

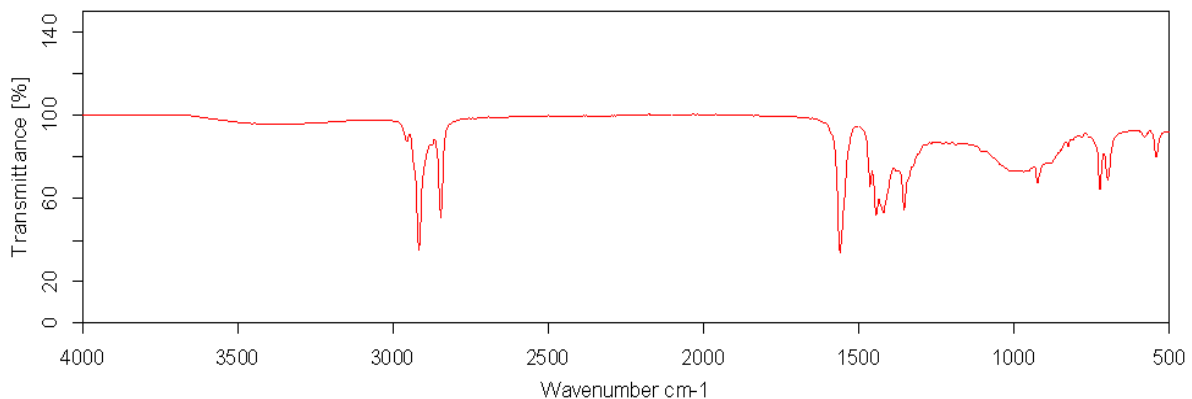


Fig 19: IR Spectrum of VICAFIL SUMAC2

Figure 19 shows the various typical IR bands of a calcium stearate-based coating agent such as VICALFIL SUMAC – 2.

VICAFIL SUMAC - 2 - Defined as a drawing agent used to treat unalloyed welding wires. It also contains the major portion of stearates and with the addition of Potassium hydroxide and Nitric acids. The significant physical property of this chemical is that it is highly soluble in water.

3. TRAXIT 2145 -

Traxit International GmbH presented Traxit 2145 as a drawing agent to treat unalloyed and high alloyed welding wires (CrNi, Cr-steels). The drawing agent is white, has soapy odors, and is solid. Between 700 and 800 kg/m³ is the specific gravity.

Chemically Traxit 2145 consists of a mixture -

| | |
|---|------|
| Stearates, CaC ₃₆ H ₇₀ O ₄ | >50% |
| Calcium hydroxide | >20% |

Prohibit the creation of dust and keep it away from ignition sources. While the significant chemical property of soluble in water at 20°C, it is insoluble.

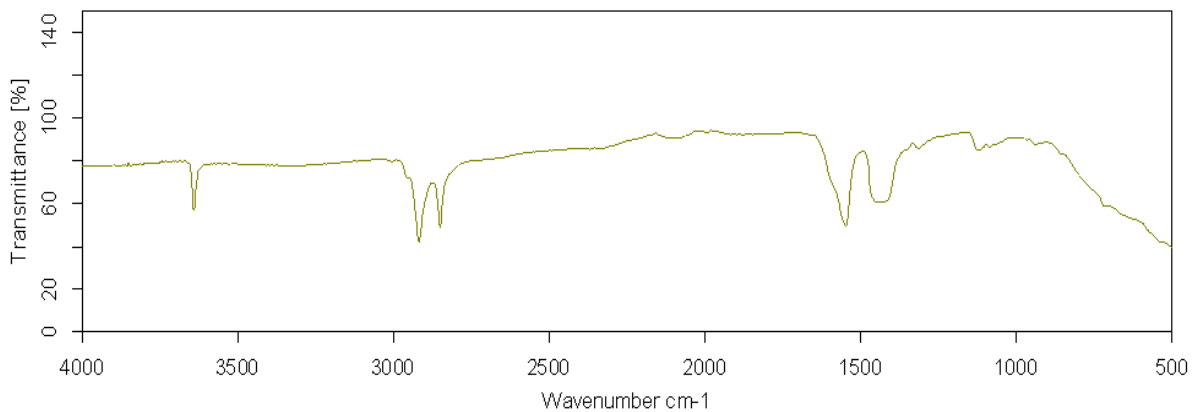


Fig 20: IR Spectrum for TRAXIT 2145

Figure 20 shows the various typical IR bands of a calcium stearate-based coating agent such as TRAXIT 2145.

TRAXIT 2145 - A drawing agent is used to treat both unalloyed and high alloyed welding wires, whose main content is stearates and calcium hydroxide. While one drawback is, there is the release of harmful gases when it comes under contact with fire or spark. The primary chemical property is solubility in water; it is highly insoluble.

3.2.2 Drawing Agents used for highly alloyed welding wires

1. TRAXIT TNA 1680CSB

To treat high alloyed welding wires that include (CrNi, CrSteels), Traxit TNA 1680 as a drawing agent to treat the wires. The physical properties include tan color, with an odor like soap and solid as physical form.

Chemically composition of Traxit TNA 1680 consists -

| | |
|---|-------|
| Disodium tetraborate pentahydrate, $\text{Na}_2\text{B}_4\text{O}_7 \cdot 5 \text{H}_2\text{O}$ | < 20% |
| Calcium hydroxide ($\text{Ca}(\text{OH})_2$) | >20% |
| Sodium nitrite NaNO_2 | <3% |
| Stearates, $\text{CaC}_{36}\text{H}_{70}\text{O}_4$ | >50% |

The most important environmental precaution is to eliminate surface water or drains. Also, to keep it from causing dust to accumulate while it is being prepared. Wear protective equipment when working with this sample because the release of dangerous gases will damage the eyes and skin while breathing. While it is insoluble in water at 20 ° C.

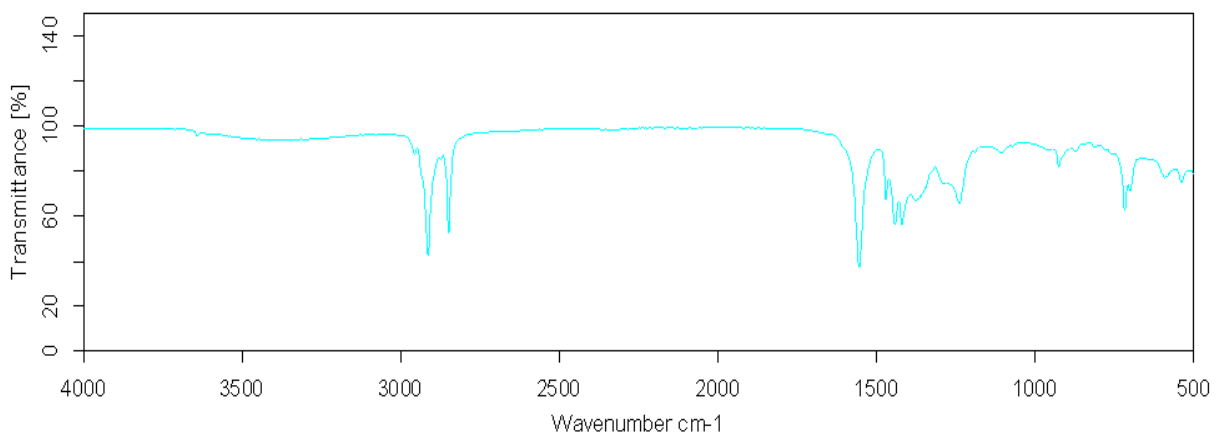


Fig 21: IR Spectrum for TRAXIT TNA 1680CSB

Figure 21 shows the various typical IR bands of a calcium stearate-based coating agent such as TRAXIT TNA 1680.

TRAXIT TNA 1680 - To treat high alloyed welding wires, this is the drawing agent used. It includes the contents with a majority of stearates, calcium hydroxide, and Disodium tetra borate pentahydrate. The chemical properties attained by this liquid are it is highly insoluble in water.

2. TRAXIT C4550 -

Sodium soap is the main active ingredient for this sample used as a drawing agent for high alloyed welding wires. TRAXIT International GmbH presents this drawing agent sample. The color, whitish with a soap-like odor and comes in solid powder, is the primary physical property that sets Traxit C4550 apart from the competition.

Chemically composition of Traxit C4550 consists of -

| | |
|---|-------|
| Sodium hydroxide (NaOH) | < 1% |
| Sodium carbonate (Na_2CO_3) | < 20% |
| Stearates, $\text{CaC}_{36}\text{H}_{70}\text{O}_4$ | >50% |

In terms of the precautionary declaration, it is mandatory to wear eye, mouth, and nose protection and skin protection when coming into contact with fire or moving from one location to another due to the release of carbon dioxide (CO₂) and hydrocarbons. In addition, the sample must be protected from the generation of dust and ignition sources. It is insoluble in water at a temperature of 20 ° C.

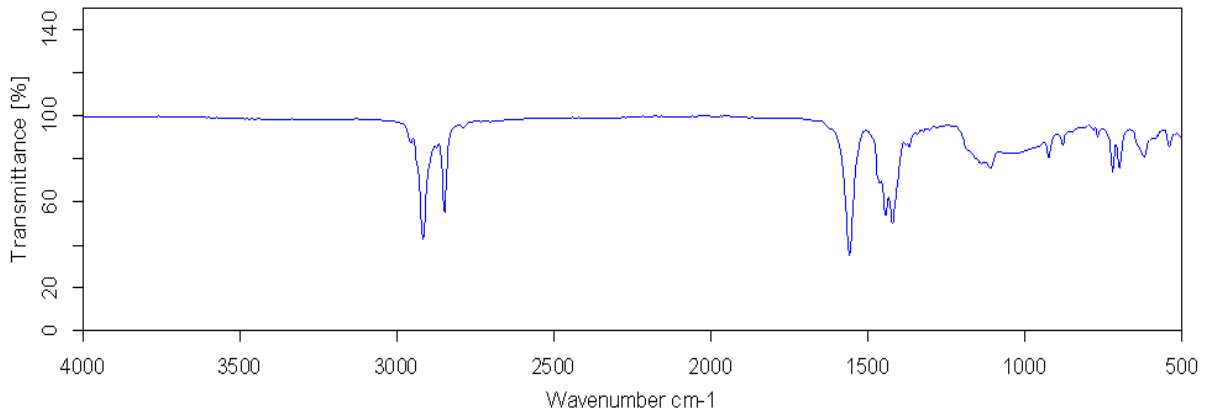


Fig 22: IR Spectrum for TRAXIT C4550

The IR spectra of TRAXIT C4550 (displayed in figure 22) are pretty similar to the TRAXIT TNA 1680CSB. Therefore comparisons in the upcoming chapters are applying to both of the materials.

TRAXIT C4550 - For the treatment of unalloyed welding wires, one of the drawing agents used is TRAXIT C4550 is having the composition of stearates and sodium hydroxide, and sodium bicarbonate. It reacts in front of fire and spark, and in terms of solubility, it is insoluble in water.

3. TRAXIT ZEL 760 AB -

Traxit International GmbH provided the drawing agent Traxit ZEL 760 AB to treat high alloyed welding wires and have a specific use against wet coating. The primary physical characteristics that distinguish this sample are its beige color, odorless nature, and solid powder form. This sample's specific gravity ranges from 1100 to 1200 kg/m³.

Chemically composition of Traxit C4550 consists of -

| | |
|--|--------------|
| Stearates, CaC ₃₆ H ₇₀ O ₄ | >50% |
| Disodium tetra borate pentahydrate, Na ₂ B ₄ O ₇ * 5 H ₂ O | ≥ 15 - < 20% |
| Lithium hydroxide, LiOH | ≥ 1% -< 10% |
| Sodium silicate, (Na ₂ O) _x · (SiO ₂) _y | ≥ 1% -< 10% |
| Boric acid, H ₃ BO ₃ | ≥ 0.5% -< 1% |

Because the sample is highly reactive in front of ignition sources, it should be kept away from them. It can react and produce hydrocarbons and NO_x, which are dangerous to the eyes, skin, and lungs. Wear protective clothing when working with this sample, in addition to preventing the accumulation of dust. It has a particular gravity of 1100-1200 kg/m³ and is soluble in water at 80 °C.

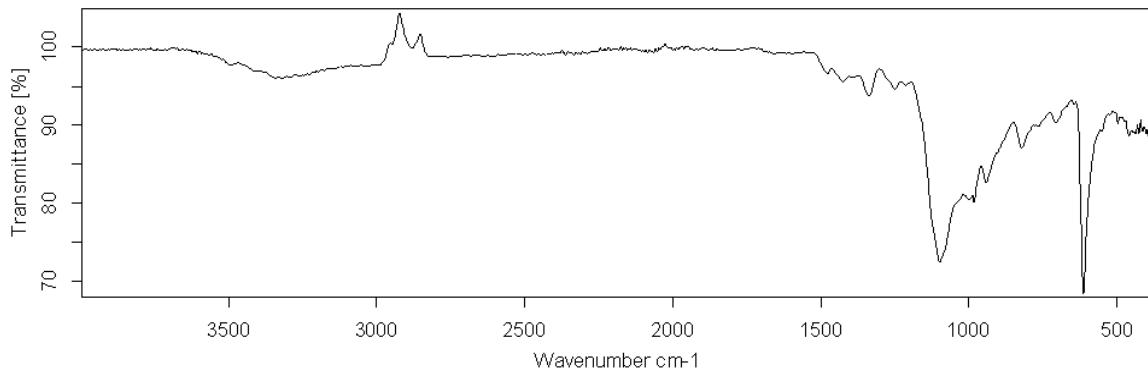


Fig 23: IR Spectrum for TRAXIT ZEL 760AB

Compared to all the other IR spectra of industrial-grade drawing agents, this one looks somehow different. So far, no rational explanation could be given for the various IR bands' behavior, despite that the measurement was repeated a couple of times.

TRAXIT ZEL 760AB - For treating the high alloyed welding wires and especially to treat against wet coating, TRAXIT ZEL 760AB is used. With the contents such as stearates and in combination with lithium hydroxide, Boric acids, and sodium silicates. The chemical properties of being soluble in water, it is highly soluble in water at high temperature.

3.3 Comparison of the IR measurements

In chapter 3.2, a short description of the used drawing agent and coating liquids was given together with the IR spectra measured on an AT-IR spectrometer of type S2000 ALPHA-T (Fa. Bruker). All IR measurements were repeated twice to guarantee that no impurities or mistakes during the sample handling influence the results.

As a not unexpected side effect, the spectra in chapter 3.2 are also suitable to determine if water is included in the coating oils or the drawing agents, showing the well-known water band around 3.500 cm⁻¹.

The first and fundamental step was to investigate if IR spectroscopy can distinguish between the pure wire and coating oils. Also, if one can quantify the amounts of the coating oil sticking on the wire had to be considered.

To simplify the investigations and get proof of a general concept for all further IR measurements, only Ballistol® was used. However, Protec should not behave much differently, and the available findings for Ballistol® can be applied to Protec.

In figure 24, the IR spectra of one of the original wire samples supplied by the cooperation partner are shown. By comparing these spectra with the one of pure Ballistol® (Fig. 25), it can be demonstrated that traces of Ballistol® are sticking to the surface of the wire.

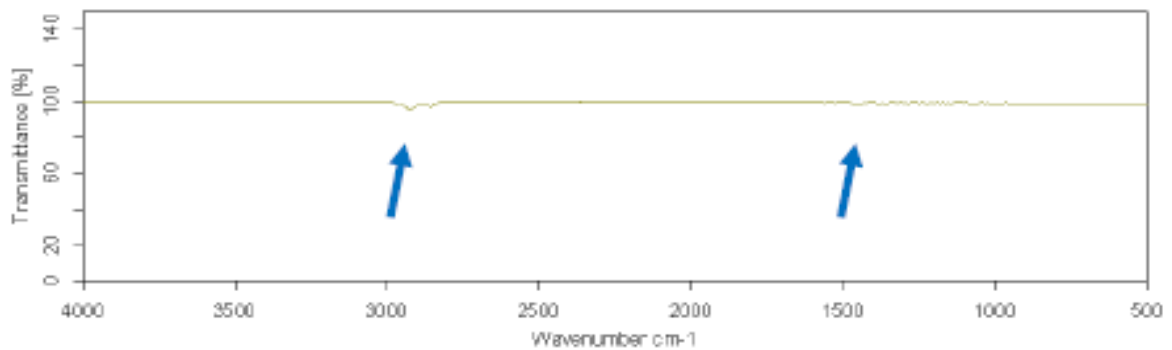


Fig 24: IR spectra of the original wire

IR spectra of the original wire that have been issued are compared with Ballistol®; it can be clearly seen that traces of Ballistol® are sticking on the surface of the wire (indicated by the blue arrows).

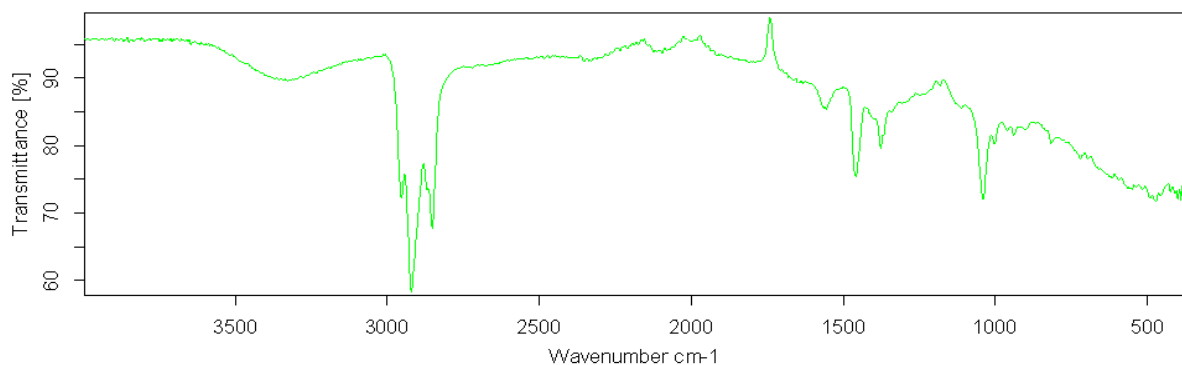


Fig 25: IR spectra of Ballistol®

It was necessary to get an IR spectrum of an utterly blank wire without any residues of drawing agent or coating oil for further investigations. First attempts by wiping the wire with a paper towel (Fig. 26) or using n-hexane (dipping the wire in n-hexane; Fig. 27) still left residues of the Ballistol® on the surface.

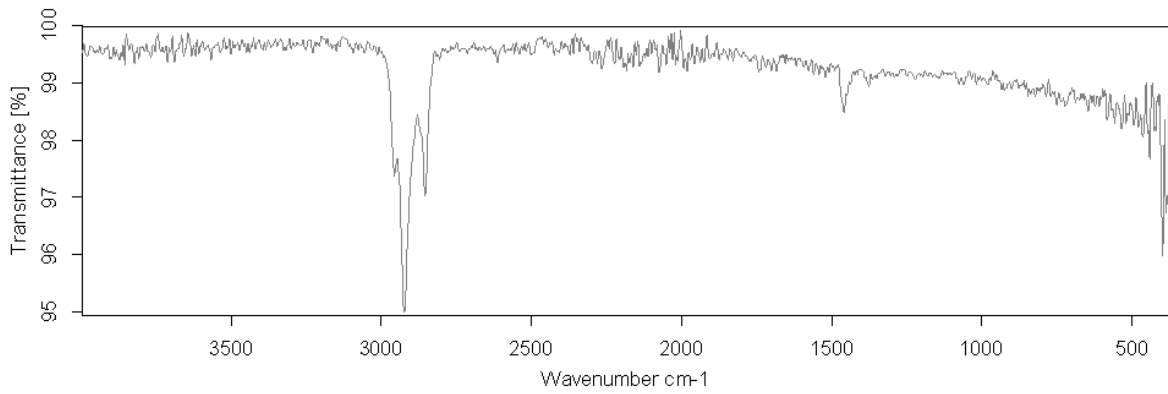


Fig 26: Wire cleaned by a paper towel

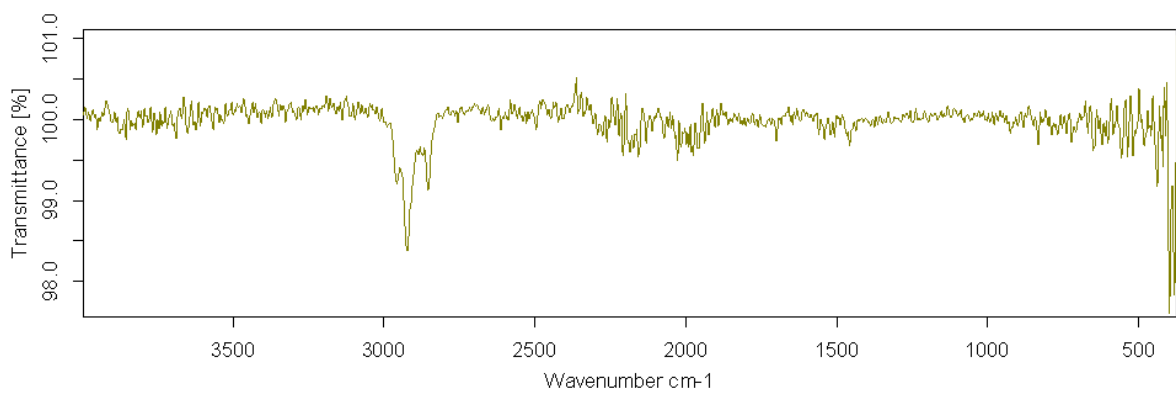


Fig 27: Wire cleaned with n-hexane

Only by treating the wire in n-hexane in a beaker and using an ultrasonic bath, the coating oil could be eradicated (Fig. 28) to receive the required IR spectra of a “blank wire” needed as a base level for further investigations.

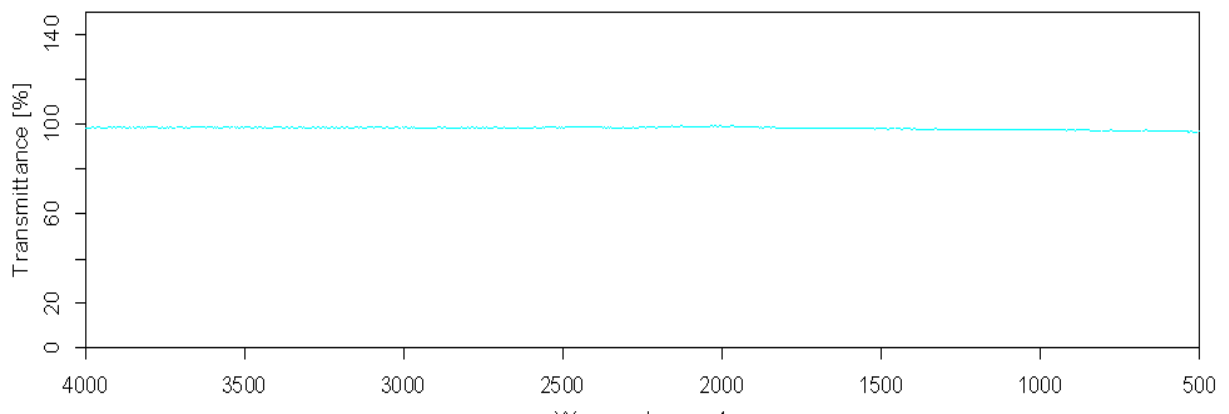


Fig 28: Cleaned wire after treating with n-hexane by using an ultrasonic bath for 30 minutes

Since, in the end, a quantification of the amounts of drawing agent and coating oil is needed, the next series of IR measurements was performed by dipping the wire in the oil in the typical fashion, placing it in a straight line so that the oil finally reaches every point. The wire was then left outside the oil until no oil dropped down anymore, and the sample was investigated via IR spectroscopy. The IR spectra displayed in figure 29 show the usual IR bands of Ballistol®.

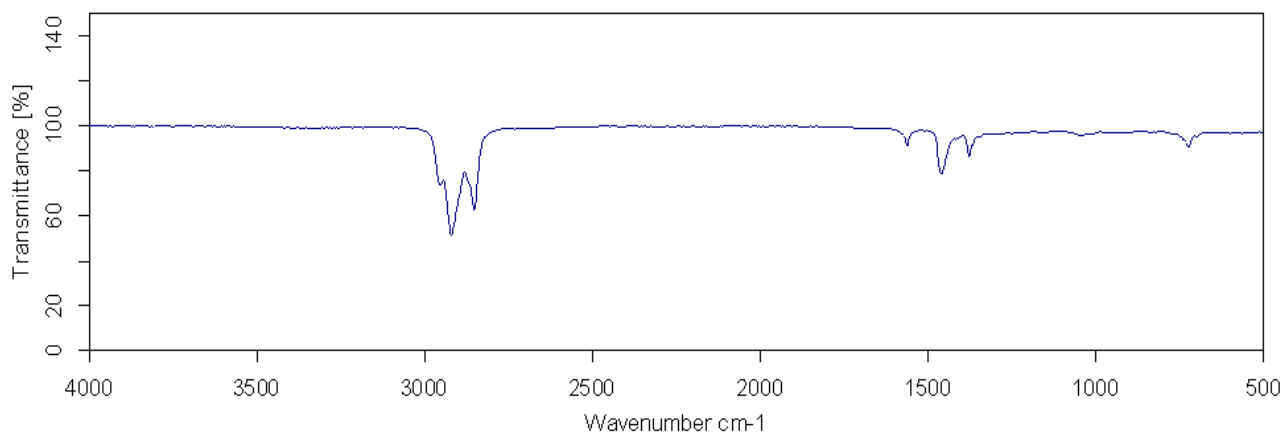


Fig 29: Wire with Ballistol®

By comparing these IR spectra (fig. 29) with the spectra in figure 24 or 25, respectively, it can be clearly shown that the intensity of the IR bands is depending on the amounts of Ballistol remaining on the wire. Therefore, it can be concluded that IR spectroscopy can generally be used to determine the amounts of coating oils such as Ballistol® or Protec remaining on the wire. Nevertheless, for exact quantification of the amounts of coating oils, a more significant number of experiments have to be performed in a separate investigation. In the next step of this work, it should be determined if IR spectroscopy can be used as a versatile tool for distinguishing between drawing agents and coating oil remaining on the surface of the wire.

As shown in chapter 3.2, the drawing agents' display, due to their changing compositions, sometimes significant differences in their IR spectra. However, one point all the discussed drawing agents have in common, the base of all of them is Calcium stearate. Due to the time limit, the further investigations were focused on a proof-of-concept approach by comparing just chemically pure Calcium stearate with Ballistol®.

The figures 30a to 30c are displaying the individual IR spectra of pure Calcium stearate (fig. 30a), pure Ballistol® (fig. 30b), and a mixture of Calcium stearate with Ballistol® (30c) on a wire.

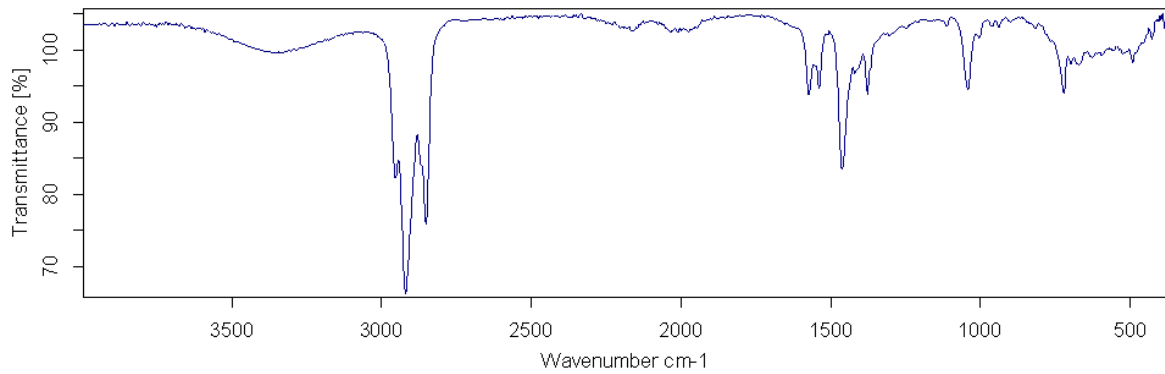


Fig 30a: IR spectrum of pure Calcium stearate on a wire

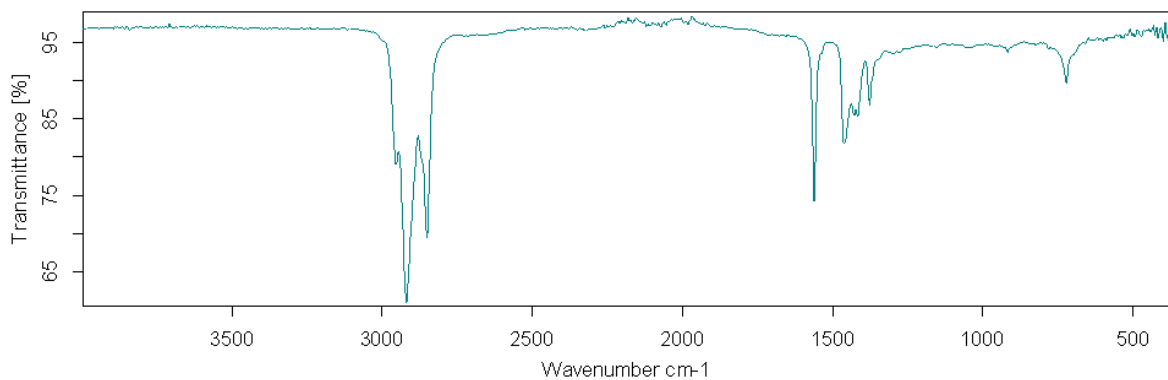


Fig 30b: IR spectrum of pure Ballistol® on a wire

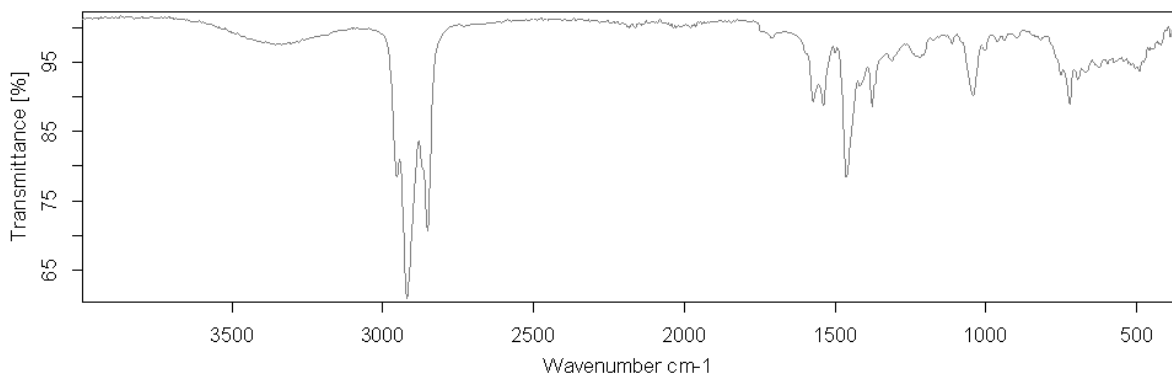


Fig 30c: IR spectrum of a mixture of Calcium stearate and Ballistol® on a wire

In figure 30d, all three spectra are displayed in one picture. It can be seen that the IR bands between 2700 and 3000 cm^{-1} are not suitable to distinguish between pure Calcium stearate and Ballistol®.

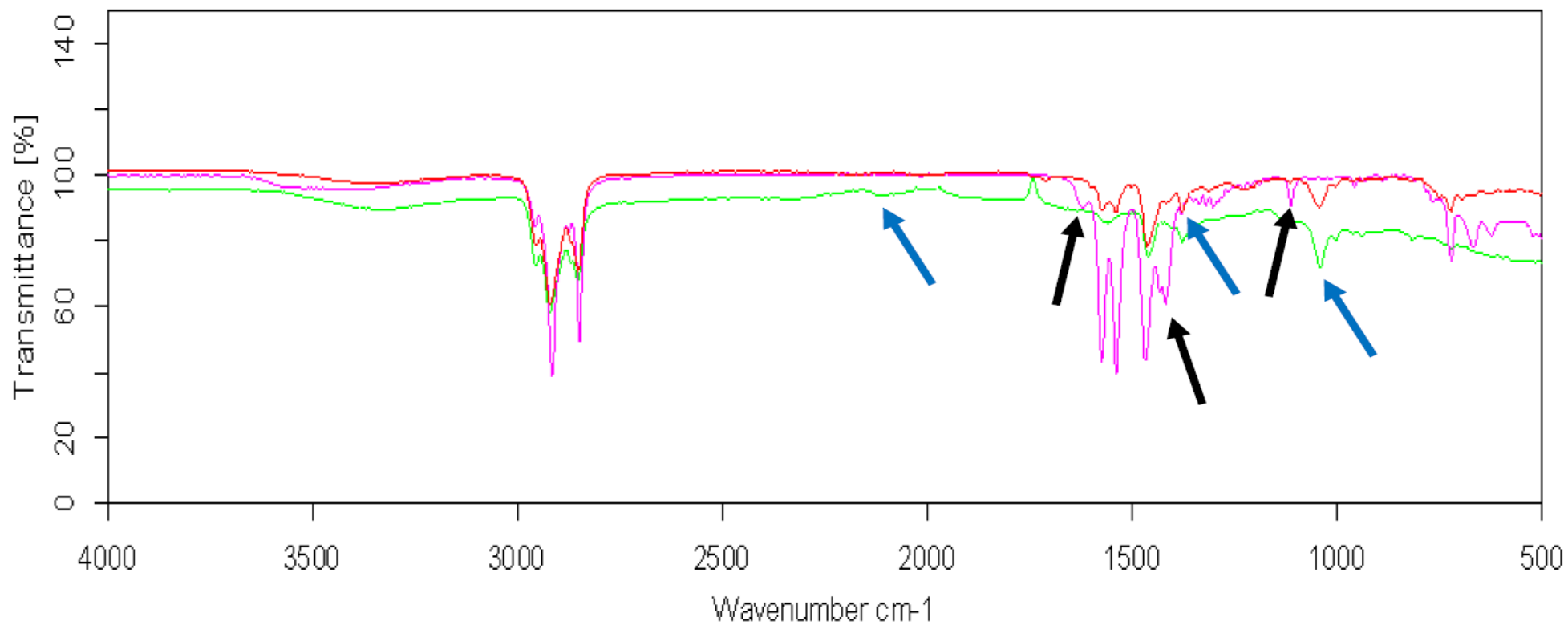


Fig 30d: Comparison of Calcium Stearate with coating oil Ballistol® and mixture of both via IR spectroscopy

- Redline; Wire, Ballistol®, and Calcium stearate
- Greenline; Ballistol®
- Pink Line; Calcium stearate

Blue arrows indicating IR bands specific for Ballistol; Black arrows indicating IR bands specific for Calcium stearate

However, some other regions of the IR spectrum can be used for the required purpose. Blue arrows in figure 30d are indicating infra-red bands specific for Ballistol®, while Black arrows indicate IR bands specific for Calcium stearate. By using those specific IR bands, one can not only clarify the presence of Calcium stearate besides Ballistol® and the other way around, but those bands can also be used to quantify the ratio between Calcium stearate and Ballistol® to a certain amount.

In this respect, the expected proof-of-concept is given. Nevertheless, further investigations are necessary, especially to quantify the ratios between Calcium stearate and Ballistol® more clearly and transfer the general proof-of-concept from pure Calcium stearate towards the drawing agents used in wire making industry.

The first step in this direction was done by comparing the IR spectra of a selected number of drawing reagents with pure Calcium stearate to see more clearly how different the natural drawing agents behave.

Figures 31a to 31d are displaying the individual IR spectra of pure Calcium stearate (fig. 31a), Vicafil Salvia 2 (fig. 31b), TNA 160CSB (fig. 31c), and Traxit C4550 (fig.31d).

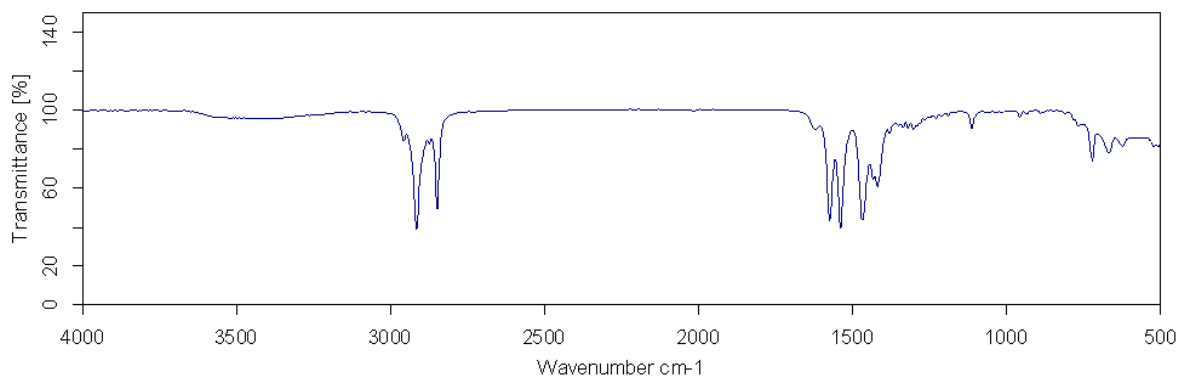


Fig 31a: IR spectrum of pure Calcium stearate

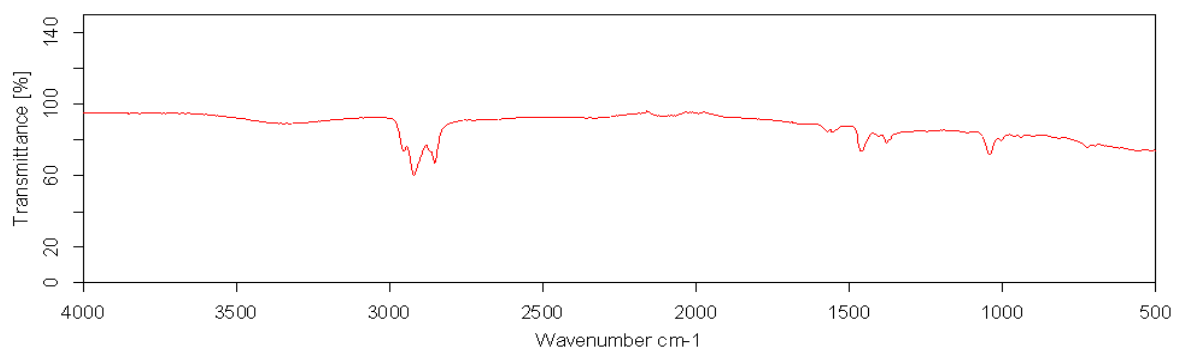


Fig 31b: IR spectrum of Vicafil Salvia 2

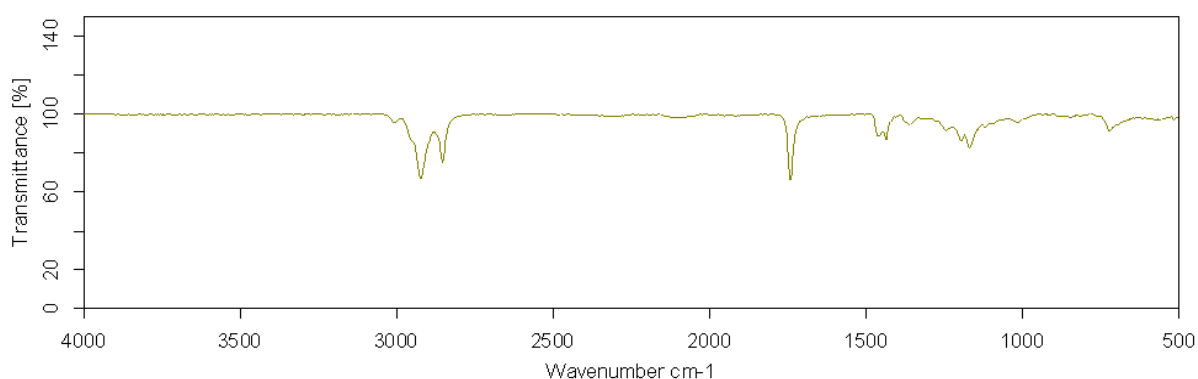


Fig 31c: IR spectrum of TNA 160CSB

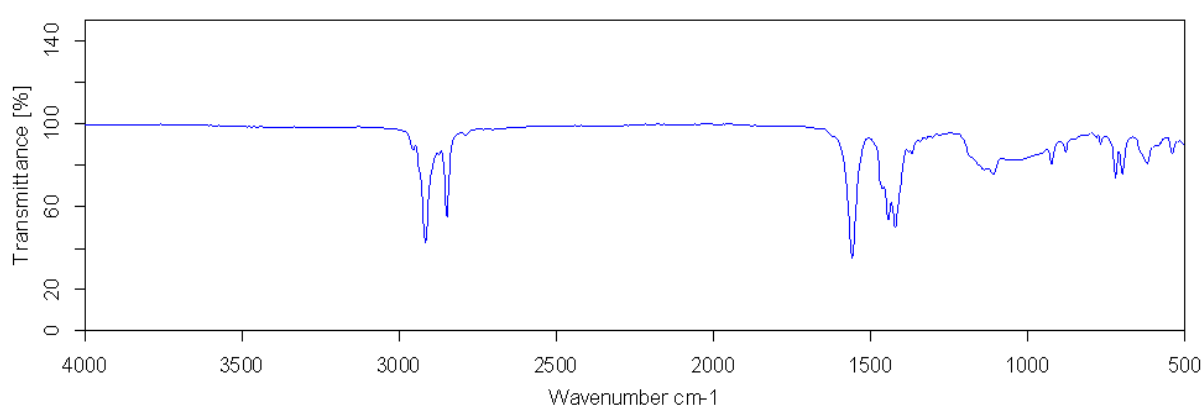


Fig 31d: IR spectrum of Traxit C4550

When comparing the IR spectra of the selected drawing agents to pure calcium stearate, which was used as model compounds of the drawing agents, it can be seen that each drawing agent has slightly different IR bands than the others.

In figure 31e, all spectra (fig. 31a to 31d) are displayed in one picture. It can be seen that the IR bands between 2700 and 3000 cm^{-1} are also not suitable to distinguish between pure calcium stearate and the selected drawing agents.

However, in general, the IR bands are indicated in figure 30d for distinguishing between pure calcium stearate and coating oils. Ballistol can also be used for distinguishing the drawing agents used in industry from Ballistol respectively.

The IR bands marked with a green arrow exist in the IR spectra of Calcium stearate and the industrial used drawing agents. The IR bands marked with a dark yellow arrow only exist in Traxit TNA 160CSB and Traxit C4550. In Vicafil Salvia 2, this band has only a reduced intensity and cannot be used for further quantification between coating oil (e.g., Ballistol) and drawing

agent. However, in this case, the two IR bands marked with green arrows should be sufficient for successful quantification investigations.

Nevertheless, for the mentioned quantitative approaches, individual comparisons must be made for each drawing agent with coating oil in future work.

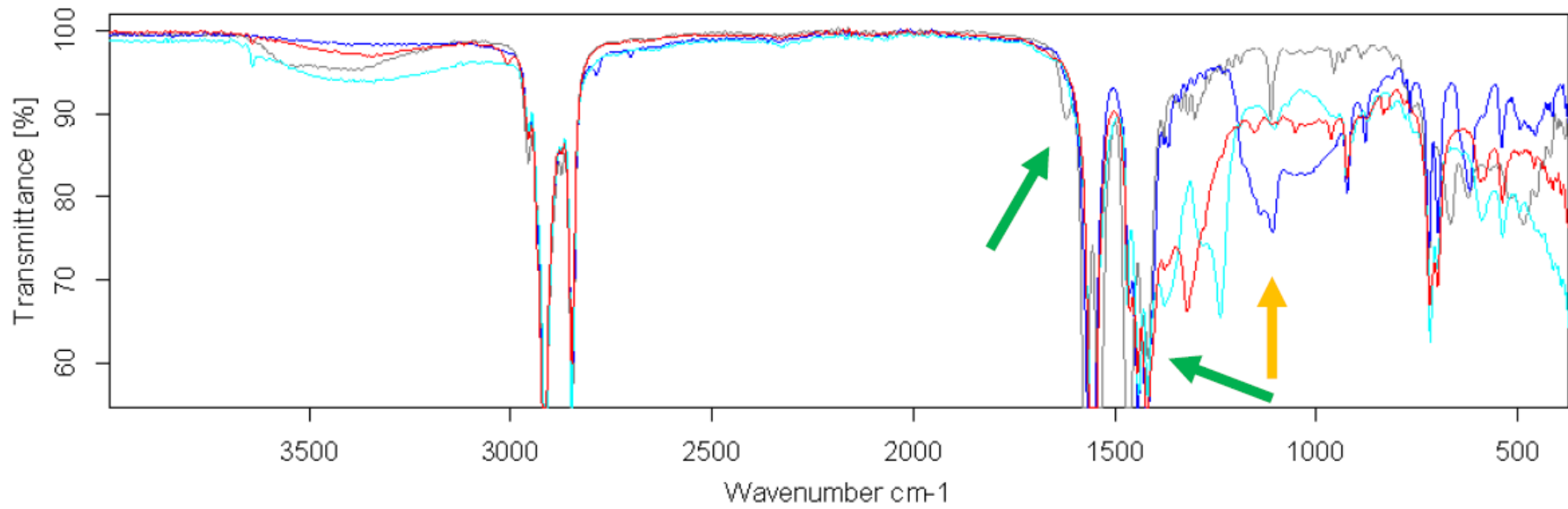


Fig 31e: Comparison of selected industrial drawing agents with pure Calcium stearate through IR spectroscopy

- Grayline; calcium stearate
- Dark red line; Vicafil Salvia 2
- Light blue; Traxit TNA 160CSB
- Dark blue line; Traxit C4550

4. SUMMARY & CONCLUSION

Time and cost savings, accuracy, and ease of understanding for both the consumer and the task performer are advantages of employing IR Spectroscopy over other forms of analysis. This study was able to determine the different functional groups using atom vibrations. The analysis technique included analyzing all of the samples with an IR spectroscopy instrument to discover the basic properties of the sample liquids and then integrating all of the samples into one to determine the commonalities and dissimilarities in characteristics of the sample liquids. Aside from the presented proof-of-principle for distinguishing pure calcium stearate from the coating oil Ballistol® by infrared (IR) spectroscopy, the approach must be applied to real drawing agents used in industrial wire production processes. Under IR Spectroscopy, all of the samples revealed that the bands signify light absorption. This point may be utilized to differentiate between the various drawing agents and the quantity of coating withdrawn from the wire under particular conditions.

The IR spectra of selected drawing agents were compared to the IR spectrum of pure Calcium stearate in a first attempt, demonstrating that the proof-of-concept works for real drawing agents utilized in the wire manufacturing sector. However, more research in this part and stream is required for quantification and more dependable and precise results.

To summarize, the infrared spectroscopy method is perfect for distinguishing between various types of drawing agents and can also determine the number of agents present.

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