PR2 Toolkit for flexible learning EXERCISES

KNOWBOND

Boosting Knowledge of Adhesive Bonding Personnel

Project No. 2021-1-PT01-KA220-VET-000033229

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Introduction

KNOWBOND project aims to update the EAB curricula in order to enable the certification of individual skills related with specific professional activities. Through the project, the target groups composed by operational staff at the executive level will have the opportunity of developing knowledge and skills as they are being required in their workplace from a lifelong perspective. The goal is to qualify these staff fundamentally and exclusively focused on their specific activities in the adhesive bonding workshop.

The PR2 concerns the development of digital training materials, the development of exercises using a problem-based learning approach and case studies. To promote a more flexible learning and give trainees (and trainers) a more agile and learner-centred way of achieving the learning outcomes for the updated EAB qualification, a series of resources were developed to support the implementation of the training courses and be part of the curriculum. This will also demand organisations to learn how to deal with these assessment methods and know how to measure learners' achievements, in order to adjust their practices or redirect their training. Especially after the pandemic situation in the last period and all the adjustments required from VET providers to deal with it, the urge for more flexible approaches to teaching is seen as necessary and this output aims to contribute to that. The tools developed under this result will target trainers, as the tools will support their practice and work in implementing the training courses associated to the EAB qualification; and the trainees, as these tools will give them the possibility to learn in a more flexible way and forcing them to think about what they are learning and take on a more active attitude towards learning.

The table below sums up the case studies and exercises that were thought and developed by partners, making the liaison with the competence unit, consequently the tackled subjects:

Competence unit	**Innovative resource**		**Context of use**	
	Case study	Exercise ID	Face to face	Online (self-study)
All	Case study 1		x	
All	Case study 2		x	
All	Case study 3		x	
All	Case study 4		x	
All	Case study 5		x	
All		Bonder Quiz	x	x
All		2. Identification and sequencing of the main steps in the production process of adhesive joints	x	x Bonder quiz – first challenge
• Introduction to adhesive bonding • Surface treatment		3. Evaluation of surface treatment	x	
• Introduction to adhesive bonding • The main families of adhesives and sealants - basics		4. Evaluation of the main families and sealants	x	x

• Construction and design • Final inspection		5. Analysis of defects in adhesive joints	x	x
• Introduction to adhesive bonding • The main families of adhesives and sealants - basics		6. Bond test aim	x	x
• Introduction to adhesive bonding • Benefits and limitations of adhesives		7. Evaluation of benefits and limitations of adhesive bonding	x	
• Introduction to adhesive bonding • Health and safety		8. Working instructions	x	
• Introduction to adhesive bonding • Surface treatment • Quality control		9. Preparation of workplace/Manufacturing of work samples	x	
• Introduction to adhesive bonding • Durability of adhesively bonded joints		10. Bus and Train windshield bonding	x	
• Introduction to adhesive bonding • Durability of adhesively bonded joints		11. Car side-mirror bonding	x	
• Introduction to adhesive bonding • Quality assurance / Quality management	Final inspection Defect analysis	Final inspection	x In practical training using bonded samples	x Bonder quiz - Final Inspection step Exercise in training materials

The exercises created as a result of PR2 are presented below.

1. Case studies

By analysing all the proposed scenarios, the trainees should understand whether the production process will be successful or which scenarios should be reversed, how and why. In these stages, besides the revision of theoretical knowledge, the trainee is invited to correlate facts, to consider the effects of an execution error in each of the stages and to have a holistic vision of the whole production process.
The trainer needs to moderate a discussion using the following topics per case:

Case study 1

- We have run out of nitrile gloves
- The adhesive is within its expiry date
- I Sandblasted and cleaned the surface of the metallic substrate with acetone
- I used a moisture-curing adhesive within the skinning time
- I applied the adhesive as a triangular bead according to the working instructions
- I used spacer to ensure the minimum layer thickness
- I followed the information available in the working instructions and used the appropriate temperature for the required period of time.

Case study 2

- The workshop has a good ventilation system
- The metal has an oxide layer
- I grinded the surface of the metallic substrate and only cleaned the surface afterwards
- The resin/hardener ratio was wrong of a two-component adhesive
- I applied two parallel beads of adhesive
- I Closed the adhesive joint in one movement from top to bottom
- I am short on time, so I increased 50^{o}C to the advised hardening temperature.

Case study 3

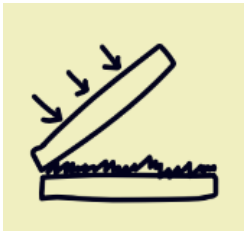
- I don't have the safety data sheet available
- The workshop was temperature and humidity-controlled
- I observed the wettability of the plastic substrate after surface treatment, and the contact angle was high
- The adhesive was removed from the refrigerator (4°C) and used immediately
- I applied a closed-circle bead
- I guaranteed alignment of substrates
- I used weights to ensure the joint closed, and let it cure at room temperature.

Case study 4

- I have all the PPE I need
- I opened the container of adhesive and noticed that a film had formed on the surface
- I used plasma to prepare the surface of the composite substrate
- I mixed the two-component adhesive manually with a spatula
- I applied a lot of adhesive to ensure that the entire overlap will have plenty of adhesive
- I closed the joint like a book
- D - I waited a week for the adhesive to harden

Case study 5

- I know how to analyse the pictograms on the adhesive container and what they mean
- There has been a heat system failure in storage room in the last winter days
- The solvent that is usually described in the working instructions ran out, so I used acetone instead
- I used a gun to mix the two-component adhesive
- My cartridge is almost empty, so I applied a thin layer of adhesive to save adhesive
- I closed the adhesive joint in one swift movement without ensuring the alignment of the substrates
- I did not use pressure to harden the adhesive joint



These case studies should be discussed in the classroom face to face, reading and discussing what each condition means in real practice, what it implies and what is the best way to approach the situation.

In the next pages of the document are gathered the exercises using a problem-based learning approach, directed to trainers to apply them face to face in a more dynamic method.

2. Identification and sequencing of the main steps in the production process of adhesive joints

In this exercise, trainees should be able to identify the main steps of the adhesive joint production process and sequence them in the correct order.

TACKLED LEARNING OUTCOMES	Identification of stages in the production process Sequencing of stages Understanding the activities performed in each task
NUMBER OF PARTICIPANTS	1-4 - there is more sharing if the groups are small
DURATION	5 minutes

OBJECTIVE	Understand the stages of the production process and the importance of the sequence of the stages.
EQUIPMENT DEMANDED	Cards with images representative of each step of manufacturing procedure
HOW TO CONDUCT	1 - Cards (paper or digital) are presented with the main step of the manufacturing procedure; 2 - Trainee has to identify the step; 3 - Trainee must correctly sequence the manufacturing steps; 4 - Trainee should explain the sequence he/she has chosen; 5 - Trainer is responsible for brainstorming mediation.
CLOSING REMARKS	At the end of the exercise, trainees should be able to understand the adhesive joint manufacturing procedure, comprehending each of the steps and the need to respect the correct sequence.

3. Evaluation of surface treatment

During the production of bonded joints a physical surface treatment of the polypropylene substrates is necessary. The surface treatment is done by colleagues and treated substrates are stored like the untreated substrates in boxes. The boxes are normally marked with labels “untreated” and “treated – ready for bonding”. Today the labels were removed by accident and now it is unclear which box contain the treated substrates. Is there any way to find out which box contain the treated substrates?

COMPETENCE UNITS AND SUBJECT	CU1 Fundamentals on adhesive bonding technology Introduction to adhesion and adhesives; Surface treatment; CU2 Specific surface treatment methods Physical treatment
TACKLED LEARNING OUTCOMES	Name the requirements on substrate surfaces for effective bonding and the objectives of surface treatment prior to bonding

	-Identify the different methods of surface treatment and their objectives -describe the objective of physical treatment, the procedure and heeding points during the procedure
NUMBER OF PARTICIPANTS	Whole group can discuss the exercise or smaller groups like 2-4 persons
DURATION	15 min
OBJECTIVE	To know the objective of physical treatment (increase of surface tension, improvement of wetting and bondability) and connect it with test methods to evaluate the wetting behaviour of substrates.
EQUIPMENT DEMANDED	Not necessary but recommended two polypropylene substrates (one only cleaned but not treated and one cleaned and plasma treated), water/pipette or test inks when requested
HOW TO CONDUCT	The trainer explains the situation (and is possible to hand out both substrates. The participants were asked to discuss possible solutions within the group(s) for 15 minutes After 15 minutes, the group(s) will present the solution. The trainer assists in case of further question (e.g. what possibilities in the work shop exists) or give hints. Finally, the water/pipette or test inks can be used by the participants to demonstrate the solution.
CLOSING REMARKS	After the solution is presented and discussed a short repetition of the requirements for effective wetting should be done and the procedure/influencing factors of physical treatments summarized, too.

4. Evaluation of the main families and sealants

There are several families of adhesives and sealants, all with different properties and characteristics which depend on their composition and how they are formed. Curing mechanisms or hardening processes define the formation of the adhesives and are important to know.
The participants will review the main families of adhesives and classify them according to their curing mechanism and some key properties.

COMPETENCE UNIT AND SUBJECT	CU1 Fundamentals of adhesive bonding technologies The Main Families of Adhesives and Sealants
TACKLED LEARNING OUTCOMES	List the different families of adhesives and their curing mechanism. Classify the adhesives according to: - Their curing mechanism - Their mechanical properties (rigidity, flexibility, tenacious)
NUMBER OF PARTICIPANTS	Whole group can discuss the exercise or smaller groups like 2-4 persons
DURATION	15 min
OBJECTIVE	Repeat/summarise the main families of the adhesives and sealants and their curing mechanism. Classify the adhesives according to their curing/hardening mechanism.
EQUIPMENT DEMANDED	Computer. Blackboard. Pen and paper
HOW TO CONDUCT	The participants are asked to list the different curing or hardening mechanism. Then, they have to name and classify the main families of adhesives following these questions: - Is a reactive or prepolymerized adhesive? - Is it rigid, flexible or tenacious? - What is its curing mechanism? * Drag and drop exercise in case of online format.
CLOSING REMARKS	The trainer should complete any missing points and add further information if necessary.

5. Analysis of defects in adhesive joints

In this exercise, trainees are expected to be able to identify the main defects that can occur in adhesive joints. In addition to identifying them, they should be able to determine their origin and the appropriate actions to be taken to avoid the defects under study.

TACKLED LEARNING OUTCOMES	Identification of defects Origin of defects Best practices to prevent defect formation
NUMBER OF PARTICIPANTS	1-4 – more effective learning if the groups are small
DURATION	15 minutes
OBJECTIVE	Identify the main defects, understand their origin and how to prevent their occurrence
EQUIPMENT DEMANDED	Cards with images/scheme of each type of defect
HOW TO CONDUCT	1 - Cards (paper or digital) are presented with the main defects that may occur in an adhesive joint; 2 - Trainee has to identify the defect; 3 - Trainee has to identify the cause for the defect presented; 4 - Trainee must list measures to prevent the occurrence of a certain defect. 5 - Trainer is responsible for brainstorming mediation
CLOSING REMARKS	At the end of the exercise, the trainees should be endowed with a global vision of the production process and how the existence of bad practices can lead to defects in adhesive joints.

6. Bond test aim

A range of tests are available to ensure Adhesive Bonding quality assurance and its quality control. Each type of test has different purposes and can lead to the determination of different quality parameters. The “BondTest aim” exercise consists in a simple association between the image of an adhesive bonding test and a statement describing its objectives.

TACKLED COMPETENCE UNITS AND SUBJECTS	CU1 Fundamentals of adhesive bonding technology

TACKLED LEARNING OUTCOMES	Recognise common modes of operating methods involved in the quality control of bonded structures. Identify quality control techniques applied to bonded structures.
NUMBER OF PARTICIPANTS	1 to 2 participants can be involved in the exercise
DURATION	10-15 minutes are required to apply the exercise
OBJECTIVE	Recognise the adhesive bonding quality test presented in the given images Relate the type of quality control test with its specific function and aim. Discuss about the limitations and advantages of the range of quality control tests used in bonded structures
EQUIPMENT DEMANDED	Computer; Additional resources such images of tests applies to adhesive bonding structures (annex 1)
HOW TO CONDUCT	In order to conduct the exercise, the trainer needs to follow these steps: ➔ Present the images (ask the students to identify (write or name) to which adhesive bonding test images corresponds to) ➔ Present the statement aims description ➔ Request the trainees to relate the 5 images to the 7 objectives. ➔ Promote discussion between trainees in order to make the proper association; ➔ Promote moments for active brainstorming during the exercise about the limits and advantages of each type of test.

7. Evaluation of benefits and limitations of adhesive bonding

The group of participants will be split in two groups. One group should find benefits and advantages of adhesive bonding related to other joining techniques like welding or riveting. The other group should find arguments against adhesive bonding (limitations/disadvantages of adhesive bonding compared to welding or riveting).

COMPETENCE UNIT AND SUBJECT	CU1 Fundamentals of adhesive bonding technologies Benefits and limitations of adhesive bonding
TACKLED LEARNING OUTCOMES	-List the common advantages of bonding -List the most common limits in adhesive technology
NUMBER OF PARTICIPANTS	Whole group divided in two groups
DURATION	15 min
OBJECTIVE	Repeat/summarise the most common advantages and limitations of adhesive bonding technology compared to welding or riveting.
EQUIPMENT DEMANDED	Two flipcharts/white boards, pens, maybe moderation cards
HOW TO CONDUCT	The trainer divides the whole group in two groups and explain the exercise. The participants were asked to discuss advantages and disadvantages within the groups for 15 minutes. The trainer assist in case of further questions or give hints. After 15 minutes, the groups will present the arguments for or against adhesive bonding. The trainer might cluster the arguments on the flipchart/whiteboard (then moderation cards are advantageous)
CLOSING REMARKS	The trainer should finally after each presentation add missing points or let the opponent group add missing points

8. Working instructions

The compliance with workplace instructions and storage conditions represents examples of measures for guaranteeing the quality of the adhesive processes. The “work instructions” exercise consists in identifying the required materials corresponding to a specific adhesive bonded structure work instruction.

TACKLED LEARNING OUTCOMES	Use traceability and work instructions as key measures for guaranteeing the quality of the process.

NUMBER OF PARTICIPANTS	1 to 4 participants can be involved in the exercise
DURATION	15-30 minutes are required to apply the exercise
OBJECTIVE	Awareness about the importance to follow and verify workplace instructions, including supporting documents. Summarize the required preparation of the work place; Full fill the materials section within the given work instruction.
EQUIPMENT DEMANDED	Computer; Additional resources such as working instructions.
HOW TO CONDUCT	In order to conduct the exercise, the trainer needs to follow these steps ➔ Present to the trainees an incomplete working instruction to undertake a specific adhesive bonded structure ➔ Ask the trainees to identify and summarize the required materials missing in the working instruction; ➔ Promote discussion between trainees in order to make the proper reflection about the required material ➔ Promote moments for active brainstorming during the exercise about the importance to follow instructions and follow them

9. Preparation of workplace/Manufacturing of work samples

The participants should summarize all necessary materials/tools at the work place for a whole bonding process of a work sample starting from the surface treatment until curing (two aluminium plates should be bonded by a two component epoxy mixed by hand; surface treatment: cleaning and grinding). Furthermore, the participants should explain the necessity of work samples.

COMPETENCE UNITS AND SUBJECTS	CU1 Fundamentals of adhesive bonding technology CU2 surface treatment CU3Adhesives
TACKLED LEARNING OUTCOMES	-Identify quality control techniques applied to bonded structures

	-Identify environmental protection aspects to be considered when using bonding processes, including waste disposal rules -Name different cleaning methods their objectives and heeding points during the cleaning procedure -Know and evaluate different methods to remove dust after the mechanical treatment -Describe the adhesive type, the processing and curing -Know the term pot life and explain influencing factors on the pot life -Name different mixing techniques and explain their heeding points
NUMBER OF PARTICIPANTS	Whole group
DURATION	15 min
OBJECTIVE	Identify and summarise all materials, tools etc. to conduct a work sample and prepare the work place accordingly. Also the reason why a work sample is necessary should be explained
EQUIPMENT DEMANDED	Flipchart/white boards, pens, maybe moderation cards
HOW TO CONDUCT	The trainer explains the exercise. The participants are asked to name all needed materials, tool, documentation for the production of an assembly of two Al-plates with a 2K Epoxy. The trainer or the participants write correct answers on the board. The trainer assists in case of missing things or give hints. Finally the trainer asks (if not mentioned before) about general requirements regarding the work place (e.g. clean, dust free, silicone free, climate control, restricted access, disposal bin,…) In the end the fact that adhesive bonding is a special process should be mentioned and therefore only destructive tests could give information about the real performance of a bonded part and work samples are necessary.

CLOSING REMARKS	At least the following things should be mentioned/summarized: Documentation (work instruction, MSDS or extract of it, bonding protocol) Thermometer, Hygrometer, clock/timer Substrates and adhesive Cleaning tissues and agent Grinding paper PPE balance Fixation Spatula

10. Bus and Train windshield bonding

Windshields protect the vehicle occupants from wind and flying debris and provide an aerodynamically formed window towards the front of the vehicle. Vehicle windshields are subject to many environmental conditions, such as high-temperature fluctuations, mechanical stresses and vibrations, therefore adhesive durability in such conditions is of grave importance. The windshields themselves can also be damaged by flying debris, wherein a lot of cases repair is not possible, and replacement is necessary. We will discuss factory installation of windshields, their replacement after suffering damage, surface preparation and the type of adhesive used in such cases.

TACKLED LEARNING OUTCOMES	• Understanding of Environmental impacts on the bonded joints durability • Effects Surface preparation • Type of adhesive and the chemical composition • Uses of primers in bonding
NUMBER OF PARTICIPANTS	1-16
DURATION	30 min introduction, 1h practical work, discussion
OBJECTIVE	The participants will understand the process of bonding dissimilar adherents, preparation for bonding, environmental impacts on the durability of bonded joints and composition of the adhesive used
EQUIPMENT DEMANDED	Industrial glue applicator Primer MS Polymer based adhesive Windshield

HOW TO CONDUCT	First, the trainer will discuss the environmental conditions that affect the selection of adhesive for the chosen application. He will instruct the students in mechanical surface preparation and chemical cleaning of the newly created surface. There will be a discussion as to the use of primers in adhesive bonding, and their importance on the final quality and durability of the bond. Primer will be applied, depending on the type of the adhesive used for the purpose of the demonstration, and its functions will be discussed. A correct amount of adhesive will be applied to the newly created surface and the windshield bonded. Whilst the adhesive is curing, the impacts of the curing environment will be discussed
CLOSING REMARKS	Hopes are that the trainees will learn the very widely spread process of such an application, and its uses in the industrial environment.

11.Car side-mirror bonding

In vehicle manufacturing, adhesives have been used for the attachment of side mirrors between their plastic mounts and the glass mirror itself for quite some time. Because of extremely variable environmental conditions and the addition of mirror heating elements, the ageing of such adhesives has been further accelerated. The ageing and embrittlement of these adhesives causes mirrors to fall off. This is especially common in earlier car models.

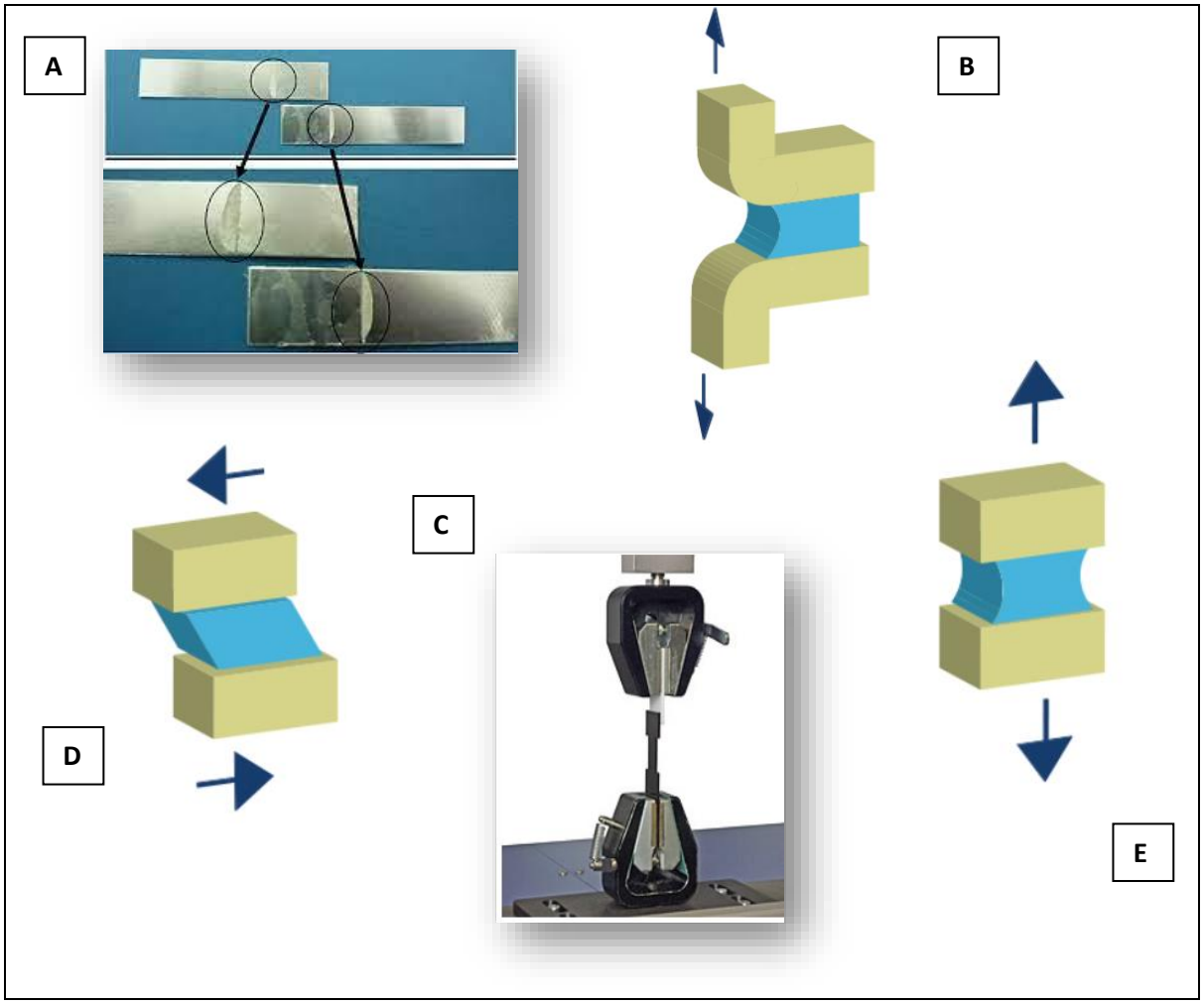
COMPETENCE UNITS AND SUBJECT	CU1 – Fundamentals of Adhesive Bonding Technology Durability of adhesively bonded joints Surface treatment
TACKLED LEARNING OUTCOMES	• The use of different types of adhesives • Environmental conditions and their effect on durability • Surface preparation for a quality bond • Processes of adhesive ageing
NUMBER OF PARTICIPANTS	16+
DURATION	90min
OBJECTIVE	The participants will understand the process of bonding dissimilar adherents, preparation for

	bonding, environmental impacts on the durability of bonded joints and composition of the adhesive used.
EQUIPMENT DEMANDED	Pen and paper
HOW TO CONDUCT	The trainer will discuss the industrial application of adhesives in the case of car side mirrors. Different types of adhesives used will be presented. He will instruct the students in the methods of mechanically creating a new surface and chemically cleaning the surface for the purpose of creating a quality bond with the adhesive. The use of primers and its functions will also be discussed. The lecturer will also discuss the mechanisms for bond failure and the environmental impacts on the durability of the bonds.
CLOSING REMARKS	Hopes are that the trainees will learn the very widely spread process of such an application, and its uses in the industrial environment.

Anexx 1

Bondtest aim - exercise

BONDTEST IMAGES



AIMS

1. Determines how strong the bond between material is and also how much it can be stretched before it breaks.
2. Determines surface materials errors such as difference in colour and shine, mechanical defects, large surface cracks and in transparent materials, as well as blisters and cavities.
3. Determines the property material mechanical performance
4. Determine the adhesive strength of a material or the strength of the adhesive bond between two materials
5. Measures the force required to remove a pressure sensitive adhesive from a testing plate or its own backing material
6. Determines the shear strength of adhesives for bonding materials when tested on a single-lap-joint specimen.
7. Determine attributes, such as shear strain, shear stress and shear modulus, report the stress, strain, modulus and failure mode (if applicable).

Solution:

	AIMS
Tensile Tests **C/E**	• Determines the property material mechanical performance • Determines how strong the bond between material is and also how much it can be stretched before it breaks.
Shear Tests; **D**	• Determines the shear strength of adhesives for bonding materials when tested on a single-lap-joint specimen. • Determine attributes, such as shear strain, shear stress and shear modulus, report the stress, strain, modulus and failure mode (if applicable).
Peel Tests **B**	• Determine the adhesive strength of a material or the strength of the adhesive bond between two materials • Measures the force required to remove a pressure sensitive adhesive from a testing plate or its own backing material
Visual inspection **A**	• Determines surface materials errors such as difference in colour and shine, mechanical defects, large surface cracks and in transparent materials, as well as blisters and cavities.