

Chapter 2

Origins of Convolution

Law of transition to the super-system subtly adds positivity to TS while deducting negativity simultaneously. System gets more suited for required application, yet does not complicate. This law is better understood through extended examples. Convolution gently enters life of TS.

When and who invented to put a slice of cheese, sausages, or something else on butter? Sandwich: two slices of bread with butter, between which there is a chunk of meat, was invented in eighteenth century by English admiral Lord Sandwich. Such sandwich was more convenient to eat during card game; butter did not dirty cards. Can we call a sandwich a bi-system composed of two mono-systems, two slices of bread, plus something extra?

Aperture of the camera was installed before or behind lens. In the former arrangement, image became a little swollen, straight lines turned into convex. In second case, image became a bit shrunk-straight lines turned into concave. This phenomenon, a kind of optical distortion, could not be eliminated for a long time. The solution was finally found: to set two apertures, one before and other behind lens. The beam first expanded, and then shrank almost identically. Distortions were mutually compensated. It is a classic case of minus and minus becoming plus in algebra. System quality appears in Bi-system from two similar elements, in case if they fulfil the counter (conflicting, contrarily directed) functions. Examples: pair of scissors, apertures in camera. System quality also appears in Bi-system from two differed elements (with shifted characteristics) like in famous twin-blade of ‘Gillette’—one blade raises hair, second one cuts it.

Look at a usual drill. Guess in which way will it evolve? We attempt inventing a new drill which is better than known. Conventionalists might offer faster production of drill or more sharpening to it. In such offers, the system stays as system: psychological inertia does not let system pass on to bi-system or to poly-system. Right answer is: drill must become binary drill. What does it means to connect two drills? It is necessary to take two drills and to turn their in one binary drill. Like a double barrelled gun with two barrels sharing single buttstock or a

two-color pencil—one end blue lead, another red lead, sharing common outer wooden cylinder. Binary drill has spiral rifling at both ends. When one end gets blunted, it can be turned around and the worker can work by second one.

Transition to bi-system and poly-system is an inevitable stage in the development of every system. For example, ancient anchor was a hook with one fluke. Then anchors with two flukes and polyflukes appeared. A drawing-pin (thumbtack) with one spike is simple system. But bi-thumbtack (two spikes) and poly-thumbtack (three spikes) were invented. Such transition increases MUF of system.

Nail is a simple single system. What will be its form if it passes onto a poly-system? Poly-nail was developed by Finnish engineers. It has a metal plate with multitude of spikes. One head is enough for 200 spikes. Wooden constructions using poly-nail is two times faster than usual. Take notice: it is incorrect and no good to simply add systems together. One cupboard stacked on top of another serves no extra purpose; it is, if at all, a low-grade invention. Addition must give benefit; bi-system should be easier or efficient than two separate systems considered together. When two guns are joined to form a double barrel gun, several parts are eliminated. The most advantageous trick is to unite something with nothing, emptiness, free of charge resources. To prevent injury during training dives, bottom layer of water in swimming pool is united with air; air bubbles are released and diffused from floor of pool. In comparison with dense water, air is almost emptiness. Together they form a ‘soft’ layer of water at bottom of pool, producing a cushion effect.

Example 1: Magnetostrictive pump: A pump with magnetostrictive elements powered by ultrasonic generator is invented. Patent 885635. Fig. 2.1.

Element 1st and 2nd are magnetostrictive working elements. If an element operates singly, it is a mono-system. It can just achieve shaking of liquid i.e. it pushes it forward–backward. Maybe in some consideration this is a useful function. When we join these two similar elements with their phases shifted, it is bi-system with biased characteristics. A novel system property, to pump liquid, is gained. Here the positive properties of elements, viz. to push liquid forward are added while negative properties, viz. to push liquid back are eliminated. This bi-system fulfils two functions:

- (a) pumping function, transferring of liquid forward,
- (b) valve function, locking the motion of liquid backward.

Both functions are actually part of single MUF of this TS—pumping liquid. It is mentionable that treatment of step-by-step working of this system is beyond context of this book.

Example 2: Welding. We begin with Laser Beam Welding frequently referred to as LBW. In this process, multiple pieces of metals are heated to a molten state and fused together using lasers. TS consist of two or more portions of metals to be jointed, laser beam along with its subsystem for optical focussing feedback and filler wire. TS is a mono-system so far. Some of you may disagree, arguing that two or more metal parts are involved. Our answer is: let the mono-, bi- and poly-nature of TS be set according to numerical value of laser beams.

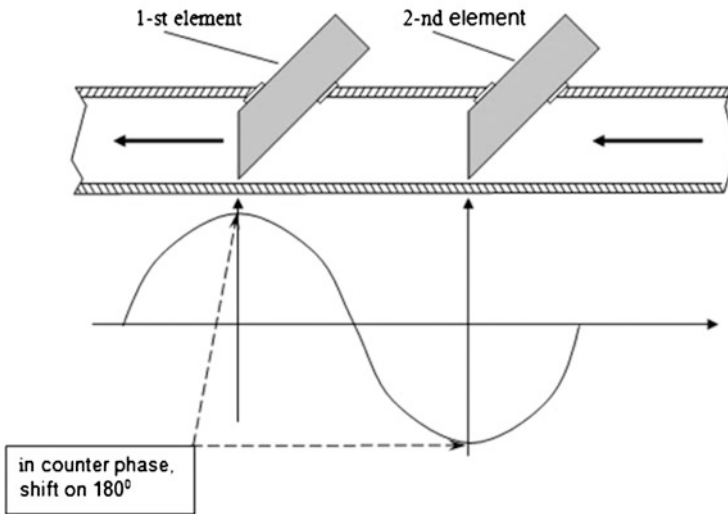
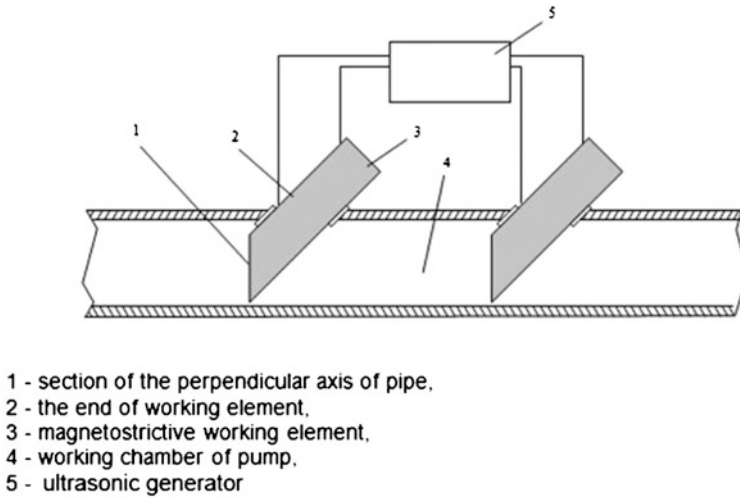


Fig. 2.1 Bi-system with biasing between parts manifested as phase lag

To increase MUF, mono-system is progressed toward bi- and poly-systems. Few possible directions are given herein:-

- (a) Either the beam is divided into two beams, or two separate beams are used. The two beams are unequal in intensity and/or frequency. They are focused symmetrically about direction of welding. This is bi-system with heterogeneous characteristics. New system property: in case of dissimilar metals

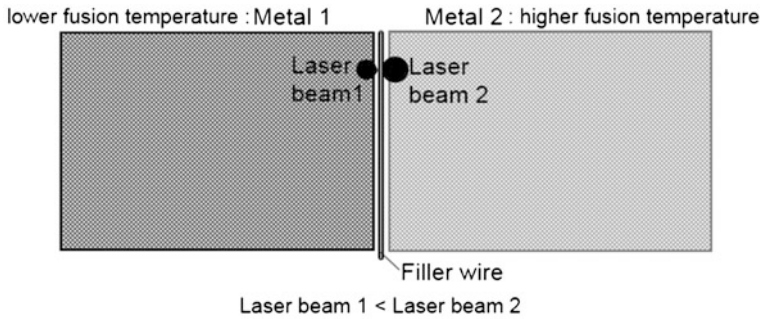


Fig. 2.2 Different metals require different heats of fusion

being welded, different thermal powers are required to melt each of them. Dissimilarity in lasers' power matches this, producing a homogeneous weld Fig. 2.2.

- (b) In case (a) above, if identical metals are used, laser beams may be identical. TS is now a bi-system with homogeneous characteristics.
- (c) The two laser foci are aligned in direction of welding with one leading the other. New system property: keyhole formed due to alloy vaporization is stable, assumedly because the keyhole is bigger and the evacuation of metal vapors is eased. Consequently there is less porosity within the weld, and blowholes (local explosions of the weld) almost disappear. Mechanical strength of weld is greater. In long run, usage of superiorly welded metal reduces scrap and repair of welded components. This is bi-system with heterogeneous characteristics (Fig. 2.3).
- (d) Galvanized steel, viz. steel coated by zinc on both sides, is currently used in automotive industry for the manufacture of car bodies, especially for its panels and structure. To produce thicker layers, galvanized steel is welded sheet on sheet with resistance spot welding. In doing so, the zinc layer is vaporized easily because of the high current used, and the high amount of heat produced at the sheet/sheet interface results in a good weld. When laser welding of galvanized steel was introduced, engineers faced a problem: vaporization of zinc perturbed the keyhole, result of which several defects like porosity were introduced. To proceed, laser beam was divided into two parts: the first advancing part was not focused on the material, so that only conduction heat was produced, but in sufficient amount so that zinc vaporized. The second part produced a keyhole for welding. New property: as zinc is already evaporated when the welding occurs, the weld is of excellent quality. Thus galvanized steel is now 'laser weldable'. This is bi-system with biased characteristics.
- (e) Laser welding of tailored blanks has becoming usual for the steel companies which sell their products to the automotive industry. Tailored blanks are usually composed of two sheets of different thicknesses which are butt welded. Corus company has developed a method of producing aluminum

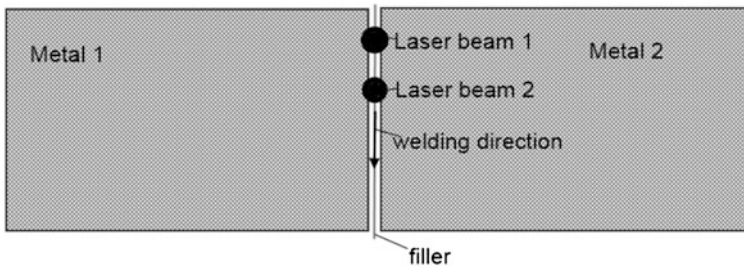


Fig. 2.3 Two laser beams following one another

tailored blanks at industrial scale for Lamborghini Gallardo. For a long time, aluminum tailor blanking was dissatisfactory due to poor quality of the laser weld root: spikes were produced because of keyhole oscillations, there was lack of fusion. Spikes are problematic for further forming (stamping), and lack of fusion may lead to forming failure or, what is worse, to a failure in service because of fatigue soliciting. In order to solve that problem, the laser beam has gone to a bi-system process: on one side, a laser beam classically welds the two aluminum blanks in butt configuration; just afterwards, a few millimetres away, on the other side, a non-focused, second laser beam (diode laser) re-melts the root of the weld or maintains further the melting of the weld root, smoothing the root weld. New property: at the weld root, the spikes are eliminated; fusion is complete. Consequently the high quality of the weld root eases the forming of the tailored blank. High mechanical resistance of the part is ensured. This is a bi-system with more heterogeneity.

- (f) MIG-welding: MIG-welding is interesting because it brings a large weld, but the depth of the weld and the welding speed are very limited. Laser welding is interesting because the welding speed is high (good for industrial productivity), and the weld is deep, but the quality of the weld is not as good as that of MIG-welding, and the width of the weld is narrow. MIG and laser welding have been put in synergy into one single welding process, called hybrid welding. New property: the process cumulates the benefits and erases the drawbacks of each process because its speed is high, the weld is of excellent quality, and its width and depth are high. This is also a heterogeneous bi-system.
- (g) Friction stir welding (FSW) is a solid-state welding process, which allows the welding of any aluminum alloy including so-called non-weldable alloys by fusion. The drawback of this process is its low speed. By adding a non-focused laser beam in front of the FSW tool, the material is heated, its plastic flow stress lowers, therefore easing the advancing of the tool. New property: the FSW tool can go at a higher speed; this increases productivity. Once again a heterogeneous bi-system.

- (h) Laser with Anti-laser: What is the inverse of a laser? Anti-laser. What is its property? When an anti-laser crosses laser, both should vanish. What could be the interest to couple a laser and an anti-laser, with still the same purpose to weld metals? If it is difficult to produce a pulsed laser beam with exactly desired characteristics, it is possible to do so optically: an anti-laser with some space–time characteristics is made to cut a continuous laser beam. Result: continuous laser beam turns pulsed with required properties. This is an inverse bi-system.
- (i) Welding conjunct its inverse: What is obvious inverse function of welding (joining)? Cutting. Indeed lasers are also used in the industry to cut metals. Actually CO₂ lasers can do both: welding and cutting. One can imagine the following: the same high power source laser is used at the same time for cutting and welding. How to do so? The laser ray is divided into multiple laser rays by the means of semi-reflecting mirrors. The laser cuts the blanks of different gauges and welds later the different blanks into so-called tailored blanks, with different parts of itself modulated in energy according to task to be done. New property: higher laser ray stability; enhanced productivity. New properties possible: one may imagine a laser that performs multi-tasks with a high degree of quality: welding, cutting, shock preening (for better fatigue performance), printing, etc. This is a partially convoluted bi-system.
- (j) Mono-substance: We have seen that for the stability of the capillary (keyhole) during the welding of aluminum alloys, it is necessary to use two laser beams. Can this stability be achieved by a single laser beam if it is coordinated with substance being welded? It has been shown that the use of one single laser beam stabilizes keyhole, if the beam is pulsed with some definite frequency, and with time gaps in some multiple of wave period. It is if these parameters are coordinated with time-driven functions of the keyhole physical phenomena, optimized result is obtained. Law of Harmonization, our third law of technical systems' evolution. New properties: better keyhole stability, and consequently less porosity and explosions (blowholes). We can call this a mono-system with monosubstance.
- (k) Multiple laser beams' welding: One may easily imagine putting together three, four identical pulsed laser beams together, so that the stability of the keyhole during welding is much more stabilized. The laser beams could be also of different energies, different shapes, etc. Other functions may be also realized. Convoluted poly-system.

Example 3: Boat. Two boats coupled by transverse beams constitute a homogeneous bi-system called catamaran. New property: horizontal stability allows higher and larger sail, so that the wind driving force is higher, and consequently the catamaran is speedier. A new TRIZ term introduced here: the joining, internally running substance is called internal medium. In this case, transverse beams constitute internal medium.

Three boats transversely connected constitute a homogeneous poly-system called trimaran. It possesses one central body and two lateral floats.

New property: same as in catamaran, plus its performances are higher than those of catamaran. For that reason, trimarans are much liked for in sailing competitions. Internal medium: beams between body and floats.

A trimaran hydrofoil with water ballasts in the lateral floats constitutes a poly-system with biased characteristics. Usually ballast is used for submarines. In our case, ballast on the side of the wind is full as while on the other one is empty. New property: Enhanced stability that allows easier hydrofoil effect.

Trimming, Miniaturization and Ideality via Convolution
Technique of TRIZ

A Guide to Lean and High-level Inventive Design

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