https://compositeskn.org/KPC/A176

A176

Hot press

Wabash hot press displaying both upper and lower platens.

Document Type	Article
Document Identifier	176
Relevant Class	Equipment
Tags	• Conductive heating • Equipment • Forming • Pressurized • Thermal transformation • Consolidation • Object • Debulking
Factory Cells	• Forming • Thermal transformation
Prerequisites	• Conduction • Effect of equipment in a thermal management system • Heat transfer • Thermal transformation

Introduction[edit | edit source]

A hot press (also referred to simply as press) is a piece of equipment that uses heated metal platens fitted with part-specific tools to apply temperature and pressure to a part. It can be used as a heating system for thermal transformation, a forming device for material deposition, and/or to consolidate parts under high pressure. The application of heat to the part functions according to the principles of thermal conduction. The pressure applied to the part is often considerable and can be applied with or without heating. Both thermosets and thermoplastics may be cured, crystallized, and/or thermoformed in a hot press. When forming using a press, the process is typically referred to as compression moulding[1][2]. If forming or consolidating aligned-fibre thermoplastic sheets, the process may be referred to as hot stamping or stamp forming[2].

Scope[edit | edit source]

This page provides general information on hot presses as devices for thermal transformation, consolidation, and forming. This includes, properties, use, safety, and supplier information. If specific information regarding brands of hot presses is desired, it is best to contact a supplier. To find information on suppliers, see the section below or navigate to the resources page.

Significance[edit | edit source]

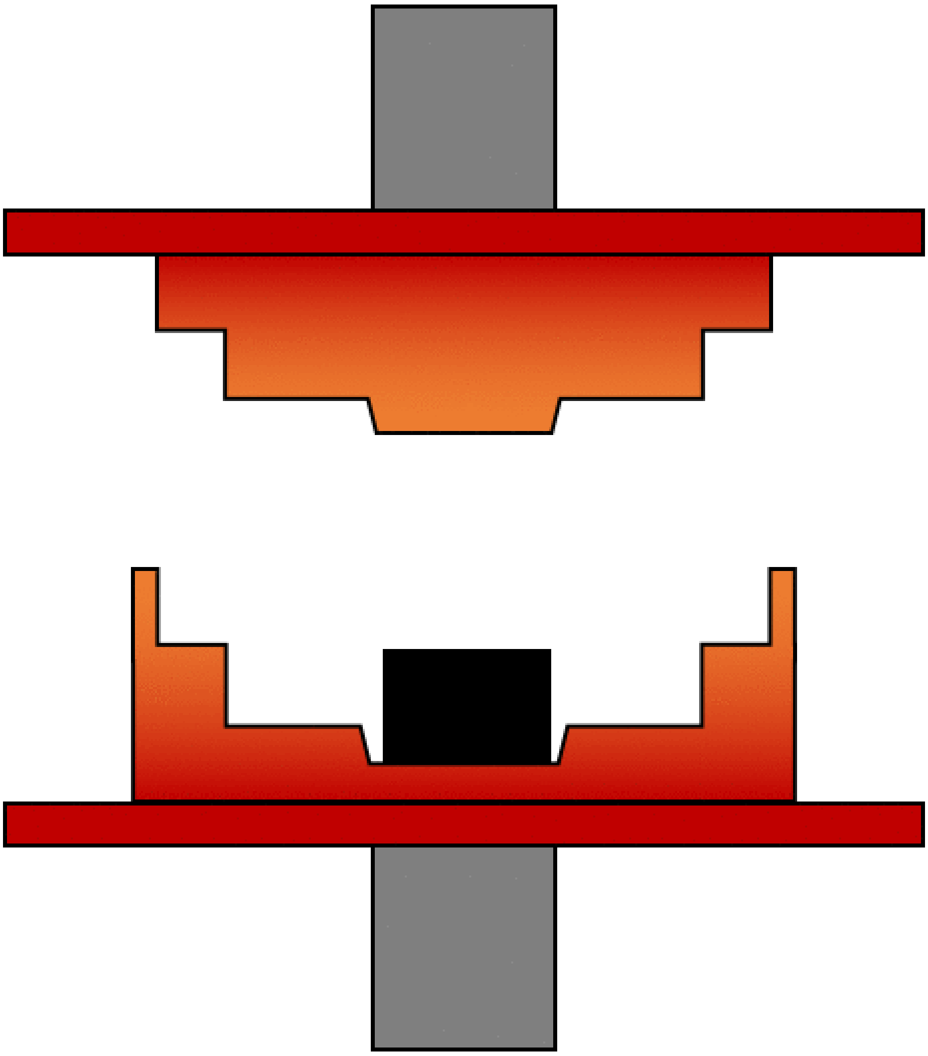
Hot presses are common pieces of equipment in composite manufacturing factories. Along with autoclaves and ovens, hot presses are one of the primary pieces of equipment used in high-temperature processing of composites. Understanding the properties of such equipment allows for one to understand their function as part of a thermal or material deposition system. Moreover, purchasing a hot press may be a significant investment and requires that the customer is well-informed.

Prerequisites[edit | edit source]

Recommended documents to review before, or in parallel with this document:

- Thermal transformation
- Heat transfer
- Conduction
- Effect of equipment in a thermal management system

Overview[edit | edit source]



Schematic showing heating and forming of a part in a hot press

A standard hot press comprises upper and lower platens which are heated to the desired temperature and apply pressure to the part. For processing of composites materials, heating is usually performed electrically, or by circulating steam or oil[3]. The platens can be cooled via air or water cooling. Typically, the platens are raised and lowered by means of hydraulics, however electrical actuation is also possible. Depending on the mode of actuation, the equipment may be referred to as a hydraulic or electric press. Heating, cooling, and pressure application are often managed by automated control systems.

During forming, consolidation, and thermal transformation, the part in question is placed between matched metal dies (also known as a doubled-sided mould, matched mould, or two-sided tool) - these are the tools in question during hot press processing. The tools are connected to the upper and lower platens of the press. Heat is transferred from the platens to the tools and from the tools to the part via conductive heat transfer. The material placed between the tools is known as a charge. During heating, and under compression, the material may flow to fill the tooling cavity[1]. Because of this, the tools dictates the final shape of the part and should be designed accordingly.

In order to limit downtime and increase throughput, typically the hot press remains on at a set temperature between part loads. This prevents the tooling from cooling down between loads, thereby reducing part heat-up time. This is especially important for fast cure cycles such as those used in the automotive industry. The tools are heated to a constant temperature and typically remain at this temperature in a production line[3]. The part(s) are placed in the hot press, cured/formed, and then removed. The part may be preheated and/or post cured in an oven prior to and following hot pressing, respectively. Furthermore, the part is typically not cooled (or at least not fully cooled) in the press before removal in order to reduce the wait time for the next batch of parts to be loaded.

Properties[edit | edit source]

Heating	Temperature	Pressure	Vacuum
Conductive heating.	Large temperature range. 20°C \(\leq\) T \(\leq\) 2200°C[4]. Typically, temperature is kept between 120°C to 170°C for compression moulding of thermosets[3].	High pressure - exact value depends on contact area between tool and part. Forces greater than 1 MN possible. Tools should be able to handle 2-30 MPa[3].	Typically no vacuum control. P\(_{vac}\) = 0.

Typical specifications[edit | edit source]

Example hot press[5]

Manufacturer	Model	Actuation mode	Heating mode	Cooling mode
WABASH MPI	V150H-36-CX	Hydraulic	Electric	Air/water

Example hot press specifications[5]

Max temperature	Min temperature	Max force	Min force	Platen size	Opening speed	Closing speed	Pressing speed (during pressure application)
426°C	Room temperature	136 metric tonnes	21 metric tonnes	91.5cm x 91.5cm	152cm/s	190cm/s	0 - 13cm/s

For the example hot press given in the table above, cooling may be a combination of air or water cooling. The mode of cooling depends on the platen temperature. Above 340°C only air cooling is implemented. Between 180°C and 340°C both and air water cooling are implemented. Below 180°C only water cooling is performed.

Part temperature profile[edit | edit source]

Thermoset parts made by compression moulding are typically thin to avoid a non-uniform temperature distribution. This allows for even curing and reduces residual stress[3]. For thick parts, the temperature gradient can be significant.

Depending on the thickness, the internal part temperature may heat/cool to the tool temperature within a matter of minutes. A good approximation for understanding heat flow through the part in a hot press is 1D thermal conduction. In this case, heat flows from the tool through the thickness of the part. The surface temperature of the part can be assumed to instantaneously jump to the temperature at the tool interface upon contact with the tooling. From here, the internal part temperature can be solved as a transient (i.e. non-steady state) conduction problem.

Although it is often assumed that the tools in a hot press are at a constant temperature, in reality there will be gradients through the thickness of the male and female tools. During a constant temperature hold, the variation in tool temperature may be upwards of 6°C. During cool down this variation can increase to greater than 40°C[6].

Advantages[edit | edit source]

- Short cure times and high throughput - allows for high volume production[1][3][7].
- Can be used to cure, crystallize, and/or form parts.
- Good temperature/pressure control
- Good surface finish and dimensional control[1][3].
- Can allow for high fibre volume fraction due to high consolidation pressure.
- Can accommodate complex part shapes.

Limitations[edit | edit source]

- High initial investment due to equipment and tooling costs[3].
- Typically, not economically suitable for making a small number of parts[3].
- Difficult to remove entrapped gases/volatiles while resin is in a liquid state due to lack of vacuum application
- Applied pressure may not be uniform across part surface if undulations or other discontinuities exist in the part.
- Often, the minimum force that can be applied is quite large, limiting the type of parts that can be processed.
- Scalability is challenging - each part with a unique shape requires its own mould (this adds to the cost).

Use[edit | edit source]

Compression moulding and stamp forming (or hot stamping) are common process steps that require use of a press for forming, consolidation, and thermal transformation. In both cases, a press applies pressure to the part to form it. Traditionally, compression moulding implies forming, where the material flows under pressure and temperature to fill the tooling cavity[2]. However, it may also refer to consolidation and thermal transformation of a part in a hot press, even without the material flowing[1]. This may also be referred to simply as hot-pressing. Stamp forming, on the other hand, is a term typically reserved for press forming or consolidation of unidirectional or woven thermoplastic sheets that do not flow and fill a cavity under pressure and temperature[2].

During compression moulding, the viscosity of the resin plays an important role. If the viscosity is low, the resin is more likely to wet out the fibres and reduce dry spots. However if the viscosity is too low, excessive squeeze-out may occur, resulting in resin oozing out of the tool if it is not air tight. This may actually reduce the overall resin content and increase the chance of dry spots. Moreover, it may add significant time to cleaning of the tool. On the other hand, if the resin viscosity is too high, then the resin may not wet the fabric, again increasing the chance of dry spots. Therefore, the resin viscosity should be tailored for the application and tooling. Potential strategies may include heating or aging[1] the resin until an optimum viscosity is achieved. Viscosities of 1,000 - 100,000 Pa\(\cdot\)s are common for thermoset applications[1].

The table below summarizes typical fibre forms that are used in compression moulding:

Typical fibre forms for compression moulding. Adapted from[1].

Discontinuous fibres	Random, continuous fibres	Oriented, continuous fibres
Sheet moulding compound (SMC)	Swirl mat/neat resin	Unidirectional tape
Bulk moulding compound (BMC)		Woven prepreg

Both thermoset and thermoplastic composites may be thermally transformed, consolidated, and/or formed using a hot press. For thermosets, sheet moulding compound (SMC) and bulk moulding compound (BMC) are common material forms. Both are sheets of chopped, randomly oriented, pre-impregnated glass fibres; usually with a polyester, vinyl ester, or phenolic resin matrix. The primary difference between the two forms is that SMCs contain longer fibres (2.5-5cm) and a higher fibre volume fraction, whereas BMCs contain shorter fibres (0.3 - 3cm) and a lower fibre volume fraction[1]. Thick moulding compound (TMC) is thicker form of SMC; up to 50mm compared to 6mm[3]. Hot press processing of SMCs, BMCs, and TMCs falls under compression moulding. During compression moulding, the SMC or BMC charges are heated and compressed, allowing them to flow and fill the tooling cavity. This method is highly appealing to automotive industries which require fast cure times and high-throughput. Compression moulding of SMCs can allow for up to 200,000 parts to be cured in a single day[8]; with each part requiring a cycle time of 30-240 seconds[8][3]. In compression moulding of thermosets, where material is required to flow, often low fibre volume fraction material forms (on the order of 30% or less) are used to allow for smoother surfaces and to reduce cure shrinkage and thermal expansion defects such as fibre print-through (i.e. fibres disturbing the part surfaces)[3]. These may be referred to as Class A surfaces. That said, continuous fibre thermoset prepregs may be thermally transformed or consolidated in a hot press as well. Additionally, prepregs containing thermoplastic/thermoset resin blends have been hot-pressed to produce parts with a high fibre volume fraction, thermal stability, and fracture toughness[9].

With the exception of SMC, BMC, and TMC material forms, thermosets are commonly formed using rubber press forming or under vacuum pressure in diaphragm forming[2]. These methods may also be applied to thermoplastics as well. However, owing to their high resin viscosity, metal-die compression moulding (using a hot press for example) is often employed to form thermoplastic parts with high fibre volume fraction and high performance[2][10]. In forming, it is not necessary for the part to be heated in the press. Typically, for thermoplastics, the part is heated in an oven and transferred to the press to be formed[2]. Finally, while forming of thermoplastic prepregs is possible[11] forming of both continuous fibre thermoset or thermoplastic prepregs is not as common or as well developed as for other material forms[2].

A common thermoplastic material form for moulding, similar to SMC for thermosets, is glass mat thermoplastic (GMT). It consists of partially consolidated sheets of random glass mat fibre (usually 40% volume[1]) with a thermoplastic matrix, typically polypropylene. The sheets are usually heated beforehand in a IR conveyor oven and then shaped on the press. The whole process is very quick, taking between 30-60 seconds[2], with pressures around 1000-4000 psig[1]. Long fibre thermoplastic (LFT) is another compound similar to GMT, with fibre lengths of 13-51 mm. Cutting, preheating, and forming of LFTs is usually automated[1]. For high performance thermoplastic parts with high fibre volume fraction, continuous, aligned fibre or woven thermoplastic sheets are used. Similar to use with GMT, the material is preheated and transferred to a press. However, unlike compression moulding of GMT, the higher fibre volume fraction sheets do not flow in the mould (tooling)[2]. As a result, lower forming pressures are used. This is typically referred to as hot stamping or stamp forming.

Another use of a hot press is in hot debulking of thermoset prepreg plies. Rather than applying vacuum to remove volatiles from solution, the applied pressure of the hot press is set to induce a hydrostatic resin pressure greater than the volatile vapour pressure in order to keep the volatiles in solution until the resin gels. Hot debulking may also be performed in an oven or autoclave, with differing methodologies. The advantage with a hot press is that the volatiles are suppressed from coming out of solution, thereby reducing the risk of void growth. A disadvantage is that the tooling must be able to withstand the high pressures and damming techniques must be employed to prevent excessive bleed out[1].

Applications[edit | edit source]

Typical sectors or products that use hot presses include:

- Automotive - compression moulding of SMC and GMT for high volume production[2]; including, roof panels, quarter panels, fenders, spoilers, doors, hoods, decklids, skid plates, radiator supports, sleeper cabs, rocker covers, oil pans, and truck bed components[3].
- High performance sporting goods - skis, snowboards, skateboards, bicycle components, tennis rackets[1], and others.
- Marine - personal watercrafts[3].
- Home applications - showers, tubs[3].
- Aerospace components
- Other - military boxes, enclosures, fuses, lamps, switches, street light canopies[3].

Safety[edit | edit source]

NOTE: This safety information is not comprehensive, and is only intended to draw the reader's attention to some important safety considerations. The reader should be refer to applicable safety data sheets (SDS) and manufacturer instructions.

The primary safety concerns surrounding a hot press is the high temperature of the platens and the high force they exert. Touching the platens when the machine is in operation can result in severe injuries and should never be done. Similarly, users should not place any part of their body between the platens when in operation. Many hot press models come equipped with a safety interlock gate to prevent such actions. The safety gate should remain closed at all times when the press is in use. The equipment should be fitted with an emergency stop button that the user should press in the event of an emergency.

Users should always wear the appropriate PPE when operating and loading parts into the press. This may include a face shield, heat resistant gloves, heat resistant coveralls, and steel-toed boots. It is good practice to have a spotter present in the event of an emergency. Finally, the operating area should be kept clear of any hazards. This is particularly important when transferring hot parts from one area of the factory to the press for forming. Steel-toed boots should always be worn on the shop floor, especially if dealing with heavy items.

Key considerations during use[edit | edit source]

While utilizing this piece of equipment, the following are some of the key aspects to consider:

Storage & Handling[edit | edit source]

When not in use, the machine should be turned off and the platens in their reset position. All hydraulic pumps should be switched off and water line valves closed.

Cleaning[edit | edit source]

After removing the tooling from the press, it will likely be coated in resin. If excessive squeeze-out occured, resin may even be on the outside of the tool. Before using the tool again, all resin should be cleaned off the tool. This can increase downtime in the press if a single tool is dedicated to each part.

Additionally, the workspace surrounding the press should be kept clean. This ensures a safe work environment. All material spills should be handled to according to appropriate spill safety procedures.

Preventative Maintenance[edit | edit source]

Servicing and calibration should be done according to the manufacturer recommendations. All maintenance should be carried out by experienced individuals and/or contractors from the manufacturer.

Suppliers[edit | edit source]

Product suppliers[edit | edit source]

Common providers of this equipment include:

- Wabash MPI
- Macrodyne
- Lauffer Pressen
- Trinks
- Grimco
- Savage
- French Oil Mill Machinery
- COMI Group
- Barwell

For additional suppliers, visit the following webpage[12]:

https://www.compositesworld.com/suppliers/product/254

References

1. ↑ 1.00 1.01 1.02 1.03 1.04 1.05 1.06 1.07 1.08 1.09 1.10 1.11 1.12 1.13 [Ref] Campbell, F.C. (2004). *Manufacturing Processes for Advanced Composites*. Elsevier. doi:10.1016/B978-1-85617-415-2.X5000-X. ISBN 9781856174152.
2. ↑ 2.00 2.01 2.02 2.03 2.04 2.05 2.06 2.07 2.08 2.09 2.10 [Ref] Long, A C (2007). *Composite forming technologies*. ISBN 9783540773405.
3. ↑ 3.00 3.01 3.02 3.03 3.04 3.05 3.06 3.07 3.08 3.09 3.10 3.11 3.12 3.13 3.14 3.15 [Ref] Mazumdar, Sanjay K. (2002). *Composites Manufacturing - Materials, Product, and Process Engineering*. ISBN 0-8493-0585-3.
4. ↑ [Ref] German, Randall M. (2014). *Sintering With External Pressure*. doi:10.1016/b978-0-12-401682-8.00010-0. ISBN 9780124016828.
5. ↑ 5.0 5.1 [Ref] Wabash MPI. "Presses for Special Applications". Retrieved 17 February 2021.
6. ↑ [Ref] Fortin, Gabriel Yves (2016). *Process-induced shape distortions in aerospace thermoplastic composites* (Thesis). doi:10.14288/1.0300417.

7. ↑ [Ref] Sapuan, S.M. (2017). "Chapter 3". *Composite Materials*. Elsevier Inc. doi:10.1016/B978-0-12-802507-9/00003-9. ISBN 9780128025079.
8. ↑ 8.0 8.1 [Ref] CompositesWorld (2016). "Fabrication methods". Retrieved 14 January 2021.
9. ↑ [Ref] Kim, Sang Yup et al. (2019). "Manufacture of carbon-fiber prepreg with thermoplastic/epoxy resin blends and microencapsulated solvent healing agents". **121** (January). Elsevier. doi:10.1016/j.compositesa.2019.03.033. ISSN 1359-835X.
10. ↑ [Ref] Land, Patrick et al. (2016). "Technology review of thermal forming techniques for use in composite component manufacture". **9** (1). doi:10.4271/2015-01-2610. ISSN 1946-3987.
11. ↑ [Ref] Tatsuno, Daichi et al. (2018). "Hot press forming of thermoplastic CFRP sheets". **15**. Elsevier B.V. doi:10.1016/j.promfg.2018.07.254. ISSN 2351-9789.
12. ↑ [Ref] CompositesWorld. "Suppliers for Presses, compression molding". Retrieved 16 February 2021.

About **Help**

The act of combining reinforcement fibre, resin to shape on a mould (tool).

There are three main methods to combine resin and fibre to deposit onto a tool (i.e. material deposition):

- Wet Processes: Mixing liquid resin and dry fibre directly in the mould, e.g. Wet Compression Moulding process for parts in BMW 7 series
- Liquid Composite Moulding (LCM) processes: Infusing dry fabric with resin using a pressure gradient, e.g. High Pressure Resin Transfer Moulding process (HP RTM) for parts in BMW i3
- Prepreg Processes: Laying up using prepreg where resin and fibre are already combined, e.g. Automated Tape Laying (ATL) process for some of the parts in Boeing 787.

A class of polymer, some common examples include polypropylene and polyethylene.

They soften and melt upon heating (i.e. potentially recyclable), high viscosity when melted, therefore difficult to saturate fibres. Usually needs a lot of pressure and heat to process.

Engineered materials (designed to have specific properties) made from two or more constituent materials with different physical or chemical properties. The constituents remain separate and distinct on a macroscopic level within the finished structure.

Volume fraction of either matrix or fibres with respect to total composite volume (matrix + fibre).

For polymer matrix composites (PMCs), resin refers to the matrix; the continuous material phase that binds the reinforcement together, maintains shape, and transfers load. Resins are divided into two main groups: thermosets and thermoplastics.

In composites processing, viscosity is an indicator of how easily the resin matrix will mix with the reinforcement and how well it will stay in place during processing. The lower the viscosity, the more easily resin flows. Resin viscosity ranges considerably across chemistries and formulations.

By scientific definition, viscosity is a measure of a material’s resistance to deformation. For liquids, it is in response to imposed shear stresses.

Thermosets are a class of polymer that undergo polymerization and crosslinking during curing with the aid of a hardening agent and heating or promoter. Initially they behave like a viscous fluid. During curing, they change from viscous fluid to rubbery gel (viscoelastic material) and finally glassy solid.

If heated after curing, initially they become soft and rubbery at high temperatures. If further heated, they do not melt but decompose (burn)

Comes in two parts: part A (resin) and B (hardener). When mixed, curing reaction starts and is not reversible.

Examples include epoxy or polyester.

Pre-impregnated (prepreg) material refers to fibre that is already combined with resin. It is the most common material form used in aerospace.

During prepreg production, (e.g. fibres are run through a resin bath), prepreg is heated and partially cured to B Stage (< 5 % degree of cure). Thermoset prepregs (e.g. epoxy prepreg) have to be kept in a freezer at around -20 °C. At room temperature, the epoxy starts to cure.

The continuous material phase that binds the reinforcement together, maintains shape, transfers load, protects the reinforcement from environment and damage, and provides the composite support in compression.

Desirable characteristics:

- Moisture/chemical resistance
- Low density
- Processability

With regards to manufacturing, risk is the combination of the probability and consequences of undesirable manufacturing outcomes. Manufacturing risk can lead to technical issues, program/schedule delays, and cost overruns.

An acronym that stands for Safety Data Sheet. These are documents that provide information about safety precautions and hazards of a product. They are typically provided by the product manufacturer. Different jurisdictions have different legal requirements for these documents.

Any manufacturing and/or decision making activity that occurs during any stage of the development design cycle (e.g. conceptual design to production).

In the context of Knowledge in Practice, practice refers to the systematic use of science based knowledge to reduce composites manufacturing risk, cost, and development time.