STUCK BY TECHNOLOGY

Sven Isaksson

ABSTRACT

This paper presents an analysis of the clasping device on brooches during Scandinavian Iron Age. It consists of a schedule of development and a cultural analysis of one of the changes. This step of development was a change of construction metal, from copper-alloys to iron, which took place around 400 AD. To test if the change implied an improvement, experimental load tests were made on reconstucted devices. A pervading intention is to point at the fruitfullness of the combination of cultural analysis, source material analysis and experimental laboratory analysis.

Introduction

Technology is part of human culture and society. It is obvious today and it is obvious throughout the history of man. But the body of technological knowledge has not been increasing constantly. Knowledge has been gained and knowledge has been lost. In this paper an analysis of the technological development of the clasping device on brooches in the Iron age of Scandinavia is presented. The device is based on the same idea as the modern safety-pin, invented in the 19th century AD (Bray & Trump 1988, Odelberg 1989). A complete list of invented, forgotten and reinvented techniques would be long. But what is important is that there have been periods of gain and periods of loss, and that it is due to the human society, "the non-technological factors" or environment, what has been retained and what has been neglected. Society decides what knowledge is important, not technology itself. My intention is to put forth some ideas on the interaction between the cultural and social man and technology.

Technological change

The definition of technology used in this paper comprises all activities, adjusted to satisfy man's wishes and needs, that result in changes in the material world. These activities result in techniques, e.g. knowledge, objects and processes with the mentioned effect (Lindqvist 1984, Nordin 1988, Teichman 1979).

Technology is inseparable from the human context it is developed in. So it is because humans create technology and the very same humans are bound by numbers of non-technological factors which affect their technological possibilities. The factors could be such as social and cultural structures, economy, regional geographic features and demographic factors. The state of all these factors, including technology, is related to all the others in a very complex manner. This results in different styles of technology, with the same effect on the material world, in different societies. These conditions make technology into a mirror of the natural environment and the human context it has developed in (Boserup 1981, Hjärtner-Holdar 1989, Hughes 1979, Lindqvist 1984). These factors also influence the dynamics of technological change, by variation between limitation and possibility (Righini-Bonelli 1979, Subbarayappa 1979).

By its influence on the material world, technology tends to backfire on non-technological factors. This can lead to changes in society by altered conditions of life, economic changes and changes in social and cultural structures (Boserup 1981, Kranzberg 1979, Tägil 1979).

A technological change is often induced by need. But as the function of technology in a society consists not only of production, but of symbolic and military functions as well, this is not always the case (Lindqvist 1984). Furthermore, a technique has to be accepted as "usable" by the society. This judgement is indeed subjective: a technique can be practically highly functional but considered as unusable by non-technological reasons (Nordin 1988). And as technology influences society, a change in technology can be used as a tool to impose changes in a society.

The most common way for a given society to receive a change in technology is not by invention, but by diffusion. This transport of ideas, knowledge and objects is not necessarily straightforward, and is influenced, to a relevant point, by the conditions in both the receiving and the giving society. Different non-technological factors can be a great obstacle for diffusion, for example different ideas of what is usable and not (Boserup 1981, Nordin 1988, Lindqvist 1984).

A way to analyse technological change

According to the ideas about technological change mentioned above a rough way to analyse a step in technological development will be proposed.

By judging the ways the change might have been induced, important clues of the characteristics of changes are received, which is necessary for further analysis. The next step is to examine technological and non-technological factors which, with limitations and possibilities, might have interacted in the change. Now it is possible to judge if the change is a primary development or a secondary effect. The last step is to conclude how the material world might have been changed by the step and what effects, if any, it might have imposed on non-technological factors.

If it turns out to be a diffusion-course, the way of analysis ought to be the same as for an invention-course, with the difference that the conditions of both receiver and giver are analysed.

The fibula and the brooch in Europe

A fibula is a decorative brooch of safety-pin form. It consists of a bow, a spring and a pin which rests in a catchplate. The name comes from the thin pointed leg bone which served from early times as a pin. The word brooch is most often used in post-Roman contexts, and will be the word mainly used in this paper.

The earliest examples date from around 1300 BC, but their origin is not yet established. There are two main families of fibulae. In the south they were made in one piece and occurred in Italy and Mycenaean Greece. To this family the long La Téne and Roman series of varieties belong and from these the final forms in the Saxon and Migration periods have derived.

In northern Europe the pin was generally made separate from the bow. This is clearly seen in the Bronze Age

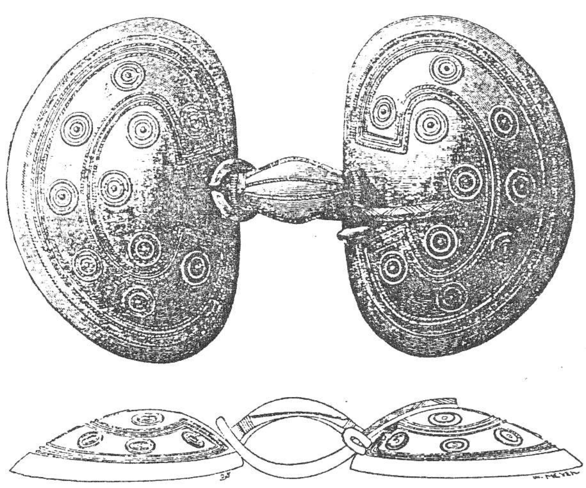

Fig 1. Bronze Age fibula from Stenbro, Slite parish, Gotland. Note that the pin is seperate from the rest of the fibula. After Montelius 1917 (1987).

springless fibulae of Scandinavia (Fig 1.), and also in the later spring equipped forms (Bray & Trump 1988).

A problem

Considerable research has been carried out on brooches. But it has usually been the ornaments and the artistic features that have been the research subject. In this work I have tried to look at the material from a slightly different angle, and "turned it upside down" to study the clasping technology. This formed a problem. Some researchers didn't have any notes on what existed on the back of the brooches. This might have influenced my results when constructing the schedule of development, as it is based on literature.

A schedule of development

The first step is to construct a schedule of development. Then one of the steps of development will be more closely examined. The development of the device in the Iron Age begins with the so called yoke device, shown in figure 2 (Almgren & Nerman 1923, Kivikoski 1973, Rygh 1885 folder 3, Serning 1966 table

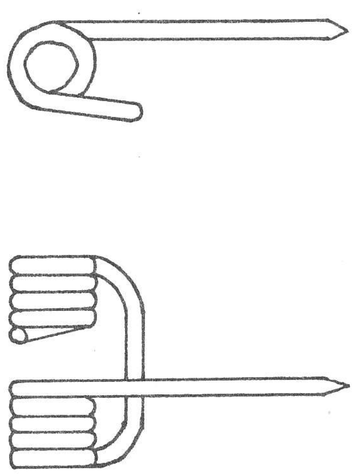

Fig 2. The construction of the yoke-device. After Isaksson 1990.

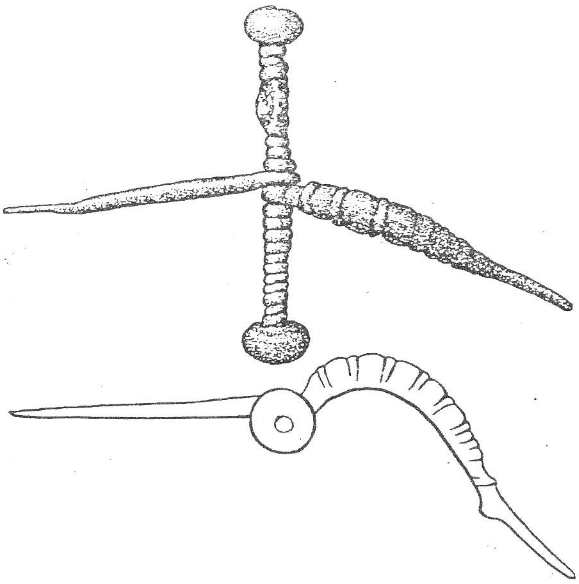

Fig 3. Brooch from Backhagen, Tingstäde parish, Gotland. Note the extreme proportions and the false coils. After Nylén 1956.

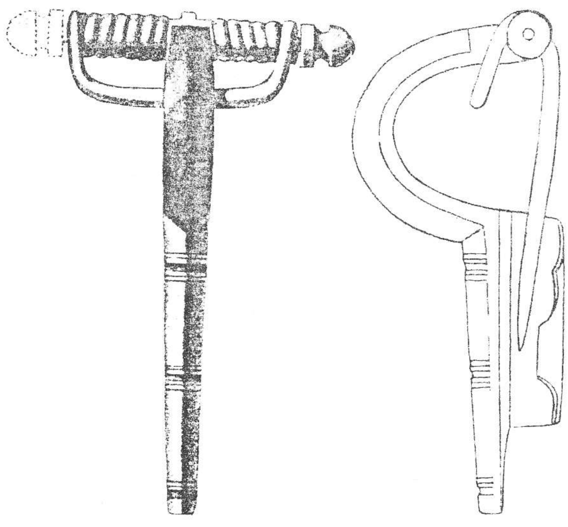

Fig 4. Crossbow-brooch from Hablingbo parish, Gotland. After Nerman 1935.

5 and 6). During the Early Iron Age the coils of the device are part of the ornament of the brooch, which leads to extreme proportions of the coils and even false coils - a change induced by the handicraft fashion trend. The result of this can be seen on brooches from both Pre-Roman and Roman Iron Age (Åberg 1956), for example as in figure 3.

During the 4th century AD the extreme proportions vanish in Norway, but are retained in Denmark and the Baltic sea area in the crossbow-brooch (Fig 4)(Åberg 1956). With the coming of the cruciform brooches (Fig 5), those with extreme coils definitely go out of fashion. The cruciform brooches have a clasping device, of the yoke-type, with very small coils hidden at the back of the brooch. In Scandinavia the clasping device is exclusively made of iron as regards this type of brooch. And this is the first time iron appears on brooches made of copper-alloys. There are earlier single brooches, but no whole groups, with iron device. These are considered as having been secondarily repaired (e.g. Hjärtner-Holdar 1991). On the Continent this type of combination of materials first appears around 500 AD (Kühn 1940, Reichstein 1975, Schetelig 1906).

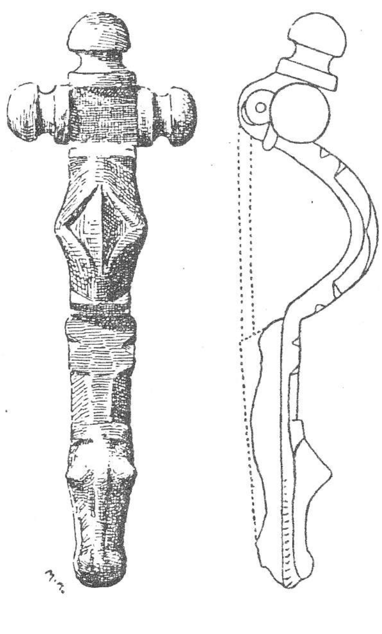

Fig 5. Cruciformed brooch from Opedal in Ullensvag, Hardanger, Norway. After Schetelig 1912.

The continuous development tends towards more and more simple clasping-devices. The spring-coil gets rare, and is replaced by the so called plate spring device, shown in figure 6. This development is clearly seen in the Viking Age brooches (Jansson 1985, Rygh 1885, Thunmark-Nylén 1983).

An analysis of a technological step of development

The step to be more closely examined is the change of metal of the device, which takes place around the year 400 AD. The analysis includes a comparison of tensile properties of the metals of interest, experiments concerning tensile properties of reconstructed de-

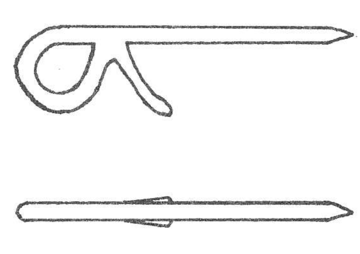

Fig 6. The construction of the plate spring device. After Isaksson 1990.

vices, a detection of possible induction of the development, the influence of economic status and social structure of society, the context of general technological status and development, a detection of possible ways of diffusion and a theoretical determination of the ways the development changes the material world.

Metals in use

To decide if the change of metal in the device implies an improvement, the tensile properties of the metals of interest will be compared.

There are very few metallurgical analyses made on clasping devices. Some are presented by Oldeberg(1942), though. These analyses show that several copper-alloys were used, but there are no analyses made on iron. Therefore the discussion below is made with a wide perspective. None of the values mentioned below are to be considered as absolute. They are only used for relative comparison.

Copper

There are domestic copper-ores in Sweden, but these sources have not been intensively used until Medieval time. Although results of recent research show that the domestic ores might have been used in the Viking Age (Arrhenius, 1989), the craftsmen were obliged to rely on imported copper during the main part of the Iron Age.

Figure 7 shows that the tensile properties of copper generally are low. At, for example, 80 % thickness reduction the rupture limit (Rm) for copper is only just above 400 N/mm² in this diagram. In this hardworked condition the difference between rupture limit and yield limit ($Rp_{0.2}$) is small. This means that the metal is brittle and will break as soon as the loading passes the yield limit.

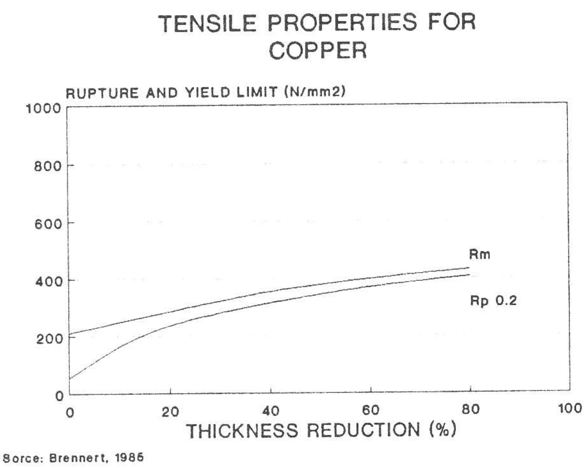

Fig 7. Tensile properties of copper. From Brennert 1985.

Brass

The domestic zinc-ores in Sweden are rare and have hardly been used in prehistoric time (Serning 1987). The brass has more likely been imported from the Continent. The Romans developed a massproduction of brass and other alloys with zinc for coinage, among other things. In south-eastern Germany there are copper-ores with a naturally high zinc content which have been used in prehistoric time (Arrhenius 1989, Tylecote 1976). The earliest proof of copper-zinc alloys in Sweden dates back to the middle Iron Age.

Figure 8 shows for a brass with 30 % zinc that this metal reaches a higher rupture limit than copper at 80 % thickness reduction: more than 700 N/mm². But the difference between rupture limit and yield limit is small for brass, too.

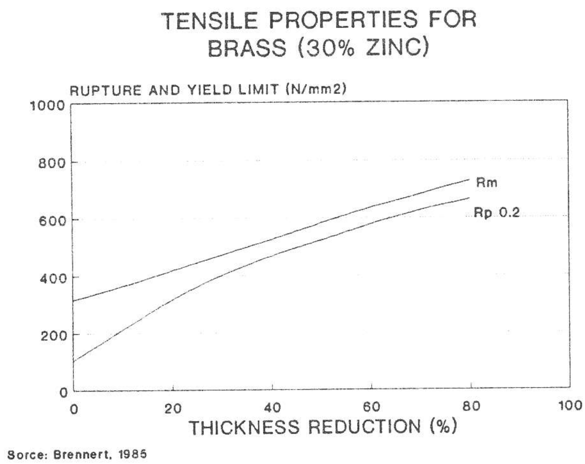

Fig 8. Tensile properties of brass. From Brennert 1985.

Bronze

Bronze, like the other copper alloys, has probably been imported during prehistoric time. The chemical composition of bronze in Scandinavia varies notably between the Bronze Age and the Iron Age. The relative amount of pure tin-bronzes is higher in the Bronze Age but the variation of tin concentration is lower in the Iron Age (Oldeberg, 1942).

A tin-bronze with 6 % tin has the highest tensile properties of the copper-alloys in this study, which is shown in figure 9. At 80 % thickness reduction the rupture limit is more than 900 N/mm², but the metal is brittle.

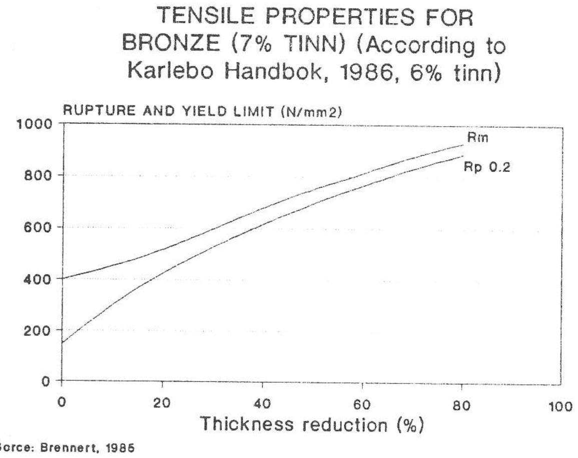

Fig 9. Tensile properties of bronze. From Brennert 1985.

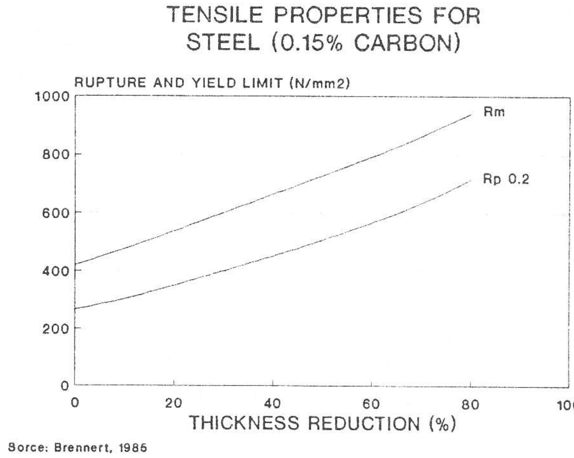

Fig 11. Tensile properties of steel with 0.15% carbon. From Brennert 1985.

Iron

Scandinavia is rich in iron-ores. Therefore there has probably never been any major import of iron to this area. The handling of iron is an old and widespread knowledge in Sweden. The oldest sites, with traces of iron-craftsmanship, date back to the late Bronze Age, and there are finds of prehistoric ironmaking in every county of the realm (Serning 1987).

Figure 10 shows that the rupture limit of steel increase, to a certain point, with increasing amount of carbon. Even steel with low carbon-content reaches higher tensile properties when worked than most of the copper-alloys, which figure 11 gives an example of.

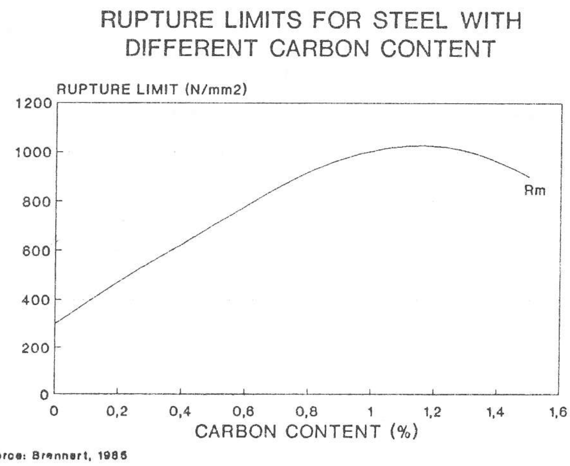

Fig 10. Rupture limit of steel with different carbon content. From Brennert 1985.

Summary

Neither copper nor brass can compete with iron as construction metal of a clasping device. Tin-bronze, with a tin content of 6%, has very good elasticity and is used as construction material for springs nowadays (Karlebo Handbok 1986). It cannot be excluded that this bronze surpasses low-carbon steel in the function of a spring.

The copper-alloys have no marked endurance limit, like steel. This means that after a certain number of loading-changes these metals will break from fatigue, see figure 12 (Metallnormcentralen 1980).

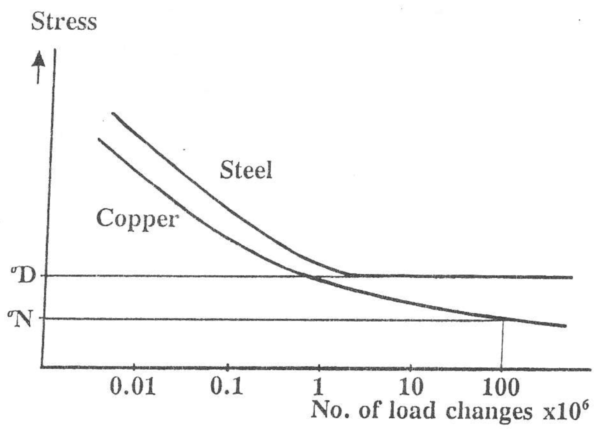

Fig 12. Wöhler diagram. D = endurance limit. N = fatigue rupture limit. After Metallnormcentralen 1980.

The conclusion drawn is that steel, on the whole, is better than copper and its alloys as construction material for a clasping device, with a reservation that certain bronzes might surpass low-carbon steel as material for springs.

Load test of reconstructions

To strengthen the conclusions above and to test the different material properties as clasping devices, load tests on reconstructed devices were made at the Archaeological Research Laboratory, Stockholm University. Of the four available materials three different devices were made of each, as presented in figure 13.

Method

The devices were stuck to a stand with a 4mm diameter coil-axis, shown in figure 14. Then the devices were loaded with weights at the distance of 45mm out on the pin counting from axis-center. At each load the elastic deflection was measured. This is the distance the pin is bent from the startingpoint. The aim was to continue loading to the point of deformation (i.e. when the pin does not return to the startingpoint after unloading).

Calculations

The calculations presented below are received or derived from Karlebo Handbok(1986). For each device a diagram of loaded force (F) and elastic deflection (f) was made. This curve is called the characteristic curve

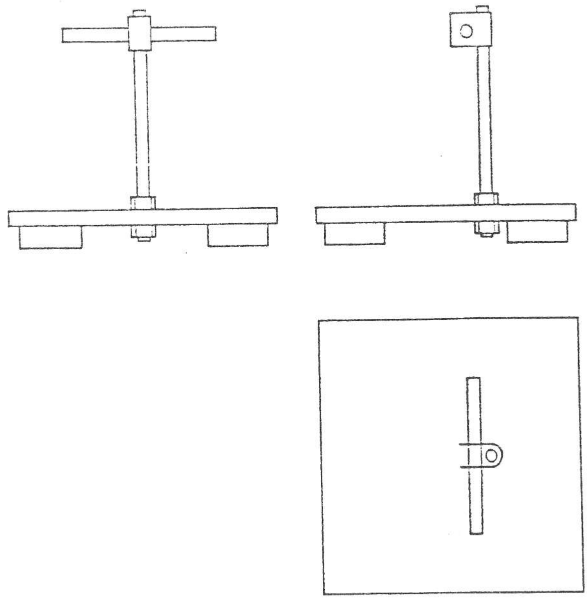

Fig 14. Test stand used in the load test.

of the spring and its inclination is defined as the formula:

$$F=k\,f$$

For most springs k is assumed to be a constant, with the unit N/mm. The higher k-value, the stiffer the spring.

The work of the spring (W) is the amount of energy contained in the spring when compressed. This energy

TABEL OF RECONSTRUCTED CLASPING DEVICES				
Device No.	**Metal**	**Alloy**	**Coil-size**	**Notes**
F1	Brass	37% zinc	2	SS 51 50-02 Annealed
F2	Brass	37% zinc	4	SS 51 50-02 Annealed
F3	Brass	37% zinc	8	SS 51 50-02 Annealed
F4	Copper	-	2	SS 50 10-02 Annealed
F5	Copper	-	4	SS 50 10-02 Annealed
F6	Copper	-	8	SS 50 10-02 Annealed
F7	Bronze	6% tin	2	SS 54 28-07 Hardworked
F8	Bronze	6% tin	4	SS 54 28-07 Hardworked
F9	Bronze	6% tin	8	SS 54 28-07 Hardworked
F10	Steel	low carbon	2	Annealed
F11	Steel	low carbon	4	Annealed
F12	Steel	low carbon	8	Annealed

Fig 13. Table of reconstructed devices.

equals to the area under the characteristic curve, W= F df, or, when k is a constant:

$$W = F\,f$$

W has the unit Nmm. To be able to compare W at the same elastic deflection, diagrams with W on one axis and f on the other were made (Isaksson 1990).

Most of the material stress in a spring is bending stress. This is calculated with the formula:

$$\sigma_b = \sqrt{\frac{W\,8\,E}{V}}$$

where σ_b is the bending stress (N/mm²), W is the work (Nmm), E is the modulus of elasticity (N/mm²), V is the volume of the spring and "8" is a constant dependent on the form of the wire making the spring.

A spring is strong if it can receive a large amount of force with low material stress. Thus, if the ratio σ_b/F is low the spring is strong.

The ratio σ_b/f one is a measure of how the material stress varies with the elastic deflection. This is a measure of the materials ability to withstand deformation.

Results

Measured and calculated results are presented in figure 15. The conclusions below refer to figures made out of this table.

Characteristic curve: The k-values for the devices of copper and its alloys show no great differences. The k-value for the iron devices is generally higher. See figure 16.

Work at 10mm elastic deflection: The values of W_{10} for the devices of copper and its alloys are here, too, well assembled and those of iron are clearly higher. See figure 17.

Material stress/force: As shown in figure 18 none of the materials stand out in comparison with the others.

Material stress/elastic deflection: The values of σ_b/f for the devices of copper and its alloys are well assembled and the values for the iron devices are notably higher. See figure 19.

Deformation: The copper and brass devices were deformed at a force of 2.0-2.5 N. The bronze device showed little or no sign of deformation at a force of 6.9

RESULTS FROM LOAD TESTS

Device No.	F	f	k	W	σ	σ/F	σ/f
F1:	0.49	3	0.16	0.74	99	200	33
	0.98	6	0.16	2.9	190	190	32
	1.5	10	0.15	7.5	310	210	31
	2.0	13	0.15	13	410	210	32
	2.5	20	D	D	D	D	D
m:			0.16			200	32
F2:	0.49	4	0.12	0.98	80	160	20
	0.98	10	0.10	4.9	180	180	18
	1.5	13	0.12	9.8	260	170	20
	2.0	17	0.12	17	340	170	20
	2.5	20	D	D	D	D	D
m:			0.12			170	20
F3:	0.49	6	0.082	1.5	70	140	12
	0.98	11	0.089	5.4	130	130	12
	1.5	17	0.088	13	210	140	12
	2.0	20	D	D	D	D	D
m:			0.086			140	12
F4:	0.49	3	0.16	0.74	110	220	37
	0.98	6	0.16	2.9	220	220	37
	1.5	8	0.19	6.0	310	210	39
	2.0	11	D	D	D	D	D
m:			0.17			220	38
F5:	0.49	4	0.12	0.98	90	180	23
	0.98	8	0.12	3.9	180	180	23
	1.5	12	0.13	9.0	270	180	23
	2.0	15	0.13	15	350	180	23
	2.5	22	D	D	D	D	D
m:			0.13			180	23
F6:	0.49	7	0.070	1.7	80	160	11
	0.98	13	0.075	6.4	160	160	12
	1.5	19	0.079	14	240	160	13
	2.0	23	D	D	D	D	D
m:			0.075			160	12
F7:	0.49	3	0.16	0.74	100	200	33
	0.98	6	0.16	2.9	200	200	33
	1.5	9	0.17	6.8	310	210	34
	2.0	12	0.17	12	420	210	35
	2.5	14	0.18	18	510	200	36
	(6.9		D	D	D	D	D)
m:			0.17			200	34
F8:	0.49	5	0.098	1.2	90	180	18
	0.98	10	0.098	4.9	190	190	19
	1.5	15	0.10	11	280	190	19
	2.0	19	0.11	19	370	190	20
	2.5	24	0.10	30	470	190	20
	(6.9		D	D	D	D	D)
m:			0.10			190	19
F9:	0.49	5	0.098	1.2	70	140	14
	0.98	12	0.082	5.9	150	150	13
	1.5	19	0.079	14	230	150	12
	2.0	26	0.077	26	310	160	12
	2.5		(NOT MEASURABLE)				
	(6.9		DID NOT DEFORM				)
m:			0.084			150	13
F10:	(0.49	2	0.25	0.49	120	240	60)
	0.98	3	0.33	1.5	200	200	67
	1.5	5	0.30	3.8	320	210	64
	2.0	6	0.33	6.0	410	210	68
	2.5	8	0.32	10	520	210	65
	2.9	10	0.29	15	640	220	64
	3.4	12	D	D	D	D	D
m:			0.31			210	66
F11	(0.49	1	0.49	0.25	120	240	59)
	0.98	4	0.25	4.5	250	170	42
	1.5	6	0.25	4.5	250	170	42
	2.0	8	0.25	8.0	330	170	42
	2.5	11	0.23	14	440	180	40
	2.9	13	0.22	19	520	180	40
	3.4	15	0.23	26	600	180	40
	3.9	17	D	D	D	D	D
m:			0.24			180	41
F12	(0.49	2	0.25	0.49	59	120	30)
	0.98	5	0.20	2.5	130	130	26
	1.5	8	0.19	6.0	200	130	25
	2.0	11	0.18	11	280	140	25
	2.5	13	0.19	16	330	130	25
	2.9	15	D	D	D	D	D
m:			0.19			130	25

Fig 15. Results of the load tests. D = deformed. Measurements in brackets is neglected.

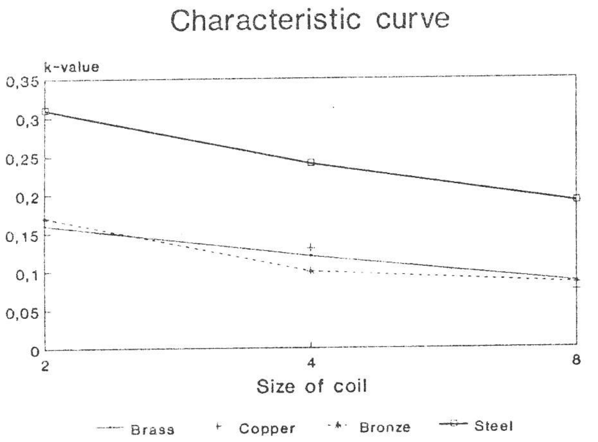

Fig 16. Characteristic curves, or k-values, of the reconstructed devices.

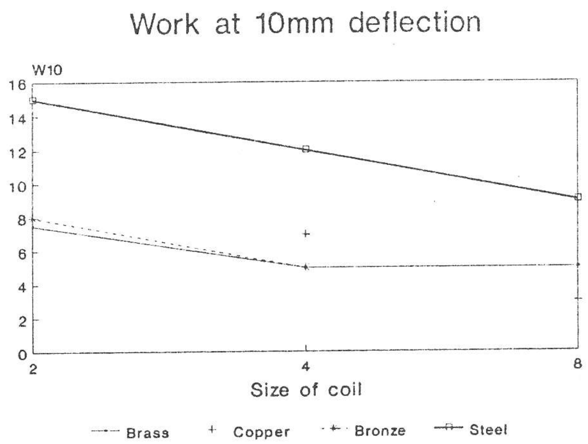

Fig 17. Work at 10mm deflection of the reconstructed devices.

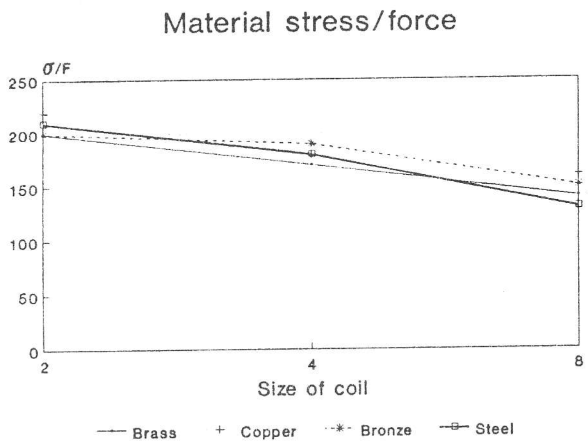

Fig 18. Material stress/force of the reconstructed devices.

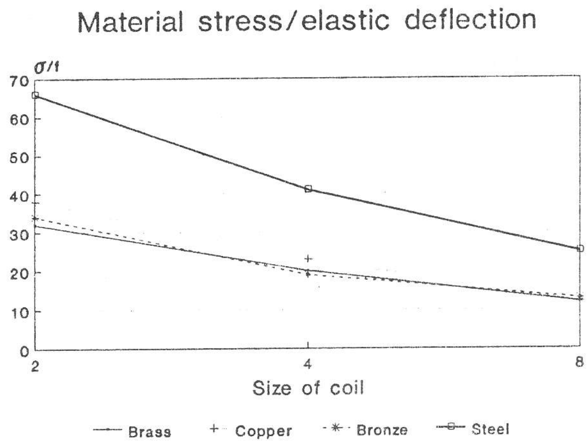

Fig 19. Material stress/ elastic deflection of the reconstructed devices.

N. Further measuring was not possible as the pin reached the table. The iron device was deformed at a force of 2.9-3.9.

Conclusions

The devices of iron are stiffer and store more energy at the same elastic deflection than do those of copper and its alloys. The higher value of stored energy makes the brooch attain better clasping, makes it more safely clasp the garment.

The bending stress of an iron device has a higher increase per increased elastic deflection than have copper and copper-alloy devices. This is to a certain degree compensated by the higher tensile properties of iron, though.

The device of bronze has very good tensile properties concerning its spring function, because the tensile properties of the material are high and the bending stress increase per elastic deflection is low. That is why the bronze devices were not deformed.

If one has in mind that the elastic deflection needed on a brooch is only a some centimeter in length, the qualities of the iron device are favourable, owing to the higher degree of stored energy and the resistance to fatigue.

Induction of clasping

The climatological history of Scandinavia has been analysed by the means of glaciology, lichenometrics and ^{14}C-analysis. These examinations show that at the end of the 4th century AD a deterioration of the climate took place (Karlén 1979). If this demanded thicker and heavier clothes it might have been the induction of the use of iron as a clasping device.

The archaeological finds of textile are few in Scandinavia. Although, some researchers claim that the four-leaved twill, which is heavier than the two-leaved twill, dominated in garment during the Migration period (Hald 1950, Bender-Jørgensen 1986). If this is the case it would strengthen the hypothesis above.

When the clasping device is made of iron, it can be made smaller than one made of copper-alloy. This allows it to be placed out of sight, on the back of the brooch. This separates the practical function of the device from the symbolic featuring of the handicraft. It is tempting to imagine a change of the symbolic language, with the result that there was no place for the coils in it, as a factor interacting in the development. This would also involve a change in garment-style, because the brooch is inseparable from the garment as part of a whole. So it is because the brooch has two functions regarding the garment. First, it is a means to close the garment, and, secondly, it is an ornament. And as an ornament it has to be seen in its context, the garment. Furthermore, the garment is not only a way to hide one's body and to keep it warm. It is also a manifestation of affiliation and difference between individuals, generations, sexes, social classes, guilds and religions (Vierck 1978). So, theoretically, a change in these expressions could lead to a change of the brooch and its clasping-device.

Raw material access

Copper and its alloys have been accessible in Scandinavia throughout the Iron Age. The Scandinavians had, though, to rely on imported material.

If the decline of the massive Roman production, caused by the fall of the Roman empire, would have resulted in a shortage of raw material in Scandinavia this could have induced the change. But the clasping device is such a small part of the whole brooch, so it is not likely to make any significant difference.

The domestic access to iron was good and a long tradition of iron-making prevailed already at the end of the early Iron Age.

In the clasp of society and economics

Without food man can do nothing but fight for survival. When there is enough food for one man to feed another this other man can do something else.

The prehistoric sites of the period of interest show that agriculture was close to the top of an expansion-phase. This included extensive hedging, manuring, and stabling of cattle (Widgren 1983). This mirrors an economically ground-based and regulated structure of society, whose character points towards social stratification (Myrdal 1988). There is a high possibility of economic over-production.

Such a society enables an economic redistribution. This is a solid ground for economic specialisation, such as professional craftsmanship (Martens 1988, Serning 1979).

In a society with these structures the ways of diffusion ought to be good. If this structure was the same in most parts of Scandinavia, there would have been few economic and social factors inhibiting the development.

These conditions indicate an advantageous context for technological development in general of which no obstructions have been found.

Technology

A necessary condition for this change is that the pin and spring are made separate from the rest of the brooch. Such a tradition existed in northern Europe, to which Scandinavia belongs.

As mentioned above the tradition of making and using iron was probably strong by the time of the development. It seems unlikely that any primary "research" would be made on the technology of clasping. This makes the change stand out as a secondary effect of a general technological development and it mirrors the good craftsmanship and profound metallurgical knowledge of the time.

The way of diffusion

As the clasping device of iron is also common in Norway, it cannot be excluded that the innovation originally came from this part of Scandinavia. Also, the spread of the cruciform brooches indicates a West-Scandinavian cultural society. This, together with the fact that the devices with extreme coils are still in use in the Baltic sea region and that the few cruciform brooches lacking an iron device are concentrated to the south-eastern parts of Sweden, are indications of a diffusion from the west to the east in Scandinavia. See figure 20.

It is possible that there was a continuous diffusion southwards to the Continent, because the iron-device does not appear there until around 500 AD.

A change in the material world

The possible result of this innovation is that the tensile properties of the brooch increased. This made it possible to wear heavier clothes and the experiment made shows that the brooch attained better clasping. It is likely that the lifetime of it became longer. And as the pin could be made thinner it could be used on finer textiles with reduced damage.

Fig 20. The distribution of cruciform brooches (accessible at the National Museum of Antiquties) in Sweden. Triangles marks brooches which has been identified as having clasping devices made of non-ferrous metals. After Isaksson, 1990.

Conclusions

The analysis shows that the change implied an improvement. Two possible ways of induction were found. First, a deterioration of the climate and, second, a change in garment style and/or change in shape of the brooch itself.

The conditions in society indicate an advantageous context for technological development in general of which no obstructions have been found.

The change is interpreted as a secondary effect of the general technological development and it mirrors good craftsmanship and profound metallurgical knowledge.

A possible way of diffusion goes from the west of Scandinavia to the east and south to the continent of Europe.

The new device made it possible to wear heavier clothes, the brooch attained better clasping, the lifetime of it became longer and it could be used on finer textiles with reduced damage.

References

Almgren, O. & Nerman, B. 1923 *Die Ältere Eisenzeit Gotlands*. Stockholm.

Arrhenius, B. 1989 Kan metallanalyser ge en anvisning om när metallurgi blir inhemsk. In *Icke-järnmetaller: Malmfyndigheter och metallurgi*. Jernkontorets bergshistoriska utskott. Stockholm.

Bender-Jørgensen, L. 1986 *Førhistoriske textiler i Skandinavien*. København.

Boserup, E. 1981 *Population and technological change: A study of longterm trends*. Chicago.

Bray, W. & Trump, D. 1988 *Dictionary of Archaeology*. London.

Brennert, S. 1985 *Materiallära: Metaller, Plaster, Gummi, Smörjmedel, Keramer och Trä*. Värnamo.

Hald, M. 1950 *Olddanske tekstiler*. Komparative tekstil- og dragtstudier paa grundlag af mosefund og gravfund fra jernalder udgivet af det kgl. nordiske oldskriftselskab. København.

Hjärtner-Holdar, E. 1989 Finns det samband mellan kopparbaserad metallurgi och tidig järnmetallurgi. In *Icke-järnmetaller: Malmfyndigheter och metallurgi*. Jernkontorets bergshistoriska utskott. Stockholm.

Hjärtner-Holdar, E. 1991 The transition from bronze to iron in the Late Bronze Age. In *Laborativ Arkeologi 5*. Stockholm.

Hughes, T.P. 1979 Regional technological style. In *Technology and its Impact on Society*. Tekniska museet symposia, symposium No 1 1977. Stockholm.

Isaksson, S. 1990 *Spännande teknik: En analys av spännkonstruktionens tekniska utveckling under järnåldern*. Graduate Thesis, Stockholm University. Not in print. Stockholm.

Jansson, I. 1985 *Ovala spännbucklor: En studie av vikingatida standardsmycken med utgångspunkt från Björköfynden*. Uppsala.

Karlebo Handbok 1986 *Teknisk handbok*. Hungary.

Karlén, W. 1976 *Meddelanden från Naturgeografiska institutionen*. NA 70. Stockholm.

Kivikoski, E. 1973 *Die Eisenzeit Finlands*. Helsinki.

Kranzberg, M. 1979 Technology assessment in America. In *Technology and its Impact on Society*. Tekniska museet symposia, symposium No 1 1977. Stockholm.

Kühn, H. 1940 *Die Germanischen Bügelfibeln der Völkerwanderungszeit in der Rheinprovinz*. Bonn.

Lindqvist, S. 1984 *Technology on Trial: The introduction of steampower technology in Sweden, 1715-1736*. Uppsala.

Martens, I. 1988 *Jernvinna på Mosstrønd i Telemark - en studie i teknik, bosetning og økonomi*. Oslo.

Metallnormcentralen 1980 *Handbok nr 8: Koppar och kopparlegeringar*. Stockholm.

Montelius, O. 1917 (New Edition 1987) *Minnen från vår forntid*. Stockholm.

Myrdal, J. 1988 Agrarteknik och samhälle under två tusen år. In *Folkevandringstiden i Norden - En krisetid mellem ældre og yngre jernalder*. Rapport fra et bebyggelsearkaeologisk forskersymposium i Degerhamn, Öland. d. 2.-4. oktober 1985.

Nerman, B. 1935 *Die Völkerwanderungszeit Gotlands*. Stockholm.

Nordin, I. 1988 *Teknologins rationalitet: En teori om teknikens struktur och dynamik*. Göteborg.

Nylén, E. 1956 *Vorrömische Eisenzeit Gotlands*. Uppsala.

Odelberg, W. 1989 Det forna Sverige. In *Svensk teknikhistoria*. Värnamo.

Oldeberg, A. 1942 *Metallteknik under förhistorisk tid*, part I. Lund.

Oldeberg, A. 1966 *Metallteknik under vikingatid och medeltid*. Stockholm.

Reichstein, J. 1975 *Die kreuzförmige Fibel - zur Chronologie der späten Römischen Kaiserzeit und der Völkerwanderungszeit in Skandinavien, auf dem Kontinent und in England*. Neumünster.

Righini-Bonelli, M.L. 1979 Some aspects of technology: the scientific instruments and the society of Medici and Lorena regimes. In *Technology and its Impact on Society*. Tekniska museet symposia, symposium No 1 1977. Stockholm.

Rygh, O. 1885 *Norske Oldsager, Ordnede og forklarede*. Tredie hefte. Christiania.

Schetelig, H. 1906 *The cruciform brooches of Norway*. Bergen.

Schetelig, H. 1912 *Vestlandske graver fra Jernalderen*.

Bergen.
Serning, I. 1966 *Dalarnas järnålder*. Stockholm.
Serning, I. 1979 Iron metallurgy and prehistoric society. In: *Technology and its Impact on Society*. Tekniska Museet symposia, symposium No 1 1977. Stockholm.
Serning, I. 1987 *Malm, Metall, Föremål*. Stockholm.
Subbarayappa, B.V. 1979 Some aspects of impact of technology on society in the classical age of India. In *Technology and its Impact on Society*. Tekniska museet symposia, symposium No 1 1977. Stockholm.
Teichman, J. 1979 Science, technology and society - past and present. A pedagogical project at the Deutsches Museum, Munich. In *Technology and its Impact on Society*. Tekniska museet symposia, symposium No 1 1977. Stockholm.
Thunmark-Nylén, L. 1983 *Vikingatida dosspännen - Teknisk stratigrafi och verkstadsgruppering*. Uppsala.
Tylecote, R.F. 1976 *A history of metallurgy*. London.
Tägil, S. 1979 Technology and social change: multidisciplinary research project at the University of Linköping. In *Technology and its Impact on Society*. Tekniska museet symposia, symposium No 1 1977. Stockholm.
Vierck, H. 1978 *Sachsen und Angelsachsen*. Hamburg.
Widgren, M. 1983 *Settlement and farming systems in the early Iron Age*. Stockholm.
Åberg, N. 1956 *Den historiska relationen mellan senromersk tid och nordisk folkvandringstid*. Stockholm.